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The Proceedings represent 30 papers from 13 countries of the Asian region dealing with water and energy problems in Central Asia (CA) and offering ways for their solution. The main focus is on the role of academic science and international cooperation in resolving conflict, legal, and economic issues of management of transboundary water and energy resources in CA. Predictive assessment of these resources is done in connection with global climate change. Hydro-ecological problems and the role of hydro power in social and economic development of Central Asian regions are discussed.

All papers are published in author's version. For authors who had not submitted the full text of papers, abstracts were published.

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PLENARY SESSION

30 June 2011, Thursday

The National Academy of Sciences
of the Kyrgyz Republic

Role of science in solving water and energy problems in Central Asia

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The role of science as a form of human activities aimed at learning and transforming the objective reality is very significant in the solution of water and energy problems in the Central Asian region.

Having analyzed in the 1990s the use of trans-boundary water resources in the Aral Sea basin in the USSR and after its collapse, the Institute of Water Problems and Hydropower, National Academy of Sciences of the Kyrgyz Republic (IWPHP NAS KR) highlighted the following key issues and proposed mechanisms to solve them.

1. In Central Asia, there is a system of limited allocation of trans-boundary waters between the countries. It was established during the socialist period for the republics of Central Asia and Kazakhstan and secured in the Schemes and Regulations on water allocation for various cross-border basins. The main criterion in determining national quotas was equal water supply to existing areas of irrigation. Beginning with 1960s, intensive development of irrigation was carried out in the plains of the Central Asian region. For the period of 1967-1987, irrigated lands area increased by 1 million 364 thousand ha in Uzbekistan, by 1 million 354 thousand ha - in Kazakhstan, and only by 189 thousand hectares in Kyrgyzstan. Distribution of water resources among the republics was made in accordance with the availability of irrigated areas. Quota for use of water resources on the territory of Kyrgyzstan is about 23% of the amount formed during an average water year of 50 km^3. The remaining water, except for our internal Issyk-Kul basin (4 km^3), goes to the territories of the neighboring states. As a result, there are substantial differences in the availability of water resources and irrigated lands in the republics situated in the Aral Sea basin. For example, in Turkmenistan, there is 0.41 ha of irrigated land per capita, in Kazakhstan - 0.3, Uzbekistan - 0.19, in Kyrgyzstan - only 0.14, in Tajikistan - 0.12, although the mountainous states (Kyrgyzstan, Tajikistan) provide the formation of 90% of surface water resources in the Aral Sea Basin. Thus, there is violation of the right for equitable access to water resources.

Such approach to allocation of water resources was justified under the planned economy of the USSR, when there were compensation deliveries of food and fuel from the Soviet Union budget to our country. Today, however, in terms of independent development and termination of subsidies, it is necessary to revise water quotas, as, having significant land resources suitable for irrigation (about 2 million ha), Kyrgyzstan does not have water resources, which restrains the development of irrigated agriculture for food independence of the present and future generations.

This problem is getting more and more serious. This is primarily due to demographic trends and the need to ensure food security for the countries of the region.

To protect national interests and ensure regional stability, IWPHP NAS KR developed the Strategy of national policy of the Kyrgyz Republic on the use of trans-boundary water resources. It reflects the fact that Kyrgyzstan recognizes that the existing system of trans-boundary rivers' water distribution in Central Asia does not meet its national interests, contradicts the Constitution of the Kyrgyz Republic, its current national legislation and principles of international water law.

There is only one way to solve this problem - redistribution of water quotas, according to key principles of international documents: "Equitable and reasonable use of international watercourses" (UN Convention 1997) and "The right of peoples and nations to Permanent sovereignty over natural resources" (Resolution 1803 (XVII) of the General Assembly of the United Nations of December 14, 1962).

We must fully realize our sovereign right for our own natural resources. This requires determining the value of Kyrgyz water quota. IWPHP calculated the criterion of maximum satisfaction of our own water needs for long-term perspective, i.e. ensuring the needs of future generations. Irrigation of 3 million hectares requires about 30 km^3 of water, and taking into account the volume of industrial and municipal-domestic water consumption, the required volume will be 35-37 km^3, instead of 11.9 km^3 allocated currently. Kyrgyzstan should claim exactly this volume. It is obvious that neither today, nor in 10-15 years, we will be able to consume 35-37 km^3 of water resources. Modern irrigation infrastructure today allows using 10-11 km^3; the remaining amount can purposefully flow into the Aral Sea as a contribution of Kyrgyzstan to maintain it.

2. Second important issue is the equal participation of neighboring countries in costs of the Kyrgyz Republic, related to the implementation of water works and services in favor of contiguous states. Numerous water facilities, built on the territory of Kyrgyzstan, are subjects of interstate significance. They are used to regulate water resources of the rivers and supply them to neighboring states. They are operated at the expense of Kyrgyz budget. The Republic also spends considerable own funds for hydro-meteorological monitoring and implementation of works to reproduce water resources in the runoff zone. These costs should be born by all the States-users of water resources. To solve this problem, IWPHP NAS KR developed an economic mechanism for trans-boundary water resources management, including methodological regulations identifying various types of tariffs for water and assessing damage caused by construction of the Toktogul waterworks facilities and its use in irrigation mode.

Compensation for losses and damages can be implemented through the introduction of economic mechanism to manage trans-boundary water resources. This mechanism was developed by the Institute for Water Problems and Hydropower of the National Academy of Sciences of the Kyrgyz Republic. It is based on interpretation of water as a commodity.

Water resources are considered to be natural resources and, along with mineral (coal, oil, gas, etc.), land, and forest resources, they are used as a source of livelihood.

Natural resources are part of public wealth of any state within the boundaries of its territory, and under capitalization of fixed assets and development of market relations, they acquire commodity form. Commodity as an economic category is considered to be:

- product of labor, made for exchange and sale;

- any product of economic production activity in a physical form;
- an object of sale between buyers and sellers,

Commodity has two main properties:

- consumer price, which determines the measure of demand for a product, its utility and necessity;
- cost that represents social labor of producers, embodied in the commodity.

Basing on these concepts, water resources meet all the definitions and properties of a commodity in the following circumstances:

1) after the dissolution of the USSR and independence of the USSR's republics, the latter declared their right for ownership and control over their social wealth, including natural resources;
2) market relations were introduced, therefore, natural resources acquired the right to be considered "commodity", provided that social labor is invested in them;
3) water resources, as a commodity, are a product of industrial-economic activity of the upstream states, which spend their budgetary funds on their formation (reproduction, monitoring, study), flow regulation in reservoirs, operation of water facilities of interstate significance and water supply, required by the downstream states;
4) water resources have two basic properties of the product (or commodity):

- Consumer price (necessity and utility), which is beyond any doubt is the highest compare to other natural resources, since existence of all living creatures is impossible without water;
- Cost (the cost of public labor for reproduction of water resources, its transportation to consumers, regulation in reservoirs, etc.).

Thus, water resources have all the grounds to be recognized as a commodity.

Besides, water is special natural substance, which always keeps moving. This requires special approach in determining economic parameters of water as a natural resource, as well as a product and raw material, in its utilization by the population and various technological industries, first of all irrigation - the main consumer of water resources in Central Asia. In addition to economic and social importance, water has a high ecological value. It can be clearly seen in the following cases. First, water, as an energy feedstock, has obvious superiority over mineral (organic) fuel, being the most affordable, environmentally clean and renewable source of energy. Second, water, impounded in reservoirs, ceases to be environmentally hazardous, therefore preventing floods, mudflows, and excessive winter discharges that cause flooding, waterlogging and glaciation of lower-lying territories of adjacent States.

The economic mechanism for management of trans-boundary water resources includes methodological regulations for identifying different types of water tariffs and assessing damage from construction of the Toktogul hydroelectric plants and its operation in irrigation mode.

During the economic evaluation of water resources, three levels were identified: 1) formation of runoff;

2) water distribution and transportation with the use of trunk and inter-farm canals in the points of water lots for consumers;

3) water supply using water-regulating facilities - irrigation and power reservoirs.

The zone of runoff formation includes surface water resources from water sources to major catchment facilities. In this part of the watercourse, where water is presented in its natural state, it already has economic cost, since the state finances the activities of several organizations, engaged in water resources monitoring and management, research, flood and mudflow control, coast work, reproduction of forest plantations. To compensate these costs, it is necessary to introduce the tariff for water as a natural resource. In order to accomplish it, the “Methodology for determining the water tariff as a natural resource” was developed.

The second level concerns water intake, distribution and water supply, using the trunk and inter-farm canals. The entire complex of works on water intake and water supply in points of water lots is performed by operational water management associations (OWMA), in Kyrgyzstan they are represented by district water management agencies (DWMA). Here we establish the tariff for OWMA water supply services, calculated according to the "Methodology for determining the tariffs for OWMA water supply services to consumers”. This tariff applies to domestic water consumers.

The third level is water supply, using water regulation facilities.

In the Kyrgyz Republic, reservoirs for long-term and seasonal regulation of the flow have been built and maintained. Some of them - Toktogul, Orto-Tokoi, Kirov and Papan reservoirs - are objects of interstate significance, serving water consumers of Kyrgyzstan, Kazakhstan and Uzbekistan. At this level, the tariff for regulation, calculated according to the "Methodology for determination of tariffs of water, regulated by irrigation and complex reservoirs”, is set.

The interstate water tariff is set for Kyrgyzstan’s neighboring States, which use its water resources, and is calculated as the sum of the water tariff as a natural resource and the water tariff, regulated by irrigation and complex reservoirs.

All developed methods are based on the cost-normative principle of costs formation, when the main determinants of prices are the actual operational costs and regulatory profit of budget organizations, serving the water industry, and the amortization and maintenance works costs are calculated not on actual basis, but according to the standards, which is the essence of the cost-normative principle. This will enable water management organizations to receive sufficient funds for current and capital repairs of fixed assets.

By the use of the calculated tariffs, it is quite easy to solve the problem of determining the equity participation of water consuming states in water management costs for a particular facility.

The methodology, used to calculate the annual loss caused by constructing and operating the Toktogul waterworks facilities of inter-state significance, is based on the principle of compensation of costs of negative consequences. They are associated with flooding and waterlogging when reservoirs are constructed, with electricity underrun in winter because of drawdown of reservoirs in accordance with the irrigation schedule, with its subsequent compensatory output at the thermal power station, causing environmental damage from burning fossil fuels.

Annual total damage made to Kyrgyzstan is estimated to be 154.9 million dollars.

The Republic is interested in compensation of these damages by Kazakhstan and Uzbekistan, because this will solve all the existing problems:

- Flooding and waterlogging in the autumn-winter period in the Kazakh and Uzbek territories:
- decrease in water supply during the growing season, and Kyrgyzstan will be able to use the received funds:
- to purchase energy resources, where it is economically advantageous;
- to modernize the Thermal Power Plants.

This approach seems to be more efficient than the existing barter exchange of summer electricity for energy resources, existing under the Agreement of 1998. Every year, it is more difficult for Kyrgyzstan to sell the summer electricity, which entails failures in the supply of gas, coal and fuel oil. As a result, there is malfunction of the technological cycle at the Bishkek thermal power station.

The above-mentioned research works, aimed at protecting national interests of the Kyrgyz Republic and ensuring regional stability in Central Asia, indicate that science in our country is capable of solving complex water and energy problems. Why doesn't the science have effective impact on hydropower relations between Kyrgyzstan and neighboring countries then?

Answering this question, we must think about the purpose of academic science. Theoretically, science cannot reflect the interests of either the majority or the minority, not to mention individual interests. It must impartially identify problems, understand the essence of these problems and propose solutions. In Kyrgyzstan, unfortunately, the proposed research findings remained unclaimed for a long time, due to well-known economic and political circumstances.

We hope that this situation will change for the better, and the academic science of Kyrgyzstan will take an important place and application in solving water and energy problems in Central Asia.

Generalist's Approach on Water Resource Management Issues in Central Asia; Some Advices with Reflections from South Korea's Experiences During Last Half a Century

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1. Introduction

Central Asia has many problems in water resource management, such as water scarcity, water quality degradation, inefficient water use, etc. These problems may be typical in many developing countries, however, particularly vulnerable environmental conditions and complex geopolitical situation of Central Asia would make it even more difficult for the countries in the region finding effective measures. Furthermore, recent trend of rapid economic development with less attention to environmental conservation would make matters even worse (Granit et al., 2010; IWP, 209).

For improving such difficult situation in the region, many regional and international expert groups are eager in delivering their professional solutions. However, this is the author's feeling that those measures are often based on rather narrow perspectives and hence sometimes may lead to some conflicting directions. For example, some experts suggest strong water conservation measures while some specialists encourage extensive hydropower development with the same water source. Expert groups' various disciplines, such as economics, energy planning, civil engineering, environmental conservation, etc. and their different interests may be the main reason which calls for those conflicting resolutions making effective water resource management at the national and regional levels even more complicated.

Often observing such embarrassments in Central Asia, the author would like to submit a generalist's approach. This is the author's wish that South Korea's successful water resource management practices, while not sacrificing economic development during the last half a century, 1960~2010, provide some insights for preparing more effective water resource management planning in Central Asia.

2. South Korea's recent experiences in water resource management

Korea’s economic success during the last half a century has become a well known legend. While contemporary Korea in terms of economic development, as well as environmental management, may seem quite impressive, particularly to the people in the developing countries, 1960s’ Korea, when its national economic development plan was first initiated, was regarded as one of the world poorest states.

As seen in Figure 1, Korea’s GDP per capita in 1960 was only 155 dollars which was smaller than Ghana and China at the time. It took about 15 years for Korea to reach a thousand dollars GDP level. Since the mid 1970s, however, a sharp GDP increase has continued except brief periods of worldwide economic crises in the 1998-9 and 2008-9.

Korea’s poverty until 1960s would be explained mainly due to deficiency of natural resources including available land, water, minerals, and energy sources such as coal and oil. In fact, Korea holds the world’s third highest population density, 450 person/km^2 after Bangladesh and Taiwan, and it’s available water resources, precipitation per capita, is only 2,705 m^3/year while world average precipitation per capita is 26,800 m^3/year. That number is

even far smaller than the ones of all the states in Central Asia.

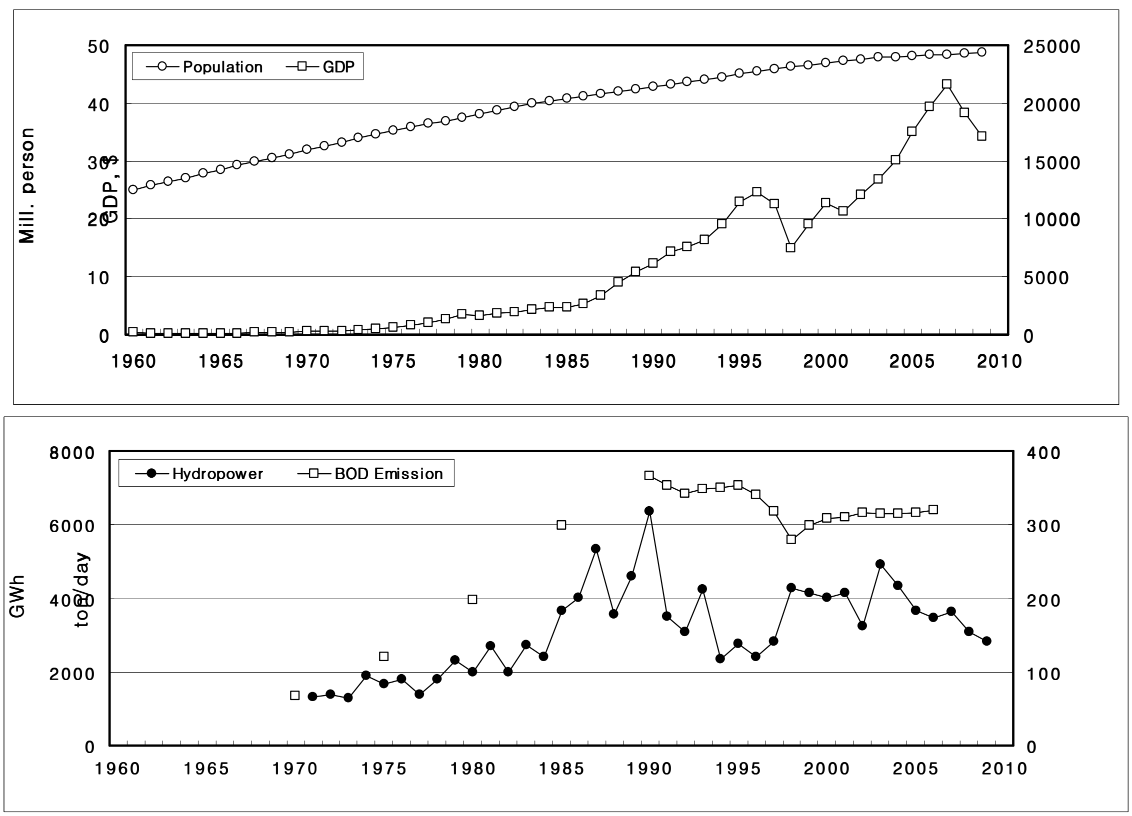

Fig.1. Trend of economic development and water resource development in Korea during the 1960-2010.

As shown in many developed countries, economic development frequently goes with water resource development. This has been particularly true in the case of Korea because of the lack of water and electricity for industrial use as well as for municipal use greatly hindered economic development. For this reason, Korean government launched a systemic water resource development plan from the early 1960s in parallel with the initiation of nationwide economic development.

Until that time, droughts and floods were annual events throughout the country and lack of electricity made even the Capital city of Seoul to be under power rationing. Hence, it was natural that the focus of the first water resource management plan was laid to the construction of multipurpose dams for the integrated control and management of water resources with power production. As a part of the National Master Plan for the Economy and Comprehensive Land Development, the Integrated River Basin Development Plan (IRBDP) of the four major river systems was established and systematically implemented. During this period of 1965-1980, great successes were achieved in the water resource development and management. Reduction of flood damage by 40 % as contrasted with the annual average, 90 % completion of channel improvements, and increase of municipal water supply from 30 % to 60 % were some examples of such achievements. Fig. 1 dramatically demonstrated the increase of hydro power production during this time. This first stage of water resource management planning continued until 1980 (http://english.kwater.or.kr/).

After the completion of IRBDP, the focus of national water resource management has been moved to individual basin development. Political democratization and spring-up of environmental movements since the mid 1980s served as a major vehicle of such changes. Sociopolitical ideology changes from ʻcentralizationʼ to ʻlocalizationʼ also provided great help. The achievements between 1980 and 1995 included the completion of multipurpose dams and multi-regional water supply systems throughout the country.

Korea has been experiencing serious water pollution problems since its first stage of economic development but the government hardly acknowledged it until the mid 1980s. Since then, government efforts toward improving qualities of drinking water sources, mostly large-rivers in Koreaʼs case, has escalated until early the 2000s by investing large quantities of money and manpower. Water quality of most rivers and lakes improved slowly from the 1990s and continued through the 2000s, but achievement in water quality seems not enough when compared to the success obtained in water resource development.

It would be worth to point out that in the early stage of water resource development during the 1960s and 1970s, foreign aids, in terms of capitals, technologies and skilled manpower, were essential. Without such supports, Korea would never have solved such problems like lack of water and electricity which were urgently needed for its economic development. In this regard, it may be fair to say that timely start-up of water resource development with maximum supports from foreign countries have served as a concrete foundation for establishing contemporary Korea.

Another thing worth mentioning is that Koreaʼs timely investment for higher education enormously contributed to pursuing water resource development and water quality protection. In the early days of the 1960s, the number of qualified engineers and scientists was significantly limited, hence most water works including planning for water resource management had to be carried out by foreign engineers. However, this dependency quickly alleviated as many domestic universities and engineering schools opened and produced enough qualified engineers as well as well-trained scientists. Since the 1990s high qualification of Korean workforces in such fields of water resource development and water quality protection have become well-known worldwide, particularly in the Middle East and South Asia.

3. Speculations on water resource management issues in the region

Like Central Asia, Korea's geographical condition is not so favorable for water resource management. Two thirds of annual precipitation is often concentrated to two-summer months frequently causing high floods in summer and long droughts from winter to the next monsoon season. In the early stage of economic development in the 1960s and 1970s, rapid industrialization and urbanization demanded significant increase of water supply while agricultural water consumption also increased by doubling every decade (Fig. 2). Until the late 1980s, when Korea gained some fruit of economic development, lack of capital, technology, and qualified manpower was overwhelmed. Probably, the current difficult situation which contemporary Central Asia is facing in terms of water demand and consumption may be comparable to that of South Korea in the 1970s and 1980s.

In this regard, Korea's experience in water resource development and management in its early stages, from the early 1960s to late the 1980s, could provide some insight for better implementation of water resource management practices in the 21st century Central Asia. The following are some speculations the author would like to share with those who are working in the fields of water resource related business in Central Asia, particularly with the scientists and engineers.

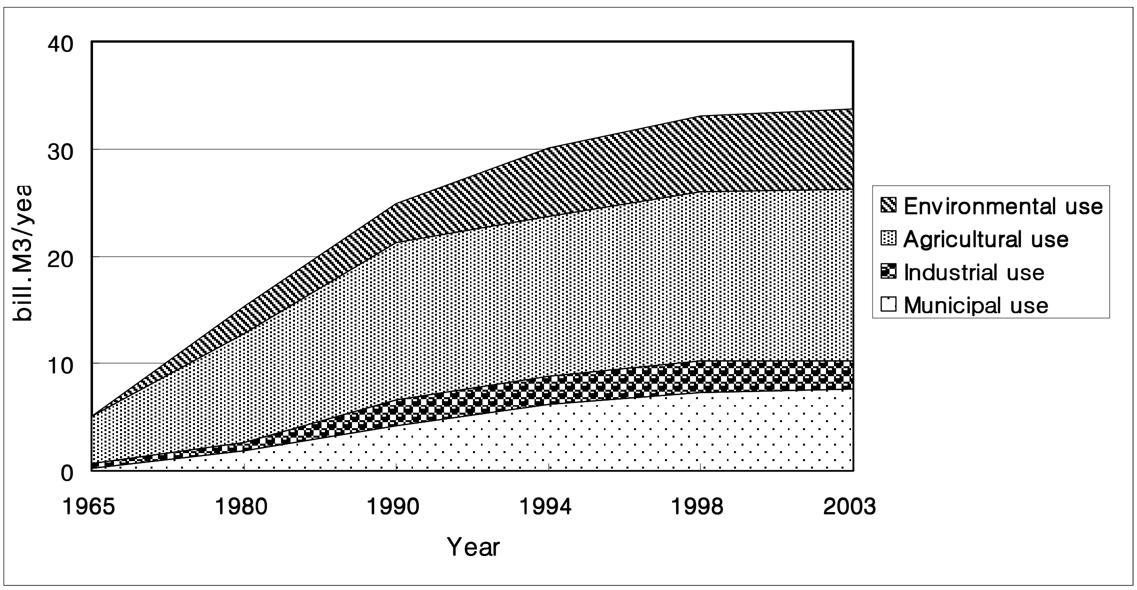

Fig.2. Trend of water consumption in South Korea during 19665-2003.

1) Short-term and long-term projections

First of all, Korea's early history of water resource development would suggest that as one country starts economic development with modernization the demand for water dramatically increases. Fig. 2 shows that in the early stage of industrialization and urbanization during the

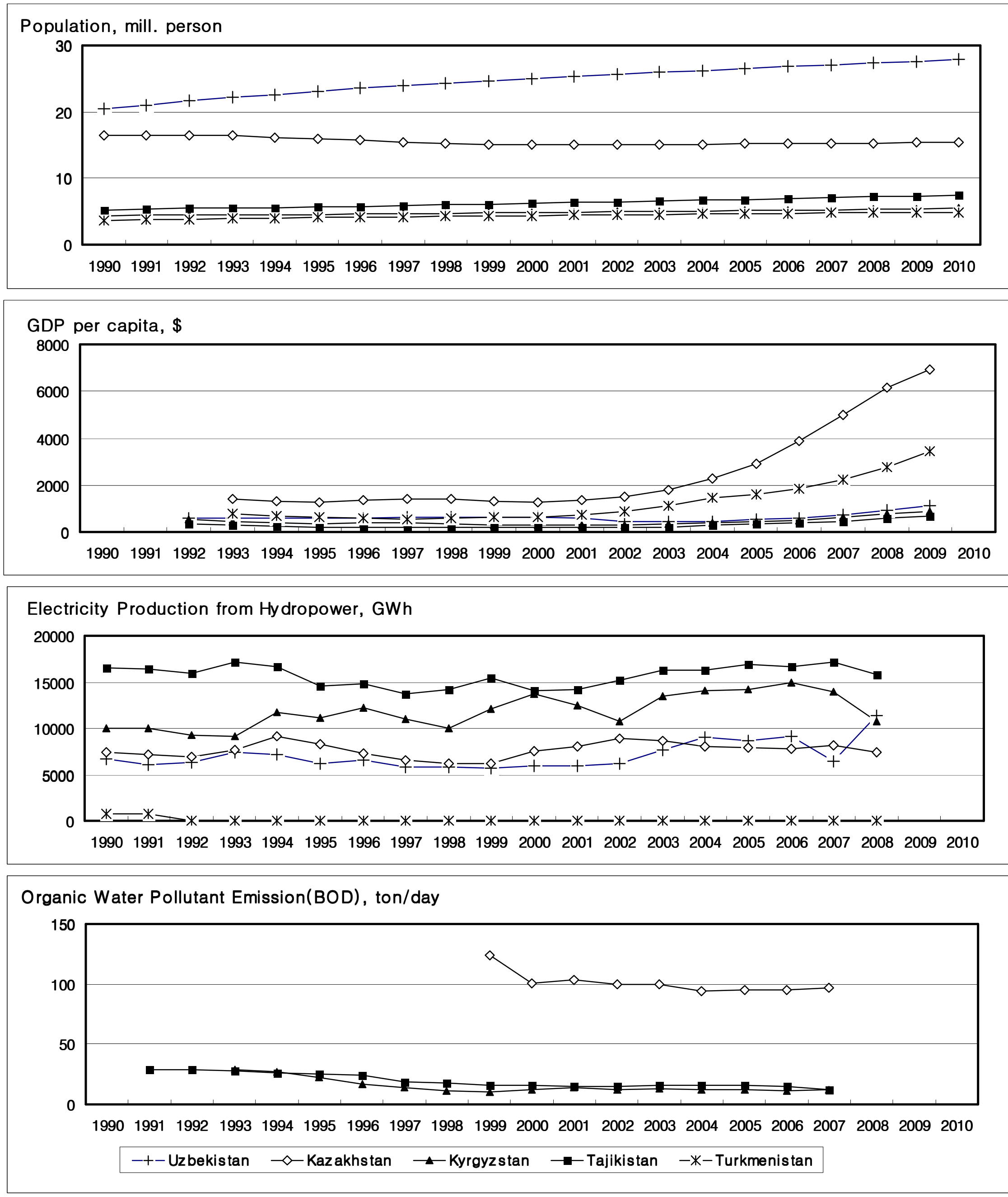

Fig.3. Trend of economic development and water resource development in Central Asia during last two decades.

1960s and 1970s Korea′s water consumption tripled from 5.12 billion M^3 to 15.3 billion M^3 within just 15 years, 1965-1980, and almost doubled up to 24.9 billion M^3 in the next 10 years. It should be noted that the most significant increase of water consumption was observed in the sector of municipal use while the increases in the industrial and agricultural sectors were rather moderate. However, as the country being more modernized with rapid industrialization, the rates of water consumption increased in the industry sector exceeding the ones in agriculture and in municipal sectors.

Korea′s such experiences in water demand would provide some insight to the prediction of how the water demand-supply relationships in Central Asia be proceeded in the next couple of decades.

Most Central Asian countries had to endure serious economic retreats throughout the 1990s and the first half of the 2000s as shown in Fig.3, however, overall economy in the region seems to take off from the mid 2000s (World Bank, 2010). Particularly, GDP increases in such countries like Kazakhstan and Turkmenistan already has tripled and doubled respectively within recent several years. Economic development in other countries may need more time to grow, but when the time comes eventually water demands in the region would far exceed the capacity that the current supply system could provide. In this regard, the most important task in the region would be increasing the water supply capabilities. Thinking such a possibility that water demands in the region could be doubled or tripled within the next decade or two, the author would like to strongly propose that the expansion of the current water supply system is the most important thing to do now, and hence dam construction projects under consideration shall be treated more favorably than many specialists are arguing. Modernization of old dam structures and improvement of water channel systems would be the next best thing to do in terms of water supply capacity increment.

Dam construction also has the advantage of electricity production which is surely a prerequisite for economic development. For this reason, Korea had given its utmost priority to the hydropower development when its first nation-scale water resource development plan was initiated. A sharp increase of hydropower production until the 1990s shown in Fig. 1 greatly helped economic development at its early stage in Korea and this example will also be applicable in most countries in Central Asia.

Fig. 1 also clearly shows water pollution problems in Korea have risen in parallel with its modernization. However, the need for water pollution protection was frequently ignored by the government and it was in the early 1990s when they finally decided to resolve water pollution problems with massive investment of capital and manpower. But Korea′s efforts for water pollution protection seemed to be somewhat late and therefore the improvement is still being continued only with limited success.

As observed in Korea, Central Asia would face significant water pollution problems in the near future whether this region get success in resolving serious water shortage problems or not. More the pace of current water resource development is delayed, more critically water pollution problems next to come shall hit.

2) Water governance vs. water resource management practices

It has been widely recognized that water-food-energy nexus in Central Asia is particularly strong. Recently this unfavorable relationship is being worsened mainly because of serious water resource deficiencies. For example, the 2007-2008 drought brought significant reductions of crop production and hydropower generation and eventually deepened long-lasting tension between countries in the region by causing so-called “upstream-downstream conflicts.”

In order to improve such a situation in Central Asia, many domestic and international expert groups have actively delivered their professional solutions in favor of water governance (ADB, 2008; Sojamo, 2008). However, this is author feels that emphasizing regional water governance too much sometimes could lose time in which is desperately needed for implementing more effective measures. In Central Asia′s case, no matter how sophisticated the water governance system is implemented in the region the possibility of fundamental improvement in the current situation shall be limited without greatly increasing water capacity by constructing new dams, improving existing dam infrastructures, and applying new water saving technologies in irrigation, municipal and industrial water use (Linn, 2011). However, since most water policy-related publications in the region are prepared by international groups mainly composed of specialists with social science backgrounds, such engineering-oriented resolutions are frequently underestimated.

On the contrary, Korea′s experience demonstrates the importance of science and engineering in water resource management. As discussed before, Korea enormously expanded its water capacity by applying hard technology and that provided a momentum for economic development. This hard technology-based strategy included not only application of such water capacity enhancement options mentioned above but also early investment to higher education particularly in science and engineering and the opening of the nationwide authority named Korea Water Resource Development Corporation which served as a main vehicle of most engineering works needed for water resource development.

In seeking strategies for lessening water-related stresses in Central Asia, Korea′s experience would serve as a model. Here, this is the author′s opinion that developing hard technology based-resolutions is tremendously important and sometimes would be more effective than pursuing social science-based strategies like water governance establishment.

3) Challenges for Integrated Water Resources Management

Integrated water resources management (IWRM) is a series of processes for managing water resources in a harmonious and environmentally sustainable way by gradually uniting stakeholders and involving them in planning processes. Ever since it′s formal introduction to the science community in the early 1990s, IWRM has been widely investigated and applied worldwide. The idea of IWRM was introduced to Central Asia at its early developmental stage, probably by the foreign experts working for international aid institutions, and actively implemented since the late 1990s (McKinney, 2003; Dukhovny et al., 2004)). For this purpose, Interstate Commission for Water Coordination of Central Asia (ICWC) even established the Central Asia IWRM Resource Center as an arm of the Scientific-Information Center (SIC ICWC) of it.

However, IWRM was considered as rather an elusive concept by many people and many countries that have implemented IWRM plans have often faced the challenge of what this means on the ground. Also, some experts pointed out that implementation of IWRM requires an enormous amount of resources and information which are hardly available in most countries, particularly in the developing countries (IWMI, 2004).

In Korea, the methodology of IWRM was first introduced in the mid 1990s and since then a series of nation-scale research has been carried out for more efficient implementation of it. However, establishing IWRM in Korea has never been an easy task and is still regarded as an ongoing research project with limited success (http://water21.re.kr/en/index.asp).

Korea is a small and very homogeneous country in every sense. However, implementation of IWRM has been frequently confronted with a strong reluctance of involved stakeholders. Particularly, opposition of some officials of central and local governments and water agencies who worry about losing their jobs made the practices often delayed and prolonged. Integration of opinions from other sectors, such as various interest groups including agriculture, industry, commercial businesses, and NGOs has also been very difficult. In other words, what makes implementation of IWRM in Korea less effective was not a lack of research, resources, or manpower but a difficulty of uniting various stakeholders and impartially distributing the costs and benefits to them.

Considering the complexities of Central Asia in terms of society integrities, economic conditions, and differences of social cultures and customs among involved countries, active implementation of IWRM in the region would require a lot more effort and time than many supporters of IWRM expected.

4. Conclusion

Central Asia's water problems are very complicated in nature and hence solving them would require enormous efforts in terms of time, money, and sociopolitical coordination. For resolving such problems numerous ideas and suggestions have been proposed, mostly by the international expert groups which usually have different backgrounds and interests each other.

Recent history shows that Korea has been quite successful not only in economic development but also in water resource management. Korea launched its first-stage water resource development plan as a part of the National Master Plan for the Economy and Comprehensive Land Development in early 1960s and since then water resource development and economic development always went together supporting each other during the last 50 years. In this regard, Korea's experience in water resource development and management would serve as a model for the Central Asian states.

This is author's speculation that water demands in Central Asia would be greatly increased in the near future with regional economy being improved. Korea's experience suggests that doubling or tripling in water demands within next a decade or two is not impossible in the region. Therefore, increasing water supply capacity would be most important task to be carried out without delays. Such measures like dam construction, modernization of old dam structures, improvement of water channels and water savings in every sector should be actively pursued by the governments, regional authorities and international aid agencies.

Establishing regional water governance and implementing integrated water resource management (IWRM) in Central Asia would be good options for distributing the costs and benefits of water use to the stakeholders, but would be not enough solving water problems if the demand and supply relationship is seriously interrupted. Korea's experience demonstrated such soft-science based approaches often required too much time and efforts while only limited successes were obtained with them.

Finally, investment to the higher education for cultivating qualified scientists and engineers should be emphasized. As water resource management becomes more and more important in Central Asia, the need for such qualified manpower will also be increased as Korea's case proved. This is author's belief that early investment for higher education should be regarded as a key for successful water resource management in the future.

References

1. ADB, Improved management of water resource in Central Asia, Project Number 41316, 2008.
2. Dukhovny, V. et al., Some ideas about IWRM implementation in Central Asia, Seminar on the role of ecosystems as water suppliers, Geneva, 13-14 December 2004.
3. Granit, J. et al., Regional water intelligence report Central Asia, UNDP, Water Governance Facility, and SIWI, Stockholm, 2010.
4. IWMI, IWRM challenges in developing countries: Lessons from India and elsewhere, Water Policy Briefing, Issue 24, IWMI-TATA Water Policy Program, 2004.
5. IWP, Central Asia: long-term challenges and short-term crisis, 17 March 2009.
6. Linn, J. F., Water-energy links in Central Asia: A long-term opportunity and challenge, Brookings Institution, June 30, 2011.
7. McKinney, D. C., Basin-scale integrated water resources management in Central Asia, Third World water Forum, Regional Cooperation in Shared Water Resources in Central

Asia, Kyoto, March 18, 2003.

8. Sojamo, S., Illustrating co-existing conflict and cooperation in the Aral Sea Basin with twins approach, Rahaman, M.M. & Varis, O. (eds.): Central Asia Waters, pp. 75-88, Water & Development Publications, Helsinki University of Technology, 2008.

9. World Bank, World Development Indicators, 2010.

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Economic Issues of Energy and Water Utilization in Central Asia

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Abstract

In contrast to Indo Basin, the Central Asian countries are closely interdependent in their water utilization. Most of the water in the Aral Sea Basin is from upstream river waters, whereas in Kazakhstan, Turkmenistan and Uzbekistan water is mostly used for irrigation in downstream areas. Competing demands for water in the region have considerably exceeded supply for a long time. In the future, water shortages will only worsen in Central Asia because of the growing population, the development of industrial and agrarian production and the expansion of irrigation. Tajikistan and Kyrgyzstan have vast hydro energy capacity, but are heavily depend on the supply of hydrocarbons from other countries in the region. During winter 2008, public electricity and heating was completely cut off in Tajikistan; production of aluminum at the Tajik aluminum plant, the country's main source of foreign currency, fell dramatically. The estimated renewable hydro energy potential of Central Asia is 460 billion kWh per year, but at the present time less than 10 per cent of this potential is used. Energy is mainly produced in Tajikistan and Kyrgyzstan. The low level of power independence and the potential of water resources explain the willingness of Tajikistan and Kyrgyzstan to develop hydro energy in their countries. However, these countries do not have the resources to finance the construction of HPPs and are forced to seek external financing. The region's countries have different attitudes to the construction of HPPs and this acts as a barrier to external investment in such projects. There are many examples across the world of successful cooperation in regulating water resources to the benefit of all participants. Resolving the issues of shared utilization of water and power resources in Central Asia has huge economic, ecological, political and international importance, since it is a major factor in preserving stability, economic prosperity and ecological security in this region. The most important issues in this regard are the management of water and energy resources and leverage of significant long term investment in hydro energy projects. At present, the Production of Primary Fuel and Energy (PPFE) in the region relies mainly on hydrocarbon fuel.). Most of the hydro potential is in Tajikistan (69 per cent), and puts Tajikistan in 8th place in the world after China, Russia, USA, Brazil, Zaire, India and Canada. Kyrgyzstan accounts for 22 per cent of the region's total hydro potential. In managing water resources and energy production, the regional governments must balance competing demands between urban and rural, rich and poor, the economy and the environment**.** However, because people have triggered this crisis, by changing their actions they have the power to prevent water scarcity and energy from devastating region's population, agriculture, and economy in the Great Asian Basin (GAB). This paper will address and discuss the issues of water and energy scarcity, management, and solutions for the governments to consider in future.

After the collapse of the Soviet Union the elaborate set of water and energy sharing agreements among the Soviet republics of Central Asia largely broke down and the previously integrated regional water and electricity infrastructure became fragmented and suffered from lack of maintenance. With overuse and poor water management, agricultural yields declined, and the water levels of the Aral Sea dropped rapidly. As a result the provinces around the Aral Sea, in particular the Karakalpakstan region of Uzbekistan, suffered great hardships and increases in poverty. An estimated one third of the population uses drinking water that does not meet quality standards and the problem is acute in Bukhara, Navoi, Khorezm and Karakalpakstan regions.

The situation in Karakalpakstan and Khorezm areas has declined further as a result of two consecutive years of drought. The drought has so far affected 2.5 million people, resulting in 2 years of crop failure in 2000 and 2001 that has deteriorated the local economy which is dependent heavily on agriculture.

By the water problems erupted, relations among the former Soviet Republics have been strained, especially between Tajikistan and Kyrgyz Republic on the one side and Uzbekistan on the other. Tajikistan, the poorest of the former Soviet republics of Central Asia, has move ahead unilaterally in the construction of a project which will allow it to become a net exporter of electricity. The Rogun Dam, which was first planned as a gigantic Soviet hydro-electric power project, stalled when a civil war erupted in Tajikistan in the early 1990s after the breakup of the Soviet Union. Uzbekistan has cut natural gas exports to Tajikistan because of the tension between two states. It is also known that, the two countries have long been at loggerheads over a number of issues from energy supplies to cultural struggle.

The main regional rivers - Syr Darya and Amu Darya with their tributaries - are the only fresh water sources for the entire five countries of the region and are of great importance to the region's economy, since agriculture contributes a large share to the countries' GDP - in Kazakhstan it is an estimated 6%, in Kyrgyzstan 34%, Tajikistan 21%, Turkmenistan 25% (2003 data), and Uzbekistan, 23% (World Bank 2007). More than 90% of the Amu Darya and Syr Darya waters are used for irrigation and about 60% of rural residents using these rivers are engaged in agriculture.

Since the Syr Darya and Amu Darya originate in Kyrgyzstan and Tajikistan, these two countries are considered upstream countries, the other three countries - Kazakhstan, Turkmenistan, and Uzbekistan – located at the lower reaches of these rivers and are called downstream countries. Central Asia's irrigated lands are located mainly in the downstream countries - 85% - while only 15% are in the upstream countries (Table 1). This kind of natural distribution pattern of water in the region gave the Soviet-era Kremlin reason to designate Kyrgyzstan and Tajikistan as water providing countries to the rest of the region. During this time, centralized water management controlled by the All-Union Ministry of Water Resources based in Moscow established water limits for each country in the region (Dukhovny 2005). Starting from the 1960s, large construction projects of dams and reservoirs were launched in the upstream countries, while at the same time irrigation systems were developed in the downstream countries. According to the barter agreements concluded during Soviet times that are still partially in force, water collected in the reservoirs in autumn-winter is released in spring-summer to irrigate Uzbek, Kazakh, and Turkmen agricultural lands. In return, the downstream countries provide the upstream countries with gas, oil, coal, and the electricity which the upstream countries cannot produce. This kind of heavily interdependent infrastructure works properly only if these countries remain united. Therefore, it is not surprising that with the collapse of the Soviet Union, this system resulted in negative consequences and caused serious cross-border tension.

Conflict potential and threats to the region

The circle of the well-established Soviet water-energy exchange process was broken after independence, as each country in the region started experiencing lack of dialogue, coordinated action, and cooperation among national authorities dealing with water management. As a result, in the post-Soviet years each state had to work out its own strategy of development based on their national interests and available resources. However, those strategies brought little if any results due to difficult economic situations in these countries. In these conditions the uneven distribution of water resources led to the clash between the providers (Kyrgyzstan and Tajikistan) and consumers (Uzbekistan, Turkmenistan, and Kazakhstan) of water. In the so called globalization era, Central Asian domestic and foreign economic, social and political developments are tightly interconnected with global events. Thus, the tense geopolitical situation around the region, accompanied by economic sanctions against a number of Central Asian states, as well as ongoing domestic transformation processes led to the reduction of foreign investment flows into large scale projects in Central Asia. Foreign financial assistance accompanied by technical and expert-consultative assistance to the countries would be timely given the world economic crisis that would radically improve their economies. Nevertheless, the countries have opted for utilising their own capital and natural resources.

Although Central Asia is abundant with valuable natural resources, their distribution in the region is uneven - Tajikistan and Kyrgyzstan are very poor in fossil fuels (oil, gas, coal) but very rich in potential hydropower, while downstream countries are rich in fossil fuels but poor in potential hydropower. For example, Kyrgyzstan almost totally depends on oil and gas imports from Kazakhstan and Uzbekistan. Oil and gas rich Kazakhstan depends on Kyrgyzstan and Uzbekistan for 60% of its electricity and buys gas from Uzbekistan. Kyrgyz and Tajik hydroelectric stations (HES) provide Uzbekistan with irrigation water during planting periods to satisfy its seasonal needs in electricity (Dorian 2006)

Therefore, while natural resource-rich Uzbekistan, Kazakhstan, and Turkmenistan can elaborate more or less independent strategies in their economies, small and economically weak Tajikistan and Kyrgyzstan have to rely on the success - and largess - of their neighbours, which can incorporate them into large-scale integrated economic projects and thus create favourable grounds for their prosperity. In this sense, the revival of the Great Silk Road with its transport branches on their territories is of special interest to Bishkek and Dushanbe in their efforts to be integrated into the regional and world economy.

Nowadays, Dushanbe and Bishkek are interested in the use of water for the production of hydro-energy to satisfy their own needs and to export it to third countries. The Tajik government, for instance, considers that the only way to become economically sustainable is to develop their hydro-energy sector "as a priority direction in modernization of the state economy" (Khairulloev 2007). As for Kyrgyzstan, it is more ambitious and wants "to occupy leading positions at the energy market of the region" (Bakiev 2009). In this regard, Dushanbe and Bishkek demand that their downstream neighbors increase financial compensation for the exploitation of their HESes in the irrigational mode. For instance, Kyrgyzstan announced its intention to sell water in the National Kyrgyz Energy Strategy for 2008-2010 (2008).

According to some sources, turning water into a commodity was pre-conditioned by the events in 1999, when Uzbekistan substantially decreased natural gas delivery to Kyrgyzstan due to the latter's debt (Business Week 2005). In response, Kyrgyzstan demanded financial compensation for water deliveries to cotton fields in Ferghana Valley. Bishkek justifies its position of receiving financial compensation by calculating economic benefits Uzbekistan and Kazakhstan gained using water that was collected and released for downstream and economic losses Kyrgyzstan experiences as a consequence. For example, they say that both Kazakhstan and Uzbekistan were able to increase the territory of irrigated lands by 400,000 hectares thanks to the reservoirs and dams built on Kyrgyz territory (Kurtov 2004). Uzbekistan alone was able to double the territory under cotton cultivation, the source claimed. Kyrgyz experts say that during 22 years of using the Toktogul reservoir Uzbekistan and Kazakhstan received 7.6-8 billion USD of net profit (Kurtov 2004). According to their calculations, annually Uzbekistan earns 360 million USD and Kazakhstan earns 240 million USD using water resources from constructions in Kyrgyzstan.

However, the idea of turning water into a trade unit has not been welcomed by other Central Asian states, especially Uzbekistan and Kazakhstan. These countries insist on the predominantly irrigational mode of HESes, both built in the Soviet era and planning to be built in the present days. These claims can by justified by the fact that Uzbekistan and Kazakhstan account for 53% and 10% correspondingly of the region's irrigated lands and constitute the biggest share of the region's population (SPECA 2004, Tables 1, 3). Kazakh and Uzbek specialists claim that charging downstream countries for water is unprecedented in international law and within the international community (Taujanov 2009, Rengum 2009a). The mere fact that water originates in a country does not give it the full right to become the sole owner of the water. The upstream countries have to realize that it is universally acknowledged that the absolute sovereignty of upstream countries over available water resources is inadmissible under international law. In this respect, the Preamble of the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (UNECE 1992) states that transboundary waters shall be used through the elaboration of agreements between countries bordering the same waters.

Lack of trust among parties in the region is another factor that impedes consensus. The upstream parties are highly suspicious of annual water allocation quotas (Bogdanov 2009) established by the Interstate Coordinating Water Commission[2] (ICWC), which is based in Tashkent and therefore sometimes does not comply with established and recommended quotas. The upstream parties may presume that calculations on water allocation quotas are done to the detriment of them and benefit only Uzbekistan.

Population growth, melting glaciers, and Central Asia's arid climate constitute natural and human causes for further pressures on drinking and irrigation water. Central Asia's population grows by 1.02% per year (Table 3) which requires additional increases in water resources up to estimated 700 million m3 annually (UNECE 2008). Climate change and global warming put additional pressure on Central Asian water problems. Scientists predict that by 2025, thousands of small glaciers in the Tajik mountains will disappear, the glaciated area will shrink by 20%, and ice reserves will decrease by 25% (Eurasian)

ing technology coupled with weak management does not allow the situation to improve (Biswas 2008).

New tendencies

The severe winter of 2007-2008 combined with serious drought hit Central Asia hard, especially the upstream countries, and resulted in a compound water-energy-food crisis in Tajikistan and Kyrgyzstan. If on the one hand, the upstream countries were unable to provide their population with electricity because the water level in their main HESes, Nurek in Tajikistan and Toktogul in Kyrgyzstan, were receding due to reduced snow melt, on the other hand, the downstream countries limited the export of fossil fuels to the upstream countries in order to meet high domestic demands. In addition, as of 1 December 2009 Uzbekistan is not a part of the Central Asian United Electricity Grid System that was partially providing electricity to some regions of four countries except Turkmenistan. Uzbekistan explained its position that it had to take this decision due to unsanctioned electricity withdrawals by Tajikistan that were threatening the security of transmission lines and caused their damage thus posing a serious threat to energy security of the country (Gazeta.uz 2009). Although Uzbekistan could provide electricity to the parts of the region that were dependent from the grid system by building new electricity transmission lines, Tajikistan and Kyrgyzstan experienced problems in providing electricity to their parts of the country (Kholmatov 2009, Central Asian News 2009).

These negative implications pushed Tajikistan and Kyrgyzstan to accelerate their plans to complete the construction of reservoirs and hydro-electric stations started in the Soviet times and to build new ones. Dushanbe plans to finish Rogun HES with the capacity of 3600 MWt and Bishkek plans to finish Kambarata-1 and 2 with the capacity of 1900+360 MWt. While by building these HESes the upstream countries hope to meet their domestic electricity requirements with a surplus for export to China, Pakistan, Afghanistan, and other countries, the downstream countries fear that the planned large-scale dams might reduce the amount of water available for irrigation and strengthen the control over water resources by the upstream countries.

The upstream Central Asian countries lean towards the notion that economic benefits are enjoyed mainly by the upstream countries that build dams and reservoirs (SPECA 2004). In these terms, Ostrom (1994) argues there are two types of issues when several countries have to use common water resources. The first problem is called appropriation and takes place when only one member enjoys the benefits of the water resources instead of making it available to others. In the situation of Central Asia, once the large-scale dams are built, the filling of empty reservoirs with water will present an appropriation issue and impact significantly on the flow regimes in downstream river sections. The second issue is called provisional and relates to the operation and maintenance of dams that will directly impact the environment and safety of people. Wegerich (2007) presented a similar explanation where he argued that the construction of large dams mainly present a zero-sum game, in which upstream countries receive the benefits and downstream countries are subservient.

Theoretically, building large scale HESes in the upstream can be either advantageous or disadvantageous for downstream countries. If the water from the dams can be used both for producing electricity and agriculture by co-riparian countries at the same time, this will result in a win-win solution. However, if water is released when it is not needed for downstream irrigation, it is only the upstream country that will have the benefits; not the downstream who experience losses in irrigation (Wegerich 2007). With the current difficult political conditions and lack of cooperation among the countries in Central Asia, the downstream countries experience to a lesser or greater extent the latter situation.

However, firstly, if on one hand the intentions of Tajikistan and Kyrgyzstan to develop large-scale dams can be understood and seen by them as a way to become economically sustainable and reduce poverty, on the other hand, such big projects need to be technically feasible, economically efficient, environmentally friendly (Biswas 2008) and most importantly, negotiated with the countries that historically have been using water from the same rivers. Secondly, there are a range of economic, ecological, and political threats to the viability and stability of the Central Asian region should these plans be carried out:

Economic threats. In regard to Tajikistan's Rogun HES, a staff member of the Institute of Water Issues at the Academy of Science in Dushanbe, has stated that the construction of Rogun is an ineffective and overly costly project (Petrov 2004), as an alternative plan for diverting the flow of the Pyanj River towards Vahsh HES would require a total cost of 340 million USD, while the Rogun project costs 2 billion USD.

According to another Tajik power engineering specialist’s view, the Rogun project is not a cure for the current energy issues the country is experiencing every year (Safarov 2008). First, according to the source, the project itself is not attractive for investors: even if the reservoir is built, several decades will pass before it starts repaying. Second, the source continues that 50-60% of the produced electricity from Rogun will go to a planned new aluminium factory, the remaining 40-50% will not be enough either for selling abroad or providing to the population. Third, every year in winter large-scale reservoirs in Tajikistan have to limit electricity production due to reduced water flow as a consequence of limited snow melting during that period (Safarov 2008). These limitations in combination with usually experienced dry years would result in shortages of electricity production that again will not be enough for its own population and commercial purposes. Thus, the country cannot escape electricity and fossil fuel dependency on its neighbours, regardless of whether or not it builds the Rogun HES.

Ecological and technical threats. Majority of HESes in the region have deteriorated due to lack of funds for needed renovations and modernization (Dorian 2006) therefore, specialists in the region do not rule out the probability of a replication of the Sayano-Shushensk type of accident that took place in Russia on 17 August 2009. Central Asian large-scale HESes were constructed during the Soviet time under the same general plan and the turbines of Toktogul HES (in Kyrgyzstan) are 35 years old and were bought from the same plant as those for Sayano-Shushensk (AKIpress 2009). The deterioration of the HES equipment in Kyrgyzstan reaches 70% (Centrasia.ru 2009; 12.uz 2009; Beliy parus 2009).

Kyrgyz and Kazakh scientists have highlighted several environmental and technical risks of building a new HES in Kyrgyzstan due to its location in a major seismic zone (Jalgasbaev 2009). The earthquake that took place in 1992 in the Suusamyr Valley, which had before been defined as a seismically weak region, clearly showed the danger of building new dams in mountainous Kyrgyzstan. Some sections of the Kambarata-2 dam dislodged as a consequence of the tremors and later in 1996 further damage to the dam took place. Indeed, Central Asia's earthquake frequency is one of the highest in the world (GeoHazard International 1997). According to the 1978 official Soviet seismic hazard map, most of the territory of Tajikistan and Kyrgyzstan can experience seismic intensity up to 9 (the highest is 12) on the Medvedev-Sponheuer-Karnik scale which is enough to cause the destruction of many ordinary buildings and heavy damage to well-built structures such as water dams.

At the same time, the radioactive and toxic waste in Kyrgyzstan can pollute its own territory and the territories of Uzbekistan and Kazakhstan in case of landslides and flooding and could cause ecological disaster at the most fertile territory in Central Asia– Ferghana Valley.

Representatives of the Institute of Seismology in Uzbekistan assert that the construction of any big hydro- technical objects in the valley of the Naryn River or on the territory of Rogun HES could stimulate a cascade effect in which an insignificant breakthrough in one place provokes a chain reaction of irrepressible flow of water and dirt masses (Usmanova 2009). This can stir up vast economic and ecological damage to downstream states and sharply increase the seismic activity of the Hyssar-Kokshaal seismogen zone. As a consequence, the Sarez Lake in Tajikistan with the volume of 17 cubic kilometres of water threatens to flood a territory with more than 5 million people (Faskh

Problems with payments due to economic difficulties and disagreement over energy and water prices among the countries in the region (Dorian 2006) provoked tensions in Kyrgyz-Uzbek and Tajik-Uzbek relations and has led to confrontations and supply cut-offs.

Although Russia had been giving financial and political support to Kyrgyzstan in building its HESes, the last official stance came during Russia's Vice-Prime Minister's visit to Uzbekistan at the beginning of 2010. He announced that construction of large-scale HESes can not be launched without the consent of neighbouring states and Russia will not finance the projects until it receives the results of international expertise (Central Asian Portal 2010). Moscow had earlier suspended giving credit for a total sum of 1.7 billion dollars meant for the building of Kambarata-1 (Eurasianet 2010). Two possible reasons were given for that: first, Russia, after discovering unexplained spending from the first credit tranche by the Kyrgyz government, was waiting for an explanation. Second, Russia did not want to upset Uzbekistan, whose discontent with Russia was increasing due to the support Russia had given to Kyrgyzstan in building the station.

From its side, Tajikistan inclined to continue energy cooperation with Russia in the framework of the Eurasian Economic Cooperation group, but unlike Bishkek it relies on expanding trilateral cooperation with Afghanistan and Pakistan too. At the New York Summit on the Global Climate Change, Dushanbe reiterated its readiness to increase its hydro energy potential (Rengum 2009b).

During a meeting between the Presidents of Uzbekistan and Kazakhstan that took place in 16-17 March 2010, the Kazakh President announced that he totally shared the concerns of Uzbekistan in regard to the building of Rogun and Kambarata-1 and 2 HESes. He highlighted that he would support the building of the HESes subject to receiving objective international expert analysis of these projects (Panfilova 2010). If an independent international body proves that the downstream countries will not experience any negative consequences, Uzbekistan and Kazakhstan are ready to invest in the construction of large-scale HESes both in Kyrgyzstan and Tajikistan (Rengum 2009a). Thus, Uzbekistan and Kazakhstan request a guarantee that building of new large-scale dams in the upstream countries will not result in worsening the ecological environment or affect the current water usage balance, especially during irrigation seasons.

Overall, two obvious contradictory tendencies exist now in Central Asian development. The first tendency reflects the Central Asian traditional orientation towards Russia, which was demonstrated by signing a customs union agreement on 27 November 2009 by Russia, Kazakhstan, and Byelorussia with potential inclusion of Kyrgyzstan and Tajikistan (Khramkov 2009, Kirmel 2009). Simultaneously Moscow has signed an agreement with Dushanbe on the mutual cooperation in combating drugs trafficking (Khamrabayeva 2009).

The second tendency reflects efforts of the Central Asian states to reunite themselves. This can be illustrated by the intentions of the parties to continue to strengthen regional cooperation and continuation of multilateral and bilateral negotiations among all sides. It is worth mentioning that for the past many years Central Asian states have been able to find compromises, despite staging economic, tariff, custom's duty "wars" and other non-military conflicts (Joldasov 2009). A certain ethno-national and religious-cultural closeness serves to soften positions of the opposing sides in Central Asia. Therefore, there is a high probability that Tajik-Uzbek water issues and other tensions will be resolved peacefully. First, Dushanbe agreed to conduct independent comprehensive assessments on the techno-economic, social and environmental viability of the Rogun HES. The World Bank is funding a study that will evaluate technical soundness, economic viability and compliance with all relevant environmental and social safeguards of the station (World Bank press release). Second, Uzbekistan is the second biggest trade partner after Russia for Tajikistan (Gazeta.uz 2007). Third, the Tajik-Uzbek Intergovernmental Commission that was inactive for the last 10 years resumed its work in February 2009. Fourth, the cooperative approach of Tajikistan towards Uzbekistan has been reconfirmed recently by the Tajik readiness to sell electricity to Tashkent cheaper than to its own citizens. Forth, the President of Tajikistan proposed to announce the year of 2012 as an International year of water diplomacy during the 64th session of the General Assembly (President.TJ 2009).

The former Kyrgyz leader also declared his readiness for constructive dialogue on water issues with all Central Asian states (Zpress.kg 2009). He stressed that the mutually supplemental character of the Central Asian resources is a precondition for a stable energy system (Bakiev 2009). With the current ongoing transformation in the government of Kyrgyzstan and the change of the leadership, the official stance in the water issue is still unclear.In these circumstances much also depends on the success of Uzbek-American cooperation in construction of the railroad to Afghanistan. The potential success of this project can serve as an indicator for more a favorable transformation in public opinion and unite all opposing sides in the region.

Ongoing discrepancies and absence of compromise and unity among the Central Asian states on water issues have already spawned the growth of economic, ecological, political threats and challenges to the region that have possibilities for turning into local military conflicts. One must ask if this process is reversible and, if so, how to do so.

It is clear that the break-up of the single Soviet hydro-energy system in Central Asia and the absence of large-scale investments into the regional economy, aggravated by the global economic crisis, has forced the states into an autarkic situation in which they concentrate on their own resources, the usage and development of which still demand huge investments and material-engineering assistance. These facts together with the current disintegrated state of the region and circumstances of geopolitical competition have led the Central Asian states into conflict with one another due to their contradictory economic interests.

Hence, external factors coupled with internal problems, including the absence of necessary coordination and political will among the players, the absence of effective control bodies over decision-making, as well as an ineffective legal basis and the underdevelopment of the Central Asian states are the main reasons for present water crisis in the region. Thus, the solution of this problem should be also be found in both internal and external actions: internal efforts should be reinforced by the good will of the external regional players, such as Russia, China and the US, external financial-technical assistance, and objective consultation and expertise from the international structures under the aegis of the UN.

A related factor impeding the resolution of the issue is the direct participation of some of the external regional players in the water issue. Countries which are supporting the construction of new HESes in the upstream should realize that their assistance will only intensify the conflicts among Central Asian countries. This factor together with Chinese, European and other interests in the region can exacerbate the competition and interstate tensions in Central Asia, in case the regional actors do not find adequate balance of interests and do not elaborate compromise approach to Central Asia. The Central Asian countries can and must generate the necessary political will to resolve water problems themselves. Only when the countries in the region will have a unified agenda regarding water use, which will take into account the plans and needs of their neighbors, will the tensions be defused.

Water problem in Central Asia : is there a solutions

With the arrival of summer, the problem of water for irrigation is becomes increasingly urgent in the Central Asian republics. With their considerable cultivated lands, Uzbekistan and Kazakhstan are looking at a substantial water shortage this summer. By producing electricity this past winter, Kyrgyzstan delivered considerable amounts of water to Uzbekistan and Kazakhstan in non-irrigation season from its reservoirs. That, in turn, results in a shortage of water in dry summer months. As this problem affects the lives of millions of people, regional cooperation is needed on the use of this scarce resource in the most rational and mutually beneficial way.

In Soviet times, water posed no problem. The upstream states, Kyrgyzstan and Tajikistan, were collecting water in autumn and winter in large reservoirs and delivering it to Uzbekistan and Kazakhstan in the irrigation period. Downstream states, in their turn, provided upstream republics with coal, electricity and other energy resources. Thus, for 68 billion cubic meters of water collected and delivered to Uzbekistan and Kazakhstan during 1986-1991, Kyrgyzstan received large quantities of coal, lubricants, and natural gas. By contrast, 78.125 billion cubic meters of water were similarly released between 1992 and 1997, but the downstream states were increasingly selling their resources on world market prices. Without possessing rich natural resources and being in a hard economic depression, Kyrgyzstan has not been able to pay for importing energy resources on time

During energy crises these last few winters, Kyrgyzstan has been using water for the production of electric energy. But that does not allow water to be collected in reservoirs, and consequently downstream states have less water for their irrigational needs. Uzbekistan’s gas embargo in the winter of this year forced Kyrgyzstan to release water from reservoirs in order to provide the population with energy.

This will obviously cause problems to the downstream states in the irrigation of their lands. According to the KABAR news agency, Uzbekistan may lose about $400 millions of revenues from the sale of cotton as a result of water deficit this year. Kazakhstan’s losses also seem to be significant: the cultivation of cotton and rice in the southern regions depends on water supply from Kyrgyzstan and Tajikistan.

This situation requires an urgent solution. The shortage of water may to some extent be explained by the irrational use of this resource by population. Galima Bukharbaeva, IWPR's regional director in Uzbekistan writes that according to Bioecology specialists, 40% of the water was lost in irrigation system in Karakalpakistan. In this light, rationalization of the use of water seems to be the most logical step to take for the Central Asian governments. Interstate management of water resources is also becoming one of the hottest issues in relations between republics. The idea of demanding a price to be paid for the water collected in reservoirs during winter is becoming more and more popular in Kyrgyzstan. Proponents of this idea argue that downstream states should compensate Kyrgyzstan’s shortage of energy caused by water collection in winter months. Another point raised is that the large reservoirs, serving the whole region, were built on arable land that could bring considerable revenue for agriculture. But opponents argue that water is to be considered as a common good, gifted by the God, which cannot be sold at all.

With the arrival of summer, agricultural fields will soon demand water. It is doubtful whether Central Asian states will be able to cooperate to arrive at a realistic way to provide them with water for irrigation. The political implications of high-level negotiations is also an open question.

SOME SUGGESTIONS ON WATER ISSUES IN ARAL SEA BASIN

1. The data about actual water supply in Amu Darya vary. In order to reach a solution, data of water supply must be clearly put by all basin countries.

2. An expert assessment, accepted by all interested parties, of the Central Asian water and energy shortage and its impacts is needed immediately.

3. Depending on the outcomes of such an assessment, governments of the Central Asian countries need to plan emergency responses, like in the drought of 2000-2001, but at higher and more sustained levels.

4. The long-term prospects of water and energy balances in the region need to be assessed in the light of changing climatic conditions, not only in terms the existing swings of weather cycles, but also in terms of the likely impact of long-term global warming on the water and energy resources of Central Asia.

5. River basin countries should discuss the water problem by using other issues among them. This negotiation strategy may open beneficial solutions on the water issue. Downstream countries can give guarantee on energy issues especially for winter seasons to upstream countries, Kyrgyz Republic and Tajikistan, in order to feel themselves safe and downstream countries can use upstream dams as a regular flow source of water.

6. Basin countries should refrain from third party involvement on the water issue which can impose their political agenda to the basin countries.

7. Follow the statues of 1998 at Almaty between stake holders.

References

AKIpress, 2009. Turbines for Toktogul hydroelectric station purchased on the same plant as those for Sayano-Shushenskaya station [online]. AKIpress News Agency, 21 August. Available from: http://www.akipress.com/_en_arc.php?arc=1&d=21&m=8&y=2009 [Accessed 1 October 2009].

Bakiev, K., 2009. Main development resource – consent and dialogue [online in Russian]. Interview to Izvestiya, 10 July. Available from: http://www.president.kg/ [Accessed 5 October 2009]

Beliy Parus, 2009. Sayano-Shushensk HES. Tragedy causes. Lessons for Kyrgyzstan. [online in Russian]. Beliy parus internet newspaper, 31 October. Available from: http://www.paruskg.info/?p=16588#more-16588 [Accessed 3 December 2009].

Biswas, A., K., Seetharam, K., E., 2008. Achieving Water Security for Asia. *International Journal of*

Water Resources Development, 24 (1), 145 - 176.

Business Week, 2005. Uzbekistan accepts excess water from Shardarya but can return "tsunami" to Kazakhstan [online in Russian]. Business Week, Kazakhstan, 12 February. Available from: www.cawater-info.net/news/02-2005/12.htm [Accessed 29 November 2009].

Central Asian News, 2009. New power transmission line was launched in Uzbekistan, now the south of the country does not depend on Tajikistan [online in Russian]. Central Asian News, 24 November. Available from: http://www.ca-news.org/news/264811 [Accessed 30 November 2009].

Central Asian Portal, 2010. Russia's Vice-Prime Minister announced Russia's stance in building Rogun and Kambarata [online in Russian]. Central Asian Portal, 1 April. Available from: http://ca-portal.ru/index.php?view=article&catid=91%3A2009-01-19-05-27-14&id=4936%3A2010-04-01-10-51-24&option=com_content [Accessed 25 May 2010].

Centrasia.ru, 2009. Bermukhamedov - Central Asian countries have to pay for water to Tajikistan [online in Russian]. Centrasia.ru, 2 October. Available from: http://www.centrasia.ru/newsA.php?st=1254470940 [Accessed 3 October 2009].

Dorian, J., P., 2006. Central Asia: A major emerging energy player in the 21st century. *Energy Policy*, 34 (5), 544-555.

Dukhovny, V. A., et al., 2005. Integrated Water Resource Management. Tashkent.

Eurasian Development Bank, 2008. Water and Energy: Resources in Central Asia [online]. Kazakhstan. Available from: http://www.eabr.org/ [Accessed 7 April 2009].

Eurasianet, 2010. Russia is suspending giving earlier promised credit [online in Russian]. Eurasianet, 17 February. Available from: http://russian.eurasianet.org/node/30980 [Accessed 30 April 2010].

Faskhutdinov, G., 2009. How to solve the issue of the Sarez Lake: two options [online in Russian]. Deutsche Welle, 4 September. Available from: http://www.dw-world.de/ [Accessed 30 November 2009].

Gazeta.uz, 2009. Unified power grid lost any means [online in Russian]. Gazeta.uz, 5 November. Available from: http://www.gazeta.uz/2009/11/05/energy/ [Accessed 30 November 2009].

Gazera.uz, 2007, Uzbekistan is the second biggest trade partner for Tajikistan. Gazeta.uz, 7 February. Available from: http://gzt.uz/rus/ekonomika/uzbekistan_vtoroy_po_velichine_torgoviy_partner_tadjikistana.mgr [Accessed 26 April 2010].

GeoHazard International. Lessons for Central Asia from Armenia and Sakhalin [online]. Available from: http://www.geohaz.org/news/images/publications/Lessons_from_ca.pdf [Accessed 30 August 2009].

Jalgasbaev, E., 2009. Technical and ecological threats of building hydropower stations on Central Asian rivers [online in Russian]. CentrAsia.ru, 22 April. Available from: http://www.centrasia.ru/newsA.php?st=1240408800 [Accessed 10 August 2009].

Kholmatov D., 2009. Energy castling [online in Russian]. "Oazis" online journal, 21 (113), November. Available from: http://www.ca-oasis.info/ Accessed [6 December 2009].

Khramkov, A., 2009. Three states joined the Customs Union, energy and information alliances can be expected now[online in Russian]. Centrasia.ru, 2 December. Available from: http://www.centrasia.ru/newsA.php?st=1259749440 [Accessed 6 December 2009].

Khamrabayeva, N., 2009. Tajikistan and Russia signed an agreement on combating drugs trafficking. [online in Russian]. Asia-Plus, 3 December. Available from: http://www.centrasia.ru/newsA.php?st=1259829240 [Accessed 5 December 2009].

Kirmel, N., 2009. Customs Union – new way to integration [online in Russian]. Centrasia.ru, 3 December. Available from: http://www.centrasia.ru/newsA.php?st=1259872320 [Accessed 5 December 2009].

Kurtov, A., 2004. Problems with supplying water in Central Asia: position of Kyrgyzstan [in Russian]. Central Asia and the Caucasus, 6(36), 130-140.

Makhkamov, S., 2009. Water usage and water security in Central Asia [online in Russian]. Gorizont.uz, 12 August. Available from: http://www.gorizont.uz/ [Accessed 4 October 2009].

Law on interstate usage of water units, water resources, and hydroeconomic facilities of the Republic of Kyrgyzstan, 2001. Available from: http://www.cawater-info.net/library/rus/kyrg2001.pdf [Accessed 29 November 2009]

Oxford Analytica, 2007. Central Asia: Key Issues to 2012. Oxford. United Kingdom

Ostrom, E., Gardener, R., Walker, J., 1994. Rules, Games, and Common Pool Resources. University of Michigan Press, Ann Arbor.

Panfilova, V., 2010. Water tandem of Nazarbayev and Karimov [online in Russian]. Nezavisimaya Gazeta, 19 March. Available from: http://www.ng.ru/cis/2010-03-19/6_tandem.html [Accessed 10 May 2010].

Pannier, B., and Siddique, A., 2009. Ten years after IMU raids, Central Asia still battling militants [online]. Radio Free Europe, 6 August. Available from: http://www.rferl.org/content/Ten_Years_After_IMU_Raids_Central_Asia_Still_Battling_Militants/1794035.html [Accessed 7 October 2009].

Petrov, G., 2004. Energy projects in Tajikistan: past, present and future [in Russian]. Central Asia and the Caucasus, 5(35), 107-118.

President.tj, 2009. The address of the President of Tajikistan at 64th General Assembly in UN [online in Russian]. President.tj, 25 September. Available from: http://www.president.tj/ [Accessed 3 October 2009].

Rengum, 2009a. The head of the Uzbekistan Gosvodhoznadzor: The problems in ensuring dam security in Central Asia exist and grow like studge ice in winter [online in Russian]. Rengum News Agency, 1 November. Available from: http://www.regnum.ru/news/1220619.html [Accessed 30 November 2009].

Rengum, 2009b. Uzbekistan and Tajikistan expressed contradictory opinions at New York Summit on Climate Change [online in Russian]. Rengum News Agency, 24 September. Available from: http://www.regnum.ru/ [Accessed 2 October 2009].

Safarov, R., 2008. “Ice age”. Tajikistan is again buried into darkness and cold [online in Russian]. Asia-plus, 10 December. Available from: http://www.centrasia.ru/newsA.php?st=1199961240 [Accessed 4 September 2009].

SPECA, 2004. Strengthening cooperation for rational and efficient use of water and energy resources in Central Asia. United National Publications, 2004.

Taujanov, B., 2009. Is it worth for Kazakhstan to pay with oil for Kyrgyz water? [online in Russian]. Centrasia.ru, 12 August. Available from: http://www.centrasia.ru/newsA.php?st=1250061780 [Accessed 7 November 2009].

Wegetich, K., Olsson, O., Froebrich, J., 2007. Reliving the past in a changes environment: Hydropower ambitions, opportunities and constraints in Tajikistan. *Energy Policy*, 35 (7) 3815-3825.

The World Bank Group, 2005. World Development Indicators [online]. Available from: http://devdata.worldbank.org/ [Accessed 28 August 2009].

The World Bank, 2007. Key Development Data & Statistics [online]. Available from: www.worldbank.org/ [Accessed 25 August 2009].

World Bank press release, 2010. World Bank Vice-President for Europe and Central Asia Philippe Le Houerou visits Tajikistan [online]. World Bank, 29 April. Available from: http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/ECAEXT/TAJIKISTANEXTN/0,,contentMDK:22563779~menuPK:258749~pagePK:2865066~piPK:2865079~theSitePK:258744,00.html [Accessed 25 May 2010].

World Water Forum, 2008. Final Document, Third regional preparatory meeting of the fifth World Water Forum. Climate Change, Water Resources Management, Governance and Capacity Building Issues in Central Asia, 28-29 May 2008, Bishkek.

Zpress.kg, 2009. World Bank will continue works in the framework of the project "SACA 1000", which will export the Kyrgyz energy in South Asia [online in Russian]. Zpress.kg, 24 September. Available from: http://www.zpress.kg/ [Accessed 1 October 2009].

12.uz, 2009. Experts: repetition of an accident similar to Sayano-Shushensk is possible [online in Russian]. 12.uz, 27 November. Available from: http://www.12.uz/#ru/news/show/smi/2855/ [Accessed 3 December 2009].

The economical aspects of the Integrated Water Resources Management in Central Asia Region

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Abstract. Organization of International water-energy Consortium for effective and joint exploitation of water-economy objects, improvement of water supply in the countries of Central Asia Region and rational and effective use of hydropower resources is offered.

Introduction

The problem of market relations formation in water sector in any level, national or regional, is the problem of economic relations, so to say a problem of water payment (Normatov[1], 2003).

This problem is not new. Even during existence of the USSR the first attempts to solve it were accomplished. After the independence of all the states of the Central Asia in 1991 this problem turned into one of the major problems and numerous international organizations were involved in solving it.

It is complicated to introduce the market relations at the national level due to necessity to correspond to the example of the advanced countries from one hand, and due to the weak economy which does not allow to carry it out to the full on the other hand. Today full self-financing in water and agriculture sector is impossible in the countries of the Central Asia. Gradualness and support are necessary, but the states don't have sufficient budget for it. It is impossible to solve this matter without foreign support. Its task is not only to render sponsor's gratuitous help, but also to begin the process. Besides, implementation of market reforms cannot be postponed. Service life of the majority water-economy constructions in the region has already exceeded 25 years. For the last 10 years total financing of the water-economy branch from all the sources has not been covering necessary expenses even on simple reproduction and by now its infrastructure is in poor or emergency condition and requires repair work. In the nearest future the situation can become catastrophic.

Mechanism of market relation

At the regional level the complexity of the market relations is explained by the fact that water resources are common for all the regions (many rivers of the Aral Sea basins are transboundary - formation of a river runoff occurs in one country and its use - in other countries) (Normatov[2], 2003). Historical traditions in the Central Asia considered river water to bet he general blessing accessible to all people living on its banks with very rigid obligations.

But in the days of the USSR, water resources were also considered to be the national property; it was quite natural in condition of the united state. Thus, practically the whole infrastructure of the water-economy complex of the Central Asian countries, both irrigation and power, were formed those years considering principle of community of resources. Besides, all the large hydro-units in region, including such unique even on a world scale as Nurek, Toktogul, Kapchagay and others, were constructed for complex objectives, first of all irrigation-power ones.

After the independence of the Central Asian countries this integrated approach became the core of the problem as the priority of the countries where the rivers originate was water-power engineering, while the priority of the countries down the stream was irrigation. These priorities contradict one another, which leads to interstate conflicts.

The situation only worsened in 1992, when the Agreement “On mutual recognition of the rights and regulations in relations to property” was signed in Bishkek, unconditionally dividing all the uniform water-economic complexes on state interests, without taking into account its functional features. Practically all appeared to be much more complicated. For example, the Tuyamuyun hydro-unit, belonging to Uzbekistan is located on the territory of Turkmenistan; the Andizhan reservoir, which is the property of Uzbekistan, has its dam in Kyrgyzstan.

Analyzing national and regional features of the problem, it is possible to note that they have much in common. At it two basic aspects can be allocated: the relation to water and mutual relations between participants - water users.

As for the status of water, today in the countries of the Central Asia there are two opposite points of view. One considers necessity to recognize water in a river as the goods with all the following consequences, including the fact that the owner of the water is the country where the runoff is formed. Thus all the countries downriver must pay for the water. Such approach is officially accepted by the Kyrgyz Republic. In 2001 in Kyrgyzstan the Law on interstate use of water objects, water resources and water-economic constructions of the Kyrgyz Republic was accepted; in its clause 3 the following is established:

- recognition of water as natural resource, having the economic cost at all of its competing kinds of use and being the goods;
- interstate agreements and contracts provide the decision of water delivery questions, payment for water use and distribution of the profit from use of water basins and other irrigational constructions of the Kyrgyz Republic and other states;
- payment for the water resources of the Kyrgyz Republic is based on transactions of the interested parties, considering the level of the world prices and consumer demand for water.

At that, as in usual commodity relations, water supply is carried out only in case it is required and in volumes coordinated during preliminary arrangements. During the winter period when the downriver countries do not require irrigation water and even prefer to reserve it for summer, countries - owners of the water must stop its supply, but it contradicts to their national interests. In case of such uncoordinated water supply, recovery of damage to the aggrieved country should be fulfilled. Also it is not clear, what to do, if a river flows through several countries. For example, the basic runoff of the Sir-Darya river is formed in Kyrgyzstan, and in downriver Tajikistan, Uzbekistan and Kazakhstan are situated. In this case the countries located in the middle of the watercourse, as a matter of fact, should be considered to carry out the transit of the goods (water). But then such transit should be coordinated, and paid as well. Such scheme is used in electric power industry and oil-and-gas complexes where transit is carried out in conformity with preliminary concluded contracts and under the coordinated prices. But all these questions are practically insoluble in case of river water resources. And it is not surprising, that the approach of Kyrgyzstan to solve the problem by accepting the law on water payment was considered to be unsuccessful by other states. Moreover, it worsens trust between the states.

The approach based on charges for hydro-units exploitation is more productive.

There also are several options. One of them is to provide proportional participation of all the countries, located in the basin of the river, in payment for hydro system maintenance. Such approach seems to be rather logical. By the way, the similar method was applied in water relations in the historical past. (In Fath-al-Kadir vol. IX):

- A deepening and cleaning of the rivers should be performed by society, not by private individuals. Covering of charges are is done at the expense of universal tax.
- Charges for maintenance of the public river are divided between all the participants.

Besides, the above mentioned Muslim Law divided the rivers into the general purpose rivers (analogue of modern concept of the Transboundary rivers) and the private rivers (today's national rivers). Concerning the general purpose rivers the same Fatkh-al-Kadir vol. IX established:

- Everyone has the right to drink, wash the cattle and to irrigate the land from large rivers such as the Jayhun, the Saykhun, the Efrat and the Tiger rivers.

Today hydro-units not only regulate runoff with a view of irrigation, but also produce electric power. In this case it is difficult to understand why the other countries on a river should only pay the operational expenses, nothing receiving any profit from production.

This paradox could be resolved if to recognize necessity of participation of other countries in paying only parts of the working costs such as accumulation and water supply. In general this variant looks as follows. The countries of zone of formation of the runoff as base for calculation of indemnifications develop national treatment of work of the hydro-units (Kyrgyzstan – for the Toktogul, Tajikistan - for the Kairakkum) without taking into account interests of the downriver countries. Then they develop the second variant of operating modes of the same hydro-units, but this time considering interests of the countries of lower reaches. The difference between these two variants, losses and damages, define necessary volume of indemnifications.

This approach is secured by special Bishkek "Agreement between the Government of the Republic of Kazakhstan, the Government of the Kyrgyz Republic, the Government of the Republic Tajikistan and the Government of the Republic Uzbekistan about the use of the water-power resources of the Sir-Darya River basin" from March 17th, 1998. Article 4 contains the substantive provision of this agreement:

- Excess of the hydropower produced by cascade of Naryn-Sir-Darya hydropower station in vegetation period at the expense of seasonal regulation of the runoff in the Toktogul and Kairakkum reservoirs is transferred to the Republic Kazakhstan and Uzbekistan equally.
- Indemnification is carried out by deliveries of power resources (coal, gas, black oil, the electric power), and also other production (works, services) or in money terms as agreed in the Kyrgyz Republic and the Republic of Tajikistan in equivalent volume, for creation of necessary annual and long-term water reserves in water basins for irrigational needs.
- At realization of payments the equal tariff policy on all kinds of power resources and their transportation should be provided.

This approach has disadvantages as well. First of all valid indemnification of losses in years abounding in water is impossible. Water in such years will be delivered simply as a by-product, without payment. And, at last, the question on division of functions between two hydro-units has not been solved: the Toktogul belonging to Kyrgyzstan and the Kairakkum belonging to Tajikistan often duplicate each other.

To improve this situation it is reasonable to create the International water-power consortium in which all the countries of Central Asia would participate. Its overall aim is effective joint operation of water-economic objects, increase of water-security of the participating states, rational and full use of hydro resources of the region. As one of mechanisms of realization of these purposes consortium could undertake the decision of a question of mutual economic relations in a water complex. As a basis of such economic mechanism it is possible to accept the circuit stipulated in the Agreement on use of water-power resources of the Sir-Darya River, but having put it on stronger basis. In general, such approach could be as follows.

The consortium buys from the countries of headwaters (Kyrgyzstan and Tajikistan) the excess of electric power, developed in summer during the vegetative flow augmentation, carried out for the downriver countries. The consortium purchases this electric power at high prices, thus providing these countries an opportunity to get the same amount of electric power (or energy carriers equivalent to it) in winter, the most scarce period when water in the reservoirs is accumulated for vegetation, as they had lost in summer. Consortium realizes this electric power at the summer prices which can be essentially lower then winter ones. The consortium will cover the difference between these prices delivering water for irrigation, which, as a matter of fact is the basic purpose of all this circuit. Payment for water supply will be carried out according to the legislation already established in the countries of Central Asia and at the tariffs authorized there. Taking into account deficiency of monetary weight in the republics, payment for water can be made to a consortium by way of barter. The consortium will realize this production in the market and as a result all calculations between the upstream and downstream will be carried out in the same monetary form.

Conclusion

There are essential advantages of Consortium establishment:

- It is not necessary to develop a new scheme of mutual relations in water power sphere; the scheme that has been operating for more than ten years can be used.
- The consortium does not replace existing administrative and managing structures, and works in parallel and in close connection with them. But at the same time it has an opportunity, both to cooperate, and to compete to them.
- The consortium will solve this problem complexly, simultaneously, in

economic and in other spheres such as international and institutional relations.

References

1. Normatov I. Sh. (2003). Water Balance and Solution of water problems in Central Asian region: Proc. International Symposium for the Basis of Civilization water science. 3-6 December 2003. National Research Council, Rome, Italy. pp.148-154.
2. Normatov I. Sh. (2003). Regional experiences in solving water resources problems in Tajikistan: Abstracts of NATO ARW of Transboundary water resources: strategies, 25-27 August 2003 IWEP: Institute for water and Environmental Problems SB RAS, Novosibirsk, Russia. p. 16-18.
3. Water resources of Tajikistan (2003). Normatov I. Sh. (Ed). SLR “Omu”, Dushanbe. Tajikistan. 112 p.

Organizational and Methodological Principles of Integrated Water Resources Management in Zone of Runoff Formation

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Water is the main economic assets and vital resource for irrigated agriculture and power generation, the two main sources of income for the economy of Tajikistan. Every year about 64 km^3 of water are generated on the territory of Tajikistan, including 62.9 km^3 in the basin of the Amu Darya River year and 1.1 km^3 year in the Syr Darya basin. Major rivers of Tajikistan are the Vakhsh, the Panj, the Kafirnigan, the Zeravshan, and the Syr-Darya Rivers; their basins occupy more than 75% of its territory. Tajikistan's rivers are fed by precipitation and melting glaciers. Occupying 8% of the territory they form 845 km^3 of water [1].

In stable ecological systems a closed cycle of functioning and complex use of water resources is observed. There is such a set of consumers and users of natural resources in such systems, that they don’t get polluted or depleted. In this connection, artificial systems that use water resources, should be formed so as not to create and/or minimize the depletion and contamination of water, providing resource-environmental safety, which is requirement for sustainable development.

In the late 20th century it became clear that uncontrolled use of water resources in Central Asia can lead not only to the Aral Sea crisis, but also to its transformation into a global crisis.

There are many water problems in Tajikistan:

- ineffective institutional foundation;
- ineffective water resources management system;
- classification of water bodies is not flexible enough for management;
- unrealistic water protection standards and lack of effective legal mechanisms of regulation (the focus is on pollution control rather than on its prevention);
- low level of public awareness;
- lack of effective economic inducement;
- lack of continuous monitoring of the water environment and lack of quality information, which is the basis for water management;
- lack of funding of water protection activities (leftover principle);
- lack of coordination, both between agencies and with development partners (civil society, state administration and private sector).

In Tajikistan state policy in the field of water use and protection is oriented to:

- ensuring safe and regular water supply to the population, industry and agriculture, considering the interests of other water users, keeping water-resource capacity and biodiversity;
- improvement of organizational, institutional, regulatory, legal, economic, informational, and socio-psychological mechanisms of water use and protection;
- measures to improve sewage treatment, reduce of pollutants, introduction of waterless and low-waste technologies.

Indicators of rational use of water resources are:

- the ratio of water dump to the volume of produced fresh water;
- repetition factor of water use, i.e. the ratio of gross water consumption to the volume of fresh water consumption
- number of users, stopping the disposal of untreated sewage to the total number of users;
- reduction of the absolute volume of water consumption by decreasing the deadweight losses and adherence to scientifically grounded standards and water use limits.

For Tajikistan, the main reserve for increasing water use efficiency is to reduce consumption of fresh water in the agrarian sector. Irrigated agriculture dominates in the structure of water consumption; it takes up to 84% of water supply; farming takes 8.5% of water supply, industry takes 4.5%, fisheries - 3% [1]. Another way to increase effectiveness is to eliminate water losses on all stages of its use, especially losses caused by water-users. Water losses also happen due to insufficient condition of plumbing and lack of flow meters. Low water rates for the population stimulate wasteful use of costly (taking into account the cost of its preparation) drinking water.

Strengthening of regulatory and legal mechanisms is achieved by improving laws, regulations, standards, contracts, etc.

Strengthening of economic mechanisms is achieved by optimizing budgetary provisions, payments for water use and pollution, taxes and benefits, the system of water protection activities funding, bonus system, etc.

Strengthening of information mechanisms is aimed at providing objective and timely information on water-saving technologies, and at promoting scientific exchange.

Socio-psychological mechanisms include education, revival of traditions and development of culture.

Comprehensive approach to water management, considering glacial and forest processes, involved in the formation of water regime, is required in Tajikistan, taking into account best international practices.

Tajikistan needs improvement of monitoring over the water environment, modernization and reformation of the existing institutional foundation of water resources management, reconstruction of irrigation systems to prevent water loss and reduce water consumption by means of introduction of more effective equipment and irrigation technology, and improvement of mechanisms for public participation and awareness [2].

Organization of integrated water resources management is necessary under present-day conditions, and it should be introduced stepwise, from the simple to the complex. Integrated water resources management should be defined as a process that aims at balanced water use and management correlating with land and other resources using methods acceptable to all water users. At that the area of a river basin is regarded as the unit of management. Within this basin surface and groundwater waters are interrelated in quantity and quality. This unit of management requires acceptable management structure, clear and stable allocation of water, clear criteria for quality assessment.

The system of integrated ecological and economic management of water resources considers:

- management of the quality and quantity of water resources;
- taking nature conservation measures;
- meeting economic interests of water users;
- ecological audit including assessment of compliance with strategies of water users;

Purposeful formation of state order for integrated environmental and economic management of water resources should be fulfilled as strategic sector.

To ensure this process it is necessary:

- to transform the structure of water management, to differentiate taxes and payments considering environmental capacity and socio-environmental characteristics of water use;
- to consider the socio-environmental component, including the interests of future generations, when determining the cost of water resources and payment for their use, which in turn implies the introduction of environmental discounting;
- to develop and introduce a system of social and environmental limitation of economic activity and choice of economy strategies at various levels of management;

- to develop and form of ecological and social needs of the population as element of culture and factor of socio-environmental transformation of aggregate demand and supply [3].

Integrated environmental and economic management of water resources requires implementation of the following tasks:

- assessment of existing water management complex and its water supply problems;
- analysis of ecological condition of water bodies and signs of harmful effects of water;
- assessment of safety of hydraulic structures;
- forecast of development of water industry and water use, taking into account socio-economic development of the country;
- determination of framework values of water use limits, taking into account surface and ground water resources;
- assessment of the need for water conservation and water-related activities on the basis of republican and regional programs and basin schemes;
- development of proposals on improvement of public administration of water resources;
- planning of the development of monitoring of water bodies, hydroeconomic systems and facilities;
- assessment of the need for water sector financing and improvement of the mechanism of economic relations when using and protecting water bodies;
- development of an integrated information system on water resources, their use and protection;
- determination of themes for legal, information, research and methodological works in the field of water bodies use and protection;
- Assessment of socio-economic and environmental consequences of its implementation.

Basin schemes of complex use and protection of water resources carry out analysis, assessment, and forecast of:

- water resources and their change under the influence of human activities and climate changes;
- water requirements in terms of runoff volume, regime of water supply and water quality;
- volume of wastewater, pollution sources and composition of the contaminants getting in the water with sewage;
- water quality and ecological condition of water bodies;
- quantity of sanitary and environmental discharges and volume of the maximum allowable runoff removals from water bodies;
- harmful effects of water and their negative consequences for the population, economic facilities and the environment;
- hydroeconomic calculations and balances, evaluation of sufficiency of water supply, selection of optimal flow regulation regime;
- future water use limits for participants of the water sector;
- technical condition and forms of ownership of the main water production funds [4].

The planned engineering measures should be aimed at:

- water supply (in proper volume, regime and water quality);

- prevention of harmful effects of water;
- ensuring safety of hydraulic structures;
- sewage and stormwater treatment, improvement of the ecological condition of water bodies.

Conclusion

It is typical for integrated environmental and economic management of water resources to include all the production functions in the process of preventing adverse effects. Water supply is important for effective environmental policy, as environmentally optimal water supply allows to minimize the burden on the ecological capacity from the moment of its initial appearance. The goal of conservation actions in the field of water use is the partial or total elimination or avoidance of overload of environment, arising in the production process. This can be done either by optimizing the existing way of water use, or by selecting a new, focused on compliance with requirements of conservation balance. The problem of integrated environmental and economic management of water resources lies in the management of goods and services produced by water users and delivering them to consumers, providing maximum reduction of load on the environment.

References

1. Water Sector Development Strategy in Tajikistan, Dushanbe, 2006. p. 94.
2. O. L. Yushmanov, V. V. Shabanov, I. G. Galyamin, E. S. Beglyarova, P. E. Tkachenko, A. S. Berezner, N. F. Yurchenko. Integrated use and protection of water resources, M. Agropromizdat. 1985. p. 82.
3. "Implementing the principles of integrated water resources management in Central Asia and Caucasus" - a project of the Regional Technical Advisory Committee of the Global Water Partnership for Central Asia and Caucasus. 2004. p. 128.
4. Project "Guidelines for development of the integrated water resources protection", ZAO PO. Sovintervod. Moscow. 2003. (Second Edition)

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Ways to Improve Water Use Efficiency and Optimal Use of Water

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In Tajikistan, surface water watercourses are rivers, reservoirs, streams, canals of inter-basin redistribution and complex use.

Water can be used in technological process (for example, in hydropower engineering) and in its pure form it can then be directed to users; later it can be consumed by another water user (for example, in irrigation), and in form of sewage in the event of natural drainage it can be reused. Water scarcity occurs when some natural phenomena such as drought reduce rainfall, which is the source of renewal of this natural resource before the active melting of glaciers begins.

By the end of the twentieth century, water resources became limiting factor for sustainable development, both in Tajikistan and in Central Asian region as a whole. Some areas began to experience water shortage. This situation conditioned necessity of qualitative and quantitative conservation of water resources.

Tajikistan is rich in water resources, but lately water problems considerably worsened here due to natural and anthropogenic changes in river runoff. Agro-technical measures, the reduction of mountain forests, irrigation reclamation, regulation of runoff with water reservoirs, water withdrawals for irrigation, industrial and municipal water supply, discharge of polluted water into water sources, and other things have significant impact on runoff and water quality. Modern methods of solving water problems, such as the regulation of runoff and its territorial redistribution, in their turn cause a number of technical, environmental and socio-economic problems.

In Tajikistan, major water users are irrigated agriculture (up to 84% of intake), economic - drinking and agricultural water supply (8.5%), industry (4.5%) and fisheries (3%). The main and priority water user is hydropower engineering. These major parties of water industry determine the strategy of national development [1].

Further development of the agrarian sector is formed and at the same time limited by two major resource components - land resources, which are minimal, and water resources, which are expensive for their delivery to the field.

Significant population growth has led to decrease of the irrigated area per capita; especially arable land – it is 0.07 hectares per capita. It is the minimum rate in the Central

Asian region. Because of the shortage of land of Tajikistan was forced to develop wasteland (Bad Land): sand-stony, saline, soils subsidence of loess plateau, and large areas of mountainous areas with slopes above the critical level for the application of surface irrigation. Due to the absence of water - soil conservation technologies it has led to soil erosion. Currently, Tajikistan has about 720 thousand hectares of irrigated land; 22% of them are sandy and stony soils, 16% are saline, 8-10% are affected by water and wind erosion, and 10-12% of irrigated land are located in subsiding area.

Thus, 55-60% of irrigated farmland have not favorable properties limiting their fertility. Keeping such lands productive requires high energy and resource costs to introduce advanced technology and irrigation technology both during reclamation and exploitation. Before such efforts were put, and as a result in 80-es Tajikistan had the highest in Central Asia productivity from its irrigated lands.

The complexity of the mountain-valley terrain in Tajikistan predetermined creation of modern water management system, consisting of a system of complex and somewhat vulnerable to impact of debris flows and flood events waterworks. In the end of the 20th century up to 60-70 per cent of the irrigation systems were well equipped; modern water-saving technologies were actively introduced. The cost of major land reclamation fund was 1.5 billion U.S. dollars. To control the level of groundwater and salt balance in irrigated lands, quite an extensive collection and drainage network on the area of 311.2 thousand hectares, an average of 36.2 n.m./ha and drainage module of 0.3 -0.4 liters/hectare was built. Drainage wells covered 47.4 thousand hectares, out of which about 60% do not work now due to lack of funds for their restoration and spasmodic power outage. 5,896 km of water-lifting networks, 432 km of relief network, about 8 thousand waterworks, 517 pumping stations, 26.6 km of tunnels, 3,272 km of roads and other operating funds belong to off-farm part of the irrigation system. 26,000 km of irrigation networks, 1610 km of waste networks, about 15 thousand of hydraulic structures and other assets are on the books of household of water management system. All the expenditures were carried out by the state. As the market relations were introduced, the payment for water supply services to consumers was put to use. However, sectors - water users can only cover an insignificant part of all the expenses of irrigation and drainage systems maintenance, resulting in their considerable deterioration, reducing in the effectiveness of water supply and accelerating processes of deterioration of irrigated lands, covering more than 100 thousand ha. Thus, over the last 20 years not more than 5-6% of the statutory funds were spent on irrigation and collector - drainage systems maintenance. Besides 30% of these systems require reconstruction.

After 1992, commissioning of new irrigated lands almost stopped. All the efforts are focused on maintenance of existing irrigation and collector – drainage systems. With some economic recovery and growth of collected fees it was possible to increase cleaning of irrigation and collector – drainage systems from 25% in 1999 to 43% in 2001 (compare to 1990, when the volume of these works was more than 32 million m^3) [1].

Population growth and shortage of land with possible gravity irrigation led to the expansion of lift irrigation, which was the most vulnerable in market conditions. In Tajikistan, 40% (about 300 thousands hectares) of irrigated land are served with the pumping stations, and 64% of them are situated in Sughd region. Almost 30% of the pumping stations are cascaded; they pump water with 5-7 levels to a height of 250 - 300 meters or more. They have complicated construction and require highly skilled exploitation. International consultants unreasonably propose to transfer zones of cascade pump stations to zones of pasturable cattle-raising. Socio - economic consequences of such transfer will cause great calamity for their residents. It will cause secondary desertification and a large number of environmental migrants. It will be much more expensive to resolve their problems than to maintain pumping stations. Based on this, the country is taking measures to use the most profitable but little-water-consuming crops, and favorable energy supply for transitional period is provided.

Tajikistan has faced complicated, capital-intensive and long-term task of rehabilitation and improvement of the technical level of irrigation and collector–drainage systems, since the constructed irrigated agro-landscapes, providing certain level of employment, play an important role for habitat for 75% of the population (4.6 million). To solve this problem it is necessary to carry out an inventory of fixed assets, which hadn't been implemented since 1990. On the basis of it, primary, medium and long term measures for rehabilitation and further development of irrigation and drainage systems will be developed. Fruitful cooperation of Tajikistan with international financial institutions in these areas should be noted. Supported by the World Bank and Asian Development Bank, the work on rehabilitation of inter-farm and in-farm irrigation and collector - drainage infrastructure has been carried out for over the last 10 years.

Rational use of water, improving of soil agro-landscape and reclamation zoning, introducing scientifically-based irrigation regimes, advanced water-saving technologies, and amelioration of land are very important for economy and ecology. Increased efficiency of irrigation systems, improved irrigation technology, capital and current land planning and comprehensive reconstruction of irrigated land will be decided on the basis of long-term programs. The necessary investment will come from:

- funds collected from water users;

- funds from the republican and local budgets;

- land tax

- foreign investments and other sources not prohibited by law (the private sector funding, the proceeds from the alienation of land for nonagricultural purposes, tariff and tax regulation to improve the efficiency of irrigated agriculture, etc.)

Total funding from the normative content of the irrigation com- complex will largely depend on investment activity for its rehabilitation.

In order to meet the needs of the population and national economy in grain products, special comprehensive program is designed to increase its production and bringing it up to 1 million tons with productivity of 1 ha from irrigated land of wheat and rice not less than 4 000 kg/ha, maize - 5 000 kg/ha, and soybean 3 000 kg/ha. At the governmental level, the decision to phase out the cotton growing on rocky and sandy soils, requiring large material inputs and irrigation water, and on steep slopes causing soil erosion, and switching to less energy-intensive technologies for sustainable, economically viable crops, was made.

Tajik law establishes administrative liability for violation in water use and protection. Such violations:

- unauthorized usurpation of water body and unauthorized water use;

- implementation of projects without affirmative conclusion of state ecology expertise;

- water pollution or violation of regime of use of water protection zones;

- commissioning of industrial, municipal and other facilities without structures and devices that prevent water pollution;

- water intake exceeding the established limits;

- unauthorized engineering works;

- the use of water bodies not for their designated purpose.

Water consumption in the nearest 10 - 15 years and will depend on National development strategy and Poverty Reduction Strategy realization. These strategies consider sustainable economic development, demographic situation, formation and realization of the system of living standards and sustained improvement of financial state of population, introduction of water saving technologies, development of all sectors of the economy [2,3]. The food problem should be solved by increasing the productivity of existing lands, and development of all potentially suitable new irrigated areas, with the total area of 1.6 million hectares. They will be developed gradually, it will take years, so the states of the lower courses of the Amu Darya and the Syr Darya rivers will be able to reconstruct their irrigation systems.

Tajikistan requires a gradual transition to a system management method within the hydrographic rather than administrative units; establishment of sustainable water user associations; ensuring differentiation of payments for water supply depending on specific conditions; the development of a variety of forms of private, collective and joint use of water based on the market water management.

To accelerate the development of industrial production, the following aspects are important: the valuation amount and quality of water consumed in various industries per unit of output; further capacity expansion of recycling, reuse water and closed water systems and water management; full reduction of water leakage.

To improve agricultural water needs the following things are important: introduction of the centralized water supply and sanitation facilities with bio waste water; increase of recycling and reuse of water; the optimal wastewater treatment and its use for irrigation; improvement of water withdrawals from surface sources.

Fish industry in Tajikistan is characterized by high productivity, but the potential of water resources is underutilized. Important condition for successful development of fisheries is to maintain the required quality of water, its temperature, as well as the corresponding depths in streams and ponds.

In the structure of water sector, hydropower engineering takes an important place in Tajikistan. Its water bodies are the main regulator of the flow, and it allows to use water resources not only for its own needs, but also for irrigation, water supply, fisheries development.

Control of harmful effects of water isn't usually associated with consumption of water resources. It includes protection from flooding and debris flows, draining wetlands, protection of banks of rivers, reservoirs and seas shores, preventing water erosion, etc.

It is necessary to complete the creation of protection zones of rivers, lakes and artificial reservoirs on all the small, medium and large water bodies. All this should be controlled by the established regulations of land and water use, ban on construction of polluting facilities, landscaping, etc.

References

1. Water Sector Development Strategy in Tajikistan. Dushanbe. 2006. -94p.
2. The National Development Strategy of the Republic of Tajikistan for the period from 2006 to 2015. 2006.
3. Poverty Reduction Strategy for Tajikistan (1-2005, 2 - 2007, 3-2009) for the period from 2006 to 2012.

Ecological-Meliorative Problems and Technology of Increase of Fertility Irrigated Soil

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The territory of Kazakhstan borrows nearby 272,2 million hectares and located on forest-steppe, steppe, arid steppe and deserted zones. On these natural zones form the cores - steppe and deserted and transitive - forest-steppe, arid ecosystematical steppe zone. Soil scientists of the country within the limits of specified ecosystems allocate the following soils: chernozem soils, chestnut soils, brown and gray-brown soils, sierozemic soil. Thus, borders of the main natural zones well enough coordinate with hydrothermal factor [1].

The analysis of natural-economic conditions of Kazakhstan specifies the necessity of irrigated agriculture development. It provides reception of the guaranteed gather of agricultural crops. For example, till 90th years of the last century irrigated agriculture in agricultural production of Kazakhstan played the leading part and from components of 5 % (2,3 mln.hec) arable lands are received more than 30 % of all production of agriculture in cost expression.

But, because of economic crisis in republic it has begun to proceed intensively degradation processes (salinization, solonetzization, alkalization of soil) and growth of water resources deficiency on irrigational systems. There was a reduction of the areas of the irrigated grounds. Nowadays in irrigated soil areas make nearby 1,4 mln.hec. Though more than 90 % of irrigated soil areas are located in the southern territory: Almaty, Zhambyl, South-Kazakhstan, Kyzylorda [2]

The factors of influence on fertility and watering of irrigated grounds are:

In Southern Kazakhstan (Kyzylorda, South-Kazakhstan, Zhambyl and Almaty regions):

- decrease of hydromeliorative systems' technological level and accordingly low coefficient of efficiency (CE) of irrigational systems (0,30-0,35);
- deterioration of collector-drainage line's (CDL) technical condition, failure of vertical drainage chink (VDC) and decrease of drained irrigated grounds;
- increase of unproductive loss sizes of irrigating waters from the channels and irrigated grounds;
- level lifting of ground waters above critical depth;
- growth of mineralization and deterioration of irrigating waters;
- absence of the strict water account at irrigation;
- deficiency of water resources during the vegetative period, under watering agricultural crops;
- growth of the areas of salted, solonetzic and alkaline irrigated soils;
- decrease in stocks of organic substances (humus) and nutritious elements (mobile forms of nitrogen, phosphorus, potassium);
- set of the small country economy which has the irrigated earths by the area as much as 10 hectares;

In other regions of Kazakhstan:

- failure of water abstractive constructions and closed irrigating networks out of operation;
- deterioration and failure of sprinkling machine and units;
- heavy hydrological condition and propensity of the irrigated earths to salting;
- solonetzic sodium and alkalinization of soils;
- decrease of stocks humus and nutritious elements (nitrogen, phosphorus and potassium);
- high cost of machine water lifting and impossibility of carrying out the cheap superficial waterings on furrows and strips.

For example, the inspections in Southern Kazakhstan have shown that 81,5 % of inter-economic and 79,2 % of inter-farm channels on these grounds are executed at earthen channel, in side-hill fill – semi fill**.** Dams of channels overgrow with the weed acid vegetation and at creation of necessary horizons it is observed strong filtration of water. The channels are strongly deformed, and the majority of hydraulic engineering constructions demand repair or replacement. Troughing and the reveted lines have undergone to destruction (it is broken blending seams, there were cracks, concrete plates are damaged or displaced, etc.), therefore their ECE come nearer to the channels which are passing the earthen channel [2].

Deterioration of technical condition of irrigational systems does not provide a tap of filtrated waters for limits of files of irrigation. Therefore the ground water bedding level is risen on all irrigational systems (table 1).

The main cause of risen ground water bedding level on irrigated soils of Kazakhstan is insufficient their drainage conditions. It is connected with failure of all chinks vertical drainage (CVD) on irrigational systems of Kazakhstan and deterioration of technical condition of collector-drainage lines (CDL) (deformation of channel and overgrow of vegetation). In the result the drainage drain was reduced [3].

For strengthening of drainage condition of irrigated grounds first of all it is necessary to restore work of service operation CVD and to spend dredging and cleaning works of the open collectors.

Table 1 - Distribution of the irrigated grounds on depth of subsoil waters, thousand hec/%

WEC pools	Total irrigated grounds, %	Groundwater depth, m			
		<1	1,0-3,0	3,0-5,0	>5
Syrdarya					
Kyzylorda region	300,0/100	20,4/6,8	275,0/91,7	4,6/1,5	-
South-Kazakhstan region	511,7/100	0,4/0,1	162,0/31,7	175,6/34,3	173,6/33,9
Shu-Talas					
Zhambyl region	152,8/100	2,30/1,5	44,2/30,0	68,6/44,9	37,7/24,6

Balkash-Alakol					
	581,6/100	32,9/5,6	240,0/41,3	177,6/30,5	131,1/22,6
South Kazakhstan	1546,1/100	56,0/3,6	721,2/46,7	426,4/27,6	342,4/22,1

Generalization of available materials show that the present time one of the factors of increased water-security of irrigated grounds is utilization of ground waters with mineralization up to 3 g/l. Thus, almost on 50 % of irrigated grounds of Kazakhstan have ground waters with mineralization up to 3 g/l. Therefore their utilization on subirrigation is possible on these grounds during the vegetative period [4].

Hence, the restoration former drainage condition of irrigated grounds by construction of new and the reconstruction of existed chinks of vertical drainage (CVD) and collector-drainage line (CDL) will lead to decrease of ground water bedding level, to increase the sizes of water-fence from sources of irrigation and accordingly - to reduction of irrigating norms [5].

Therefore in such situation on irrigated grounds, where close ground water bedding, participating in evapotranspiration of plants can low the sizes of irrigating norms on average to 50 %, and it will demand the revision of parameters and operating mode of CVD and CDL.

Growth of irrigating waters mineralization and close mineral ground water bedding has led to increase of degraded irrigated soil areas. Now about 50 % of irrigated grounds of Kazakhstan are salted and 30 % of irrigated grounds - solonetzic (table 2).

In the Central and Northern Kazakhstan, on fertility soil influences solonetzic soils [1]. Unlike Southern Kazakhstan, the irrigated grounds have solonetzic natric.

As a result of salted and solonetzic soils there was decrease in productivity of irrigated grounds in 1,5-2 times. Therefore for increase of irrigated grounds efficiency it is necessary to salt and solonetzic the degraded grounds [1, 2].

Table 2 **-** The Area of distribution of irrigated grounds on salted soil degree, %

WEC pools	Total irrigated grounds	Also			
		Unsa lted	Wea k salted	M iddle salted	Strong salted
Balkash-Alakol	581,6	227, 4	177, 4	1 42,0	34,8

(Almaty region)	100	39,1	30,6	24,4	6,0
Shu-Talas (Zhambyl region)	142,0	101,9	24,7	10,1	5,3
	100	71,8	17,4	9,9	3,8
Syrdarya South-Kazakhstan region	511,7	340,6	105	49,5	16,6
	100	66,6	20,5	9,7	3,3
Kyzylorda region	277,7	2,7	125,8	79,2	70,0
	100	1,0	45,3	28,5	25,2
Across Southern Kazakhstan	1513,0	672,6	432,9	280,8	126,7
	100,0	44,5	28,6	18,5	8,4

The most effective way of solonetzic soils is their washing. Now the most effective way is washing of the grounds under small checks [1, 6]. The technology of washing the salted soils on small checks provides the decrease in sizes of washing norms on 25-40 %, quantities of washing the organic substances and nutritious elements on 10-20 %, durations of washing up to 30 % and it will provide the carrying out of spring-field works in optimum terms.

Washing of salted soils allows to salt the irrigated soils up to threshold of toxicity and accordingly to lead up productivity of agricultural crops up to design.

Increase of fertility solonetzic soils is reached by their chemical land improvement [1, 7]. In conditions of Kazakhstan the most accessible and cheap ameliorant is phosphogipsum (waste of phosphoric manufacture). Stocks of phosphogipsum make more than 6 mln.t., that at the norm of entering is 5-7 t/hec., it allows to reclaim about 1 million hectares of irrigated grounds.

Phosphogipsum raises fertility soils, improves their physical structure, increases stocks of calcium in structure of absorbed bases. It carries out a role of geochemical barrier (coagulator of salts), provides formation of agronomical structure at processing of soils, accelerates the growth and development of plants, raises the speed of absorb waters at watering on 25 … 35 %

Results of chemical land improvement solonetzic soils show, that they solonetzic by entering of phosphogipsum is raised with productivity of a cotton, corn and grain up to 35-50 %.

On the irrigated grounds except for salted and solonetzic soils there is having washed up humus, nutritious elements of nitrogen, phosphorus and kalium from root-inhabited layer (table 3 [1]).

Table 3 - Quantity of nutritious elements washed for 1 watering at various irrigated norms

Soil	Irrigation norm, $м^3$/ha	Humus		Nitrogen (NO_3)		Phosphor (P_2O_5)		Potassium (K_2O)	
		mg/l	kg/ha	mg/l	kg/ha	mg/l	kg/ha	kg/ha	mg/l
Black earth soil	250	0,12	4,0	44,6	1,4	0,18	0,05	25,2	0,8
	500	0,12	11,7	40,2	3,9	0,18	0,18	24,3	2,4
	1000	0,11	22,1	36,8	7,1	0,18	0,38	22,1	7,6
Chestnut	250	0,094	2,8	36,2	1,1	0,12	0,04	19,6	0,6
	500	0,092	8,7	36,0	3,5	0,12	0,12	18,0	1,7
	1000	0,090	19,8	33,8	7,0	0,12	0,25	7,4	3,5
Sierozem	250	0,066	2,2	21,1	0,7	0,44	0,14	24,1	0,8
	500	0,065	7,1	20,9	2,2	0,44	0,44	22,8	2,3
	1000	0,063	12,5	20,5	4,0	0,44	0,90	20,3	4,1

Thus washed salts and accordingly decrease in their stocks occurs at any technologies of irrigation and washing. For example, the basic parameter of fertility - humus has decreased to critical limits (less than 1 %) in the basic regions of irrigated agriculture (table 4). The main reason of catastrophic loss of humus is formation of negative balance of organic and mineral substances, owing to their insufficient entering. Needs of plants for basic feed elements are not satisfied, therefore the coefficient utilization of nutritious elements from ground increases which is degraded. It proves in productivity of leading culture of cotton (about 40% from under crops area) which has made 22,9 c/hec. in 2006, 22,3 c/hec. in 2007 and 18,2 c/hec. 2008.

Table 4 - The maintenance of humus in sierozem-meadow and meadow-sierozem soils

Administrative area	№Work output	Horizon	The maintenance of humus, % from weight of soils	
			2007	2008
Maktaaral	55	Arable	0,95	0,76
		Under arable	0,79	0,57
Otyrar	97	Arable	0,94	0,78
		Under arable	0,78	0,54
Turkestan	139	Arable	1,00	0,91
		Under arable	0,90	0,51
Shardary	235	Arable	0,58	0,80
		Under arable	0,48	0,52

Therefore for increase of nutritious element stocks it is necessary annually, during the vegetative period, entering of settlement norms of organic and mineral fertilizers that provides normal growth and development of agricultural crops.

One negative parties of irrigation is the deterioration of water-physical properties of soils, i.e. condensation of soils. Such grounds demand loosening of soils.

Thus, the low technological level of irrigational systems of Kazakhstan demands increase of CDL of system in view of technology of irrigation and condition of channels. It is established, that due to use of water-saving technologies of superficial way of watering (variable jet, discrete water delivery, watering through furrows) is possible to raise CDL of irrigated systems up to the certain limits**.** In particular, application of water-saving technology of watering through furrows the variable charge on high-permeability soils raised CDL system of irrigation from 0,18-0,28 up to 0,20-0,30, i.e. on 7-11 %, and on middle-and low water-permeable - from 0,25-0,36 up to 0,33-0,45, i.e. on 25-32 %.

The need for technical reorganization of irrigating line proves by operational parameters and calculations [8]. For example, at application of water-saving technologies of superficial way of watering and partial reconstruction of irrigating line (30-50 % of channels are reveted or arranged watertight screens), the CDL of irrigating line will raise on 0,15 or 25-30 %, and systems of irrigation with 0,28-0,39 up to 0,36-0,49 or on 25,6-28,6 %. At full reconstruction of irrigating line (more than 70% of channels are exposed to facing or the device watertight screens) and applications of overhead irrigation, the CDL system irrigation increases up to 0,46-0,6 on middle-and low-nonwatertight soils.

Thus, at overhead irrigation application of pipeline raises CDL system of irrigation on 0,24-0,26 or on 55-79 % concerning control variant where channels are laid in earthen channel.

Efficiency of use of irrigating water at drip irrigation depends not only on CDL of watering techniques, but also conditions of irrigating line. On irrigating systems of the combined type (a combination of the open channels and pipelines) when the CDL of channels changes within the limits of 0,75-0,85, and techniques of drip irrigation 0,8-0,9, the CDL of system irrigation changes within the limits of 0,6-0,77. On systems of closed type when the CDL of irrigating line increases up to 0,9-0,95, the CDL of system irrigation raises up to 0,72-0,86 and exceeds the maximal parameters of irrigating systems of the open type on 0,09-0,12 or on 15-20 % [8].

On the basis of experimental data received on various irrigational systems of Southern Kazakhstan water-saving technology of watering agricultural crops through furrows [9]**.** The given technology is high-tech and provides the reductions of loss of irrigating water on evaporation up to 2 times, infiltration - 50 %, dump - up to 2 times.

On solonetzic and alkaline soils one of size growth reasons of irrigating norms are low speed water imbibing in furrow and accordingly great volumes of irrigating waters losses on dump. Therefore water imbibing to the soil and degree increases of uniform distribution of irrigating water on the area of irrigated grounds have developed watering technology for vegetable cultures through furrow-cracks [10].

Now the irrigated grounds of Kazakhstan are characterized by low fertility soils. It leads to decrease in efficiency of irrigating water. Therefore for increase of efficiency of irrigated grounds developed technology for increase of conjoint soils fertility by entering phosphogypsum [11.] Phosphogypsum raises fertility of soil, improves their physical structure, increases stocks of calcium in root-inhabited layer, etc.

Thus, in developed ecology-ameliorative situation on irrigational systems of Kazakhstan, increase of their water-security and fertility of soil is reached by engineering system actions on water-salt economy and by food modes in root-inhabited layer of irrigated grounds.

References

1. Bekbaev R.K. Modelling of meliorative processes on irrigated grounds.-Taraz, 2002. p. 226.

2. Bekbaev R.K. Soil-ecology processes and methods of their regulation on irrigated ecosystems of Kazakhstan // Dissertation on competition of scientific degree of D.T.S.-Taraz, 2005. – p. 263

3. Magai S.D. Parameter of drainage irrigated grounds and factors defining in the south of Kazakhstan // Scientific researches in the field of amelioration and water economy. -Taraz, 2000. - p. 161-177.

4. Bekbaev R.K., Kazykenova G.V. Water resources economy on irrigated grounds of low flows of Syr-Darya // Ecological stability and the advanced approaches to water economy resources in Aral sea basins /The international scientifically-practical conference in Central Asia, Almaty/Tashkent, 2003. - p. 141-147.

5. Vyshpolskij F.F., Lygay D.A. Recommendation on ameliorative improvement of rice grounds crop rotations and correcting mode of rice irrigation (on example of Left-bank Kyzyl-Orda file of irrigation). - Zhambyl, 1982. – p. 29

6. Bekbaev R.K., Zhaparkulova E.D. Elutriate of azotes at washings of dark-chestnut salted soil. // Scientific researches in the field of land improvement and water culture/Collection of scientific works of KazSRIWE. - Taraz: «AKVA» PC, 2002. -Volume 39. p. 28-33.

7. Vyshpolskij F.F., Bekbaev R.K. Resource saving technology of salted and solonetzic soils. // Recommendations.-Taraz, 2000. – p. 36

8. Ibatullin S.R., Bekbaev R.K., Vyshpolskij F.F., Bekbaev U.K., Basmanov A.V. Volumes of water-saving at reconstruction of irrigated systems/ Water management of Kazakhstan, No.1, march 2011.-p. 38-43/

9. Bekbaev R.K., Ibatullin S.R., Vyshpolskij F.F. and others. The way of furrow watering/ Innovation patent No. 20354

10. Bekbaev R.K., Zhaparkulova E.D., Zhaysambekova R.A. Subsoil water and their influence on specific expenses of water irrigation on the river basin Asa-Talas / The material of international conference – Almaty. Tetis, 2006 p. 55-58

11. Bekbaev R.K., Muhamedzhanov H.V., Bekbaev U.K. The way of solonetzic soil amelioration/ Innovation patent No. 17024

Ground Reservoir: A New Pattern of Groundwater Utilization in Arid Northwest China. A Case Study in Tailan River Basin

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Abstract

High dams are built as engineering technical approach to solve the problem of water storage and regulation in arid inland river systems. In this paper, based on the analysis of the experiences in construction of underground reservoirs at home and abroad, the characteristics of geomorphic unit storage structures in arid inland river basins, as well as geological geomorphic structural conditions suitable for construction of underground reservoirs were analyzed; the difficult points and solving options for construction and utilization of underground reservoir were discussed, too. In the light of the characteristics of the traditional Karez Canal systems in Xinjiang, the concept of underground reservoir construction which is composed of the Karez wells across a river has been proposed. The research progress and key technical points in the feasibility model test of the case study in Tailan River Basin were discussed in the third part, and it showed that the underground reservoir with Karez wells across a river had more useful prospects in arid inland river basins. Finally, we proposed a new pattern of unified regulation of surface and ground water which takes the underground reservoir storage regulation as the main measure for water resources development and utilization in river basin, and the new pattern may be beneficial trial for effective utilization and rational allocation of water resources in arid inland river basins. The underground reservoir and its integrated regulation with surface water will have better application prospects in central Asia region, and is worthy conducting further research.

Key words: ground reservoir, inland river basin, landform unit, storage structure, the Tailan River, integrated model.

1. Introduction

Dam-construction is usually used to solve the problem of regulation and storage of water resources of inland rivers in arid areas. Although a ground reservoir is another high efficient method for solving this problem, it is often neglected by technicians and still not developed well. The reservoir was situated in shallow zones, called *aquifer zone*, consisting of rocks and spaces such as crannies and karst caves and among loose deposit. Ground reservoir included four parts: natural storage zone, a dam to enclose the storage zone, infiltration works from surface water and water-intake works from groundwater. There are four types of ground reservoirs: artificial recharge and recovery from shallow zone without dam, karst type, valley type, and hopper type. They are also divided into two types on the basis of geological structure: with a dam and without a dam (Han-xue Du et al, 2002). Compared with surface reservoirs, they had obvious advantages in the aspect of economy, technique and environment: simple structure, small investment, no dam-break disaster, long use life, easy regulation and management, insignificant issues of silt deposits in reservoirs, no occupation of land, high-efficient reduction of evaporation, larger ground reservoirs performing the multi-year regulation of rich storage and exploitation in requirement, no collapse-landslides happening at the sides of reservoir banks and no disturbance of environment or fish migration. Basing on the above reasons, developed countries now prefer aquifer storage and recovery to surface dam for water storage.

Aquifer storage and recovery for water resources storage was not a new concept, and the related research and techniques have been practiced all over the world. At the end of the 19^{th} century, the US started to practice artificial recharge by the groundwater into the balance regulation of water supply and requirement and proposed the concept of water bank. Ground reservoirs are referred to ASR (aquifer storage and recovery) in the foreign countries. Over 100 ASR systems are built in America; 26 ASR work with 330 (Xinqiang Du, 2005) wells only in Florida. The capacity of water storage in alluvial fan of the Kern River, a river in California, the USA, is at least 1.235 billion m^3, and now it stores 1.07 billion m^3 with pump capacity of about 0.3 billion m^3 per year. Holland has a 50-year history of artificial injection into sand dunes along the sea and its model of exploring water resources is to deliver water from the Rhine River, and then to purify it using aquifer by injection, finally pumping groundwater out while implementing curtain grouting for groundwater reservoir. It was done in cooperation with Japan in Amsterdam (Tianshi Zhao, 2000). The scheme of ASR is planned and constructed to solve the problem of water regulation in many countries, such as Sweden, Holland, Germany, Australia, Japan, Iran and etc.

Groundwater reservoirs were chosen to solve the problem of water-scare and water regulation in China. Some provinces except for north-west provinces implemented groundwater reservoir projects in some places (such as in the west suburb of Beijing, Longkou in Shandong Province, Lvshun in Dalian City, Changyang in Liaoning Province, etc.) as the early as in the 1990s. The Huangshui River Groundwater Reservoir, which is the first well-functioning groundwater reservoir in China, consists of a river sluice, a ground dam and lots of facilities of gathering infiltration flow for conjunctive surface and ground water system regulation. It blocks intrusion of sea water and achieves high-efficient water use while improving environment around it (Zhenfan Liu, et al, 2003). A gravity flow groundwater reservoir was built on floodplain of Laolong Gulf, the Xiaoling River, Changyang County, Liaoning Province in 1997. Its available regulation storage capacity is 360 thousand m^3; the width of river bed is 394m with the thickness of sandy gravel coating of 6.8m. Due to the constructed ground dam, water is stored among pore space of sandy gravel at the upper stream. During irrigation period the sluice is opened and water flows down into irrigation zone. It solves the problem of silt deposit and high evaporation of surface reservoirs (Guoyi Dong, 2000). Most studies and practical applications of groundwater reservoirs in China were performed mainly in east China. The related research of the groundwater reservoir in arid west inland area is still a challenge. However, the groundwater reservoir has special meaning and large prospective in northwest China considering characteristics of rich geological structure, frequent exchange between surface and ground water, and water-scare condition.

2. Characteristics of geologic storage structure in arid northwest China and conditions for constructing a ground reservoir

2.1 Characteristics of geologic storage structure in arid northwest China

Landform of most of river basins in arid northwest China can be divided into four parts along a river: mountain zone, alluvial fan in front of a mountain, alluvial plain, belt of transition between oasis and desert (Fig. 1).

1) Mountain zone (I): Rivers originate in mountain zones. The flow comes from a glacier, melt snow and rain. Most of it goes into the mainstream, and part of it flows under the ground through space among rocks. Slope of mainstream is often between 1.5% and 3%.

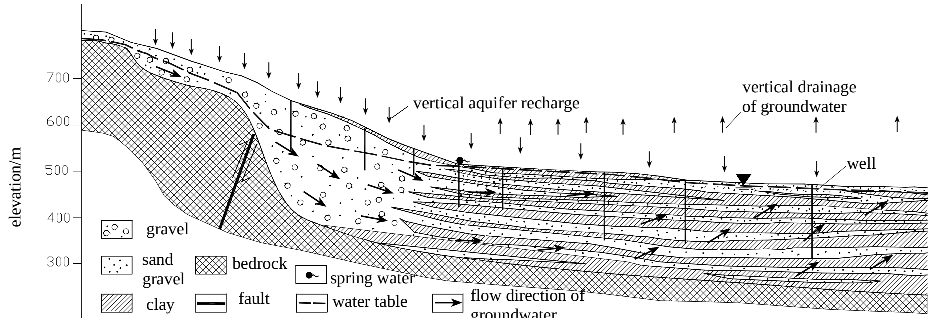
2) Alluvial fan in front of a mountain (II): this landform unit can be divided into the upper and middle part of alluvial fan in front of mountains (II 1 zone), and overflow belt at the edge of fan (II 2 zone).

II 1 zone: After the river flows out of the mouth of valley the surface water partially scatters and disappears. Its slope becomes slow and width of surface water becomes larger, water infiltrates into the ground quickly. And then the surface water transforms into phreatic water at once. Rocks there belong mostly to the Quaternary sand gravel with aquifer layer of coarse particles, good condition of water cycle, and deeper depth of water table and higher cost of pump water while the zone is far from irrigation zone and main recharge of groundwater in overflow belt at the edge of the fan. So the zone is suitable for layout of project of surface water transportation to infiltration. But in the real practice, the total quantity of water shall be strictly controlled because it limits zone of groundwater exploitation. II 2 zone: The zone is located at the groundwater overflow zone, which is on the alternate area of confined water and phreatic water, with shallow depth of water table, good permeability of aquifer zone, rich water quantity and good quality, quick recharge to groundwater and in well condition for exploitation.

3) Alluvial plain (III zone): It is in the upper and middle part of alluvial plain, which is the main oasis economic zone in most northwest China. The zone has low slope, shallow depth of phreatic water table, fine particles of rock, low water-abundance, and lower water quality, and is easy to cause salinity. It will lead to a large quantity of invalid and low-efficient evaporation. The depth of the confined water table is in the middle and run flow condition is fine. The relation between phreatic water and confined water is close. Confined water recharging to phreatic water will lead to raise the water table.

4) Belt of transition between oasis and desert (IV zone): The zone has finer, more homogeneous particles with weak permeability and bad water quality. Phreatic water is

mainly recharged from seepage from canal. Confined water is recharged from lateral flow of groundwater, and then weakly and slowly recharges to phreatic water.



landform unit	mountain zone（Ⅰ）	flood alluvial fan in front of mountain（Ⅱ）		alluvial plain（Ⅲ）	belt of transition between oasis and desert （Ⅳ）
		upper and middle part of alluvial fan（Ⅱ1）	phreatic overflow zone in the form of circular fan(Ⅱ2)		
property of aquifer	phreatic zone with simple structure	phreatic zone with simple structure	belt of transition between phreatic zone and vadose zone	phreatic water and confined water with multilayer structures	confined water with multilayer structures
model of exploitation and use of groundwater	constructing groundwater reservoir	limited exploitation zone	exploitation zone of storage and regulation	exploitation zone of regulation and control	banned exploitation zone
exploitation method	water points or delivery pipes	scattered points to intake water	united water points and scattered points	clustered zones and scattered points to intake water	

Fig.1. Sketch of Geologic Storage Structure and Property of Geomorphic Unit of Arid Inland Rivers in North-west China

2.2 Suitable zone for constructing ground reservoir and analysis of its types

(1) When river flows from the mouth of mountain, the Quaternary sand gravel with a certain thickness covers riverbed with higher porosity and strong permeability. The groundwater reservoir of valley type (Fig.2) is formed by means of water delivery & infiltration and water-intake, and by constructing ground dam to block water.

(2) Uplifted structure between mountain zone and the plain forms depression among mountains, covered by the Quaternary sand gravel with a certain thickness, which is good structure for groundwater storage. River is mainly the channel of overflow groundwater. It can play huge function to regulation storage water if only some artificial measures are implemented. This is called groundwater reservoir with depression between mountains (Fig. 2).

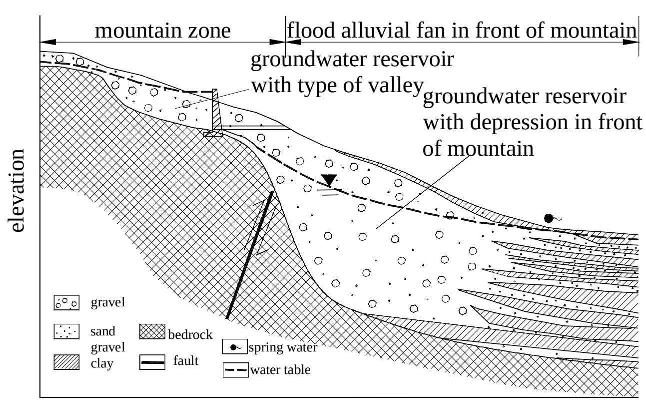


Fig.2 Sketch of Groundwater Reservoirs with Type of Valley and with Depression in Front of Mountains

(3) Overflow belt at the edge of fan in front of mountain is affected by tectonic movement of compression. Mountain zone gradually rises and plain area slowly drops, and the depression in front of the mountain has been formed. It is covered with a large thick layer of sand and gravel suitable for groundwater storage. Particles in the plain area become finer with lower permeability, which naturally forms ground dam to block water, and overflow belt of phreatic zone is formed, which is named groundwater reservoir with depression in front of mountain (Fig.3).

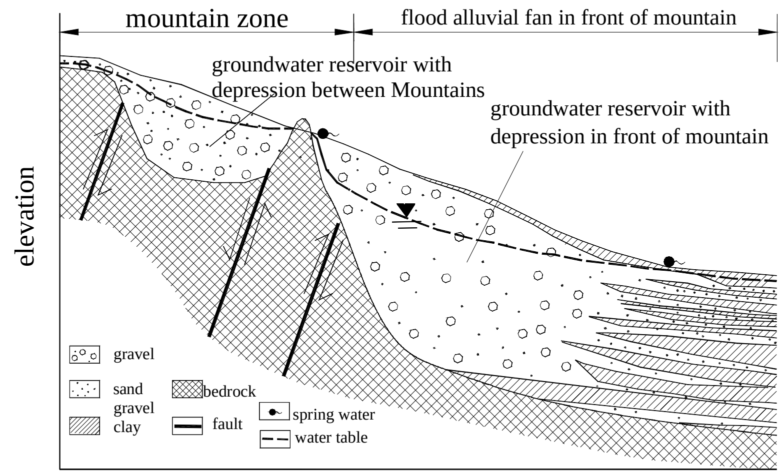


Fig.3 Sketch of Groundwater Reservoirs with Depression in Front of Mountains and Between Mountains

Suitable zones for constructing ground reservoir are mainly located in a valley with deep covering layer in mountain area, depression between mountains and in front of a mountain, corresponding to constructing groundwater reservoir of valley type, groundwater reservoir with depression between mountains and groundwater reservoir with depression in front of mountain, and valley groundwater reservoir.

3. Materials and methods

3.1 Site study

The Tailan River is in the Akesu River basin in Xinjiang and belongs to water system of the Tarim River. It originates from glacier of the south slope of the Tuomuer Peak in the Tian Shan. The river with the length of 217km feeds on snow-melt. The total catchment area above Tailan Hydrometric Station in the mouth of the river is 1338km^2 with annual average runoff of 0.71 km^3. According to landform unit along the river, the Tailan River is divided into the mountain zone, alluvial fan in front of the mountain, alluvial plain, belt of transition between oasis and desert, and desert (Fig.4). Its geological condition in mountain zone is complex and dam has not been constructed until now. It has geologic structure and hydrologic condition for constructing ground reservoir of depression in front of the mountain because of its rich land resources in slope plain in front of mountain, strong infiltration capacity, deep depth of water table and higher water quality of recharge.

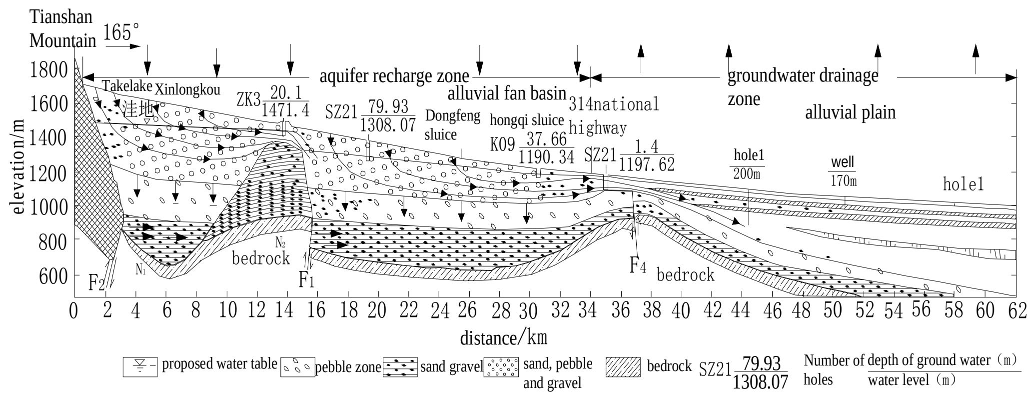


Fig.4. The Tailan River Hydrogeologic Profile of Groundwater Reservoir with Depression in Front of Mountains

3.2 Methods

(1) Construction of groundwater reservoir has many advantages comparing to surface reservoir, but it has weaknesses, such as small mouth and big belly. That is, the storage space is big, but it is difficult to enter it, to deliver water there and to use it. At the same time, the main condition for constructing groundwater reservoir is having natural storage space in a special zone. Determining its storage capacity is complicated; it is precise hydro-geological exploration. The complicated key points are to enhance capacity of water injection and delivery, considering difficulty of artificial recharge to aquifer, infiltration velocity and quantity, clogs, changes in groundwater quality, interaction between water and rock and etc.

(2) There are four key moments in construction of groundwater reservoir of the valley type. Aquifer hydrogeology condition, construction technique of a ground dam, diversion of infiltration system, and water-intake system should be considered.

1. Determining aquifer hydrogeology condition of reservoir. The specific property of the rock in deep covering in riverbed of arid inland river is usually the Quaternary sand gravel with capacity for good infiltration, loose structure, porosity with the value of 50～100mPd and gravity water yield with the value of 0.115~0.125. It is necessary to study aquifer hydrogeology condition well and selection the prefect storage structure for constructing valley groundwater reservoir. There are suitable study techniques to accomplish it.

2. Dam construction techniques. Dam is constructed under ground, so some changes are to be made in surface dam construction technology. Ground curtain grouting dam, continuous

wall construction and high pressure jet grouting with structure of geomembrane lining are applied. They been tested and accepted and there are no questions in dam construction under different geologic structures.

3. Infiltration diversion system. Groundwater recharge in deep covering of valley is composed of lateral inflow of upstream riverbed and vertical inflow of river in reservoir. However, the above recharge can not meet the function of regulation and storage of surface water. So it is necessary to plan artificial diversion of infiltration system in order to deliver surface flow into the ground reservoir. Design of reasonable infiltration canal, pot and pitch for efficient delivery of surface water into the ground reservoir must be proved and confirmed scientifically considering technical and economic condition.

4. Water-intake system. Groups of electromechanical wells, wells of big diameters, and radial wells are used for water intake in the world. At present, the technique of digging wells and pumping water tends to be perfect. But ground reservoir is usually situated far from irrigation zone and the cost of wells is higher. Water intake system is the key question in using groundwater.

4. Results

4.1 Artificial aquifer recharge test

The silt content of the Tailan River is high and its annual average silt content of suspended sediment is 4.37kg/ m^3, the largest sediment delivery ratio among the rivers in Xinjiang. As a result, the key point of Artificial aquifer recharge in Tailan River Basin is to prevent it from clogging. The task is to construct a new sand deposition tank, a settling tank, two holes of infiltration wells, 18 infiltration tanks for rebuilt water delivery canal system to enhance infiltration method, artificial recharge combining infiltration canal with infiltration wells, recharge construction combining infiltration wells and infiltration tanks (Fig. 5), recharge construction based on a series of ladder infiltration tanks with shallow depth (Fig. 6) and etc.

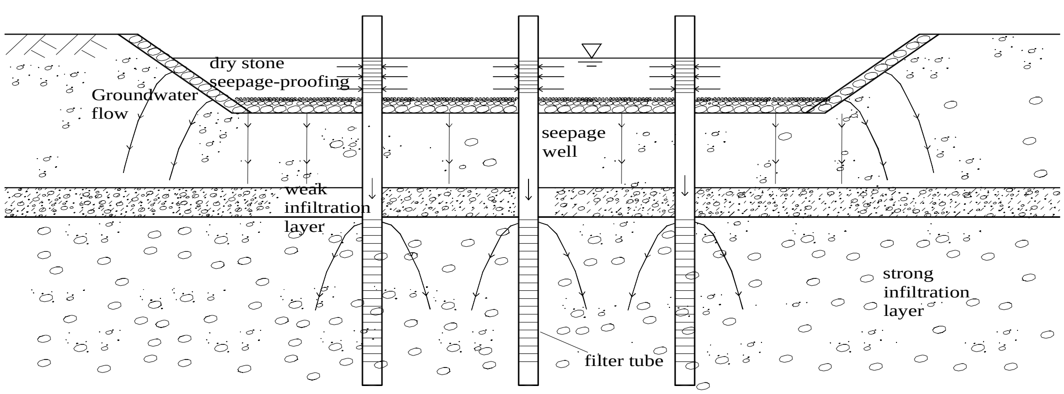


Fig. 5. Sketch of Recharge construction of Conjunctive Pit-pond and Seepage Well

4.2 Water intake test

It is very popular to use electromechanical well to pump water because its technique has advantages: simple construction, short construction period. But its weaknesses include higher operation cost, small water yield of a single well and scattered layout. Radial wells with larger diameters have big discharge of a single well, lower operation cost, they are easy to manage and etc. It is usual practice to increase discharge of a single well with larger diameters in the area of weak infiltration of aquifer.

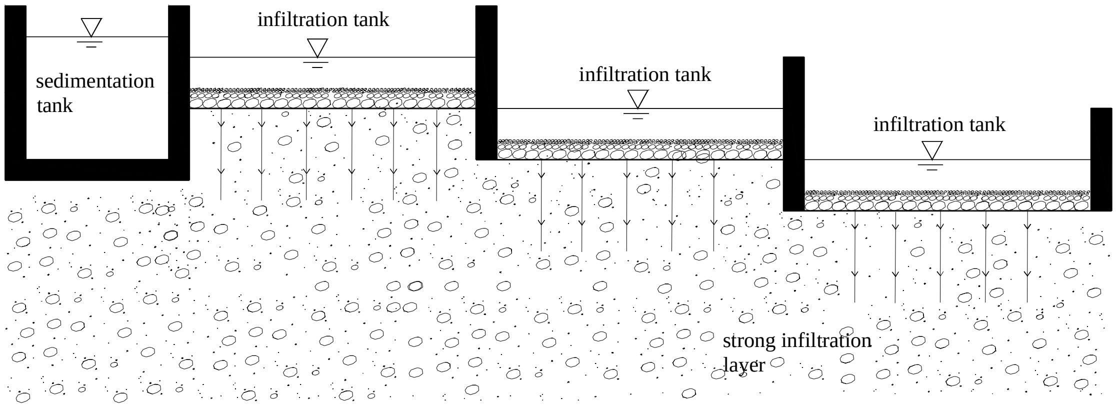
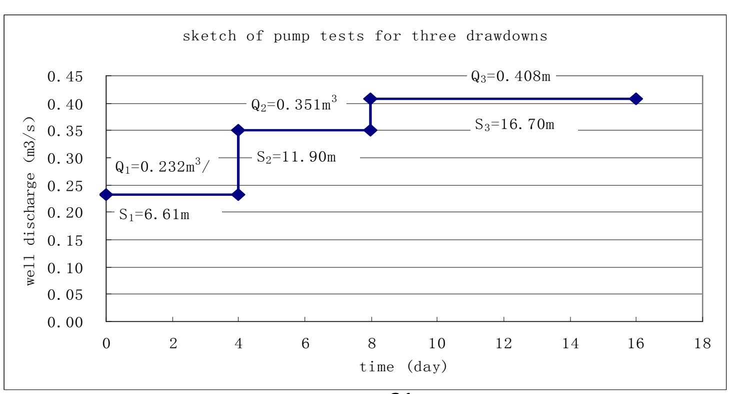


Fig.6 Sketch of Recharge construction based on a series of Ladder Infiltration Tanks with Shallow Depth

Aquifer zone of ground reservoir in the Tailan River contains sand and gravel with coarse particles and high level of infiltration. Diameters of radial wells can be increased, but higher technology of construction is required. At present, to build a hole in layer of sand and gravel injection method is usually used in China, which is to inject pipes into the layer of sand and gravel with hydraulic jack. However, it will be difficult to use this method in the coarse layer of sand and gravel: the distance of injection is limited to10m and discharge can not meet the requirement.



The technology of horizontal injection with hydraulic jack using vibratory drilling was tried. The vibratory equipment is installed and the main drilling pipe is rotated by the hydraulic motor into aquifer. As compared to current drilling, it can decrease resistance of drilling pipe and the length of drilling is over 20m. Using this method, four radial wells with bigger diameters (diameter of 3.5m, the well depth of 30m, 3 layers of radial pipes, 8 pipes with length of 15m for each layer) have been built. Figures 7 and 8 show that discharge of the well is 0.408 m^3/s with 16.7m of aquifer drawdown. It can be easily seen that as the aquifer drawdown increases, the water yield increases as well. Water yield of the well is 0.331 m^3/s with 10.8m of aquifer drawdown. Considering disturbance among wells, discharge of four wells can reach 1.152 m^3/s.

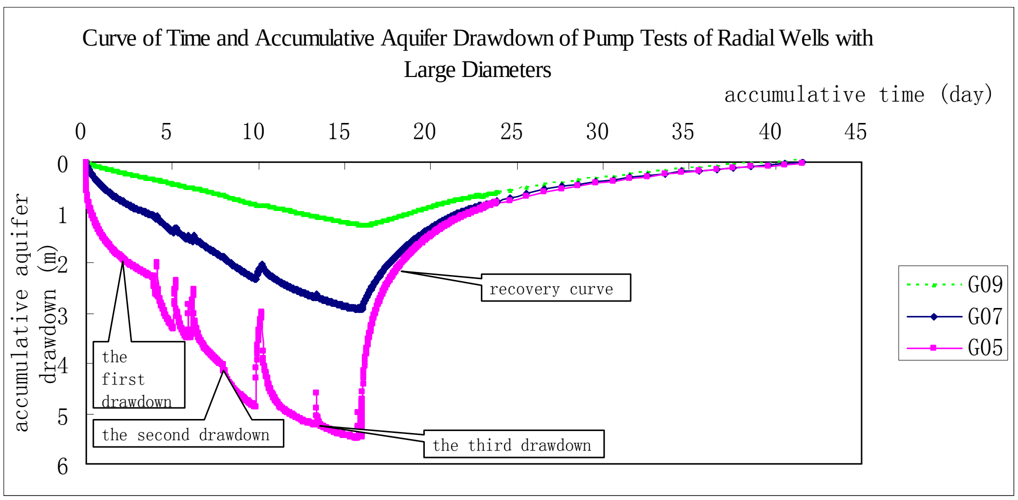
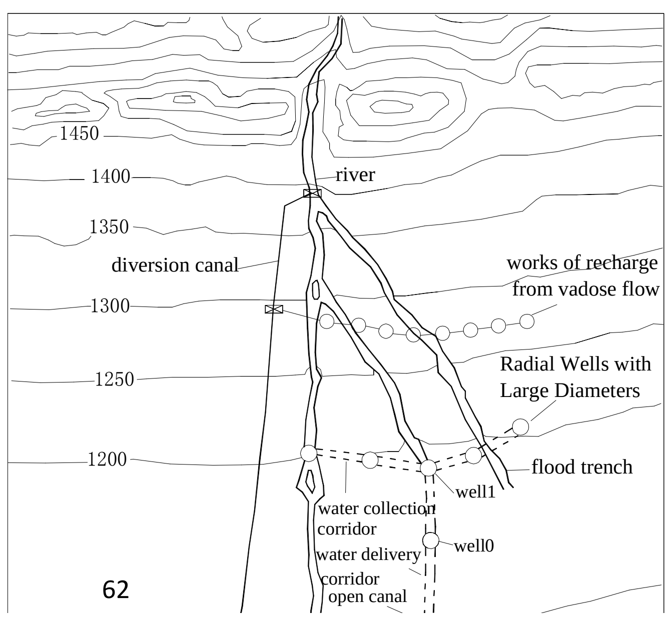


Fig.8. Curve of Time and Accumulative Aquifer Drawdown

4.3 Water delivery system with Karez wells system across a river

Old Karez well system is meant to collect groundwater. Overflow belt of the ridge of alluvial fan in arid inland rivers has the thickness of layer of sand and gravel and Karez wells system across river can be designed and arranged near overflow belt (Fig.8). It is possible to control



quantity of water flowing out of the ground reservoir.

Following the principle of Karez wells system, a pipe is built across a river connecting with radial wells under the designed dynamic water table and Karez wells system across the river is formed. A water delivery pipe is built along the river to the downstream of the river. The slope of land is 5‰ and the water delivery pipe with the length of 4m leads water to the surface, and then a 3 meters long pressure pipe connects it to drip irrigation system. This method doesn't require power and decreases operation cost of a groundwater reservoir.

5. Discussion

5.1 Difficulties in reservoir dam construction

It is very popular to construct surface reservoirs in the mountain valley to regulate and store water. However, it is difficult to construct dams there. Thickness of the dam of the Laolongkou Reservoir in the Tailan River Basin reaches 65m in thickness. Construction of such dams is expensive and demands complex technologies to build it in short period.

5.2 Relationship between surface and ground water in ground reservoir

According to the landform unit property and water storage structure in arid land area, the traditional view should be suitable for the real situation. Building ground reservoirs in suitable zone, combining them with scattered electromechanical wells in alluvial plain, consists of conjunctive surface and ground water regulation system, mainly depending on ground reservoir (Fig.10).

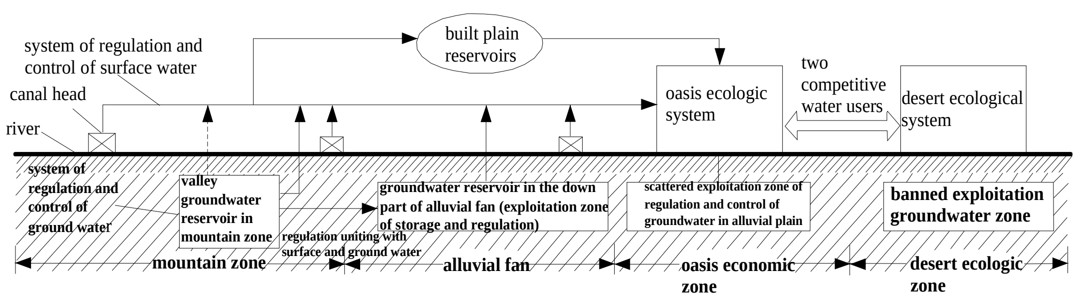


Fig.10 Model of Exploitation and Use of Water Resources in Basin Mainly Depends on Regulation and Storage in Groundwater Reservoirs

The model of water resources exploitation mainly depending on regulation and storage of groundwater is meant to solve the following problems:

(1) Being a basin as a unit, surface and ground water are defined as a united part of water resources. To meet water requirement of industries and environment it is necessary to work out conjunctive regulation of surface reservoir, ground reservoir with a dam in a valley, ground reservoir without a dam in overflow belt at the down ridge of alluvial fan and electromechanical wells.

(2) It is necessary to provide rational and scientific method of delivery and recharge of groundwater in order to decrease non- and low-efficient evaporation of phreatic water, decrease salinity disaster of soil and improve water use efficiency. Ground reservoirs in valleys, depressions between mountains and depressions in front of mountains should be the main units to regulate and store water in basin. Water table in alluvial plain can be controlled in rational way by scattered electromechanical wells implementing drainage and irrigation.

(3) In accordance with change rules of water quality in basin, water protection zones should be divided. Repeated use of water resources should be controlled and managed in order to meet water requirement of different water users.

(4) Taking into consideration water use in urban, industries, irrigation and environment, plans of water resources allocation should be optimized. Considering basic requirement of environment, limited condition of runoff regulation should be proposed and relationship between a dam and environment shall be treated suitably.

(5) The feasibility of constructing a valley ground reservoir should be actively explored. Storage space for groundwater in alluvial fan and alluvial plain should be arranged rationally.

6. Conclusion

(1) Conjunctive surface and ground water as a whole is a creative model of utilization of water resources in small and medium basins in arid area. A ground reservoir is a method of regulation and storage of water resources on the basis of basin as a unit. It is hydro-geological structure without high expensive dam and with numerous economic advantages. Groundwater reservoir prevents severe evaporation and losses of surface water, improving water use efficiency. It can actively and efficiently control water table and decrease non- and low-evaporation of phreatic water in soil and decrease salinity problem. It provides a new view, method and prospective for planning small- and middle- basins. It creates new future of high-efficient and rational allocation of water resources in arid inland rivers.

(2) Recharging by delivery infiltration and pumping by delivery water are the key techniques of this new model whether it is successful or not.

(3) A large quantity of plain reservoirs and dams has been built. We emphasized the height of the large dams. But we neglected the ground reservoirs. Researching the model of high-efficient water use must be trend in future when contradiction between water supply and requirement grows. We should make decision on basis of real situation and follow the concept of harmonious relationship between human beings and nature. Researching of ground reservoir should become an important task in the process of regulation and storage of water

resources, both surface and ground waters. As a new model of high-efficient water resources use, it should be practiced in suitable areas.

(4) Most areas in Central Asia, especially in Kyrgyzstan, Tajikistan, Uzbekistan, Kazakhstan and Turkmenistan, belong to the Tian Shan and are connected with the China; they have similar condition of hydrogeology, climate and water resources. In the process of climate change and during development of economy and society in future, water problem will become more complicated. Ground reservoir and the model of water resources exploitation and utilization will have prospective to practice.

References

1. Deng Ming-jiang, Pei Jian-sheng, Wang Zhi. Landform unit characteristic and its underground storage structure for inland river basin in arid area. *SHUILI XUEBAO*, 2006, 37(11). Pp. 1360-1366. (in Chinese)

2. Dong Guoyi. Underground reservoir, an effective way of settling the shortage of water resources in the mountainous regions in north China. *China Water Conservancy*. 2000. (5). P. 46. (in Chinese)

3. Du Han-xue, Chang Guo-cun, Zhang Qiao-sheng, etal. Preliminary study on utilizing groundwater storage. *Advances in Water Sciences.* 2002. 13 (5). Pp. 618-622. (in Chinese)

4. Du Xinqiang. Study of actuality and prospect of underground reservoirs in regulating and storing water resources. *Progress and Countermeasure of Science and Technology*. 2005 (2). Pp. 179-180. (in Chinese)

5. Liu Zhenfan. Binhai underground reservoir system project in Longkou City. *Survey Science and Technology.* 2003 (6). Pp. 47-52. (in Chinese)

6. Zhao Tianshi. Important choice of sustainable development strategy in Liaoning Province in 21st century. *China Geology.* 2000 (2). Pp. 26 -28. (in Chinese)

Water issues and supply solutions in Israel

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Most of the Israel is arid, and while the amount of rainfall in the north is on the average about 600mm/y it is about 200mm/y on the verge of the desert and almost zero in the desert in the south of the country.

Israel has a limited supply of water, not enough for the ever increasing demand of the agriculture, industry and domestic uses. However, the country has the innovative technologies and variety of means to meet the growing needs.

The total amount of water supply in the country is about $2Km^3$ per year, but About 80% of the water potential is in the north of the country and only 20% in the south. To meet water demand all over the country an extensive water distribution network was built to bring water from the north to the desert in the south. This solved some problems and enabled to develop the south, but after drawing on nearly all of its readily available water resources and promoting vigorous conservation programs, Israel has long made it a national mission to stretch existing sources by developing non-conventional water sources, while promoting conservation. These efforts have focused on the following: reclaimed wastewater effluents; intercepted runoff and artificial recharge; artificially-induced rainfall - cloud seeding; and desalination.

The talk will focus on the ways in which proper management and innovative technologies can increase water supply.

Water Issues in Pakistan

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Pakistan's agriculture is heavily dependent on irrigation water supplies as 68% of its area receives annual rainfall of about 250 mm, 24 % area has annual rainfall of 251 to 500 mm, therefore categorizing it as an arid to semi arid country. Agriculture is still the main sector of the country contributing 22% to GDP, employing more than 45% of its labor force and is a source of providing livelihood to more than 65% of its population (167 million) residing in the rural areas. But agricultural production and food security of the country are coupled with the water security. Water is the most precious resource and its judicious use has become imperative for survival of the people and economic development of the country. The country had surplus water availability in the range of 5000 m^3 per capita in the earlier period of 50s but now it has become a water scarce country with the water availability approaching to 1000 m^3 per capita, which is resulting in shortage of water, insecurity of food, and raising conflicts and environmental repercussions. Under this scenario, there is an urgent need to address water issues both in terms of quantity and quality on urgent basis to ensure food security, and improve livelihood of the rural people. Although Pakistan has the largest contiguous irrigation system of the world but it is operating at a very low level of irrigation efficiency i.e. 40%.

According to an estimate, water demands for agriculture are fulfilled as below:

Surface water supplies	40 to 60%
Groundwater	40 to 50%
Rainfall	10 to 15%

This distribution is dependent on the climatic conditions, rainfall patterns, river flows and canal diversions.

Surface Water Issues

Irrigation efficiency is low i.e. 40%, which means when on the average100 MAF (million acre foot) river water is diverted to canals, about 40 MAF is used by the crops and 60% is lost during conveyance through canals, distributaries and water courses. Although this is the loss yet it may contribute as recharge to the aquifer where groundwater is fresh but it may be loss if groundwater is brackish. To improve irrigation efficiency, model farms need to be developed to demonstrate the water saving technologies with participation of the farmers and local industry so that these technologies would be technically feasible, economically viable and socially acceptable for sustainability of these technologies. Followings are the options to improve on farm water management based on the site specific conditions of the farm.

Options:

- Gated Furrow irrigation
- Raised bed furrow irrigation
- On farm water storages and efficient irrigation application through perforated pipes
- Drip irrigation
- Sprinkler irrigation
- Conjunctive application of sprinkler and furrow irrigations

These methods may need modifications keeping in view the affordability of the farmers, technical know how, operational skill and ability of the farmers / local industry and energy prices. There is possibility of developing sprinkler units to be operated using tractor driven PTO power because tractates are available with the farmers and they know how to operate them. Similarly significant amount of water is needed to fill the dead storage of farm water courses before water starts irrigating the fields. This amount of water filling the watercourses becomes more expensive when these storages are filled by pumping groundwater because watercourses, made for canal water supplies, are used for groundwater. That means sizes of farm water courses are larger and not feasible for use of groundwater. Therefore, there is a dire need to have farm water storage which can be used to store and convey water to the field of application through pipes to save conveyance / application water losses as well as save land under the farm water courses.

Groundwater

Groundwater is an important source of water for irrigation especially during the drought period and it is meeting about 40 to 60% of the crop water requirements. Groundwater is also a flexible water market, which supplies water on demand basis and provides flexibility to the farmers and according to the needs of the crops. This resource is under threat because of its continuous falling of water table at the rate of about 1 ft per year as a result of increased water demands. Cropping intensity has increased from 75 to 150% while canal water supplies have decreased due to decrease in river flows and climate change impact. Groundwater is the only option left with the farmers to irrigate their crops but this resource is facing the following problems.

Groundwater Issues

- Falling groundwater levels
- Deteriorating groundwater quality
- Increasing pumping cost
- Inducing secondary salinization
- Non availability of technical guidance to design and install efficient well
- Training of the local technicians
- Auditing of existing tubewells to save energy and increase pumping efficiency
- Identifying the formations to skim fresh groundwater

Options

Resistivity survey can be used to assess the potential of the aquifer as well as identify the formation having fresh groundwater quality to minimize the secondary salinization issues. Technical training centers be established to provide technical guidance regarding installation of efficient well and size of prime mover on site specific basis. Pumping schedule needs to be developed to skim fresh groundwater for minimizing the secondary salinization problems.

Efficient well design can also improve pumping efficiency and save energy and decrease the pumping cost. Groundwater recharge program needs to be initiated to control the falling water tables.

Reuse of Wastewater

The rapid urbanization and industrial growth has increased the sewage and industrial wastewater effluents many folds. This untreated wastewater is being used for growing vegetables, food crops and fodder because of the nearby markets in the city and also due to water scarcity problems. The other reasons for wastewater irrigation are the high contents of plant nutrients and consistent availability of this effluent resource round the year. It has been reported that application of 400 mm of sewage water can add plant nutrients in the range of 100 – 200 kg Nitrogen, 6 – 20 kg Phosphorous and 100 – 250 kg Potassium.

Wastewater Issues

This untreated wastewater irrigation, however, is very dangerous due to its composition of having all kinds of pathogens, viruses, trace elements and heavy metals, which are posing a serious health concern for producers, handlers, consumers and community living adjacently to such production areas where this untreated wastewater is being used. This wastewater can become a resource if treated properly prior to its use for agricultural production.

Wastewater Options

Treatment of wastewater is must prior to its release to the nature to minimize its adverse effects on the land, water and food crops. Treatment may result in two major accomplishments, which are environmental protection and availability of safe water for agricultural production to overcome the increasing water scarcity issues. As a pilot project, it the proposed project may be implemented in one of the sections of Faisalabad, the third largest city of Pakistan, which is generating drainage effluent of about 6.45 m^3/sec. This wastewater is mixing of 2.94 m^3/sec from domestic sewage and 3.51 m^3/sec from industrial sector. The city is known as “Pakistani Manchester” because of its textile industries. There are about 512 large industrial units of which 328 are textiles, 92 are engineering works and the remaining are related to food processing industries.

The outcome of the project will result in availability of treated safe sewage water for irrigation purposes and environmental protection. A model of viable and sustainable wetland for treatment of sewage effluent will be developed, which can be replicable for other cities and may also serve as fish ponds and recreational areas.

Water is the most crucial factor for increasing agricultural production and to bring new area under cultivation to meet the food and fiber demands of the growing population and also to ensure food security for the region. Therefore, there is a need of integrated approach first to devise methods for its efficient application and then secondly to increase crop productivity per unit of water and land.

The CEWRE, UET, Lahore is working on water issues with major focus on water resources related to reservoir building, canals, distributaries and their related civil works. Similarly IWMI, Lahore is working on water issues related to institutional factors and their impacts on water productivity whereas the University of Agriculture, Faisalabad (UAF) is the land grant university with the mandate to devise and promote the best agricultural management practices for ensuring food security, improving land and water productivity and improving livelihood of the farming communities.

Keeping in view the above mentioned water issues, their options and use for increasing agricultural production, the UAF has the best human resource and capacity to manage this precious resource and use it efficiently. The UAF has the following infrastructure to launch water related projects:

1. Department of Irrigation and Drainage, Faculty of Agricultural Engineering and Technology. The Department has 3 PhD(s), 4^{th} one will be completing his PhD this year in Germany and 5^{th} one is pursuing his PhD in the Netherlands. The Department is offering MS and PhD degree programs in the area of irrigation, drainage and groundwater. The Department has developed national and international linkages and a number of national and international projects are being executed. The Department has the capacity to contribute in developing on farm water management practices.
2. Department of Agronomy at UAF is conducting studies on water stress effects on crop productivity under different management practices.
3. Department of Plant Breeding and Genetics is working on developing drought resistance varieties.
4. Institute of soil and environmental sciences is conducting studies on the aspects of water quality, saline water usage and its effects on the soil and crop production.
5. Department of Agricultural Economics is studying the socio-economic aspect of the water management practices on the farming community in the rural areas.
6. The water management research center at UAF is imparting technical training to the professionals and engineers for promoting best management practices to conserve water and use it efficiently.

Effectiveness of Drip Irrigation in Kyrgyzstan

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Research Institute of Irrigation of the Kyrgyz Republic

Results of study of drip irrigation and its effectiveness in sandy soils in countries of Central Asia are presented. Technique and technology of drip irrigation of apple gardens in the Issuk-Kul region are described.

Drip irrigation doesn't only save water and increase crop capacity, but also preserves environmental safety in regions and gives opportunity to solve the problem of the Aral.

Drip irrigation considers continuous water supply directly to the roots of plants through a network of pipes of a small diameter with special water outlets (droppers), placed on the surface or under ground.

At present drip irrigation is applied in all the countries of the world on the territory of more than 1 million ha; 380 thousand ha are on the territory of the USA.

Drip irrigation method saves up to 60% of irrigation water; in sandy soils it saves up to 300% of water. It is also very effective on slopes. In Tajikistan, in vineyards situated on 40^0 slopes, drip irrigation allowed harvest of 220 centners of grapes for each hectare, while without drip irrigation there wasn't any harvest at all. Increase in pomegranate crop capacity was 35 centners per hectare (compare to furrow irrigation), while irrigation rate became 2.5 times less.

Uzbek researches found, that water saving is 60% (1500 m^3 per hectare) and increase of grapes crop capacity is 60% when using drip irrigation instead of furrow watering (with irrigation rate of 2200 m^3 per hectare).

According to K. M. Kulov, maximum harvest of apricots was 170-180 centers per hectare when drip irrigation method was applied in the Issyk-Kul region.

According to A. J. Atakanov drip irrigation increased crop capacity 2.7 times (203 centners per ha) in vineyards in Batken region, while water saving was 50% compare to furrow watering.

In 1995-1999 P. M. Jooshov studied techniques and technologies of drip irrigation in sandy soils of the Issyk-Kul region for apple trees. Drip irrigation has positive effect on irrigation regime and crop capacity. On the experimental plot average irrigation rate was 2150 m^3/ha, while on the field with furrows the irrigation rate was 6000 m^3/ha. Productivity increased 1.5 times.

To ensure optimal water supply for apple trees in sandy soils of the Issyk-Kul region, feasibility of drip irrigation with flow rate of 4 L/hour was experimentally determined and verified by statistical processing of data. Each tree needs 3 droppers, supplying water simultaneously.

Drip irrigation doesn't only save water and increase productivity, it also preserves ecological safety in regions. To solve the problem of the Aral, Kazakh scientists proposed the use of drip irrigation in Turkmenistan, Uzbekistan, and Kazakhstan in order to decrease use of irrigation water.

Trends of Irrigation Development in the Chu Valley within the Context of Shortage in Surface Water Resources

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Keywords: Ground water flow, influence of irrigation development, climate change protection, Kyrgyz Republic, Chu Valley

1. Introduction

Irrigation farming is the basic source of foodstuffs for population of Kyrgyzstan. Mountainous rivers cover the demand for water resources for irrigation, therefore any persistent change of climate influencing their water discharge appears to be a threat to food safety of the country.

Sources of the rivers alimentation in the area of interest are melt-waters of snows and glaciers, which suggests the dependence of runoff on the occurring climate warming. Even now, rivers of glacier-and-snow type of alimentation prove the obvious runoff increase, along with reduction of it on the rivers in low-hill zones. This happens due to increase of intensity of glacial retreat. Its average rate makes about 6-8 meters a year. On retention of this tendency of warming, starting from a certain time (this time differs depending on the river), the decrease of the stream flow will become appreciably notable.

To mitigate the serious consequences of this phenomenon the following groups of problems are to be solved.

I. Water loss reduction and implementation of water-efficient processes of irrigation. Now, water losses both in the irrigation network and on the farmlands make about 70 percent of the total water draw-off at the irrigation source.

II. Design and construction of additional reservoir storages to accumulate river run-off for subsequent irrigation.

III. Use of waste and drainage waters for irrigation.

IV. Use of groundwater for irrigation.

V. Effective monitoring of resources of ground and surface waters, as well as of reclamative conditions of irrigated lands.

2. The impact of irrigation development on changes in the groundwater balance

Below the examples of irrigation development for two objects in the Chu valley in Kyrgyzstan are considered. In these examples, the consequences of use of groundwater for irrigation and increase of the irrigation systems efficiency in the context of climatic change are assessed. The impact of the mentioned factors on changes of groundwater budget is assessed.

A. THE WESTERN PART OF THE CHU VALLEY

In the area of groundwater recharge (Fig. 1), fundamental reconstruction of the irrigation system was carried out, and consequently the inflow of groundwater has decreased significantly at the expense of irrigational losses. It is necessary to assess changes in reduction of the groundwater flow to subjacent areas of the Chu valley. See a typical cross section in Fig. 2.

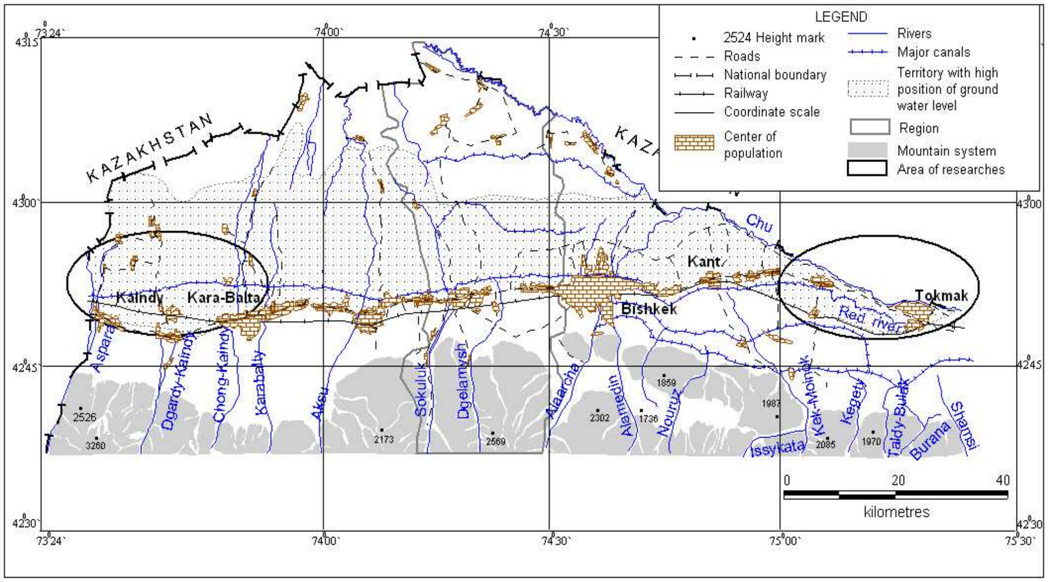

Fig. 1. Scheme of the Chu Valley

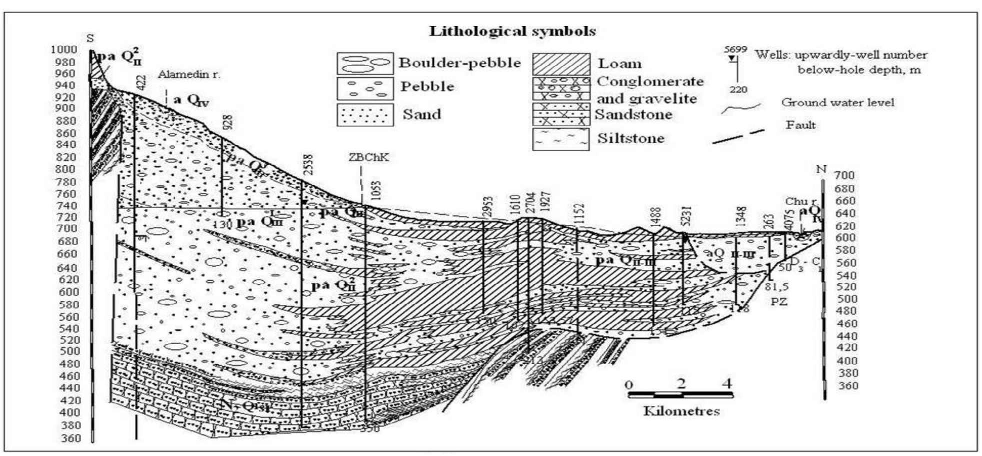

Fig. 2. Typical cross section of the Chu Valley, west part

This problem can be solved by means of ground water modeling. However, the more convenient approach is to derive an approximation formula with parameters defined by means of one-off simulation (Litvak, R.G. and Nemaltseva, E.I., 1990). Then, the derived formula will be used to solve various problems concerned with assessment of the impact of the groundwater recharge area on subjacent hydro-geological areas. The following general dependence can be offered:

$$Q(t) = Q_e + (Q_s - Q_e)\cdot e^{-t\cdot\beta(t)}, \qquad (1)$$

Where Q(t) – the groundwater outflow from groundwater recharge area into downstream areas of groundwater discharge (assessed value), m^3/day;

Q_s, Q_e – initial and final stabilized groundwater outflows (assessed by means of simple balance estimations), m^3/day;

e – the base of the natural logarithm;

t – period of time, days;

$$\beta(t) = \frac{a}{L^2}\cdot\gamma(t) \qquad a = \frac{T}{\mu} \qquad (2)$$

T – transmissivity (characterizes both the groundwater recharge area and the area of groundwater discharge), m^2/day;

μ - storage coefficient;

L – a representative distance from a mountain framework to the border of a discharge area, m;

γ(t) – a dimensionless parameter characterizing the specific natural settings of the considered hydro-geological areas, it is assessed by the results of simulation of the area of interest, and it can be time dependent.

The following approach for estimation of γ(t) of conditions in central and western parts of the Chu valley is suggested. In the beginning, the outflow from the area of groundwater recharge within specific periods is estimated based on the simulation results: t1=1 year, t2=3 year, t3=5 years, t4=10 years, and t5=25 years. By summing up the obtained results, the following dependence for γ (t) can be offered:

$$\gamma(t) := \begin{cases} \gamma 1 & \text{if } t \le t_4 \\ \gamma 2 & \text{if } t \ge t_5 \\ \gamma 1 + (\gamma 2 - \gamma 1)\cdot\dfrac{t - t_4}{t_5 - t_4} & \text{if } t > t_4 \wedge t < t_5 \end{cases} \qquad (3)$$

γ_1 is assessed by means of minimization of the following function

$$F(\gamma) = \sum_{i=1}^{4} (Q(t_i) - \overline{Q}_i)^2, \qquad (4)$$

Where,

$Q(t_i)$ is set by expression (1) at the time point t_i, m^3/day;

Q_i is outflow of groundwater from groundwater recharge area into groundwater discharge area at the time point t_i, assessed by the filtration simulation, m^3/day.

γ2 is defined by the following dependence::

$$\gamma_2 = \frac{L^2}{\alpha\, t_5} \mathrm{Ln}\, \frac{Q_S - Q_E}{Q_5 - Q_E} \qquad (5)$$

The filtration model of the western part of the Chu valley, created by the authors, was used for the above formulas and estimations. The following filtration parameters have been accepted for the formulas: T = 3000 m^2/day; L = 12000 m; μ = 0.2. In accordance with one of possible scenario of development QS = 3.88 m^3/s, QE = 0.93 m^3/**s** (Kaplinsky M.I., 1977).

In this case, γ_1 and γ_2 equal to 2.175 and 1.320, respectively. Fig.3 depicts the required curve of change of groundwater outflow from the groundwater recharge area in response to reduction of filtration losses.

Within 8 years or so, the outflow of groundwater into subjacent areas will reduce to a value of 0.5 (Q_S - Q_E). The expected reduction of outflow to a value Q_S - Q_E will became obvious within 30 or 40 years. The obtained results show that reduction of feed of groundwater in the area of recharge resulted from the climatic change, will not trigger immediate changes of hydrological budget in subjacent areas, which awards enough time for making necessary aquicultural decisions. Multiple estimations of the "response time" can be made with the use of the suggested formulas (1) - (5). As for the central and western parts of the Chu valley, values γ_1 and γ_2, defined by authors, can be used in calculations.

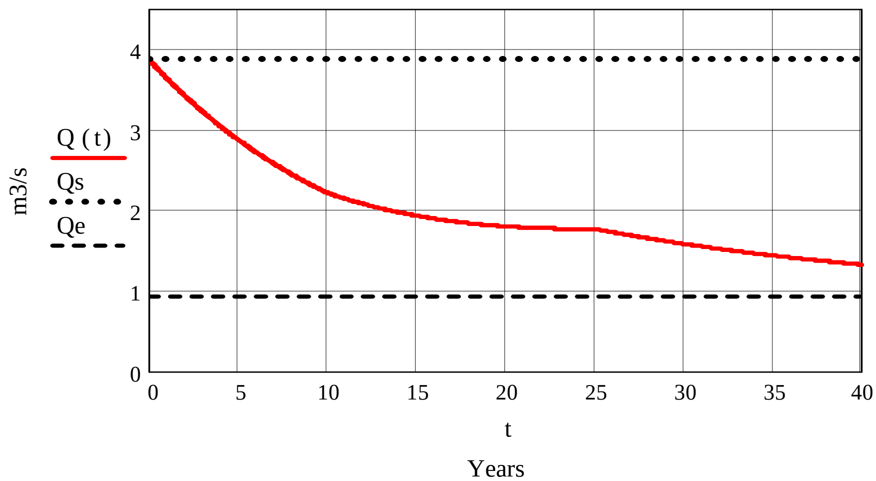

Fig. 3. Changes of groundwater inflow from the groundwater recharge area into the discharge area at reduction of filtration losses from value Q_S to value Q_E.

B. THE EASTERN PART OF THE CHU VALLEY

One of the major problems of irrigation development in this area, in conditions of river flow reduction resulted from the climatic change, is to prevent filtration losses from the Chu River at the reach of 48 km along the river entry into the Chu valley. A rough estimation of losses in view of this area (the so-called "crevasse zone") makes 20 m^3/s. The problem can be solved by means of construction of the second bypass canal with a concreted streambed.

It is necessary to point out that filtration losses are discharged into the Chu River downstream (below Tokmak town). Reduction of filtration losses will result in reduction of discharge into downstream areas. To find out if it is expedient to construct a bypass canal it is necessary to estimate the time interval within which the reduction of losses will have major impact on the groundwater discharge into the riverbed.

See a diagrammatical section of the area of interest along the riverbed in Fig. 4.

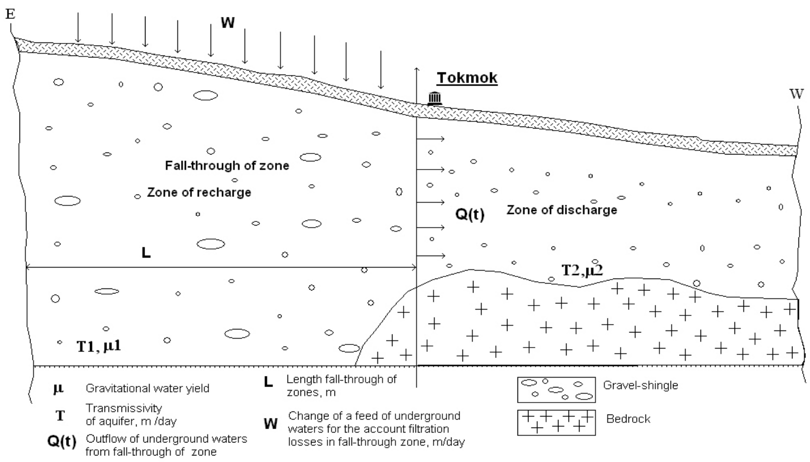

Fig. 3. Cross section along the Chu River, east part of the Chu valley

Alteration of discharge downstream Tokmak town is characterized by the change of stream underflow of ground waters near Tokmak ΔQ(t). In order to estimate the required value, we suggest dependence obtained from derivations of S. F. Averyanov (Kostiakov A. N., Favorin N. N., Averianov S. F., 1956). For short, no intermediate conversions are shown

$$\Delta Q(t) := \Delta QN\cdot\left[1-\frac{8}{\pi^2}\cdot\sum_{n=1}^{\infty}\frac{(-1)^{n+1}}{(2\cdot n-1)^2}\cdot\sin\left[\frac{\pi}{2}\cdot(2\cdot n-1)\right]\cdot\exp\left[\frac{-\pi^2\cdot(2\cdot n-1)^2}{4}\cdot\frac{a\cdot t}{L^2}\right]\right] \quad (6)$$

Where

ΔQN – the amount of filtration losses change in the crevasse zone of the Chu River, m^3/day;

$$a = \frac{T}{\mu}$$

t - a period of time from the moment of the filtration losses change, days;

T - water conductivity, m^2/day;

μ - storage coefficient.

According to data of hydro-geological investigations made in the considered area (Ovdienko A. P. et al., 1993; Litvak R. G., 2010), the following values of hydro-geological parameters are accepted: T = 10 000 m^2/day, μ = 0.18, and L = 48 000 m.

Typical value of filtration losses in the crevasse zone: 20 m^3/s (Ovdienko A. P. et al., 1993; Tsytsenko K. V., Sumarokova V. V., 1990). Two events have been considered: losses decreased by 10 m^3/s, and losses decreased to zero (reduction by 20 m^3/s). The results of calculations in graph form see in Fig. 5.

The estimations show that reduction of filtration losses will result in decrease of discharge, however, it will occur many years later. Within the period of 20 years, the outflow into the groundwater discharge area will decrease only for a value of 50 percent of the filtration losses reduction volume.

3. Conclusions

As it is stated above, the major potential hazard to conditions in the Kyrgyz Republic from the climatic change is reduction of the mountain rivers runoff. This statement is correct as agriculture (being a basis of economy of the state) is based on irrigation farming. Mountainous rivers are the main source of irrigation. Because of shortage of surface water resources, it is necessary to increase the irrigation systems efficiency and to use ground waters for irrigation.

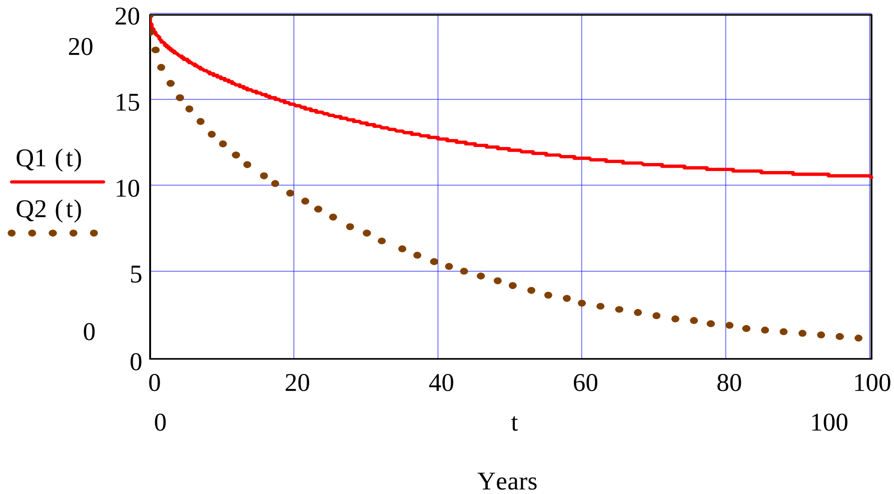

Fig. 4. Alteration of the stream underflow near Tokmak town in response of filtration losses reduction (Q1(t) – decrease of losses by 10 m^3/s; Q2(t) –decrease of losses by 20 m^3\s).

It is necessary to keep in mind, that surface and ground waters of intermountain valleys in Kyrgyzstan are closely interdependent. The increase of the efficiency of irrigation systems reduces recharge of ground waters and, from the perspective of their balance, is the same as using ground waters for irrigation. The mentioned factors reduce flow of ground waters into downstream areas, where they discharge into surface water sources. That is, replenishment of shortage of surface water resources at the expense of ground waters leads to reduction of surface and ground water resources in the underlying areas. The present paper shows that the mentioned process occurs but with a big delay. The periods of delay may be more than 20 years, and this gives time for introduction of agriculture technologies intended for use of smaller quantities of water.

The dependences suggested in this paper can be used for similar calculations as far as other intermountain valleys of the Central Asia are concerned.

References

1. Kaplinsky M.I. Prediction of changing of the drainage runoff under the influence of' the water economical measures. Frunze. "Ilim". 1977. 96 p.
2. Kostiakov A. N., Favorin N. N., Averianov S. F. Influence of irrigated systems on ground water regime. USSA Academy of science. Moscow.1956. 451 p.
3. Litvak, R.G. and Nemaltseva, E.I. Derivation of the analytical relation between infiltration changes in piedmont and flow from piedmont to the discharge zone with the use of ground water modeling. Proc. VNIIKAMS. Frunze. 1990. pp. 57-61.
4. Litvak R. G. Study of the interdependences between the Chu River and ground water in the zone of Tokmak for the problems of the water resources control. Report OSCE. Bishkek. 2010. 36 p.

5. Ovdienko A. P. et al. Irrigation of the Chu Valley on the base Nijne-Alarchinsky reservoir, TER, report, Kyrgyzgiprovodhoz. Bishkek. 1993. 660 p.
6. Tsytsenko K. V., Sumarokova V. V. Hydrogeology bases of irrigated land reclamation in the basins of the Chu and Talas rivers, GGI, Leningrad. Hydrometeoizdat. 1990. 334 p.

Long-term Forecast of Glaciation and Evaluation of Glacial Resources of the Central Asia with the Use of Isotopic Methods

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Abstract.

The decrease of runoff caused by climate change is the reason of interstate contradictions on water question in the states of the Central Asia, in due course the opposition will only amplify. The glaciers of highlands quickly degrade at global climate change. This will eventually result in reduction of glacial runoff. Therefore in the nearest future, the Central Asian states will face a water, hydropower, and environmental catastrophe. In view of this, the ability to make reliable long-term climate and glaciation change forecast is so important.

Keywords. The Central Asia, glaciations, forecast of ice resources

Introduction

Errors in forecasting of dynamics of climate change are fraught with large economic accidents. Miscalculations of experts of 50-60s of the last century, concerned with fall in the level of the Caspian Sea 30 years later turned into social and economic tragedy for the whole region. Reliable forecast will allow taking timely measures on adaptation in the conditions of changing climate and mitigation of consequences of such changes.

The existing models of long-term glacial and climate change forecasting don’t enable us to make reliable forecasts even for the next 100 years.

Modern warming represents a part of a natural cycle of fluctuations of climate. In this connection, a pattern of natural climatic and glacial changes which had been taking place throughout long period of time - at least Holocene (more than 10 thousand years) should be put in a basis of long-term forecasting of climate and glaciation. By this time, such patterns are not established due to imperfection of methods of dating of morains, which are reliable witnesses of the last glaciation. It is impossible to establish a pattern in disintegration time of Holocene glaciation without absolute dates of moraines and to make reliable forecast for future, too.

We have found a method of accurate radiocarbon dating of moraines with the use of autochthonous specific organic matter dispersed in them; dynamics of stadial glaciation in Holocene is determined and the age of three earliest stages of glaciation in the Tien Shan is estimated, which makes predictive estimate of the ice resources possible.

1. Problems of ice resources forecast

Glaciers are the main source of renewable water and hydropower resources in the arid mountainous states of the Central Asia. The glacial runoff plays a significant part in the formation of the overall river runoff; in mountainous glacial system of the Tien Shan, it reaches 64% [1]. The contribution of the glacial runoff to the total inflow of the Toktogul, the largest in the Kyrgyz Republic (KR) reservoir, is 29 % [1]. Hydroelectric power stations, located in mountainous regions produce approximately 93 % of all the electric power in the Kyrgyz Republic [2].

2. Moraines dating with the use of autochthonous organic matter

Moraines are traditionally considered to be chronologically “dumb” formations. At this point all the calculated absolute dates of moraines are unreliable due to the following reasons:

- they are either relative (in case of radio carbon method of dating of moraines with the use of allochthonous organic substance), as they show how much younger or older than the substance these morains are;
- or they had been received by physical methods of little use for dating of moraines. Such dates are the cause of serious contradictions, existing in paleoglaciological reconstruction. It is not possible to make the necessary long-term forecast on the basis of such dates. We have found a method for accurate radiocarbon dating of moraines with the use of autochthonous specific organic matter dispersed in them [3]. This method has been successfully applied in the ISTC project #Kr-330.2 in the Issyk-Kul basin [4]. At that the morphologically expressed pattern of disintegration of Holocene glaciation [5] was established. It consists of not less than seven basic stages (Fig.1). It was demonstrated that the Holocene glaciation disintegrates in stages following fade-out scenario. Radiocarbon dating of the first three (oldest) stadial moraines of Holocene glaciation has been obtained.

The schematic model of long-term forecasting of glacial changes is constructed on the basis of the received data (Fig. 2) [3].

Dating of other stadial moraines is a way to long-term glacial and climate change forecast. It is necessary to combine radiocarbon dating of stadial moraines with isotope-oxygen (basing on ratio of isotopes O16/O18) glaciers investigation for more detailed paleoglaciological reconstruction of the Holocene glaciation. It will enable us to define temperatures of the climatic past.

Isotope-oxygen studying of glaciers became rather popular among glaciologists; they count on the results of such researches to use them in paleoclimatic reconstruction and in long-term forecast. For this purpose, in mountains of Eurasia a number of the Tien-Shan, Caucasus, Altai, Tibet, Himalayas, Scandinavia and Antarctica glaciers has been drilled by this time. However, a weak point of the isotope-oxygen studying of glaciers is definition of absolute age of ice cores. It is performed with the use of models of age and depth of glacial thicknesses ratio, constructed on the basis of characteristics of ice flow. Since various theoretical assumptions are used at that, the established ages of cores are not completely reliable.

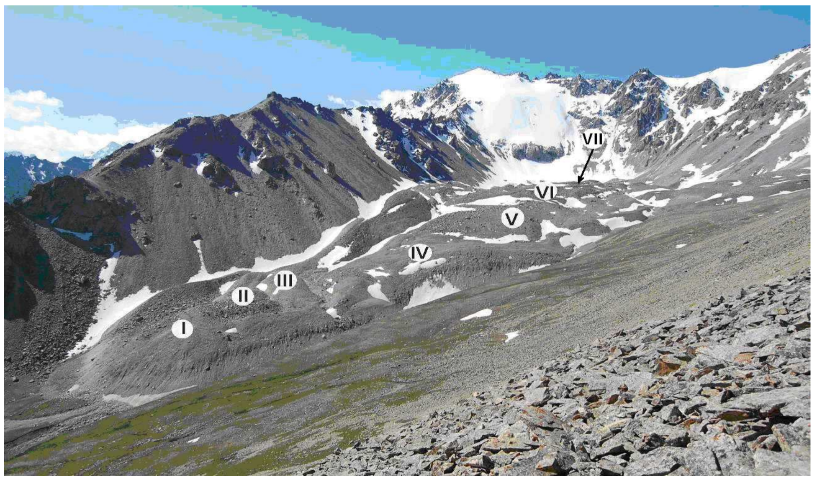

Fig. 1**.** Morphologically apparent staged moraines (I-VII) in the Tez-Ter moraine glacial complex (basin of the Ala-Archa River, the Northern Tien-Shan)

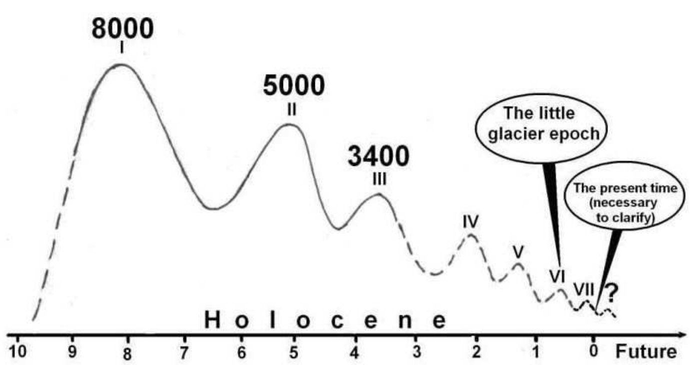

Fig. 2. Schematic model of long-term prognosis of natural glacial transformations: Horizontal axis – time scale (thousands of years); I - VII – glaciation stages associated with morphologically articulated moraines of the Holocene glaciation; 8000, 5000, and 3400 – established radiocarbon ages of stadial moraines; **?** – estimated next stage of the Holocene glaciation.

The method of radiocarbon dating of moraines we offer will allow to date the isotope-oxygen curve (that is to adhere it to a reliable age scale) received during drilling of mountain glaciers. For this purpose, it is necessary to select series of samples on contacts of glacial ice and a superficial (ablative) moraine covering it (Fig. 3). Samples of ice will be used for isotope-oxygen analyses and samples of autochthonic organic substance from moraines will be used for radiocarbon dating (Fig. 4).

The mountainous glaciers do not only retreat; they are also being shielded with surface moraines. In the foreseeable future both will lead to considerable reduction of glacial drain. During the first stages of glaciers' shielding (when the thickness of moraine cover is insignificant), their thawing is accelerated and the drain module is increased. Further, increase of the moraine cover thickness leads to retardation of ice thawing up to its full termination. Glaciers thus appear to be sort of preserved. It is important to forecast glaciation as well as glaciers' shielding and the following reduction of glacial runoff.

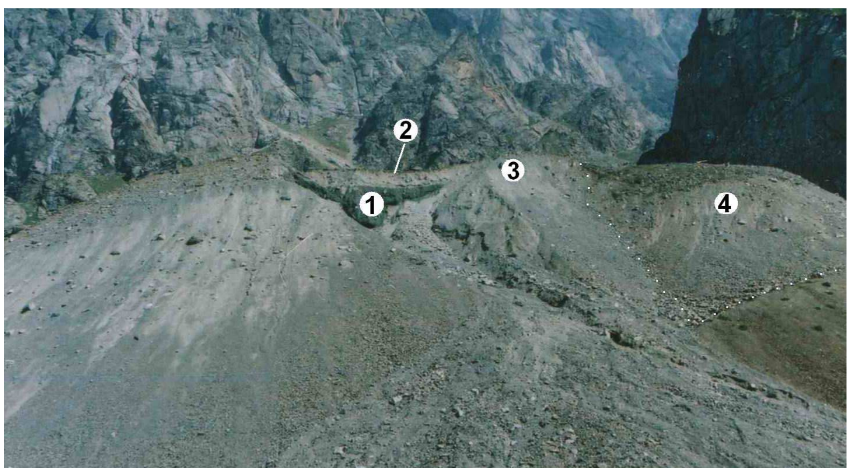

Fig. 3. The frontal ledge of Holocene moraine-glacial complex in one of valleys of the Northern Tien-Shan: 1 – exposure of glacial ice; 2 – ablative moraine; 3, 4 – stadial moraine-glacial generations.

How quickly will modern glaciers in future "go" under moraine? What will affect glacial drain more – reduction of glaciers sizes or their shielding factor? We need to answer these questions studying shielded glaciers, as well as tendencies and speed of shielding in forecasting aspect.

The glacial runoff from shielded parts of glaciers is in contact with moraines depositions and as it had been shown earlier [6, 7] it leads to increase of isotope shift in the uranium of glacial waters, i.e. to increase not only of general content of uranium in thawed snow, but also to increase of 234U excess in them. Complex researches of open and variously shielded glaciers with use of isotopic methods are required. It is necessary to study modern representative moraine-glacial complexes as analogs for future forecast objects. It is important to allocate morphologically apparent stadial moraine-glacial generations in them and to define a share of actual glacial runoff and runoff from variously shielded moraine-glacial generations.

There are reports on threateningly fast degradation of glaciers in the Central Asia. Thus, in [8] it is stated that the thickness of Himalaya glaciers thaws with a speed of 10-15 m/year and 2/3 of glaciers of China will have disappeared by 2060, and by 2100 the glaciers will have melted down completely. According to [9], the quantity of glaciers in the Tien-Shan located on the territory of the Kyrgyz Republic can be tens times reduced by 2100. Certainly, in all these cases only open parts of glaciers were considered, because nobody had studied the shielded glaciers. In this connection, the forecast of glacial disaster in above-stated sources is not well-founded. To obtain the objective picture, it is necessary to study shielded glaciers, including their historic-genetic aspect. We need to revalue the ice resources of the mountain areas, listed in the catalog of glaciers [9]. Methodology to evaluate volumes of the shielded glaciers should be worked out. The shielded glaciers were not listed in the catalog of glaciers of the Kyrgyz Tien-Shan [9]. In this connection ice resources are considerably underestimated while the component of long-term frozen ground isn't considered at all. The key error [3, 5] is considering the shielded Holocene glaciers to be moraines, which implies the absence of buried ice inside them (or, at the best, the presence of some ice fragments).

We established that in mountains of the Tien-Shan there aren't any separate Holocene glaciers and moraines; there only are moraine-glacial complexes. On Fig. 3 a fresh uncovering of glacial ice is shown in one of moraine-glacial complexes of the Tien-Shan. Considerable reserves of ice are contained in these complexes in the form of glaciers shielded by moraine covers. Ice resources in moraine-glacial complexes are some kind of preserved stocks of ice, which give water at a slower rate than open glaciers do. Their runoff is rather steady during all the seasons of a year. Fig. 4 shows the Holocene moraine-glacial complex of a glacier and the Karabatkak lake, which are under study of the Laboratory of glaciology of TSHMSC at Institute of Water Problems and Hydropower of the National Academy of Sciences of the Kyrgyz Republic. Not moraines, but glaciers of generations of different ages shielded with moraines are situated in the foreground (all around the lake). They (and other, similar to them in different cases) are not listed in the catalog of glaciers of Tien-Shan. Only the morained glacier sites named by authors [9] are in the catalog (see Fig. 4: number 1 within the ice stream the glacier).

Fig. 4.Moraine-glacial complex of the Karabatkak, Basin of the Chon-Aksuu river, the Terskey Ala-Too range.

To make long-term forecast of glaciers shielding and reduction of glacial runoff caused by it, it is necessary to execute uranium-isotope researches on the moraine-glacial complexes together with morpholitological studying and radiocarbon dating. We rely on features of glacial litho geneses and formation of moraines of mountain glaciers, established by us. Organic matter in form of glacio-chionophilous microorganisms inhabiting glaciers, as well as any other organic substance, sorbs uranium and its isotopes. The uranium-isotopic investigations will let us allocate generations of different ages in Holocene moraine-glacial complexes and establish a share of each component in general runoff of mountain rivers, including the runoff from open and shielded parts of glaciers.

3. Conclusion

To solve the stated tasks, we should stop endless monitoring of glaciers and glacial runoff and switch to highly productive investigations with the use of isotopic methods. In order to achieve it, it is necessary to combine international efforts.

References

1. Dikikh, A.N., Sokalskaya, A.M., Durgerov, M.B., and others (1995) Glacial runoff // Glaciation of the Tien-Shan. Moscow. – pp. 131-168.

2. http://www.regnum.ru/news/1236021.html

3. Shatravin, V. I. (2007) Radiocarbon dating of moraines with the use of dispersed organics // Climate, Glaciers, Lakes: Journey to the Past. Bishkek: "Ilim". pp. 74-92.

4. ISTC project#Kr-330.2 (2007) Final report. Bishkek, IWP&HP, Academy of Science of the Kyrgyz Republic.

5. Shatravin, V. I. (2007) Reconstruction of Pleistocene and Holocene glaciation in the Tien-Shan from new starting positions // Climate, Glaciers, Lakes of Tien-Shan: Journey to the Past. Bishkek: "Ilim". -pp. 26-46.

6. Tuzova, T.V, Shatravin, V.I. (1994) Specificities of formation of isotop composition of uranium in ices and waters of high-mountain cryolithogenesis // Izvestiya of Academy of Sciences of the Kyrgyz Republic, #3, -pp. 55-59.

7. Tuzova, T.V., Romanov, V.V, Vlasova, L.V. (1994) Uranium and tritium in glacial lakes of the Northern Tien Shan // Water resources, volume 21, #2, -pp. 236-239.

8. www.climatechange.ru/node/4; www.glaciology.ru;

9. Catalogue of the Tien Shan glaciers (1967) – Leningrad, volume 13, issue 2, part 1, 2.

Monitoring of Ground Waters Flooding in Chu Area

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Underflooding of ground territories is a dangerous physical process related to natural or anthropogenic increase of ground waters level to values that are worsening engineering-geological, land reclamation and geological-ecological conditions of these territories operation [1]. Ground waters level lifting leads to bogging of lots, flooding and destruction of private houses bases and farm lands, it puts out of action lawn-and-garden lots and creates danger of bogging and flooding of agricultural lands (Figures 1, 2, 3). Before proceeding to underflooding control problem-solving, it is necessary to reveal the main reasons that cause it, i.e. to study ground waters mode and balance, to carry out detailed monitoring of hydro-geological conditions of underflooding area.

Territory underflooding can be related either to underground waters afflux or to watering of formerly waterless grounds strata in the zones that adjoin water basins.

In order to avoid damaging, it is reasonable to consider not only the threatening level of underground waters standing, but also its duration. For example, it is considered in the USA, that the horizon of underground waters on the irrigated areas should be 1.8 m below the earth surface. The soil condition is considered to be good if steady level of underground waters is lower than 2.1 m below the surface and its lifting to 1.8 m is observed not more than 30 days a year. An unsatisfactory condition is 1.2-1.8 m below the surface and bad condition is 1.2 m below the surface with further increase [2].

In the Kyrgyz Republic (KR) there is a different classification of extreme situations with the following parameters of flooding [3]:

1. Strong underflooding, causing damage and destruction of engineering constructions– with level of underground waters (LUW) of 0-0.3 m;

2. Moderate underflooding – with LUW of 0.3-2 m;

3. Weak underflooding - with LUW of 3-5 m.

Employees of the Kyrgyz Complex Hydro-geological Expedition (KCHGE) at the Ministry of Natural Resources KR carry out constant monitoring of underground waters on representative areas of the state basic network and wells. Despite the observation stations quantity run-down, it is possible to reveal long-term laws of underground waters mode formation and to make forecasts about its expected maximum level positions.

The 2010 Chu area observation showed that underflooding process still covers considerable territories. Underflooding spreads on ground waters pinch-out zone of the Chu cavity - from the East to the West on transition border of mountain apron into foothill plain. Underflooding areas were formed along the pinch-out zone and have been causing considerable damage to apartment blocks in settlements; lawn-and-garden lots become boggy, many peasant areas under crops are damaged.

In cities and on industrial platforms in order to avoid underflooding of underground parts of constructions and service structures, level of ground waters should not rise above the bottom of foundations and basements of these constructions, that usually makes 3-3.5 m below the earth surface.

According to the monitoring results, maximum levels of underground waters on territories of cities and settlements areas for 2008 – 2010 are shown in Table 1.

As it is shown in Table 1, levels of underground waters were higher in 2010 than in 2008 and 2009 in many areas (Bishkek, Tokmak, Stavropolovka v., Sretenka v., Kaindy, etc.)

And it is necessary to note, that critical depth levels (above 3) are observed not only during one month, but during two or three months – all the spring period, and sometimes during June as well.

In some areas levels rise went on for half a year (from April till July in Tokmak), and level rise speed (0.6-0.7 meters a month) exceeded the level rise speed in high-water 2003 two times in size and duration.

During the whole 2010 critical depth levels (0.1-1.2 m) were observed in underflooding area of Sretenka village.

74 settlements are in the zone of partial or full underflooding in Chu area. That is 25% (1659 km²) of the Chu cavity plain area.

Borders of underflooding areas haven't changed much, but the intensity of flooding increased. For example, during the spring period (April - May) on some lawn-and-garden lots in Sretenka village ground waters outcropped, bogging the lots.

Relied on raise of ground water levels till the end of 2010 on Tokmak city and Chu village areas, it is forecasted also for the whole 2011.

Proper processing of observation materials is necessary to solve the questions that are considered during study of regional underflooding mechanisms. We have constructed chronological charts of underground waters regime, then its forming factors and qualitative association between them were defined.

The basic groups of factors:

- hydrological: underground inflow and outflow;
- irrigation-economic: irrigation technology, water supply, presence of artificial drainage;
- climatic: air temperature, humidity, deposits and evaporation.

Table 1. Zones of Chu area underflooding, according to KCHGE regime supervision

Cities and villages	**Absolute maximum levels of underground waters in 2008 – 2010, meters**

Bishkek city	0,8 - 2,2
Kant city	1,6
Kara-Balta (north side) city	0,6
Shopokov city	0,8
Tokmak city	0,2-1,6
Belovodskoe village	1,1
Sretenka village	0,14-1,2
Chatkel village	1,4
Stavropolovka village	1,1-2,5
Stepnoe village	1,1
Milyanfan village	1,3-2,0
Altyn village	1,7
Kenbulun village	1-1,7
Kamyshanovka village	1,8-2,5
Leninskoe village	0,15
Maevka village	0,8-1,4
Sokoluk village	1,5
Gavrilovka village	0,6-0,8
Kaindy city	0,9-1,3
Kosh-Debe village	0,3
Lebedinovka village	0,5-1,3

Figure 1. Sretenka, Lenin street Figure 2. Sretenka, Central street

Figure 3. Petrovka, Kolhoznaya street

Estimating a role of atmospheric precipitation, it is necessary to consider its average annual sums for many years and its year seasons distribution, and the form of precipitation. In high precipitation years a short-term infiltration in non vegetative period is possible in areas with superficial bedding of underground waters (1-2 m). Infiltration increases in the areas with sandy ground and in relief lows. The long-term sums of precipitation render certain rhythm [4]. Small (2-3 years), average (10-11 years) and long (70-80) rhythms are marked out. For the analysis of underground waters regime small and average rhythms are taken into account.

Considering the above-listed factors, correlation dependences (for example, between precipitations and level of underground waters) are deduced. At present big work is carried out on this matter.

The analysis of long-term monitoring of underground waters shows that levels of underground waters in 2011 will rise, as there comes the period of the maximum position of the levels, expected in 2012 (a long-term branch of level rise connected with solar activity).

Drainage intercepting a filtration stream, as well as artificial regulation of ground water level in most protected territory is used as the basic means for protection of territories from underflooding by ground waters. Drainage can change an unfavorable structure of water-salt balance radically. Withdrawal of drainage waters is carried out on impounded territories. Horizontal, combined and vertical drainages are used. To make horizontal drainage effective, first of all it should be intensive enough – canals have to be of necessary depth and length, depending on hydro-geological conditions of territory. However, in many examined areas there are apartment blocks built in place of drainage canals. Many drain lines are not being cleared of plants and drifts, irrigation water is disposed into it. A strict control of drainage system is necessary.

Conclusion

Recommended actions for mitigation of underflooding negative consequences:

- clearing and deepening of open collector-drainage network;
- washing out closed drainage system;
- reduction of the main feeder canals and irrigation ditch system water losses;
- construction of new open and closed drain lines;
- replacement of the usual area flood of the irrigated lands with overhead irrigation as a more rational method;
- water throughput systems organization below the artificial waterproof barriers - highways, canals.

In order to avoid negative consequences caused by underflooding, it is necessary to forecast it. It is a priority. A big work is carried out on this matter; employees of KCHGE underflooding group annually give forecasts to the Ministry of Emergency Situations. In case of danger, letters with recommendations go to the corresponding ministries and departments.

References

1. Monitoring, forecasting of dangerous processes and the phenomena in territory KR. Bishkek, 2011. 38 p.

2. D.M.Katz. The control of a mode of ground waters on the irrigated lands. Moscow. 1967.

3. Classification of emergency situations and criteria of their estimation in KR. Governmental order KR, November, 29th. 2000. #702.

4. N.S.Tokarev. Rhythmic fluctuations of climate and their influence on a mode of superficial and underground waters. Works LGTP. 1949.

The Linear Subsidence Rate

of the Tien Shan Mountain-Valley Glaciers

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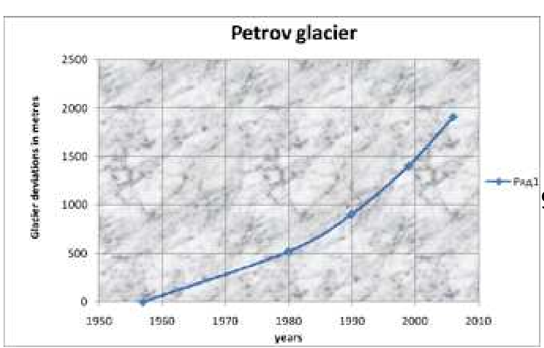
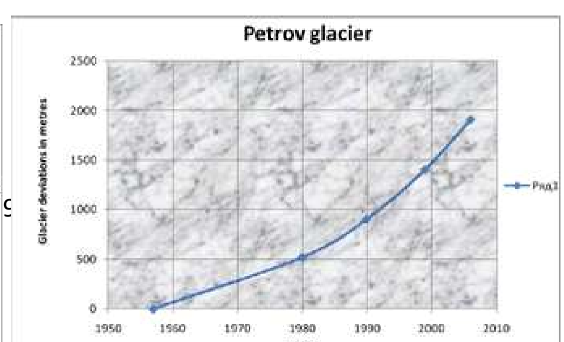
The subsidence rate of glaciers lately causes great interest in public and state structures of Kyrgyzstan. Some control results of our observations on development dynamics of glaciers in the Central Tien-Shan (the South Inylchek glacier), Akshiirak massif (the Petrov glacier), north slope of the Terskei-Alatoo range (the Karabatkak glacier), south slope of the Kungei-Alatoo (the Choktal-1 glacier), north slope of the Kyrgyzskii range (the Adygene glacier) are shown in the article. On the basis of interpretation of air- and space-photos of various years, we obtained the information on past edge position of the glaciers and it has enabled us to determine their subsidence rate.

Fig. 1 doesn't show the diagram of the South Inylchek glacier retreat, because its edge position hasn't changed much for the last 50 years. The rest glaciers retreat at increasing rate. It is clearly shown in the Petrov glacier where the retreat increased by 34,4 m per year (from 22.6 to 57 m. per year) (Fig. 2) from 1957 to 2006. The retreat rate of the Petrov glacier might have been affected by the lake washing its edges (Fig.3).

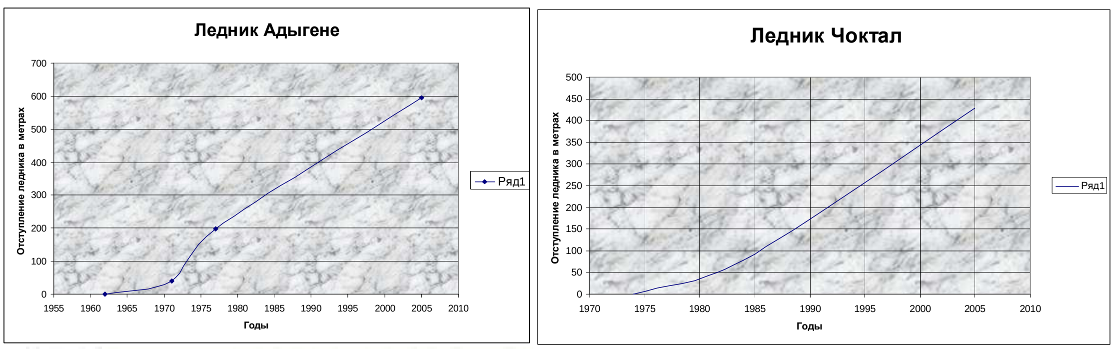
The recession rate of the Choktal glacier also considerably increased during the period from 1974 to 2006 (from 7,9 m to 19,5 m per year) (Fig. 3A). A more complicated picture is observed in the Adygene glacier where the subsidence rate considerably increased first from 4.4 (1962-1971) to 26,3 (1971-1977) meters per year, and then decreased to 14,1 (1977-2005)





meters per year (Fig. 3B). However, now it exceeds the speed of 1962 by 9.7 m. The subsidence rate of the Karabatkak glacier has increased the least of all, from 4,6 (1967-1980) to 5.3 meters per year (1980-2005); the increase is just 0,7 meters.

Fig. 1. Diagrams of glacial recession for the last 50 years.



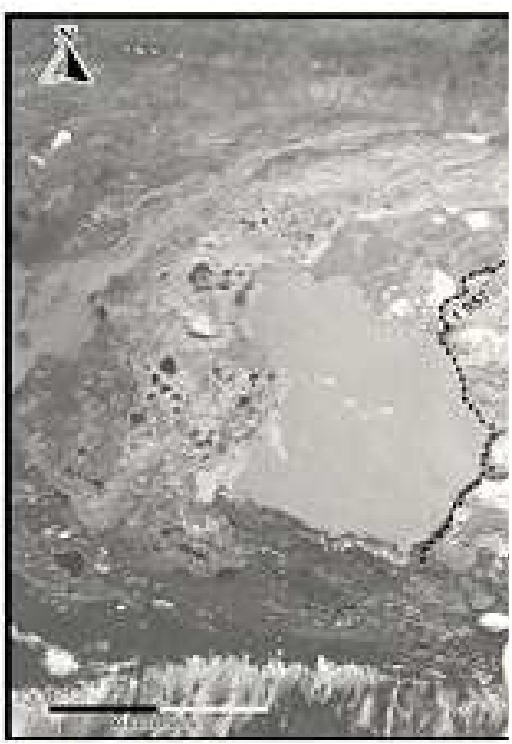


Fig. 2. The border of the Petrov ice stream retreat in various years.

A B

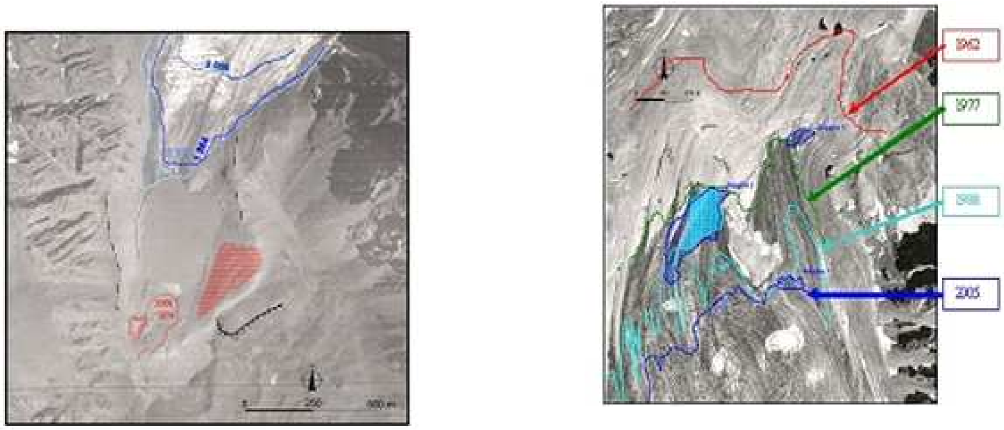


Fig. 3. The borders of ice streams retreat in various years:

A - Choktal; B – Adygene

Therefore, we can conclude that the Tien Shan glaciers retreat at various rates which are lately increasing.

The reasons why some glaciers retreat faster than others are related to a number of factors which can be divided into 4 groups.

1. The first group of factors deals with the exposure of a mountain valley to the sunlight and directions of regional moisture carrying airflows. The comparative analysis shows that glaciers on the southern slopes of the Tien Shan mountain ranges retreat faster than those on the northern slopes. It depends not only on the solar radiation intensity but also on the fact that airflows that carry the moisture encounter the northern flanks of mountain ranges where most moisture precipitates as rain and snow. Hence, precipitation in glacial zones of mountain ranges largely compensates the losses of retreating glaciers on the northern flanks, consequently slowing up their retreat.

2. The second group of factors is connected with the size of glacier's accumulation area and elevations above sea level. The larger the glacier's accumulation area is and the higher the elevations a glacier is located at above the snow line, the more ice is brought into the glacier and the less the glacier retreat is. Large glaciers of the Himalayan type confirm this assumption. The speed of their retreat is less than that of usual valley glaciers. The edge position of the Inylchek glacier, which is the largest glacier in Tien-Shan, virtually has not changed over the past 50 years (see Fig. 4)

3. The third group of factors is related to the morphology of a mountain valley that contains a glacier. It is well known that each mountain valley has a step-like bottom. These "steps" (riegels) are formed as a result of tectonic movements and glacial and nival processes. The observations show that the rate of glacier retreat in such riegel areas increases

considerably. The explanation is that the glacier bottom is steeper in these areas and the glacier flow increases accordingly resulting in icefalls (Fig. 5).

Fig. 4. The lower boundary of the Inylchek glacier has been stable for the past 50 years

Fig. 5. An icefall in the lower part of the Karabatkak glacier (the Chon-Kyzylsu river basin on the north slope of the Terskei-Alatoo Range)

The morphology of mountain valley also influences the exposure of glaciers to sunlight: the higher the valley slopes are, the more shadow they cast onto the glacier surface and thus the less glacier melting is. Finally, the valley morphology and rock lithology influence the formation of moraine and glacial lakes on glacier edges. On sunny days water in these lakes heats up to 8-10^{0}C and triggers thermokarst processes, which increase the rate of glacial retreat. An illustration of how a moraine glacial lake influences the rate of glacial retreat can be Petrov's Lake (Fig. 6). As the lake was getting bigger, the rate of the Petrov glacier retreat was increasing. In recent years, it has increased to 57 meters per year, which is very unusual for glaciers of this type (the Petrov glacier is one of the largest complex valley glaciers of the Tien Shan).

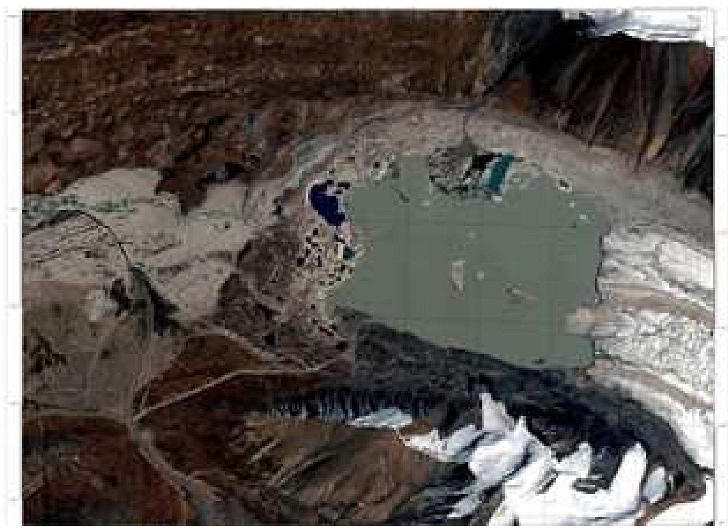


Fig. 6. The lake near the edge of the Petrov glacier triggers thermokarst processes that increase the glacier retreat rate

4. The fourth group of factors describes the ability of glaciers to slow down the retreat process through the armoring of the glacial surface with fragments of rocks that comprise the glacial valleys. In this case, the intensity of the glacier armoring process depends on the rock lithology and extent of rock resistance to the destructive effects of glacial erosion and periglacial weathering. For example, so-called rock glaciers or armored glaciers (Fig. 7) occur commonly in valleys that consist of unstable stratified rocks: sandstones, conglomerates, shales, limestones. Armoured glaciers are rarely found in the areas where intrusive rocks are widespread: granites, diorites, etc. This is explained by the fact that unstable rocks fill a glacier with debris and thus armour it faster than more competent and stable rocks would do.

Based on the similarity of glacial formation, development and retreat processes, the Kyrgyz Tien-Shan is divided into 5 glacial regions: South, West, North, Internal and Central [2]. Each region contains several glaciation centres that are confined to the higher parts of mountain ranges. Glacier retreat is currently observed in all glaciation regions and centres. Glacier retreat is caused by certain factors, and some group of factors plays the main role while the others play a minor part.

The role of each group of retreat factors depends on both geological and climatic conditions in glaciation regions and centers. The study of these conditions will enable us to assess the role of each group of factors contributing to the retreat of each specific glaciation center and forecast the dynamics of such retreat.

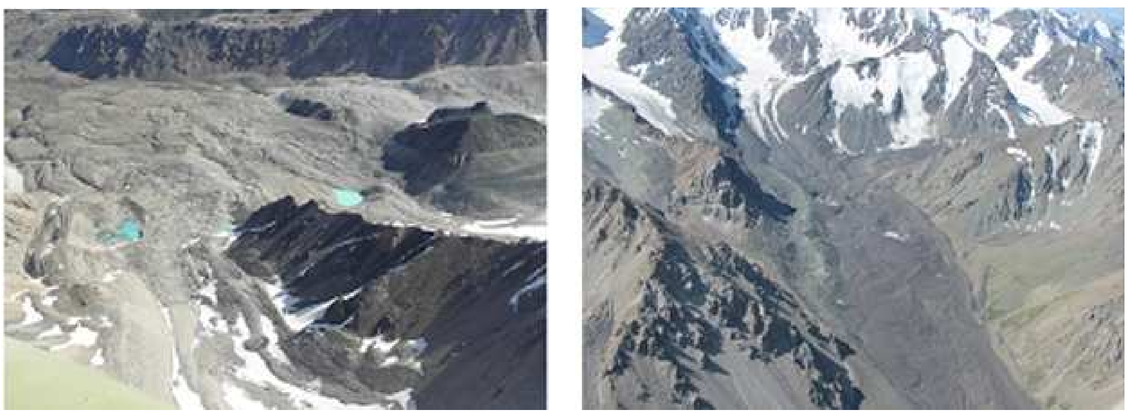


Fig. 7. Armored glaciers in valleys on the northern slope of the Kyrgyz Range: A – in the upper reaches of Djelamysh Valley, B – large Kentor rock glacier in the Nooruz Basin

References:

1. L. Dolgushin, G. Osipov. Glaciers. Moscow: Mysl, 1989. 447 pages.
2. M. Cherny et al. Mountain Lake Outburst Risk Analysis and Mitigation. A report prepared under the joint development project of the Czech Republic and the Kyrgyz Republic. Czech Republic. GEOMIN, 2010. Archives of the KR Ministry of Natural Resources. Bishkek, 2011.

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New directions in Desalination R&D – Are we on the right track?

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Abstract

The population in the world increased significantly during the last 50 years. The quality of life is generally increased along with higher need for energy and water beside increase of environmental issues to be solved. High quality drinking water is essential for day-to-day living, for food production, for better standard of living, for the somehow neglected nature and for industry. The need for water is rapidly increasing and the resources of fresh water cannot deal with all the requirements. Water is not accessible to all as a natural, self-renewable low cost resource. The drought at various regions on earth followed by "desertification" and movement of population towards this "essence of life", calls for different considerations in terms of economic and social effects.

Having used the natural renewable freshwater capacity, many countries are developing several non-conventional sources. Some involve further utilization of natural resources that were hitherto considered of low quality unsuitable to develop. Others involve the creation of new usable waters, of improving qualities so additional water will be suited for a wider array of specific uses (e.g., reclaimed sewage for irrigation and drinking).

The reverse Osmosis technique seems to take over the market that used to belong to the evaporation processes. Many researchers are trying to develop new techniques like Forward Osmosis, Membrane distillation, Humidification-Dehumidification, Solar based desalination processes, and more. On the other hand, there is a need to improve the quality of the membranes in terms of flux, while maintaining good rejection, overcoming the boron problem, reducing energy consumption, preventing fouling of different types, in order to reduce the overall production cost. Better heat transfer surfaces are needed beside better design to prevent salt precipitation in the evaporation processes. Analyzing the efforts in the different directions, bring the important question: are we doing the right things? Are we going in the right tracks?

Introduction

Desalination of salt (or saline) water has been practiced regularly for over 60 years, however the industry itself is relatively younger. Commercialization of industrial processes started only in the 1970's. It is already recognized as a legitimate source of water supply in many countries all over the globe. Large quantities of excellent water quality at affordable costs for drinking purposes are now being produced. The challenge, however, still exists of producing desalinated water at affordable costs for safe usage in industry and agriculture so as to assure continuous growth and good health.

Membrane and evaporation techniques were developed and have matured as industrial processes, mainly for large communities. The cost was reduced over the past few years to the level of 50-70 cents/m^3 of desalinated seawater, depending on energy availability, and the trend is continuing depending on the cost of energy resources. Brackish water desalination ranges between 20-35 cents/m^3 if a good solution is available for the rejected brine. Membrane techniques have penetrated deeply into water treatment processes wherever possible; wastewater is also treated occasionally with membranes up to drinking water quality and even up to the best industrial quality for micro-electronic production systems

(Hai and Ryck, 2005). Solutions are still needed for remote communities based on sustainable resources to prevent desertification and the gravitation of populations to the large cities.

Main Desalination Techniques

Evaporation and membrane techniques are the two main desalination methods that became commercial and survived a long evolution process over the past 50 years. The Multi-Stage Flash (MSF) technique, used mainly in the Persian Gulf, was developed by Siver at Weir Co. Glasgow (Awerbuch, 1997a), used to be the most commonly used technique. Multi-Effect Distillation (MED), with or without thermal or mechanical water compression, with either vertical or horizontal smooth tubes, is a competing evaporation technique while vapor compression is very popular for remote locations, resort areas and islands.

Reverse Osmosis (RO), the main membrane process, is the fastest growing water desalination technique. It is considered the most promising technique for brackish and seawater desalination (Furukawa, 1997). Other membranes processes such as Nano-Filtration (NF) and Ultra-Filtration (UF) are used for quality improvement of water containing lower salts concentrations and for wastewater recovery.

Reverse Osmosis

The Reverse Osmosis membrane process is considered universally to be the most promising technology for brackish and seawater desalination (Furukawa, 1997). It is also currently the cheapest technique for every type of water source. In the RO desalination process, a pressure greater than the osmotic pressure is applied to saline water exposed to a selective membrane; the selective membrane allows fresh water to permeate through it while holding back the dissolved salts.

A schematic diagram of a Reverse Osmosis flow sheet desalination plant is shown in Figure 1. Removal of suspended particles, bacteria and organic matter in the pretreatment unit is done either by sand filtration followed by media filtration, or by using UF/MF membranes in modern plants. Energy recovery devices such as pressure exchangers, independent turbines for secondary stages or turbo-pumps are used to reduce the energy consumption of the desalination process (Voutchkov & Semiat, 2008). Post-treatment may include more membranes for boron removal and salt content reduction, and the addition of calcium and magnesium salts to the final product.

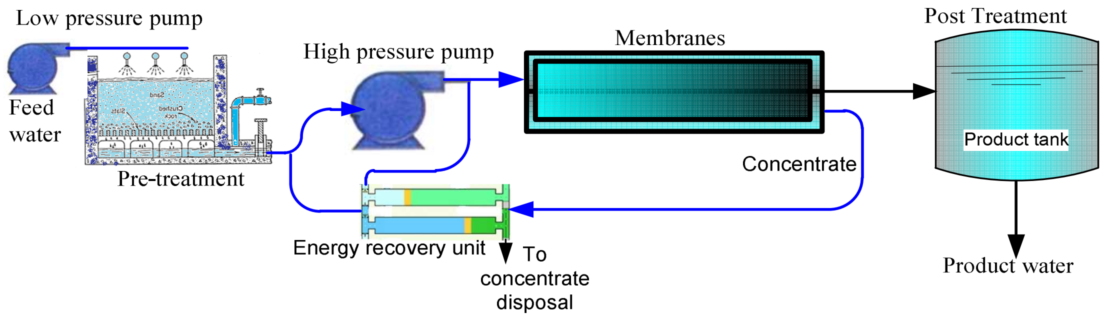


Fig. 1: Schematic diagram of a Reverse Osmosis desalination plant.

Fig.2 displays the Hadera Desalination Plant - one of the two largest RO plants in Israel. Recent study on developments in RO systems may be found in Li & Wang, (2010) and Park et al. (2010). Analyzing the cost components may provide directions for possible reduction in RO desalination costs. Table 1 presents an estimated cost breakdown of desalinated water produced in different projects. The capital expenses are usually the main constituent if energy consumption is required. This is based on the cost and investment cost of the main equipment items: feed tanks, pretreatment filtration units, pumps, turbines and piping, controls, membranes and membrane housing, post-treatment and product tanks. Investment is required in sophisticated automation and control equipment that will in turn lower water costs by maintaining stable high-throughputs and savings in energy and labor costs. Table 1 also shows that labor costs are not a significant cost item since modern desalination plants may operate largely unattended.

Fig. 2: Hadera RO plant in Israel, 127 million m^3/year. (IDE) http://www.ide-tech.com/news/largest-swro-desalination-plant-world-inaugurated-hadera.

Energy is second in significance as a cost component. Energy consumption is about 3.3-4 KWh/m^3: About 2.2 KWh/m^3 is the energy consumption of the process itself, and about 1.5KWh/m^3 is the energy consumed to pump seawater from a distance through the pretreatment stage, the energy needed to send the concentrate back, and the energy consumption for light, controls, etc. Energy costs may be reduced by using a high-efficiency gas turbine power station. A dedicated power station that constantly supplies its power reduces energy costs since it is insensitive to the known *sine* curve of power consumption related to day-night energy consumption fluctuations as well as summer-winter electricity demand. More information on different aspects of desalination processes was reported by Semiat (2000).

Thermal Desalination

Multi-Stage Flash

Table 1: Cost distribution of water in a desalination project

Item	%
Investment	33-34
Energy	30-43
Labor	4-11

Multi-Stage Flash (MSF) distillation was considered for more than 40 years to be the simplest and most common desalination technique (Awerbuch, 1997b). The process is based on the evaporation of seawater using low-grade steam extracted from a power station. Figure 3 shows a schematic diagram of an MSF desalination plant. Feed seawater flows is preheated by flowing through a set of heat exchangers condensing steam emanating from flash chambers.. The temperature of the feed water is raised to a top temperature, usually 120^{o}C, before entering into the flash chambers. The heating steam is generated by burning fuel using a low-level heat source, or more often, by extracting a low-pressure steam from a back-pressure turbine of a power station. The pressure in the flash chambers is gradually reduced, allowing the feed water to flash partially along the chambers. Water flows from chamber to chamber under reduced pressure conditions. The condensate drips into collectors and is pumped out as the plant product. Exhausted brine, is pumped out of the last flash chamber and disposed of at sea.

The technique consumes considerable thermal energy, of the order of 220 MJ/m^3 (60 KWH per m^3) if steam is generated by burning fuel for the plant. The energy consumption is reduced to below 10 KWH/m^3 when the desalination plant is connected to a power plant and gets the steam from a back-pressure turbine (Semiat, 2008). The MSF process is not sensitive to the concentration of seawater. However, significant problems are associated with the possible precipitation of calcium salts. The first is calcium carbonate, followed by the precipitation of calcium sulfate. Information regarding the costing of this process may be found in Jassim and Ismail (2004).

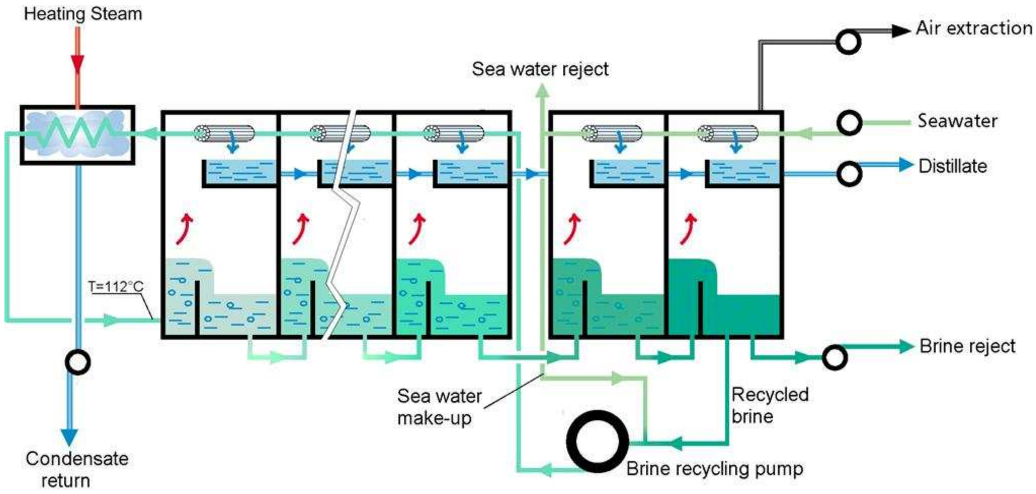


Fig. 3: Schematic diagram of a Multi-Stage Flash desalination plant (Sidem MSF Design, http://www.sidem-desalination.com/en/ 2010).

Multi-Effect Distillation

The multi-Effect Distillation (MED) technology originated from the multi effect evaporation techniques used in the chemical industry for solution concentration, crystallization and solvents recovery. The process was introduced for seawater desalination in the early 1960s.

An advantageous feature of the MED process over the MSF process is that heat transfer in the various effects is carried out at a constant temperature difference while the heat recovery in the MSF process in the feed preheating exchanger occurs at a varying temperature difference. This acts to reduce the energy irreversibility losses in the MED process resulting in lower thermal energy consumption. Also due to the higher heat transfer coefficients in the MED process, the method can use low-temperature energy sources, The MED process has recently started to take a market share at the expense of the MSF technique.

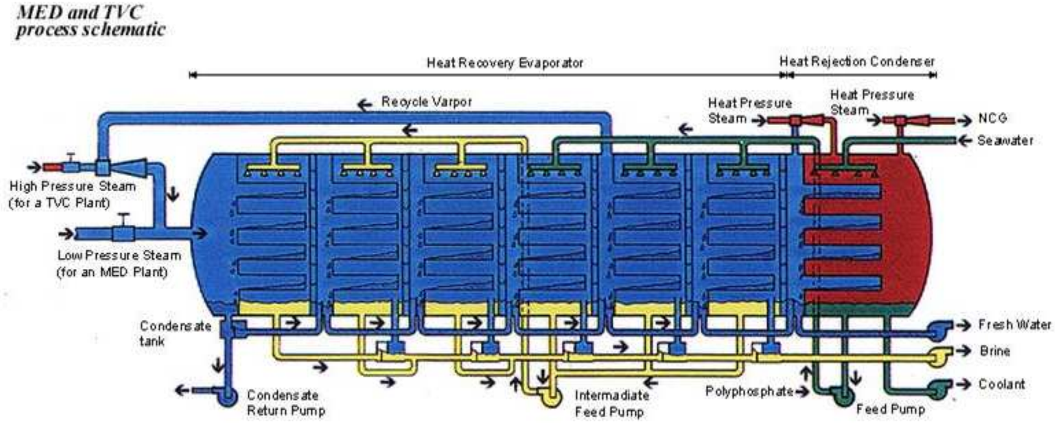


Fig. 4: Schematics of a horizontal tube Multi-Effect Distillation plant (IDE design).

Figure 4 presents the schematics of a horizontal tube Multi-Effect MED unit (IDE design). The steam enters the plant under vacuum and evaporates the heated seawater in a double-falling film type of heat exchanger. The secondary vapor generated on the evaporating side is used in the same way to generate a tertiary steam at a lower pressure. This process is repeated from stage to stage in the plant, towards the lowest temperature and vacuum in the last chamber. The primary steam condensate, being a very clean gas, is returned to the generation chamber or the steam generator of the power station. The latent heat is transferred at each stage from the condensing steam through the heat transfer piping to the evaporated falling film of seawater.. Condensate accumulates from all stages as product water. The final vapor generated at the coldest stage is condensed by using cooling water from the sea, followed by a vacuum pump or an ejector that purges the remaining water vapor containing non-condensable gases after condensation.

The Performance Ratio, or Gained Overall Ratio (GOR), which is the tons of water produced per ton of initial steam, is considered relatively high. The ratio in MED can reach 16 in comparison to the MSF unit where it is lower, around 10. The MED efficiency of water production in terms of GOR and energy used is essentially higher than in the case of MSF distillation (Ophir and Weinberg, 1997). Information on MED costing may be found in Ophir and Lokiec (2004).

Other Techniques

Enormous efforts have been invested in many techniques over the past 50 years, especially during the operation of the US Office of Saline Water. Despite significant developmental efforts, numerous researched processes did not survive the tough evolution path. Because of the wide familiarity of humans with water, the field of desalination continues to attract unqualified laymen to "invent" novel desalination processes most of which lack either a sound scientific basis or disregard the essential requirement of viable economics.

Solar desalination stills are not included in this category. A solar still, is an enclosure having a transparent cover in which solar radiation is used for evaporative heating of the enclosed saline water. Desalinated water is obtained from the vapor condensing on the enclosure cover.

A serious disadvantage of solar desalination is the low radiation density which averages 250 w/m^2 at 23^o latitude. Furthermore, only a fraction of the radiation energy amounting to about 40% is absorbed by the water as heat energy. The end result is that solar energy desalination requires vast areas, about 250 m^2 to produce 1 m^3 of fresh water per day. Solar cells can be used to generate the electrical power required for operating a VC or RO unit. Other types of energy collectors, such as steam-producing parabolic mirrors, hot oil collectors or chemical storage techniques, may be used for electricity production. However, solar energy is still expensive and therefore not normally used for electricity production. Without major improvements, solar techniques can only survive at low production scales in rare conditions for desert communities where no access to electricity increases the cost of water production or transportation. However, a significant Increase in the cost of crude oil can change this trend.

Environmental Aspects

Like any industrial process, desalination may affect the environment, the air, the nearby land and the sea close to the plant. Energy is consumed, commonly based on fossil fuel of a conventional power station. The emissions associated with energy consumption include all types of related air pollutants, viz. NO_x, SO_2, volatile compounds, particulates, and CO_2.

The main effluent of a desalination plant is the concentrate left after fresh water production. Its salt content and concentration depend on the water source used – seawater or brackish water, and the recovery ratio of the process. The rejected brine is close to twice the feed concentration in seawater desalination. The concentrate may also contain chemicals used in the pretreatment of the feed water, a low concentration of antiscalants, surfactants and acid added to the feed water for pH reduction. To this may be added occasionally washing solutions or rejected backwash slurries from feed water pretreatment. In small-scale operations, the problem is mild and no serious damage is caused to marine life. In large-scale water production, the problem is somewhat more severe. Dilution and wide spreading of effluents can resolve the problem entirely.

Concentrates produced on land from brackish water desalination are usually less concentrated than seawater yet they contain some other salts, possibly organic chemicals that do not exist in seawater. In most cases, the solution contains more calcium and magnesium, silica, and sometimes other components, such as traces of heavy metals and fertilizers, depending on the composition at the source. The problem is less severe when the solutions are purged into the open sea.

Where no access to the sea is possible, the concentrate is treated in evaporating ponds or by infiltration to deep sites below the aquifers. This may increase groundwater salinity. Zero Liquid Discharge (ZLD) treatment may recover more water so that precipitated solids may be stored properly on land.

Treatment of Sewage and Polluted Water

Reclamation of polluted waters is a “must” in terms of environmental needs to prevent pollution of soils, aquifers, rivers, lakes and seas. This is also a large source of water for reuse. Polluted water comes from different sources as domestic wastewater, industrial waste solutions, agricultural effluent as runoff water, recirculated greenhouse effluents and fish pond wastewater.

Fig. 5 schematically illustrates the wastewater treatment process. Primary wastewater effluents are strained or pre-settled. Secondary effluent improves quality after biological treatment. Both may be used for tertiary treatment with membranes, Proper usage of the biotreatment may remove most ammonia and phosphates from the water. Anaerobic operation may remove nitrates. When membranes (MF or UF) are submerged in the bioreactor, it is called a Membrane Bioreactor (MBR). It is also possible to use the effluent of the bioreactor with external MF or UF membranes and circulate the concentrate back to the bioreactor.

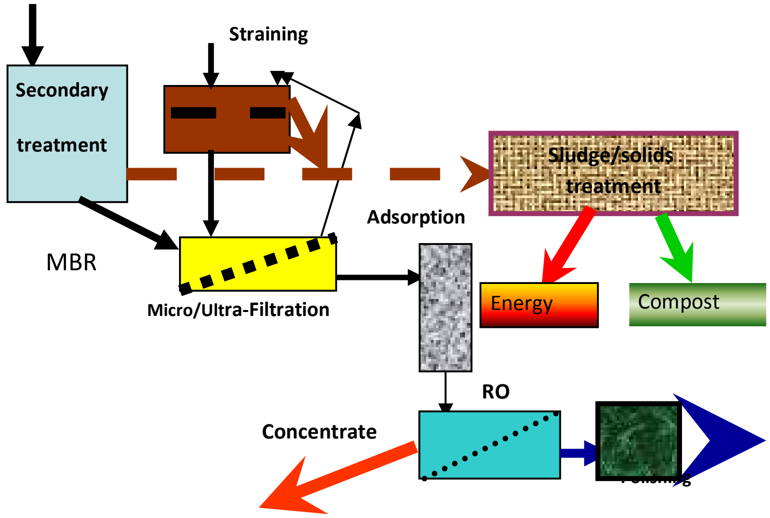


Fig. 5: Schematic presentation of a wastewater treatment plant.

MF and UF membranes are capable of achieving complete removal of bacteria (6 to 9 logs of removal) and waterborne protozoa, and of reducing the virus content of surface water by two to three orders of magnitude. Particulate agglomeration occurring next to the membrane followed by possible adsorption to the cake layer causes cake and gel layer build-up on the membrane followed by pore size reduction that can prevent the passage of most viruses. Some parameters affect membrane fouling: particle nature, particle size and size distribution, membrane type and structure, surface interactions and the clogging mechanism. An important parameter is the method applied to the filtration technique, namely, cross flow or dead-end filtration. The latter demands less pumping energy but may clog easier.

MBR-treated effluents could be fed directly into the RO/NF system. The final effluent, after RO/NF, will by far surpass current (and future) environmental requirements, as well as those for unrestricted use in agriculture and aquifer re-infiltration, and eventually even municipal use. A second membrane stage of RO or NF membranes can remove salinity, TOC and some dissolved organic matter. Water may then be disinfected by UV chlorine and chloramines and used for any purpose.

The critical issue for successful RO plant operation is pretreatment. Long-term operating experience proves the advantage of MF/UF pretreatment of a wide variety of water sources. . MF/UF pretreatment can simplify the traditional pretreatment technique of deep-bed media filtration However, UF/MF pretreatment is currently more expensive. Polishing with activated carbon to remove trace organics may be used as a means for reducing RO/NF membrane fouling and deterioration Different aspects of wastewater treatment using membranes can be found in many papers, for example, Harussi et al. (2001) and Johnson et al. (1997).

Product quality

Insufficient removal of organic matter and ammonia in early stages may lead to their presence in the product. A low ammonia content of the order of 1-2 ppm may react with chlorine to form chloramines, a long-term disinfector. Chlorination of organic matter may produce harmful halogenated organic matter. Insufficient removal of phosphates at the secondary stage may reduce recovery of the RO process due to calcium phosphate precipitation. Insufficient denitrification will lead to high nitrates concentration in the concentrate and create a disposal problem.

High-recovery RO can usually be used to solve the problem in relatively inexpensive ways depending on the saturation level of calcium carbonate with the use of antiscalants. Industrial wastewater represents a completely different situation due to the diverse types of solutes. Each stream should be considered separately. Treatment of wastewater for general use is a problematic issue since many societies refuse to accept the idea. Treated water may be used in many cases for agriculture, with precaution, if RO/NF membranes were not used. Gagliardo et al. (1998) documented their efforts in Southern California.

The most successful usage of recovered wastewater is the NEWater venture of Singapore, which produces treated water clean enough to be used in the microelectronics industry. Part of the high-quality treated water is mixed with a natural source of water for regular water consumption. Many countries purge secondary-treated water to the sea. This causes an environmental problem, very similar to purging RO concentrate directly to the sea. –Other countries do not treat wastewater at all.

It is important to mention that in Europe and many other places around the world, wastewater treatment plants are located close to the large cities along the large rivers. Secondary-treated water flows into the river, is pumped again at a distance of about 200 meters, treated with active carbon, UF membranes and sometime NF membranes, undergoes ozone disinfection and is then distributed to the main system. This is wastewater treatment without the RO step, which is possible due to the low salinity of water that originates from snow. The process cannot deal with dissolved medicines, hormones, drugs and other contaminants that can only be removed with RO membranes. Information on wastewater costing may be found in Adham and Kumar (2004).

New membrane-based desalination processes

Significant attention has been paid over the past decade to other types of membrane processes notably Forward Osmosis (FO) (McCutcheon et al., 2005; Cath et al., 2006), and

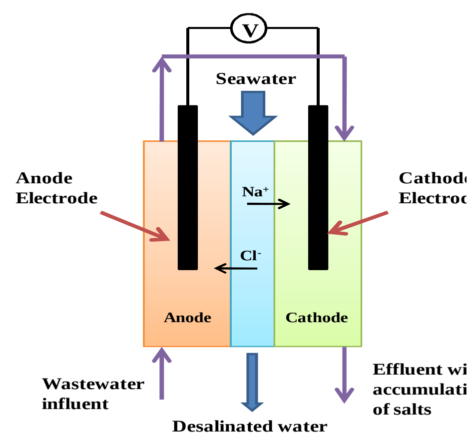
Membrane Distillation (Alklaibi and Lior, 2005; Song et al., 2007). Forward Osmosis, or direct osmosis, is a process whereby water diffuses through a membrane from a salty or polluted solution to a higher osmotic pressure solution. The high concentration solution, called a draw solution, is based on “easy to separate” salts such as ammonium carbonate, which can be recovered by evaporation using a low-grade heat source. The technique may be used for the backwash of RO/NF membranes and in chemical/pharmaceutical and food industries to concentrate solutions. The evaporated gases must be re-adsorbed for further use.

Some problematical aspects of FO are that trace contaminants of the high osmotic pressure material will find their way into the product water and in the concentrated solution on the other side of the membrane. Also FO is carried out at high concentrations and hence the energy consumption and investment needed are much higher in comparison to the RO process (Semiat et al., 2010).

Membrane Distillation is another novel technique based on porous hydrophobic membranes that enable passage of water vapor only. Vapor condensation occurs on colder surfaces adjacent to the membranes or outside the membrane module where vapors are pumped out. Another way is to condense the vapor in direct contact with a cold water stream. This technique is based on water evaporation and suffers from poor heat recovery. As stated before, the energy demand for this process is around 650 KWh/m^3. This enormous amount of energy may be reduced by adopting methods used in other thermal processes utilizing similar energy sources. Since the heat transfer is poor and energy demand is high, the only possible advantage is a smaller stack of membranes instead of the large volume of thermal devices, yet in terms of energy demand, the technique cannot compete with RO and not with the current MSF and MED processes.

Other directions

Another approach is the “humidification-dehumidification” process. Again, this is a new variation of an old idea to remove humidity from air. The need for pumping enormous amounts of air in order to get 1 m^3 of water, and the need for a high amount of energy in order to increase humidity in the air, makes the process energy intensive.



Capacitive deionization is a technique for removing salts from water. Passing saline water between two charged electrode surfaces causes the ions of the different salts to ‘stick’ to the electrode, leaving a diluted salt solution in the center between the electrodes (Welgemoed and Schutte, 2005). Once saturated, the charge must be reversed and the ions released from the electrodes redirected to the discharge brine stream. Clearly, economic performance demands a high surface area available per unit volume of the separation unit. Hoang et al. (2009) reviewed the subject, identifying key carbon-based materials under investigation to improve efficiency: carbon aerogels, activated carbon cloth with metal oxide nanoparticles and carbon nanotubes. Treating a synthetic brackish water of 2,000 mg/L TDS [163], CDI required only 0.59 $kWh.m^{-3}$ to recover 70% of product water at a concentration of 500 mg/L (Kim et al., 2009). Zou et al. (2008) used a high surface area activated carbon to reduce the salinity of water effectively in the laboratory and also found that modification of the electrodes with titania nanoparticles increased electro-sorption efficiency.

Fig. 6: Schematic MDC.

Commercial systems are used in polishing ultra-pure water or treating low-salinity brackish or wastewaters (Farmer et al., 1996). Limitations of the process include preference for removal of monovalent ions over divalent ions, limited sorption capacity of carbon-based electrode materials, and electrodes organic fouling when used in natural waters.

The development of fuel cells, especially Microbial Fuel Cells (MFCs), based on wastewater treatment led to the possibility of using this type of energy source for desalination. Since MFCs need ion transport to maintain charge balance and generate electricity (Rozendal et al., 2006a), salts can be removed during the electricity generating process. For the purpose of desalination, the modified MFC is called a microbial desalination cell (MDC) (Cao et al., 2009). MDCs contain an additional chamber installed between the cation and anion exchange membranes in which salts (e.g., NaCl) in feed water such as seawater dissociate into cations and anions (Fig. 6). When electricity is produced through anode bacterial oxidation and cathode reduction, anions migrate into the anode chamber via an anion-exchange membrane and cations are transported into the cathode chamber through a cation-exchange membrane. As a result, salts are “relocated” into the wastewater stream and salts concentration in the feed water can be greatly reduced. MDCs have an interesting potential as a low-cost, low-salinity desalination process.

Better membranes

Analyzing the main components of RO desalination costs, energy costs and equipment investment are the main contributors. Some energy may be saved, of the order of 20-30%. The equipment contains membranes, pressure vessels, pumps, tubing and flow devices, and energy recovery units. There is no single item that is significantly more expensive than the others. Membranes, however, play the most important role in future cost reductions. For example, the cost of RO membranes is about 8% of the overall investment. Improved membranes may increase permeability while maintaining similar rejection properties. This will allow lower operation followed by lower energy costs at the same recovery ratio. Reduction in operating pressure will reduce costs of the expensive high-pressure equipment. This will be followed by a reduction in the cost of pumps and flow devices.

It is also important to improve resistivity to extreme pH, resistance to oxidizers, organic solvents and particulate fouling, as well as the spacers and means against biofouling. Other types of membranes in use such as MF, UF and NF membranes must be improved in the same way. Improved membranes may be used in other separation processes not necessarily related to water (Akthakul et al., 2004; Vainrot et al., 2008).

Final remarks

Desalination techniques are the main tool for alleviation of the mankind water scarcity problem. Analyzing the water distribution on earth will show that even doubling mankind water usage by using desalination techniques will not significantly affect the environment. Energy consumption for RO desalination is low and insignificant in comparison to the energy consumption for other purposes as electricity and fuel in most countries, usually far less than the energy required to pump water long distances. Treatment of wastewater using membranes alleviates the water scarcity problem while solving environmental problems. However, implementing water techniques in existing water systems is an issue that requires intelligent policies. When governments try to solve water problems, they usually build a large facility next to a large city. Farmers and settlers living far away from the main cities do not have access to the water, and in severe cases must leave their homes to join the cities, seeking to survive. Solutions for remote locations are urgently required based on known technologies as well as on future directions that will provide cheaper solutions. Water is needed in locations where agriculture is still the basis for life and simple agriculture cannot afford the costs described here. It is a global question of the same type of the usage of diminishing natural energy resources and solutions for environmental problems. The future of humankind depends on proper answers related to these three questions, together with the questions of global peace and human wealth on earth. At the moment, without international acts, only local solutions may be given in some places for the water problems.

Development of low-cost water sources could also be a basis for increased industry toward a thirsty world. It is not enough, however, to produce low-cost water. It is also important to educate people towards proper usage of water that will improve their way of life.

References

1. Adham, S., Kumar, M., Pearce, W.H. (2004). Development of a model for brackish and reclaimed water membrane desalination costs, Proceedings of the International Conference on Desalination Costing, Limassol, Cyprus.

2. Akthakul, A., Salinaro, R.F., Mayes, A.M. (2004). Antifouling polymer membranes with subnanometer size selectivity, *Macromolecules* **37**(20), 7663-7668.
3. Alklaibi, A.M., Lior, N. (2005). Membrane-distillation desalination: status and potential, *Desalination* **171**(2), 111-131.
4. Al-Sahali and M., Ettouney, H., Developments in thermal desalination processes: Design, energy, and costing aspects, (2007) Desalination, 214 (1-3), pp. 227-240.
5. Awerbuch, L. (1997a). Current status of seawater desalination technologies, IDA Desalination Seminar, Cairo, Egypt.
6. Awerbuch, L. (1997b). Dual purpose power desalination/hybrid systems/energy & economics, IDA Desalination Seminar, Cairo, Egypt.
7. Awerbuch, L. (2004). Hybridization & dual purpose plant cost considerations, Proceedings of the International Conference on Desalination Costing, Limassol, Cyprus.
8. Cao, X., Huang, X., Liang, P., Xiao, K., Zhou, Y., Zhang, X., Logan, B.E. (2009). A new method for water desalination using microbial desalination cells, *Environmental Science and Technology* **43**(18), 7148-7152.
9. Cath, T.Y., Childress, A.E., Elimelech, M. (2006). Forward osmosis: principles, applications, and recent developments, *Journal of Membrane Science* **281**(1-2), 70-87.
10. Farmer, J.C., Fix, D.V., Mack, G.C., Pekala, R.W., Poco, J.F. (1996). Capacitive deionization of NaCl and $NaNO_3$ solutions with carbon aerogel electrodes, *Journal of the Electrochemical Society* **143**, 159-169.
11. Furukawa, D.H. (1997). A review of seawater reverse osmosis, IDA Desalination Seminar, Cairo, Egypt.
12. Hai, O.H., De Ryck, L. (2005). Water reuse and Ulu Pandan NEWater Project, IDA World Congress on Desalination and Water Reuse, Singapore.
13. Harussi, Y., Rom, D., Galil, N., Semiat, R. (2001). Evaluation of membrane processes to reduce the salinity of reclaimed wastewater, *Desalination* **137**, 71-89.
14. Hoang, M., Bolto, B., Tran, T. (2009). Desalination by capacitive deionisation, *Water*, **36**(1), 132-135.
15. IDE publication (2010). http://www.ide-tech.com/news/largest-swro-desalination-plant-world-inaugurated-hadera.
16. Jassim, A.A., Ismail, S. (2004). Fundamentals and costing of MSF, Proceedings of the International Conference on Desalination Costing, Limassol, Cyprus.
17. Johnson, W.T., Phelps, R.W., Beatson, P.J. (1997). Wastewater reuse using membranes, IDA World Congress on Desalination and Water Science, Madrid.
18. Kim, S.J., Ko, S.H., Kang, K.H., Han J. (2010). Direct seawater desalination by ion concentration polarization, *Nature Nanotechnology,* March 21, 2010.
19. Li, D., Wang, H., Recent developments in reverse osmosis desalination membranes, (2010) Journal of Materials Chemistry, 20 (22), pp. 4551-4566.
20. McCutcheon, J.R., McGinnis, R.L., Elimelech, M. (2005) A novel ammonia--carbon dioxide forward (direct) osmosis desalination process, *Desalination* 174(1), 1-11.
21. Ophir, A., Lokiec, F. (2004). Review of MED fundamentals and costing, Proceedings of the International Conference on Desalination Costing, Limassol, Cyprus.
22. Ophir, A., Weinberg, J. (1997). MED (Multi-Effect Distillation) desalination plants: a solution to the water problem in the Middle East, IDA World Congress on Desalination and Water Science, Madrid.
23. Park, C., Park, P.-K., Mane, P.P., Hyung, H., Gandhi, V., Kim, S.-H. and Kim, J.-H., Stochastic cost estimation approach for full-scale reverse osmosis desalination plants, (2010) Journal of Membrane Science, 364 (1-2), pp. 52-64.
24. Reddy, K.V., Review and evaluation of desalination cost and costing methodologies (2008) International Journal of Nuclear Desalination, 3 (1), pp. 79-94.

25. Rozendal, R.A., Hamelers, H.V.M., Euverink, G.J.W., Metz, S.J., Buisman, C.J.N. (2006). Principles and perspectives of hydrogen production through biocatalyzed electrolysis, *International Journal of Hydrogen Energy* 31, 1632-1640.
26. Semiat, R. (2000). Desalination – present and future. Invited article for IWRA'21, *Water International* **25**(1), 54-65.
27. Semiat, R. (2008). Energy demands in desalination processes, *ES&T* 42(22), 8193-8201.
28. Semiat, R., Sapoznik, J., Hasson D. (2010). Energy aspects in osmotic processes desalination and water treatment, *Desalination and Water Treatment* 15, 228-235.
29. Song, L., Li, B., Sirkar, K.K., Gilron, J.L. (2007). Direct contact membrane distillation-based desalination: novel membranes, devices, larger-scale studies, and a model, *Industrial and Engineering Chemistry Research* 46(8), 2307-2323.
30. Vainrot, N., Eisen, M., Semiat, R. (2008). Membranes in desalination and water treatment, *Materials and Technologies for Water Purification MRS Bulletin* January, 33, 5-9.
31. Voutchkov, N. and Semiat, R., "Seawater Desalination", in "Advanced Membrane Technology and Applications". Edited by N. N. Li, W. S. Winston Ho, A. G. Fane, and T. Matsuura 2008 John Wiley & Sons, Inc.
32. Welgemoed, T.J., Schutte, C.F. (2005). Capacitive deionisation technology™: An alternative desalination solution, *Desalination* 183, 327-340.
33. Zou, L., Qi D., Morris, G. (2008). Using activated carbon electrode in electrosorptive deionisation of brackish water. *Desalination* 225, 329-340.

Protection of Water Resources from Mechanical Pollution in the Transboundary Region of the South Caucasus during the Formation of Natural Disasters

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The main objective of the work refers to protection of water resources of the transboundary Mtkvari(Kura) River located in the South Caucasus Region (Georgia, Azerbaijan, Armenia) from mechanical pollution using modern methods and technologies.

To protect water resources from mechanical pollution in the South Caucasus Region the Mtkvari River watershed will be studied, assessed and forecasted from the environmental point of view.

The results expected from the implementation of a work will have the following impacts in the ecological, economical and social dimension, especially: Ecological - Qualitative pollution indices of water resources in the Mtkvari River will be fully investigated for the transboundary regions of the South Caucasus; Economical - Adoption of new scientific researches will have a great economical impact taking into account that profitable complex activities implemented in the watersheds of the rivers mentioned above will decrease potential expenditures on drinking water purification; Social - Work implementation will be of a great social importance because of new ecological engineering activities, which will be implemented to provide safety of population living in ecologically unstable sections within the watershed of the Mtkvari River.

Key word: South Caucasus, Transboundary Region, Mtkvari - Araksi Rivers,

1. Introduction

The Mtkvari – Araksi (hereinafter the Mtkvari river) can be considered as the main catchment basin of the South Caucasus and, a lot of transboundary questions are connected to this river system and its tributaries. The basin of the Mtkvari river is one of the main water catchment in the South Caucasus and any kind of transboundary questions is connected to the river system (see photo 1). Taking into account the above-mentioned, we should consider differences in the interests regarding its resources and, also, the fact that both countries, Armenia and Georgia, i.e. “Roofing Countries”, produce and supply water to “Water Consumer” Azerbaijan. The above-mentioned can have an influence on water control[1,4,6,8,10].

Photo 1. The Mtkvari River System in the South Caucasus

Also, during the last decades, the countries of the region underwent some changes, which had a great influence not only on the field of water management, but also on the whole society. Taking into account their past experiences, Georgia, Armenia and Azerbaijan try to use any possibility, to look for the ways of its development, to protect the environment and to avoid heavy pollution of the Mtkvari system, which impede social and ecological development.

Thus, the most important measures for the region are to find not only short-term, but also long-term solutions of the existing problems and to preserve environmental conditions for the future and contemporary generations. Information about the environment is the most important to get the appropriate decisions.

Thus, the main task is to assess water status, its suitability and date and information about water resources of the Mtkvari basin. This activity consists of the following two parts: description of water resources in the Mtkvari basin using the existing data and analysis of informational gaps on the basis of the requirements of Water Frame Directive (WFD).

2. Methods

The methods needed to study the Mtkvari-Araksi basin can be described as collecting and finding of field-expeditionary, theoretic and bibliographic data as well as selection of specific indices.

To represent water status of the Mtkvari basin, a set of indices was presented and used for all its components. The indices were selected in such a way that they allowed us to identify the interaction between different elements of the catchment basin and the main control issues regarding drainage. The article identifies the following topics:

- Motivating forces (natural phenomena; development and economic activity);
- Overloads (water supply; sewage water and pollution);
- Status (conditions), water quantity; water quality;
- Impacts – completeness of eco-system;
- Reacting strategy and control including institutional organizing.

3. Data About Quantity of Surface Waters

Water law of Georgia determines property survey of state water, necessity to develop territorial schemes and water resources of the whole basin as well as balance materials of water supply.

Georgia

The monitoring of surface waters is carried out for the purposes of hydrologic forecasting and status of water resources. Data about water level are recorded twice a day by 9 stations; flow indices are measured at the intersections occasionally (35-40 times per annum at all stations).

Azerbaijan

The hydro-meteorological station of Azerbaijan provides measurements, implements recording and delivers appropriate information to state structures and society. Hydrologic data are collected from 88 hydro-meteorological stations.

Armenia

The *surface water monitoring* program is carried out by 100 hydrometric stations. It is based at and consists of measurements of water level and flows based on the appropriate curves.

4. Assessment of Erosion-Debris Flow Processes

The *debris flow catchment basin* area on the South Caucasus range is equal to 8600 km2, including the area of catchment basin - 4800 km2, and talus train - 3800 km2. The hypsometric indices of debris-type water conduits located within the boundaries of the

Mtkvari - Araksi catchment basin are characterized by constant indices[1,4,6,8,10]. Their quantitative indices are given in Table (see table 4.1)

First of all, erosion-debris flow should be forecasted to assess index of mechanical pollution of water resources within the boundaries of the Mtkvari catchment basin. It is connected to geologic, temperature, hydrologic and hydraulic degrees as well as degree of plant cover degradation.

On the basis of field-reconnaissance surveys, it was determined that erosion-debris flow processes became more active in some sections of central part of the South Caucasus and slower in others. For example, debris flows were not observed on the Duruji River (the Alazani catchment basin, Georgia) after 1999. The similar conditions can be seen on the *Kishchai, Shinchai, Kurmukhchai (Azerbaijan); erosion processes became more effective on some rivers, i.e., Telavi-Khevi (the Alazani River Basin), Mleti-Khevi (the Tetri Aragvi River Basin, Georgia) etc[2,3,5]*.

Table 4.1. Hypsometric Description of the Mtkvari and the Araksi Rivers

Catchments area of the river basin (km2 and %)	Height(m)				Total
	< 1500	1500 - 2400	2400 – 3000	3000 >	
River Mtkvari (km2) (%)	1886,2	2213,2	746,3	331,4	5177
	36,5	42,7	14,4	6,4	100
River Araksi (km2)	416,7	378,5	126,5	63,3	985
(%)	42,5	38,4	12,7	6,4	100

Taking into account the above-mentioned, we represent methods and sequence, which will be used to assess mechanical pollution of water resources in the Mtkvari River basin.

On the basis of a study of statistical data and field investigations, carried out by the author and scientists of Georgia, Russia, Germany , Japan, China, the USA, Austria, France and other countries [2,6,9] an empirical dependence has been derived, enabling to determine the maximum discharges $(Q_{0.1\%})$ of highly concentrated (turbulent) debris flows of various provision[4]:

$$Q_{0.1\%} = 2.4(34 + 400\ i)F^{0.61}, \quad \text{(m3/c)} \qquad (4.1)$$

where i - is the average inclination of the riverbed; F is the catchment area of the river basin s (m2).

The mean diameter of drift (d_s) transporting the maximum discharge of a turbulent debris flow $(Q_{\max})$ is calculated by means of the following empirical dependence [5]:

$$d_s = \left(0.2 + 6.55\ i^{2.73}\right)Q_{\max}^{0.64} \quad \text{(m)} \qquad (4.2)$$

Taking into consideration the field-expedition observations (1984-2000) and treatment of statistical series, a dependence has been obtained, determining the hydromorphometric values (width of the riverbed – B, depth of the turbulent debris flow – H, average speed of flow - V) at transit sections of mountain rivers [3]:

$$\begin{cases} b = 3.0 \cdot d^{0.51} \cdot Q_{\max}^{0.59}, & (m) \\ H = 0.08 \cdot d^{-0.19} \cdot Q_{\max}^{0.44}, & (m) \\ V = 0.16 \cdot d^{0.37} \cdot Q_{\max}^{0.37} & (m/c) \end{cases} \qquad (4.3)$$

The field surveys implemented in the catchment basins of the Shavi and the Tetri Duruji Rivers have produced a conclusive evidence that the ecological conditions of the mentioned areas as disastrous, which requires immediate implementation of appropriate measures.

To assess the erosive processes for the gullies with active erosive – debris flow processes in the catchment basin of the Duruji River, the erosion coefficient (E) has been calculated on the basis of dependence obtained as a result of field works and interpretation of aerial and satellite images [3,5]

$$E = \left[0{,}58 + 1{,}40\,(F_1 / F_0)\right] \cdot (t / T)^{0{,}21},$$

(4.4)

where, F1 – erosive area (km2) in the catchment basin of the river, F0 – area (km2) of the whole catchment basin, t - time interval surveyed (year), T – total observation period (in our case T=30 years).

(4.4) – limit dependencies are as follows:

$$0.061 \leq (F1/F0) \leq 0.24 \,;\; 0.1 \leq (t/T) \leq 1.0; \qquad (4.5)$$

The values of erosion coefficient for the mountainous slopes of the Duruji river basin are calculated by the dependencies (4.4) taking into account the appropriate values of damage rate given in Table 4.2

Table 4.2 Erosion coefficient and erosion class of mountainous slopes

in the catchment basin of the Duruji River

N	River	Values of erosion coefficient				Erosion class (2010)	Intensity of Erosion annually (t / ha/ year)
		1980	1990	2000	2010		
1	Nakhechi Gully	0.077	0.08	0.195	0.207	second	2-5
2	Samali Gully	0.05	0.061	0.072	0.171	second	2-5
3	Salesavi Gully	0.30	0.45	0.68	0.75	third	5-10
4	Utkhovari Gully	0.84	0.92	0.98	1.00	fourth	10-50
5	Mshrali Gora Gully	0.76	0.94	1.00	1.05	fourth	10-50
6	Savepkhvo Gora Gully	0.82	0.96	1.11	1.15	fourth	10-50

7	Tsipel Gora Water	0.83	0.99	1.21	1.23	fifth	50-100
8	The Upper Duruji (Shavi Klde)	1.00	1.45	1.95	2.01	sixth	100-500

The frequency of ravines and flumes observed in some sections of so called "Black Mountain" in the upper reaches of the Duruji River (2002) is equal to 15-20m. In accordance with the classification of Prof. R. Morgan[7], this value is appropriate to the 7th class of erosion with the intensity of erosion more than 500 (t/ha) per year.

As about the association (Table 4.2) between the erosion class and the erosion coefficient, it has been calculated in accordance with the scale of Prof. R. Morgan [7]

The results of granulometric analysis concerning the samples of solid composition obtained from the talus train of the Duruji river are given in Table 4.3[1]. The chemical analyses of colloidal mass needed to use debris mass in production [4] are given in Table 4.4 (value of chemical elements is given in %).

As for the mass slid from the mountainous slopes in the catchment basin of the Shavi Duruji River, it is equal to 300 000 m3 according to the data of June-July, 2001. This value can be considered as an average one for the conditions of this channel.

Table 4.3 Mechanical composition of debris mass obtained

on the Debris Flow Cone of the Duruji River

o	Dimensions of Factions (mm)	Weight (kg)	Percentage (%)
	Stones >30	116.0	42.0
	Breakstone 30-10	48.9	17.7
	Gravel and Coarse Sand (10-1)	43.4	15.7
	Fine-Grained:	68.0	24.6
	(1-0.05)		8.4

	(0.05-0.005)		8.8
	(0.005-0.001)		4.0
	< 0.001		3.4

Table 4.4 Chemical analysis of colloidal mass of the Duruji River, %

Si O2	Al2 O3	Fe2 O3	Ti O2	Ca O	Mg O	Mn O	Na O	K2 O
49.5	27.0	12.02	0.29	0.90	2.90	0.80	1.08	5.60

Thus, the field investigations implemented in summer (2001-2010) in the catchment basin of the Shavi and the Tetri Duruji Rivers revealed that the condition of erosion processes on the mountainous slopes are disastrous and, in some sections, it can be considered as equal to the 7th class of erosion.

Conclusions

The Mtkvari River, which *starts in Turkey* and flows into the Mingechauri Reservoir and the Caspian Sea, is one of the main water catchment basin of the South Caucasus and a lot of a lot of transboundary questions are connected to this river system and its tributaries.

Data and information needed to assess water status of the Mtkvari River basin is limited and differs from country to country. Using DPSIR model, we have determined defects and limits of available data needed to assess water status in the region.

The lack of investments into the cleansing stations needed for sewerage and water supply schemes of the Mtkvari River basin has a negative impact on water quality and water eco-systems.

Average annual concentration of surface water quality parameters is similar to some European rivers. But, the concentration of nutrients – nitrogen and phosphorus is very high. It can be caused by insufficient cleaning of sewage waters and a small percent of population connected to sewerage systems.

The South Caucasus states (Georgia, Azerbaijan, and Armenia) signed water convention. It will provide collaboration and common measures needed to protect transboundary water resources. According to the principles of integrated water resources control determined by the European Water Frame Directive (WFD), all partner countries have possibilities and obligations to provide water resources control at best level.

Aiming to determine mechanical pollution indices needed for transboundary water resources of the Mtkvari River, methods are represented to assess intensity of erosion-debris flow processes and to allow forecasting of inactive capacity of dams in the future.

References

1. Gagoshidze M.C. (1970) - Debris flow processes and their prevention measures. Tbilisi, 385(in Russian).
2. Gavardashvili G., Schaefer M. & King L. (2006) – Debris flow at the River Mletis Khevi in the Great Caucasus (Georgia) and its assessment methods. Center for International Development and Environmental Research. www.uni-giessen.de/zeu. Germany , Giessen, #31, August, , 15 p.
3. Gavardashvili G.V. (2003) - The Forecast of erosion-debris flow processes in catchment basin of the River Duruji and new engineer – Ecological Measures. Tbilisi ,,Metsniereba", 116 (in Georgian).
4. Gavardashvili G.V. & Chakhaia G. G. (2002,) - Evaluation of present ecological situation of the River Duruji drainage basin. Bull. of the Georgian Academy of Sciences. Tbilisi, Vol. 166, # 12, 174 – 177.
5. Gavardashvili G.V.(2011), Measures for the Safety of Mountain Landscapes During Natural Technogenic Disasters, //Monograph, "Universal", Tbilisi, Georgia, 237 p. (In Georgian).
6. Mirtskhoulava Ts.E. (1998) – The assessment of frequency of catastrophic debris flow occurrences. Hydrotechnical Construction, 5, M .:, 19-26.
7. Morgan R.P.C. & Hann M.J. (2001) - Shah Deniz Gas Export Project: erosion risk assessment. Crafield University, UK, Silsoe, 25.
8. Natishvili O.G. & Tevzadze V.I. (1996).- Hydraulical principles of Mud flow. Tbilisi, Metsniereba, 154 (in Russian).
9. Takahashi T. (Head Investigator) (1994), Japan-China Joint Research on the Prevention from Debris Flow Hazards, Kyoto University, Japan, 195.
   Tsereteli E.D., Berdzenishvili D.P., Tatashidze Z.K., Chelidze T.L., Tavelishvili O.G., Tevzadze V.I. Kherkheulidze G.I. (2001) – Formation of Debris Flow Hazards in River Duruji Basin and Safety of Town Kvareli (Eastern Georgia). Transactions of International Conference, Tbilisi,, 229-234 (in Russian).

Sustainability of groundwater and its effects on ecosystems

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Abstract

Groundwater's global role as a vital source of fresh drinking water is well documented, and efforts are underway in many parts of the world to manage groundwater reserves responsibly and sustainably. A large percentage of the world's population lives in cities and either depends on or is affected in some way by groundwater. This ever increasing demand on groundwater has led to overexploitation of the aquifers and degradation of groundwater quality particularly in the last 50 years. Available evidences indicate that regional changes in climate (i.e., increases in temperature and reduction in precipitation totals and patterns) have already affected groundwater resources and ecosystem in many parts of the world. In future, climate change is expected to intensify groundwater related problems due to reduced recharge rates and increased demand for domestic, agricultural and industrial water supply. Thus, the basic concern is the sustainable management of groundwater resources such that it is not depleted while the increasing demand is effectively satisfied. Based on these fundamentals, the purpose of this study is to present an overview of groundwater problem in different parts of the world and to present an overview of the current knowledge in the area of climate change impacts on water resources. Case studies from the Mediterranean Region, the Caspian Sea Region and the Aral Sea where safe water resources are typically scarce and became steadily scarcer are presented. In particular, access to high quality drinking water will become more of a problem than it currently is in these and in many other parts of the world. Decreasing precipitation and reduced recharge of groundwater resources are now considered to be one of the reasons for declining groundwater quality. Finally, these drastic changes in the hydrology of the groundwater system are also responsible for many changes in ecosystems where some are irreversible.

Keywords: groundwater, sustainability, climate change and ecosystem

This paper is a general summary of the outcome of the NATO Advanced Research Workshop on "Climate Change and Its Effects on Water Resources" held in Çeşme-Izmir-TURKEY on 1-4 September 2010.

1. Introduction

National and global security can be assessed in many ways but one underlying factor for all humanity is access to reliable sources of water for drinking, sanitation, agriculture, construction, daily living, energy, fishing, forestry, manufacturing, public health, recreation, and transportation. The world's population is estimated to reach 7 billion in 2011. Projections recently issued by the United Nations suggest that world population by 2050 could reach 8.9 billion (UN, 2004). Therefore, in many parts of the world, population growth and associated increased demand for water already threaten the sustainable management of available resources (Baba et al., 2011). Furthermore, there is increasing evidence that global climate patterns are changing and creating major influences on human survival on earth (Santer et al., 1996; Baba, 2011). Global warming, climate change and sea level rise are expected to intensify problems related to the sustainability of available resources in many water-stressed regions of the world by reducing the annual supply of renewable fresh water and promoting the ingress of saline water into aquifers along sea coasts where 50% of the global population inhabit (Baba et al., 2011).

Climate change is an important factor effecting water resources. Thus, the focus of scientific research in the first half of the 21st century is towards finding ways to mitigate the negative consequences of climate change on water resources (Arnell 2000, Alcamo et al. 2000, Kamara, Sally 2004, Iglesias et al. 2006, Bates et al. 2008). As a consequence, water management is becoming a critical factor and is playing a decisive role in the geopolitical, economic and social grounds (Hrkal, 2011). Most scientists are confident that if current emissions of greenhouse gases continue, the world will be warmer, sea levels will be higher and precipitation distribution will be altered from their current conditions. As a consequence, regional climate patterns will likely to change and influence every day life in many parts of the world. According to Houghton et al. (1996), global temperatures are expected to rise faster over the next century than over any time during the last 10,000 years (Baba, 2011). On the other hand, Hrkal (2011), bring in a different perspective to the issue and link climate change phenomena with geological events. According to him, data from geology show that the mean temperature on the Earth were about 12oC higher during the Eocene period (i.e. roughly 50 million years ago) than its current level (Zachos et al. 2001, Katz et al. 1999) and the content of CO2 reached values fluctuating around 1000 ppm during the same era (Figure 1).

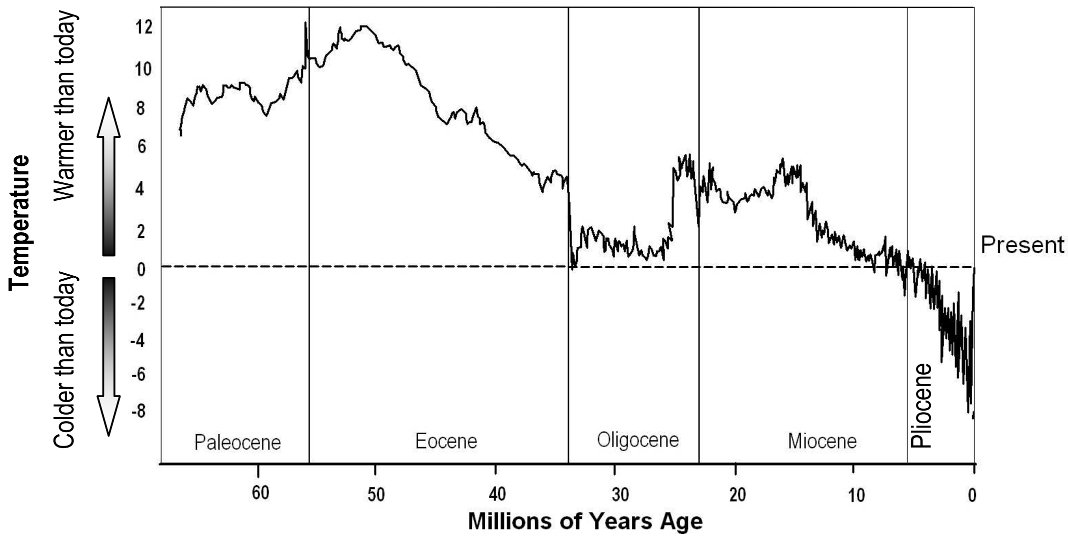

Figure 1. Changes in temperature on the Earth during the last 65 million years (Hrkal, 2011)

According to Hrkal (2011), in the period between the Eocene and Oligocene the climate began to gradually cool down so that the Antarctic was covered with ice for 10 million years. This period was then followed by a warming up interval when the Antarctic glacier melted completely away. Another wave or spell of cooling down arrived as late as in middle of the Miocene, which is characterized by fierce, short-term climate oscillations, by alternating the so- called glacial and interglacial ages (Hrkal, 2011). On the contrary, recent studies on climate change and climate modeling indicate that, with at least a 90% probability, global warming is due to human activities and more specifically to gaseous emissions since the beginning of the industrial revolution in 1750 (IPCC, 2001; Ganoulis and Skoulikaris, 2011).

Recent reports from the Intergovernmental Panel on Climate Change (2007) confirm that climate change is occurring at a larger and more rapid rate of change than was thought before. Eleven of the last twelve years (1995-2006) rank among the twelve warmest years in the instrumental record of global surface temperature (since 1850). The 100-year linear trend (1906-2005) of 0.74 [0.56 to 0.92]°C is larger than the corresponding trend of 0.6 [0.4 to 0.8]°C (1901-2000) (Jia et al., 2010; Baba, 2011). Climate models are able to predict temperature increase after 1950 only if the man-induced gas emissions are taken into account (Figure 2). Climate change primarily and additionally man-made modifications in land use result in modifications of different components of the hydrological cycle, such as evapotranspiration and precipitation. This is already the case in arid or semi-arid climates like the Mediterranean, where data time series recordings have shown a decreasing trend in precipitation over the last few decades (Ganoulis and Skoulikaris, 2011).

Constituting about 30% of all freash water, groundwater is a significant component of the freshwater cycle and its significance is becoming more prominent as the more accessible surface water resources are increasingly more exploited. In many cases, groundwater is a sufficient, secure and cost-effective water supply. However, it is increasingly becoming stressed due to overexploitation, contamination and in some areas of the world due to climate change. It was emphasized in a technical paper by the second working group of the Intergovernmental Panel of Climate Change (Bates et al., 2008) that the information about the water-related impacts of climate change is insufficient, especially with respect to water quality, aquatic ecosystems and groundwater. Therefore, impacts of climate change on groundwater quantity and quality need to be comprehended and determined (Elci, 2011).

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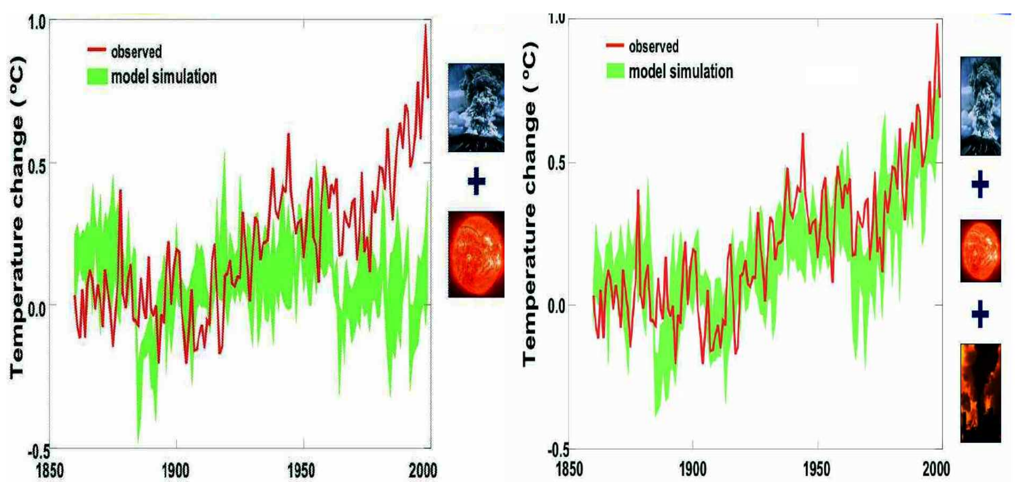


(a)

(b)

Figure 2. Comparison between observed and simulated temperature change (a) without and (b) with taking into account human gaseous emissions (Hadley Centre, 2005) (Ganoulis and Skoulikaris, 2011).

The purpose of this study is to present a brief summary of the findings of a NATO Advanced Research Workshop that took place in Cesme-Izmir-Turkey during 1-4 September 2010 to discuss the fundamental effects of climate change on surface and subsurface water resources. The study is complied to emphasize the main points of some of the research presented in this meeting. It also aims to present an overview of groundwater problem in different parts of the world (including case studies from the Mediterranean, Caspian and Aral Sea regions and other parts of the world) and to present an overview of the current knowledge in the area of climate change impacts on water resources.

2. Effect of climate change on groundwater

The most important pressure that climate change will exert on groundwater resources will be the changing rate of recharge which is closely related to the changes in precipitation. Therefore, following similar trends with precipitation, groundwater recharge rates will either decrease or increase for different geographical regions. For instance, IPCC reported that a more than 70% decrease in groundwater recharge is computed in north-eastern Brazil, southwest Africa and along the southern rim of the Mediterranean Sea, whereas more than 30% increase in groundwater recharge is computed in Sahel, the Near East, northern China, Siberia and the western USA (Kundzewicz et al., 2007). However, the most dramatic impacts of changing recharge rates on groundwater resources is foreseen at the locations where precipitation and accordingly recharge is expected to decrease. Decreasing recharge rates will definitely affect the quantity of the available groundwater resources, while the quality of the groundwater resources, especially in coastal regions, will be threatened by the saltwater intrusion and salinisation due to the increased evapotranspiration (Mimura et al.,2007). Consequently, decreasing recharge rates will also enhance the impacts of processes which have already been observed, such as saltwater intrusion (Yazıcıgil et al., 2011).

Climate warming observed over the past several decades is consistently associated with changes in a number of components of the hydrological cycle and hydrological systems such as: changing precipitation patterns, intensity and extremes; widespread melting of snow and ice; increasing atmospheric water vapour; increasing evaporation; and changes in soil moisture and runoff. There is significant natural variability in all components of the hydrological cycle, often masking long-term trends. There is still substantial uncertainty in trends of hydrological variables because of large regional differences, and because of limitations in the spatial and temporal coverage of monitoring networks (Huntington, 2006). At present, documenting interannual variations and trends in precipitation over the oceans remains a challenge (IPCC, 2008; Baba, 2011).

The changes in temperatures and in precipitations levels and distribution will directly affect the water demand, quality and watershed. Pollution will be intensified by runoff in catchments and from urban areas. Rivers will have lower flows particularly in summer, and the sea temperature, salinity and concentration of CO2, nitrates and phosphates will also be affected. The most visible impact will be the floods, which will be higher and more frequent. In addition, increased evapotranspiration will also lead to higher irrigation water withdrawals and declining levels in groundwater aquifers. The changes in the frequency of extreme events might be the first and most important change registered in the Mediterranean and Aral Region. Many scientists have been working about the effect of climate change on water resources. Most studies have been carried out around Mediterranean Region. For instance, Howard (2011) reported on the impact of climate change on Mediterranean Region. He mentioned that the combined population of countries that rim the Mediterranean Sea is projected to increase by over 100 million between 2000 and 2025 with the vast majority of this growth occurring in the 12 drier SEMED countries (Benoit and Comeau, 2005). Due to population growth alone, it is estimated that by 2025, 10 of the 12 SEMED countries will be consuming over 50% of their renewable water resources, with 8 of them exceeding 100%. Most of the demand increase will come from irrigation and domestic supply needs. Yılmaz and Yazıcıgil, (2011) reviewed the situations of the current knowledge in the area of climate change impacts on Turkish water resources with emphasis on past and predicted future trends in atmospheric variables (precipitation, temperature) and hydrologic variables (streamflow and groundwater levels). Prominent long-term observed changes that are consistent over Turkey include increase in annual minimum temperatures and summer temperatures and decrease in winter precipitation. Streamflow and groundwater levels are found to respond to the changes in atmospheric variables, indicating potential water scarcity problems in many regions. This situation is exacerbated due to population growth and over-exploitation of water resources. General Directorate of State Hydraulic Works (DSI) is the main investing institution responsible for the utilization of all water resources of Turkey. DSI have been monitoring water levels in different part of Turkey. Data from DSI demonstrate that groundwater levels of western Anatolia are on a declining pattern from 1970 to 2009 (Figure 3) (Murathan, 2009). The factor responsible for declining water table is the significant increase in groundwater pumping coupled with decreased recharge rates. Gunduz and Simşek (2011) also investigated the influence of declining precipitation totals and anthropogenic stress in The Torbali-Bayindir aquifer in western Turkey (Figure 4). They mentioned that long term analysis of the data demonstrated a general declining pattern in groundwater levels at an average rate of about 0.75 m/year, which is partly associated with decreasing precipitation patterns and partly with overexploitation of the aquifer. The results further indicated a very fast response of the groundwater levels to precipitation events (Gunduz and Şimşek, 2011).

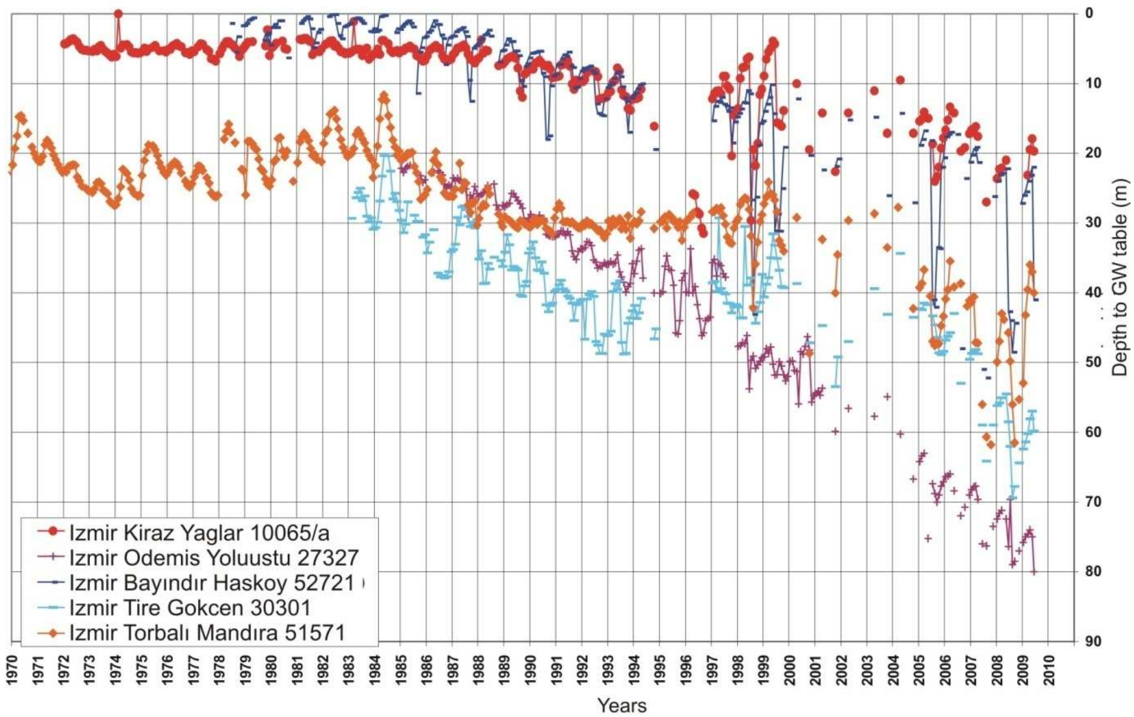
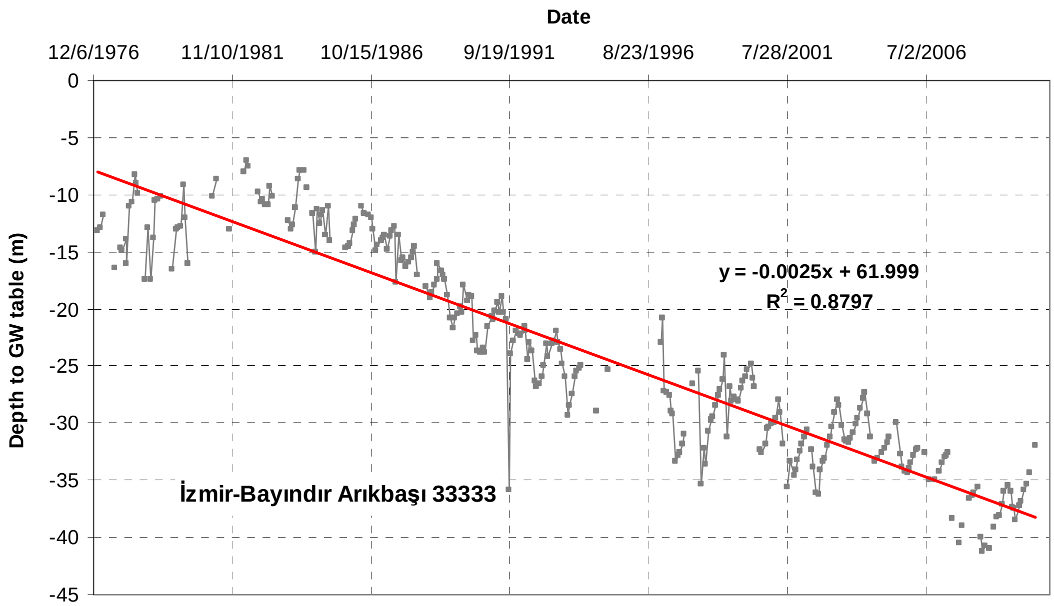


Figure 3. Distribution of groundwater level in Kucuk Menderes plain, Western Turkey, (Murathan, 2009)

Elçi (2011) presented the results of a modeling study on the impact of climate change on Izmir-Tahtali (western Turkey) groundwater system., where Tahtalı dam reservoir was built on the Tahtalı stream to meet about 35−40% of Izmir's total drinking water demand. He used a numerical groundwater flow model by considering the IPCC's "Special Report on Emission Scenarios" (SRES) scenarios. Based on these results he concluded that the largest component in water budget is and will be net groundwater recharge, which is predicted to decrease for the 2050 scenario causing a reduction of 29062 m3/d in the water inflow to the system. Furthermore, he also found out that spring discharge rates are predicted to decrease by 5.2%. Groundwater seepage to the Tahtalı reservoir and Izmir bay is predicted to decrease by 2.4%. Another significant outcome from the water budget analysis is the change in the water interaction between the streams and the aquifer. For the current climate, streams are gaining 6207.20 m3/d of water. The overall net direction of water flow is expected to reverse for the 2050 scenario, as the net loss of water from the streams is predicted to be 477.81 m3/d (Elçi, 2011).

Same problem can be observed in the Caspian Sea Region and in Aral Sea basin. For example, the major potential hazard of climate change on Kyrgyz Republic is expected to be the reduction of the mountain rivers runoff. This statement is correct as agriculture (being a basis of economy of the state) is based on irrigation farming. Mountainous rivers are the main source of irrigation. Because of shortage of surface water resources, the problem arises as to increase of the irrigation systems efficiency and use of ground waters for irrigation (Litvak,



2011).

Figure 4. Change in groundwater levels in a monitoring well in Torbalı-Bayindir plain, Western Turkey

It is also reported that mismanagement of water resources increase the influence of the impacts associated with climate change, particularly around Aral Sea basin. It is determined that the size and water balance of Aral Sea is fundamentally determined by river inflow and evaporation from its surface. Once the world's fourth largest lake, the Aral Sea has dramatically shrunk since 1960s (Figure 5). In 1900s, the area and the volume of the Aral Sea were 68,320 km2 and 1066 km3, respectively. The Aral Sea Basin receives the bulk of its water from the two major rivers of the region, the Amu Darya and Syr Darya with a combined average annual flow of 115.6 km3. The average annual river flow in to the Aral Sea during 1927-1960 periods was stable. The large-scale development of water resources, mostly for irrigation, has changed the hydrological cycle in the region and caused serious environmental problems in the Aral Sea Basin including but not limited to the shrinkage of the sea (Kokishev, 2011).

3. Groundwater and ecosystem

An economic gain of use has led to a global explosion of groundwater development in the last several decades. Groundwater processes have been severely threatened, mostly by human actions such as changing soil uses and vegetation, modifying surface and groundwater flow systems, and introducing pollutants in the soil and water systems (Arellano, 2005). Consequently, groundwater reserves have been depleted extensively. Continuing use of groundwater, which is initially supplied from the storage, causes increasing derivation of additional water from surface water bodies such as, streams, lakes and wetlands (Bayarı 2005). Groundwater dependent ecosystems can only maintain their current composition and functioning by the groundwater input. Ecosystems are significantly influenced by changes in groundwater depth, pressure, flow rate and quality. Various pollutants such as pesticides, herbicides, fertilizers and other chemicals affect groundwater quality. Other pollutants having highly toxic features for environment such as industrial effluents, irrigation return-waters, and leachate from waste disposal areas may also affect groundwater quality (Yüce, 2005). The quality of groundwater, the main source of drinking water in the most countries, is increasingly threatened by anthropogenic activities such as industrial processes, intensive agriculture, irrigation, tourism, transportation.

Once vulnerability of water resources to climate change is assessed, the reactions of habitats and consequently the ecosystems to these changes are estimated. This requires the essential knowledge of ecohydrological variability of ecosystems. The next step is then to establish a true interdisciplinary study highlighting the ecohydrological approach, to adequately address the questions related to the space-time links between climate-soil-water-landscape and vegetation (Ekmekçi and Tezcan, 2005). For example, the hyporheic zone refers to the saturated pore space in sediments beneath and lateral to a stream/river channel, that is strongly influenced by the interactions between surface and subsurface waters as a biologically important ecotone. The hyporheic zone can be defined in many ways; however, it essentially describes the extent to which nutrient-rich surface waters penetrate the shallow subsurface in the immediate vicinity of a flowing surface water body, to provide essential life support for a distinct and often dynamic community of invertebrates (the hyporheos) and micro-organisms (Howard, 2005). Agricultural activity is the major factor effect quantity and quality in most country. Also, illegal drilling for water and the excessive use of pesticides have been effected water resources. Mismanagement has affected the quality of fresh water, the pollution of resources by pesticides and their residues, the intrusion of seawater into coastal aquifers, and the gradual desertification of land by diverting rivers toward cultivating crops or poorly placed ornamental plants that require huge quantities of water.

4. Sustainability of water resources

Scientific studies show that water challenge, which will be faced particularly by Asian countries in next decades, has to be set in the development strategies in order to ensure a healthy environment and a well being for the local populations. The effective management of a water resource requires us to strike a balance between the water requirements of humans and the natural ecology of catchments. To achieve this objective more data needs to be obtained for a better assessment of the situation. Hence the following tasks are deemed important:

Installation of multi purpose monitoring equipment for measurements of climate conditions such as precipitation and temperature.

Installation of multi purpose monitoring equipment for measurements of groundwater and surface water levels and quality indicators.

Identification, characterization and monitoring of groundwater-surface water interactions.

Monitoring the impacts of groundwater abstractions and contaminants on groundwater fed rivers, lakes and wetlands.

Monitoring and advancing binational cooperation in transboundary groundwater management.

Monitoring efficient use of surface and ground water for irrigation.

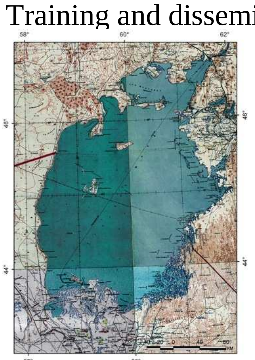
Use of water-saving irrigation technologies.

Reduction in water demands and promoting conservative use of water in agricultural and industrial sectors.

Design of comprehensive water policies and integrated planning

Use of improved technologies for water treatment and re-use.

Training and dissemination of information.



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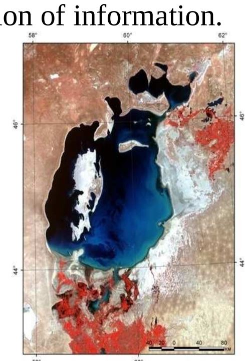

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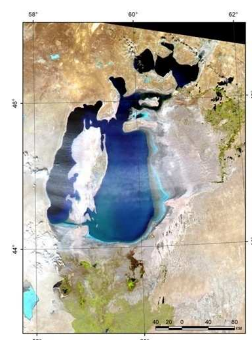

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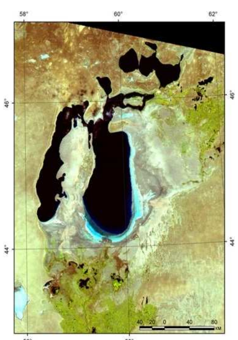

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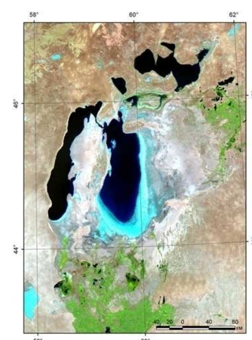

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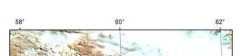

Consequently; water sustainability is crucial problem for all living beings. Therefore it required levels of decision-making, good governance, law, and administration, economic and other policy instruments, roles of users, politicians, and groundwater experts, data collection and monitoring, preferable management regimes. In addition, efforts should focus on water conservation, which includes reducing losses, enhancing saving and promoting management of this resource as an economic commodity (apart from the portion that must be considered as a human right) and less as a political asset or as a national privilege. Increased water prices for all users, particularly for the consumers in agriculture and industrial sectors, would help regulate the demand for water. Consequently, pricing could be used effectively for achieving sustainability in water management.

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Conclusion

Population growth and a changing climate seriously threaten water resources of the world, with particular emphasis on Mediterranean Region, Aral Region, Africa, and South of Asia. Important resource management decisions will be required but any such effort will prove inconsequential unless reliable predictions can be made of the influence that changing conditions will have on the hydrologic cycle and available water reserves (Howard, 2011). By 2050, it is expected that world population could reach about 9 billion and many countries will face water shortage conditions. An inevitable consequence of this phenomenon would be an increase in over-exploitation and increased use of unsustainable water supplies (i.e., deep groundwater). Furthermore, decreased recharge due to changing climate patterns and associated declines in groundwater levels, deterioration in water quality due to increased demand, sea water intrusion along coastal aquifers and salinization could also be other listed as other consequences of this problem. Finally, sustainable management, of water resources should be seen as the key for sustainability of life in this planet.

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References

1. Alcamo J, Heinrichs T, Rösch T (2000) World water in 2025 – global modeling and scenario analysis for the 21st century. Report A0002, Center for Environmental Systems Research, University of Kassel, Kassel, Germany.
2. Arnell N (2000) Climate change and global water resources. Global Environ Change 9:531–549.
3. Araus J L (2004) The problems of sustainable water use in the Mediterranean and research requirements for agriculture, Ann. appl. Biol. (2004), 144:259-272
4. Arellano M. M (2005) Groundwater-dependent wetlands, Hydrological and ecological aspects, Groundwater and Ecosystem, NATO ARW Abstarct book, p.1.
5. Baba A., Gunduz O., Friedel M.J., Tayfur G., Howard K. W.F. Chambel A (2011) Climate change and its effects on water resources, NATO Science for Peace and Security Series, Springer, The Netherlands. p.1
6. Baba, A (2011) Climate change mitigation with renewable energy: Geothermal, in Climate Change and its Effects on Water Resources (edit by Baba et al.), NATO Science for Peace and Security Series, p.24-33.
7. Bates BC, Kundzewicz ZW, Wu S, Palutikof JP (2008) Climate change and water, technical paper VI of the Intergovernmental Panel on Climate Change. IPCC Secretariat, Geneva, 210 pp
8. Bayari S (2005) Groundwater Age: critical information in the interaction between groundwater and surface aquatic ecosystem, Groundwater and Ecosystem, NATO ARW Abstarct book, p.5.
9. Benoit G, Comeau A (2005) A sustainable future for the Mediterranean: the blue plan's environment and development outlook. UNEP. Earthscan, London, p 464
10. Ekmekçi M. and Tezcan L (2005) Assessment of vulnerability of water resources to climate change: ecohydrological implications, Groundwater and Ecosystem, NATO ARW Abstract book, p.7.
11. Elçi A (2011) Assessing the impact of climate change on groundwater resources using groundwater flow models, in Climate Change and its Effects on Water Resources (edit by Baba et al.), NATO Science for Peace and Security Series, p.63-74
12. Ganoulis J and Skoulikaris C (2011) Impact of climate change on hydropower generation and irrigation: A Case Study from Greece, in Climate Change and its Effects on Water Resources (edit by Baba et al.), NATO Science for Peace and Security Series, p. 87-95.
13. Gunduz O. and Simsek C (2011) Influence of climate change on shallow groundwater resources: the link between precipitation and groundwater levels in alluvial systems, in Climate Change and its Effects on Water Resources (edit by Baba et al.), NATO Science for Peace and Security Series, 225
14. Howard K.W.F (2011) Implications of climate change on water security in the Mediterranean region, in Climate Change and its Effects on Water Resources (edit by Baba et al.), NATO Science for Peace and Security Series,p.9-15.
15. Huntington TG (2006) Evidence for intensification of the global water cycle: review and synthesis. J Hydrol 319:83–95.

16. Hrkal Z (2011) Climate change and water resources –challenge of our civilisation in Climate Change and its Effects on Water Resources (edit by Baba et al.), NATO Science for Peace and Security Series, p.35-41.
17. Iglesias A, Garrote L, Flores F, Moneo M (2007) Challenges to manage the risk of water scarcity and climate change in the Mediterranean. Water Resour Manage 21:775–788.
18. IPCC (2001) Climate change, (2001) The scientific basis. Contribution of working group I to the third assessment report of the Intergovernmental Panel on Climate Change. In: Houghton JT, Ding Y, Griggs DJ, Noguer M, van der Linden PJ, Dai X, Maskell K, Johnson CA (eds). Cambridge University Press, Cambridge and New York, pp. 881.
19. IPCC (2007) Climate change 2007: synthesis report, 2007, Intergovernmental Panel on Climate Change. http://www.ipcc.ch/
20. IPCC (2008) Climate change and water. In: Bates BC, Kundzewicz ZW, Wu S, Palutik JP (eds) Technical paper of the Intergovernmental Panel on Climate Change. IPCC Secretariat, Geneva, p 210.
21. Kamara AB, Sally H (2004) Water management options for food security in South Africa: scenarios, simulations and policy implications. Dev South Afr 21(2):365–384.
22. Katz ME, Pak DK, Dickens GR, Miller KG (1999) The source and fate of massive carbon input during the latest Paleocene thermal maximum. Science 286(5444):1531.
23. Kokishev, N (2011) General assessment of surface and subsurface water quality in southern Kazakhstan, Dokuz Eylül University, Graduate School of Natural and Applied Sciences, Thesis of Master Sciences, Izmir.
24. Kundzewicz ZW, Mata LJ, Arnell NW, Döll P, Kabat P, Jiménez B, Miller KA, Oki T, Sen Z, Shiklomanov IA (2007) Freshwater resources and their management. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Climate change 2007: impacts, adaptation and vulnerability, contribution of working group II to the fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge,
25. pp 173–210
26. Litvak R.G., Nemaltseva E.I., and Poddubnaya I.V (2011) Trends of irrigation development in the Kyrgyz Republic within the context of climate change, in Climate Change and its Effects on Water Resources (edit by Baba et al.), NATO Science for Peace and Security Series, p.175
27. Mimura N, Nurse L, McLean RF, Agard J, Briguglio L, Lefale P, Payet R, Sem G (2007) Small islands. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Climate change 2007: impacts, adaptation and vulnerability, contribution of working group II to the fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp 687–716
28. Murathan A (2009) Potential of groundwater resources of Izmir and its surrounding (Gediz, Bakıcay, Kucuk Menderes, Banaz Cay Basin), Izmir water symposium, 2 October 2009, Izmir, p.21-46 (in Turkish)
29. Santer B, Wigley TML, Barnett TP, Anyamba E (1996) Detection of climate change and attribution of causes. In: Houghton JT et al (eds) Climate change 1995: the science of climate change. Report of IPCC Working Group I. Cambridge University Press, Cambridge, pp 411–443.
30. UN (2004) World Population To 2300, Department of economic and social affairs, population division, United Nations New York, 2004
31. Yazicigi H., Yilmaz K.K., Erdemli B.U. and Yagbasan O (2011) Impacts of decreasing recharge rates on sustainable groundwater management, in Climate Change and its Effects on Water Resources (edit by Baba et al.), NATO Science for Peace and Security Series p.43

32. Yilmaz K. K. and Yazicigil H (2011) Potential impacts of climate change on Turkish water resources: a review in Climate Change and its Effects on Water Resources (edit by Baba et al.), NATO Science for Peace and Security Series p.105
33. Yuce G (2005) The Vulnerability of groundwater dependent ecosystems: a study on the Porsuk river basin (Turkey) as a typical example groundwater and ecosystem, NATO ARW Abstarct book, p.44.
34. Zachos J, Pagani M, Sloan L, Thomas E, Billups K (2001) Trends, rhythms, and aberrations in global climate 65 Ma to present. Science 292(5517):686–693.

IMPACTS OF CLIMATE CHANGE ON FRESHWATER RESOURCES AND THEIR ECOLOGY

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Based on the monitoring data and climate projections scientists highly agree that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change in the long-run. However, there is no consensus about the degree of impact of human activities on climate change. By modeling studies, Intergovernmental Panel for Climate Change (IPCC) estimates the expected changes in the climate on a global scale for different emission scenarios. Then these results are used as an input for regional climate models. If we assume that climate change scenarios will be realized in the future, we can foresee that there will be effects of climate change on watershed ecology and on the water resources. For example variations in precipitation and temperature will increase the risks of flooding and drought in many areas, will directly affect the water demand and water quality. Changes in water quantity and quality will in turn affect food availability, stability, access and utilization. Water quality of surface runoff from urban and rural areas will change. Function and operation of existing water infrastructure (including water treatment, hydropower, drainage and irrigation systems) will be effected. Increase in water demand may result in insufficient capacity of reservoirs and transfer of water from other watersheds might be necessary.

Within the scope of this paper, the impacts of climate change on freshwater resources; their availability, quality, quantity, uses and management is evaluated. Impacts on ecology are mentioned. Several management alternatives to reduce the potential adverse effects of climate change are identified; merits and tradeoffs involved are discussed.

Introduction

Intergovernmental Panel on Climate Change (IPCC, 2007) refers in the Fourth Assessment Report, AR4, to the warming of the global climate system and states that “most of the observed increase in globally averaged temperatures since the mid-20th century is very likely [this likelihood statement can be interpreted as probability in excess of 90%; comment added] due to the observed increase in anthropogenic greenhouse gas concentrations” (Szwed et al., 2010). It is also expressed that on the global average, surface temperatures have increased by about 0.74°C between years 1906 and 2005 during which the warming has not been steady and not kept the same both temporally and spatially (IPCC, 2007). According to the recordings taken since 1901 only a few areas have been cooled, among which one of the most notable one is the northern North Atlantic near southern Greenland. However, during this period warming has been experienced more over the continental interiors of Asia and northern North America. As referred by IPCC (2007), the most evident warming signal has occurred in parts of the middle and lower latitudes whereas the duration of the frost-free season has increased in most mid- and high-latitude regions of both hemispheres. Besides, most mountain glaciers and ice caps have been shrinking since 1850.

Observations so far indicate that over most land areas, cold days and nights have got warmer and fewer, while hot days and nights have got warmer and more frequent. Area affected by drought has been increased. This trend is expected to continue in the future.

Currently, the effects of climate change have been highly sensed in sectors like agriculture, and water related applications. As stated by Szwed et al. (2010), agriculture in the northern Europe has been temperature-restricted, while in the south it has been water-restricted. Both conditions lead to decrease in the crop yields and require the selection of new irrigation techniques, new crop patterns etc. for the sustainability of agricultural production. Water-related studies frequently mention that water budgets may become increasingly stressed. In some cases evapotranspiration exceeds precipitation in summer, leading to depletion of the water storage. This deficit is projected to increase further in the future that will necessitate additional water supplies.

Moreover, researches and model-based studies indicate that weather-related extremes are expected to get more frequent and/or more severe and coping with these events will become more difficult. Countries facing such conditions are attempting to take mitigation measures and develop national and/or regional adaptation strategies.

This paper points out the effects of climate change on especially freshwater resources and mentions the common adaptation strategies.

Effect of Climate Change on Freshwater Resources

Climate change may have short and long term effects on water resources. Short term effects take place because of the extreme events that are related to climate change. For example, during a flood shock loading of sediments, organic matter and nutrients can be transported into lentic freshwater ecosystems such as lakes and reservoirs. Those ecosystems respond to such forcing by instantaneous changes in water quality. Recovery of the system depends on the intensity of the effect, internal structure of the system and in case of engineered systems on the operating schedule and may take from a couple of weeks up to a couple of years. Climatologists estimate that frequency of extreme events may increase due to climate change. Long term effects on water resources occur due to climatic trends and extended periods of droughts. Effect of climate change on freshwater resources is illustrated in Figure 1 and discussed below.

To be able to figure out the effect of climate change on the water balance of a watershed, the relation between the components of the historical water balance and climatic variables may be needed as reference. This task is straightforward if historical data on both; the climatic variables and the water balance components exist. However, if one is missing the other could be reconstructed using simulation techniques. Kavvas et al. (2009) used a regional hydroclimate model (RegHCM-TE) for Tigris-Euphrates transboundary watershed located in the Middle-East for reconstructing the historical precipitation data to perform water balance computations for infiltration, soil water storage, actual evapotranspiration and direct runoff.

Changes in Water input to Freshwater Systems from their Watersheds

Climate change can result in average temperature and total precipitation increase. However the temporal and spatial heterogeneity of meteorological parameters may increase as well resulting in increase of number of dry days in summer (or dry season) and increase in flood frequencies in winter (or wet season). Another consequence of average temperature increase may be increase of average temperature in the warm season and decrease of it in the cold season.

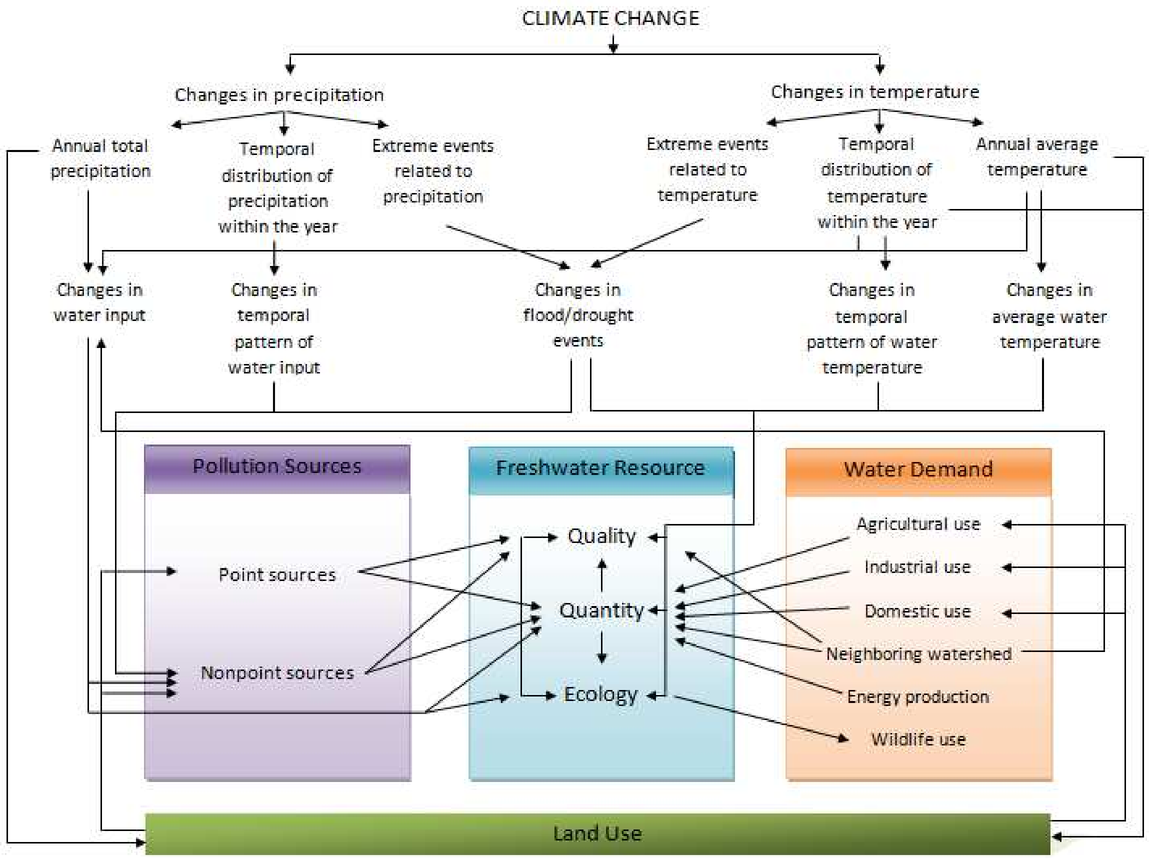

Figure 1. Effect of Climate Change in Freshwater Resources

Changes in precipitation and temperature do not only change the total amount of runoff to freshwater systems from their catchments but also the temporal distribution of water inputs. Generally, intensification of the global hydrological cycle is expected as a result of temperature increase. However, if the land surface hydrology is dominated by the winter snow accumulation and spring melt, temperature increase will definitely cause a change in the outflow hydrographs of the watersheds where time of peak flow will be shifted towards winter. This phenomenon is discussed by Barnett et al. (2005) in great detail. Forbes et al. (2011) analyzed the water cycle in a small snow dominated Canadian catchment (Beaver Creek, Alberta) using hydrological simulation model (ACRU agro-hydrological modeling system) and concluded that regions with snowmelt-dependent water supply may experience severe changes to the hydrological regime due to temperature increase. The consequences were reported by Forbes et al. (2011) as less available soil water with potential negative impacts on agriculture, and also increased stresses for the natural vegetation, lower streamflows in late summer and fall with potentially adverse impacts on the aquatic ecosystem and anyone who withdraws water from the river.

Furthermore, as temperature rise the winter precipitation may shift from snow to rain and the timing of peak streamflows in many continental and mountainous regions will change. The spring snowmelt peak flow may shift to earlier days of the year or even get eliminated entirely and winter flows increase (Kundzewicz et al., 2008).

Changes in frequencies and intensities of extreme events such as floods and droughts are projected as well. According to IPCC (2007), the proportion of total rainfall from heavy precipitation events will increase and tropical and high latitude areas will experience increases in both the frequency and intensity of heavy precipitation events.

Döll and Flörke (2005) stated that many of the current water-stressed areas will suffer from decreasing amount of water since both the river flows and the groundwater recharges are expected to decline. In addition, Kundzewicz et al. (2008) reported that drought frequency is projected to increase in many regions, in particular, in those areas where reduction of precipitation is projected.

Shortage of Reservoir Capacity Due to Increase in Water Demand

Temperature increase may increase evaporation from surface waters and evapotranspiration and thus water loss from plants and soil will result in increased irrigation water demand. However, Barnett et al. (2005) states that there is little agreement on the direction and the magnitude of historical and/or predicted evapotranspiration trends. Temperature increase alone is expected to enhance evaporation and eventually evapotranspiration. On the other hand, temperature increase also affects other variables such as wind speed, humidity, cloudiness which have their amplifying/dampening effects on the evaporation and evapotranspiration as well. Therefore, the magnitude and the direction of the total response of evapotranspiration to temperature increase should be considered as spatially and temporally variable. This should be considered when deciding on the operational schedule of reservoir systems and especially on those that have the purpose of irrigation water storage and supply.

Temperature increase may also stimulate water consumption. More water consumption may result in future shortage of reservoir capacity that is sufficient today. In this case two options are available: Promoting decreased water consumption (change in way of life in urban areas, change in crop patterns/irrigation methods, shifting to water saving processes in the industry, application of ECOSAN in rural areas, etc.) or transfer of water from another watershed. Water transfer from other watersheds should be planned carefully and managers should not only consider the quantity but also take into account the ecological effects on both watersheds.

According to Mirza et al. (2003) the benefits of expected annual runoff in several regions such as South-Eastern Asia will be tempered by negative impacts of increased variability and seasonal runoff shifts on water supplies. Flood risk will increase especially in low-lying river deltas. Furthermore, additional precipitation during the wet season in those regions may not solve the water stress problem occurring in dry season if the extra water cannot be stored because of the shortage of reservoir capacity. Similarly, Barnett et al. (2005) states that changes in precipitation patterns will not offset the problems as associated with warming.

Changes in Water Quality of Runoff

Another response of ecosystems to climate change is the change in the quality of surface runoff from agricultural land, forests and urban areas.

Changing meteorological conditions may necessitate changes in crop patterns and thus manure/fertilizer/pesticide applications and irrigation schedules may change. Some areas may loose the ability of any agriculture whereas other frozen wastelands may become appropriate for agriculture. Hence water quality of surface runoff from agricultural areas is subject to change.

Forests, depending on their ecological characteristics emit nutrients and organic matter that are transported into aquatic ecosystems sooner or later. Forest ecology is complex and more inertial compared with aquatic ecology. Therefore it is much harder to estimate the short term effects of climate change on surface runoff quality from the forests. Annual and seasonal average temperature increase generally eases the photosynthesis rate and plant yield changing vegetation and forests. Forests can succeed in higher elevations. However extreme increase in temperature may result in higher plant respiration rates and shift the photosynthesis-respiration balance towards respiration. Droughts have an adverse effect on forests favoring succession of steppes and shrubs. Soil organisms will be affected by climate change as well thus the biogeochemical cycles will be shifted to different equilibria. Change in both natural vegetation and soil biology will cause different water quality and quantity from forest runoff.

Increase in storm event intensities and frequencies will result in more wastewater containing stormwater release to receiving waterbodies in case of combined sewer systems.

In case of droughts, accumulation of contaminants on land can be expected as there will not be storm event for extended periods. Hence, a storm event following an extended dry period will have an increased shock loading effect on water resources.

Changes in Water Quality and Ecology in Lakes and Reservoirs

Climate change may affect the ecological processes in lentic ecosystems which in turn will affect the water quality. Increase in average annual water temperature affects the primary producers (mainly phytoplankton) in lake and reservoir systems in following ways:

• Change in primary production rates

Temperature changes will affect both; the photosynthesis and the respiration rates. Initially, increases in temperature will promote higher photosynthesis and respiration rates. However, for each group of primary producers, there is an optimum temperature range. If the water temperature exceeds the upper limit for optimum conditions, temperature stress will decrease photosynthesis rates and increase respiration rates. This mechanism will accelerate the nutrient recycle and making nutrients available for primary producers adapted to higher temperatures causing a shift in dominant phytoplankton group. More increase of temperature may completely suppress some phytoplankton groups and/or cause sudden breakdown of their blooms eventually leading to decreased water quality.

• Change in species distribution in primary producers

As stated previously; because of the water temperature increase phytoplankton groups that can adapt to higher temperatures for example cyanobacteria will be favored. Cyanobacteria that are generally better adapted to higher temperatures may dominate the algal community. Genera such as *Anabaena* and *Aphonizomenon* produce algal toxins, taste and odor problems. Some species of cyanobacteria are capable of nitrogen fixation and hence increase nitrogen loads through watershed outlets.

• Change in vegetation/bloom period

More days or longer photoperiods during a day may occur due to the climate change. Those conditions may extend the vegetation period as well as earlier blooms may be possible. A large portion of the nutrient inputs to lotic ecosystems generally occur in late winter and early spring related to rain events and snowmelt. In this period although the nutrient concentrations increase in water, lower water temperatures limit phytoplankton growth. However, if the water temperatures increase because of the climate change in this period, two factors needed for phytoplankton growth, more suitable temperature and high nutrient concentrations, will synergistically favor phytoplankton growth. If these conditions are followed by better light availability, phytoplankton blooms will be stronger and more frequent and adversely affect the water quality.

Adaptation to Climate Change

It is stated by Rosenzweig et al. (2007) that some climate change impacts on hydrological processes have already been observed and further changes are projected. Thus, mitigation measures are needed to be taken as well as adaptation to climate change is necessary. Below common adaptation measures are referred.

Efficient and effective use of water

When water demand increases and water availability decreases one of the most widely used solution towards decreasing water consumption is using the available water effectively and efficiently. Water demand management considers measures to improve efficiency of water use.

Among sectors, agriculture is the leading sector in terms of water consumption. Climate change is expected to directly and indirectly increase demand for agricultural irrigation.

Adaptation measures to climate change in the agricultural sector include changes of agrotechnical practices (e.g., use of crop rotation, advancing sowing dates) and introduction of new cultivars (heat-wave- and drought-tolerant crops). Soil moisture should also be conserved (e.g. through mulching). Besides, timing and frequency of irrigation need to be optimized considering the crop requirements. This is important for reducing irrigation return flows which in turn deteriorates the quality of the receiving water.

Industrial water consumption may also be reduced by developing less water using technologies as well as in-plant control measures. Clean technologies are preferred due to their optimized water consumption.

Domestic uses may be decreased by encouraging public to use water-saving home appliances, through water pricing, legal sanctions and raising public awareness. In the big cities in developing countries, water loss through leakages in the water distribution lines constitutes a significant amount. Thus, it must be aimed to decrease water losses below 10% by renewing the old pipelines.

Alternative water resources

In cases of severe water scarcity, reducing water consumption may not be a remedy and thus searching for alternative water resources become crucial.

Desalination of seawater or brackish water is considered as an important option of producing freshwater. Recent technologies and advances in the sector allow producing freshwater at affordable costs when higher amounts are intended. However, water withdrawals for desalination purposes may alter the well-being the related ecosystem. Thus, it is necessary to take into account the environmental impacts that might occur due to the planned water withdrawals. Also brine that is produced in desalination process should be properly disposed.

Another alternative source is reuse of treated wastewater. It is known that treated wastewater may be used for irrigating green land, parks and gardens in big cities. It can also be used for irrigating agricultural land if the national standards are satisfied in terms of irrigation water quality. Industries can also utilize treated wastewater in their processes providing that the quality of the goods manufactured remain unchanged (Asano et al., 2007).

Aquifers can be thought as storages where water loss through evaporation is relatively low. Thus, recharge of groundwater aquifers with treated wastewater is applied in different countries such as Israel and Spain (Esteban and Miguel, 2008; Salgot, 2008). However, it should be underlined that advanced treatment is necessary to protect the aquifers from pollution.

Another option is ecological sanitation (ECOSAN) practices. By such applications generated wastewater is separated into three streams at the source (yellow water, grey water and black water) that may be recycled after applying simpler treatment techniques. For example treated grey water may be used for irrigation and for recharge of aquifers. However, in most of the cases existing and usually old fashioned infrastructure is not compatible with ECOSAN.

Reuse and/or disposal of each wastewater stream should be carefully planned. For example, yellow water could be used instead of fertilizer but if not desalinated salinity in human urine can harm the crops and the soil (Beler-Baykal et al., 2011).

Inter-basin water transfer

Szwed et al. (2010) states that water transfer from an area of relative abundance to an area of scarcity may smooth the spatial water variability. It is applied in many arid and semi-arid regions. Three points are important in water transfer: Feasibility regarding engineering works, hydrological and ecological conditions of the basins. Pre-screening in terms of engineering works focus on costs of the work and on the length of water transmission lines. Besides, head loss/energy consumption of the pumps, natural and artificial barriers along the pipeline and its vicinity are also important factors to be considered.

Inter-basin water transfer depends on the availability of excess water from where the water is withdrawn. Especially the climatic conditions of both basins gain importance. If both basins face drought conditions in the same years, water transfer among them must not be considered as a feasible option. Both basins must be surveyed prior to realization of water transfer regarding their hydrological characteristics. During these surveys, long-term hydrological data must be analyzed. Basin ecology is equally important. The water intake structures must not give harm to the ecosystem. Socio-cultural conditions and economical characteristics should also be taken into consideration and sustainability should be kept in mind during water withdrawals. There are contradicting opinions on inter-basin water transfer. They argue that inter-basin water transfer may no longer be viable in a future with climate change, as climate change stresses almost every source of freshwater. Also taking more water from the natural system has biological, ethical, and increasingly legal limitations (Karakaya and Gonenc, 2005; Hall et al. 2008). Consequently, inter-basin water transfer must be considered as the last solution to water scarcity.

Maintaining the sustainability of watershed ecosystems

Natural aquatic ecosystems are among the important water resources supporting life. It is very important to maintain the ecological flows of these systems. Ecological flows are usually determined by some practical statistical approaches, assumptions and methods supported by scientific research conducted at site. During these studies it must be considered that aquatic ecosystems are in interaction with terrestrial ecosystems. Thus, any change in aquatic or terrestrial ecosystem will have an effect on the other. For example, the decrease in surface water levels will affect the groundwater levels and dependent ecosystems. Evapotranspitation increase due to climate change has also effect on the decrease of groundwater levels. As this condition may lead to change in the vegetation cover which in turn lead to habitat change regulation of groundwater use becomes more important. As renewal of groundwater lasts long, their planning must be done prior to facing water scarcity.

Continuous Monitoring and Training Activities

(Rosenzweig et al., 2007) states that there is a need to improve the monitoring networks and research capability on changes in physical, biological and socio-economic systems. This is particularly important in regions with sparse data. This will contribute to an improved functional understanding of the responses of natural and engineered systems.

In the developed countries data on water resources are available in a systematic manner. And these data are usually open to public free of charge. Sharing of data accelerates their analysis and also enables some small scale engineering services. Such advantages may lead to rapid completion of various tasks. Furthermore, these developed countries involve public to the monitoring programs. In such a way, monitoring costs are decreased and public awareness is increased.

Training activities for raising awareness on climate change and its effect on water resources for all stakeholders (decision-makers, local administrators, public, institutions, non-governmental organizations, etc.) and dissemination activities should be conducted. Participation of the public is to be encouraged.

Revision of infrastructure

Changes in water quality in water resources will necessitate revision of existing water-related infrastructure. New components of the infrastructure should be designed according to possible extremes that would occur. Resilience of the infrastructure should also be enhanced.

Water treatment systems must be designed and operated according to drinking water standards under raw water inflow with varying water quality. On the other hand, different wastewater treatment options that seem not feasible today, may be available in a world with higher annual average temperature. One example is the upflow anaerobic sludge blanket (UASB) process that is used to treat municipal wastewater in warmer countries such as India currently. Such technologies that are more cost-efficient could be applied in higher latitudes once further meteorological conditions change due to climate change.

Concluding Remarks

Changes in the hydrological regime due to climate change require adaptations to maintain a secure and sustainable water supply. From a hydrologic perspective and based on global experience, the most effective management approach is a basin-unit approach. Thus, initiation of basin-wide strategic planning is crucial considering the diminishing water supplies. Social and economic development plans have to consider carrying capacity of the freshwater systems as the first priority, and form a balance between water demand and supply.

In transboundary watercourses adaptation to climate change should be carried out jointly among all riparian countries of the basin and cooperation on a basin-wide level should be increased.

Modeling is a useful tool for estimating future conditions. In many of the climate change simulations precipitation and temperature are considered as the main state variables. However, changes in other meteorological variables such as wind speed, humidity, cloudiness are also of great importance if more accurate hydrological analyses are of concern. Also response of land cover changes associated with the climate change should be considered in simulations, as both land cover changes and climate change effect each other.

Meteorological, hydrological and ecological data should be produced systematically. This is a problem in most of the countries in the world, especially in developing countries. One solution to this problem is to establish hydrometerorological institutes that would produce and analyze all the data related to climate and water cycle as an organized center.

Capacity building, awareness raising and training activities on adaptation to climate change should continue increasingly.

The climate change increases the capital investments and operational costs and therefore indirectly impacts the business management. Thus, the costs for handling climate change should also be considered.

Water law and policies for effective use of water should be developed or revised. Water conservation and more efficient allocation of water at the local, regional, and national scales may help countries to be more prepared for the new challenges of climate change.

References

1. Asano, T., Burton, F.L., Leverenz, H.L., Tsuchihasti, R. and Tchobanoglous, G. 2007. Water reuse: Issues, technologies, and application. Metcalf &Eddy/AECOM, McGraw Hill, USA.
2. Barnett, T.P., Adam, J.C., Lettenmaier, D.P. 2005. Potential impacts of a warming climate on
3. water availability in snow-dominated regions, Nature, 438, 303–309.
4. Beler-Baykal, B., Allar, A.D., Bayram, S. 2011. Nitrogen recovery from source separated human urine using clinoptilolite and preliminary results of its use as fertilizer, Water Science and Technology, 63(4), 811-817.
5. Döll, P., Flörke, M. 2005. Global-Scale Estimation of Diffuse Groundwater Recharge. Frankfurt Hydrology Paper 03, Institute of Physical Geography, Frankfurt University, Frankfurt am Main, Germany.
6. Esteban, I.R. and Miguel, E.O. 2008. Present and future wastewater reuse in Spain. Desalination, 218, 105-119.
7. Forbes, K.A., Kienzle, S.W., Coburn, C.A., Byrne, J.M., Rasmussen, J. 2011. Simulating the hydrological response to predicted climate change on a watershed in southern Alberta, Canada, Climatic Change, 105, 555–576.

8. IPCC, 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
9. Kavvas, M.L., Chen, Z.Q., Anderson, M.L., Ohara, N., Yoon, J.Y. 2009. A Hydroclimate Model of the Tigris-Euphrates Watershed for the Study of Water Balances, in Proceedings of Conference on Transboundary Waters and Turkey, Editors: Mehmet Karpuzcu, Mirat D. Gürol, Senem Bayar, Istanbul.
10. Kundzewicz, Z.W., Mata, L.J., Arnell, N.W., Döll, P., Jimenez, B., Miller, K., Oki, T., Şen, Z. and Shiklomanov, I. 2008. The implications of projected climate change for freshwater resources and their management, Hydrological Sciences Journal, 53, 1, 3-10.
11. Mirza, M.M.Q., Warrick, R.A. and Ericksen, N.J. 2003. The implications of climate change on floods of the Ganges, Brahmaputra and Meghna rivers in Bangladesh. Climatic Change, 57, 287–318.
12. Hall, N.D., Stuntz, B.B., and Abrams, R.H. 2008. Climate Change and Freshwater Resources, Natural Resources & Environment, 22(3), 32-35.
13. Karakaya, N. and Gonenc, I.E. 2005. Interbasin water transfer, Proceedings of 2nd National Water Resources Engineering Symposium, Izmir, Turkey (in Turkish).
14. Rosenzweig, C., G. Casassa, D.J. Karoly, A. Imeson, C. Liu, A. Menzel, S. Rawlins, T.L. Root, B. Seguin, P. Tryjanowski, 2007. Assessment of observed changes and responses in natural and managed systems. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 79-131.
15. Salgot, M. 2008. Water reclamation, recycling and reuse: Implementation issues. Desalination, 218, 190-197.
16. Szwed, M., Karg, G., Pińskwar, I., Radziejewski, M., Graczyk, D., Kędziora, A., Kundzewicz, Z.W., 2010. Climate change and its effect on agriculture, water resources and human health sectors in Poland, Nat. Hazards Earth Syst. Sci., 10, 1725–1737.
17. Veraart, J.A., van Ierland, E.C., Werners, S.E., Verhagen, A., de Groot, R.S., Kuikman, P.J. and Kabat, P. 2010. Climate Change Impacts on Water Management and Adaptation Strategies in The Netherlands: Stakeholder and Scientific Expert Judgements, Journal of Environmental Policy & Planning, 12(2), 179 - 200.

Ecohydrological criterion of use of water resources in irrigation and water-power engineering and ecological aspects of management of water resources of the Transboundary Rivers in Central Asia

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Abstract

The aspects of water allocation between the countries of Central Asia are considered in terms of river runoff ecology. To decide ecological problems in the region the creation of Interstate Water Quality Control Commission of Transboundary Rivers is offered. Efficiency of construction of reservoirs in foothill districts and essential influence on formation of microclimate and change of meteorological parameters of district is shown. Influence of reservoir and temperatures of water on change of humus and efficiency of the agricultural grounds are observed. The Vakhsh river is characterized by the big degree of sediment and therefore a prominent aspect in planning construction of hydroelectric power stations is the forecast of dynamics of change of useful volume of water basins due to receipt of the weighed deposits.

Key words: precipitation; humidity; irrigation; microclimate

Introduction

Water relations between the Central Asia states at the Soviet Union were regulated by “Complex Use and Protection of Water Resources Schemes” in the Amudarya and the Syrdarya River Basins. The main purpose of the “Schemes” was to define real volumes contained within the Amudarya and Syrdarya basins and volume available for use. It also provided their fair allocation among the states of the Central Asia Region, meeting all the water users’ interests. A number of important aspects was not considered and included in “Schemes” for the situation greatly changed after 1980 (the year of the last “Schemes” specification and completion of hydraulic range composition). Mainly it concerns the ecologic and sanitary conditions in rivers and channels. According to “Complex Use and Protection of Water Resources Schemes” the maximum use of the water was planned in irrigational lands and this situation resulted in exhaustion of water resources; the following problems appeared:

- deterioration of ecological situation sometimes leading to ecological disasters in downstream of rivers of the Aral Sea Basin;
- pollution of river waters with pesticides, herbicides, other harmful elements and increase of water mineralization.

For example, Amudarya river waters after the Tuyamuyun Reservoir are characterized by sodium and nitrites (NO2) exceeding margin concentration (MC) 1.2 and 2.3 times accordingly; in Nukus region MC exceeding of heavy metals is observed (Chembarisov, 2001).

Nowadays one of the most polluted rivers of Central Asia is the Zarafshon River. The quality of its water is changed under the influence of collector of drainage water of irrigating

basin zone and wastewater of Samarqand, Kattakurgan, Navoi and Bukhara cities. Mineralization of water from origin to estuary increases from 0.27-0.30 g/l to 1.5-1.6 g/l. Among heavy metals Cr and Zn exceed MC the most. Moreover, in the Zarafshon river high content of antimony was found and its phenol pollution composes 3-7.5 MC (Chembarisov, 2001).

In spite of convincing indexes of pollution influencing human health (use of bad-quality water caused 80% of all the world diseases, 2 billion people are sick due to water factors), ecological tragedy of the Aral still proceeds. Every year 12-14 km3 of unclean used water overfilled with pesticides and toxic chemicals inflow to the Syrdarya River.

Kizil-Orda Regional Administration of Environment Protection in the Syrdarya informed that nitrogen exceeds MC 2.5 times; sulfates exceed MC 3.0-7.7 times; biological use of oxygen – 5-3.1 times; oil products – 7 times; copper – 10 times; iron – 2 times.

Mineralization of water coming from the Shardarin Reservoir increased to 1.4g/l and in Kazalinsk region up to 2g/l which exceeds the rate twice (Nurgisaev, 2002).

Heavy metals (Pb, Zn, Cr, Ni, Cd and Hg) with concentration exceeding MC tens and hundreds times were detected in the Syrdarya River and its tributaries.

In water of the Naryn-Syrdarya river basin only on the territory of Kyrgyzstan 14 suspended and working mining industry objects are situated, and volume of solid waste materials exceeds 550 million m3. Downwards of the Syrdarya River there are the Sumsar and Alabuka rivers running down from mountain frames of the northern part of the Fergana valley. Concentration of lead there is from 3 to 100 MC, zinc is more than 10 MC and copper is more than 30 MC. Three radioactive tailings dams in Min-Kush region with the total radioactive waste materials of about 2 million tons and summary activity of 1015Bk are situated in the valley of the rivers. Natural disasters can destroy water reservoir dam, causing the flood of radioactive waste materials and infecting water on a big territory (Aitmatov and et al., 2001).

However, the main purpose is not in ascertaining the existing facts of ecological disasters, but in adopting cardinal decisions for improvement of the ecological situation.

The analysis of the publications of the last five years, as well as the resolutions of regional and international meetings and conferences demonstrate that the problem of quality of water arteries in the region becomes a subject of deep researches and analyses. The problem of studying the water quality change and development of mechanisms of its control is urgent and concerns not only the countries of Central Asia but all the states of the regions. Here it is possible to recommend development of bilateral and multilateral legal mechanisms for strict adhering to 13 and 16 principles of Rio Declaration, concerning the duty and compensation for ecological damage and the approach that the contaminant pays for contamination.

To stabilize the ecological situation in the region a number of measures are offered, for example, by Jalalov (2001). According to one of them it is necessary to make as a principle the limited water intake with some changes allowing the water users down the river flow to intake the greater water volume in percentage terms. The adoption of this limited water intake system, according to Jalalov (2001) will allow regulating water intake from the rivers not only in view of irrigated lands, but also in view of water quality and degree of its mineralization.

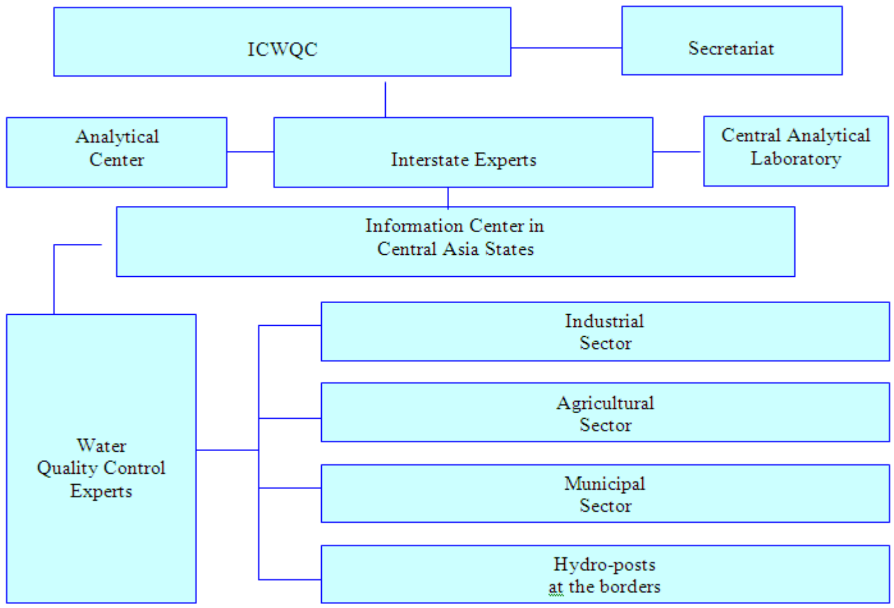
The penetrating comprehension of water importance in the region and social responsibility for steady water supply called, for example, immediate reaction of five Governments in Central Asia. In February of 1992 Interstate Coordination Water Commission (ICWC) was founded. The foundation of ICWC in difficult and unpredictable post-Soviet time enabled the countries of the region to undergo the period of water “anarchy” rather painlessly, to ensure equilibrium and consent in the region and has shown eagerness of all the countries to ensure mutual present and future understanding and respect for fruitful cooperation.

It gives the ground to hope that the problem of contamination and ascending of a degree of water arteries mineralization can be solved with the same success by creating (similar to ICWC) Interstate Coordination Water Quality Commission (ICWQC) (Table 1).

Structural subdivision “The interstate experts” unites the leading technicians in evaluating the quality and composition of waters from all the five states of Central Asia.

The main function of this body is to compare the experts’ information on water composition and to solve disputable questions by carrying out the independent expert appraisals of water quality of Transboundary Rivers. ICWQC Secretary appoints the stuff and sets terms of power of the interstate experts. In Information Center established in the each country of Central Asia the water quality control statistics in industrial, agricultural, municipal sectors and hydro-posts are gathered, generalized and systematized. Thus, the data concerning water arteries quality from the each country come to Analytical Center of ICWQC. It should be noted that after reaching the complete transparence of relative composition and quality of all the water arteries in Central Asia the next stage will be the development of mechanisms to encourage and take measures to the states polluting water environment. These problems together with other questions should be studied in ICWQC Secretariat for consideration at Meeting of Central Asia Heads of Governments.

Table1. Structure of the Interstate Coordination Water Quality Commission (ICWQC)



Ecological, Irigation and Energetic Critera of the Reservoir Construction

At present to define the efficiency criteria of the Hydropower station (HPS) with reservoirs method based on analysis of the key parameters of HPS construction such as capacity and out-put of HPS depending on area of the territory occupied by HPS is widely applied. As an index of ecology-economic efficiency of Hydropower station we used relation of capacity and out-put electricity to the one hectare of the territory used for construction of HPS (Table 2).

Table 2 Ecology-economical efficiency of HPS with reservoirs construction

Ecology-economical Index efficiency of HPS	On capacity references to the area for building HPS (MWt / ha)	On power output references to the area for building HPS (TWt / ha)
Annual for HPS with area of less than 100 thousand ha	0. 123	0.406

Using the data represented in the Table 2 we carried out efficiency estimation of the existing Nurek HPS and construction of the Rogyn HPS with reservoirs planed in the nearest future (Table 3).

For comparison in the Table 4 ecology-economic index of the considered HPS are generalized with analogous indexes of other HPS.

Table 3 Estimation of the Nurek and Rogun HPS with reservoirs

Name	P MWt	W(102) TWt·h	S Th. ha	A Th. ha	M Th.pers.	Index of efficiency P/S (MWt/ha)	W/S (TWt/ha)	P/A (MWt/ha)	W/A (TWt/ha)
Bratsk	4400	22.6	547.0	357.3	70.0	0.008	0.041	0.012	0.063
Charvak	600	20.0	4.6	2.7	9.18	0.13	0.436	0.225	0.750
Togtogul	1200	41.0	31.9	-	29.3	0.038	0.128	-	-
Nurek	2700	112	21.5	0.2	1.50	0.126	0.522	13.50	56.000
Rogun	3600	133	17.0	6.800	16.0	0.212	0.782	0.529	1.956

P- capacity of HPS, W- power output, S- area for HPS, A-area of wood vegetation, M-migration of population

Table 4 Comparison of the Nurek and Rogun HPS ecology-economic indexes with the optimal criteria of HPS construction

Ecology-economical Index efficiency of HPS	P/S (MWt/ha)	W/S (TWt/ha)
G	0.123	0.406

Bratsk HPS	0.008	0.041
Charvak HPS	0.130	0.436
Toktogul HPS	0.038	0.128
Nurek HPS	0.126	0.522
Rogun HPS	0.212	0.782

G- annual for HPS with area of less than 100 thousand ha, P-capacity of HPS, S- area for HPS

In the Central Asia Region with its inherent climatic conditions choice of place and the geographical location for reservoirs construction is one of actual problems. It is possible to estimate the degree of influence of reservoirs in Arid zones on surrounding environment with use of coefficient Ksur.env (Shirokov, 1998) :

$$K_{sur.env} = \sum S_i / S_{oi} \cdot 100\% \qquad (1)$$

Where Ksur.env. - Coefficient of reservoir influences on environment; Si -area of the territory under influences of the reservoir, km2; Soi – area of the basin, km2.

Calculations of the Ksur.env (Murtazaev, 2005) demonstrated that factor of influence of the Kayrakum reservoir on the surrounding environment is 0.11%; for the Nurek reservoir it is 0.144% and for the Muminabad reservoirs it is 0.00195 % (Table 5).

Table 5. Coefficient of influences on surrounding environment

Reservoirs	Kayrakum	Nurek	Muminabad	Golovnaya
K	0,11%	0,144%	0,002%	0,0011%

It is easy to notice that influence of small premountainous reservoirs on the microclimate is higher than in plains. The identical picture is observed for large reservoirs. Influence of the Nurek reservoir is 1.31 times higher than influence of the Kayrakum reservoir.

Apparently, the degree of influence of reservoirs on adjoining land decreases as their sizes and volumes reduce and at the same time influence of the adjoining land on the reservoir increases. This feature should be considered when constructing new reservoirs in Tajikistan and also when creating zones of rest with a greater set of recreation services.

To estimate the role of the reservoirs as local climate formations factor following ratio can be used:

$\Delta P/\sigma$sp.dif.,

where ΔP – influence indicator,

σsp.dif. – middle square deviation differences of the deposition one of indicator by two station located on the distance 10-20 km.

At $\Delta P/\ \sigma$sp.dif. ≥ 1 influence of the reservoir on formation of meteorological condition is essential.

Before filling up the Nurek reservoir with water temperature of the Vakhsh River water in the Nurek HPS dams (kishlak Tutkaul) didn't differ from its values 17 km below the dam (hydrological post Sariguzar). After filling up the Nurek reservoir (1972 year) drop of water temperatures was observed in spring (February-May) and rise of temperature in summer - autumn - winter time (July-January) in comparison with natural conditions. It can be partially explained by the fact that water is taken away from the top of the reservoir at its unachieved filling up to High surface level (HSL) which occurred only in 1980. The greatest difference of average monthly temperature (4.2 oC) of water before and after construction of the reservoir on the hydrological post Sariguzar is observed in November-December. Moving away from a dam this difference decreases to 1.2 oC. The influence of small reservoirs on change of temperature of water on length of the river is traced on along significant distance (Table 6).

Table 6. Average monthly temperatures of the Vakhsh River water before and after the Nurek reservoir construction

River-	Periods	Month

Hydropost		I	II	III	IV	V	VI	VII	VIII	I	X	XI	XII
Vakhsh Tutkaul	1946-1967	2.6	4.3	7.6	11.0	12.8	14.3	15.0	14.9	13	11.2	6.7	3.4
Vakhsh Sariguzar	1967-1971	2.0	4.0	8.1	11.5	13.2	14.4	15.0	14.9	3.5	11.2	7.6	4.8
Vakhsh Sariguzar	1972-1980	5.4	3.9	5.5	10.0	13.0	14.9	15.9	16.0	5.3	14.0	11.	9.0
Difference		-3.4	0.1	2.6	1.5	0.2	-0.5	-0.9	-1.1	1.8	-2.8	-4.	-4.2

The analysis of changes of the water temperature under influence of reservoirs shows that they are most significant at large reservoirs: distinction in daily and decade temperature of water reaches 8-12oC. The greatest difference of average monthly temperatures of water before and after construction of reservoirs is in November-January and for the Vakhsh River it is 4.2-3.4oC (Murtazaev, 2005).

The influence of warm waters dumped from large reservoirs lasts 8 months a year, while effect of cool water lasts four months (February-May). Influence of high temperature is traced on distance 1.74 times greater (209 km), than influence of the cooled waters (120 km). Hence change of annual distribution of average monthly values of water temperature below large reservoirs is not connected with change of annual means of air temperature, but is influenced by the reservoirs of the cascade. Although according to data of “Nurek” station monthly average temperature after construction Nurek HPS goes down (Fig. 1).

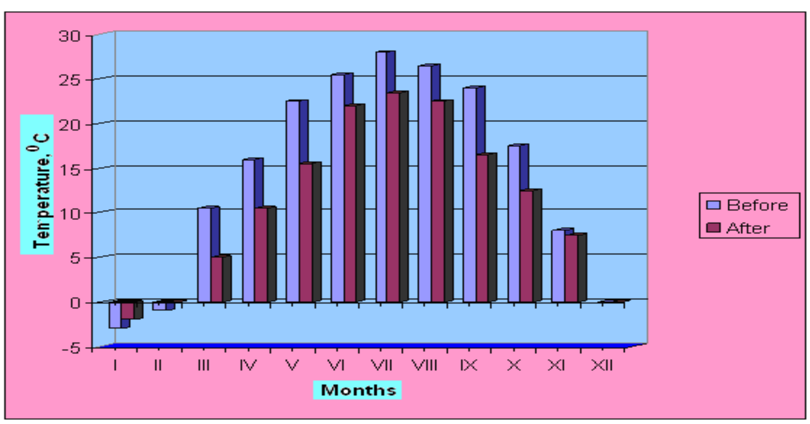


Fig. 1. Average monthly temperature before and after the Nurek reservoir construction

To establish influence of the climate change on possible changes of agroclimatic resources we carried out the analysis of climatic parameters in three districts with developed agricultural branches (Dangara, Fayzabad and Yavan) adjoined to the Nurek reservoir. For that purpose data from Hydro-meteorological stations (HMS) located in these areas has been used. Data on dynamics of temperature and relative humidity of air and atmospheric precipitations for 1968-1988 years was considered as well. The evaporation and humidity coefficients were determined (Table 7).

Table 7. Summary of meteorological indexes in each district

Hydro-post	Index	Years	
		1968-1972	1995-2000
Dangara	T (oC)	15.3	16.4
	H (%)	57.0	56.9
	F (mm)	570.5	598.5
	I (mm)	1196.7	1438.0
Fayzabad	T (oC)	13.2	15.4
	H (%)	61.6	55.2
	F (mm)	709.0	675.4
	I (mm)	1013.0	1258.8
Yavan	T (oC)	17.2	16.9
	H (%)	47.2	50.4
	F (mm)	677.4	677.3
	I (mm)	1630.8	1567.5

T-temperature, H- humidity, F- precipitation, I- evaporation

The data presented in the Table 7 demonstrated that during 20 years (1968-2000) the average annual temperature raised 1.0-1.5oC, and it led to 3-6% decrease of relative humidity and to 10-26% increase of evaporation in annual cut and 12-30% in period from May to September. However, in Yavan district dynamics of changes of the listed parameters has the opposite tendency: the temperature of air and evaporation decreases 0.5 and 7.2 % accordingly, and relative humidity and factor of humidifying raise 7.2 % and 10 % accordingly.

Reduction of evaporation in vegetative period in Yavan district reaches 12.2 %. In view of climatic changes it is necessary to bring corresponding corrective amendments in planning of water use in agriculture. During development of irrigation regime parameters of meteorological condition for all period of supervision are usually considered. But it leads to errors. Old specifications do not consider growing needs for water due to ignoring the process of global climate warming. On the contrary, in the Yavan valley the recommended regimes of the irrigation consider over-expenditure of water resources. For example, last specifications on regimes of the irrigation of Yavan valley use annual average means of humidity coefficient (0.35) and rate it to the category of droughty areas. But data presented in Table 6 shows, that during the last 20 years evaporation in the valley has decreased almost by 300 mm (17 %) and the amount of precipitation has risen to 70 mm (11 %), and the humidity coefficient is 0.45. Hence present irrigation norms for cultivation of the middle-fibrous cotton in Yavan valley (1100m3/ha) and in Lucerne (3000 m3/ha) are overestimated. Calculations show, that losses of water only in these two valleys are more 60 mln.m3.

Table 8 Average annual granulometric composition of the Vakhsh River sediment flow

Years	D (mm)							
	1-0,5	0,5-0,2	0,2-0,1	0,1-0,05	0,05-0,01	0,01-0,05	0,005-0,001	less 0,001
Komsomolabad								

1972-1976	1,43	7,05	8,56	15,29	36,97	18,03	17,57	3,76
1977-1987	1,53	7,11	8,67	14,89	37,21	17,87	17,39	3,81
Sariguzar								
1972-1976	0,63	1,77	3,92	8,7	47,3	22,12	18,31	2,95
1977-1987	0,72	1,94	3,87	9,1	48,2	21,54	19,08	2,86

D-diameter of particles in sediment flow

The analysis of the results of researches of the filtration characteristics at irrigation by the clean water and water with the weighed sediments shows that before the Nurek reservoirs construction in each cubic meter of the Vakhsh River water contained up to 10 kg of sediments and annually more than 100 tons of sediments rich with minerals inflow to the agricultural fields. According to the Hydrometeorological Agency of the Republic of Tajikistan mid-annual charges of the weighed sediments of the Vakhsh River at the Hydro-post located 17 km below the Nurek HPS since 1972 (the beginning of filling of the Nurek reservoir) decreased from 1000 g/s to 82 g/s in 1980. Nurek reservoir almost completely besieges the weighed sediments of the Vakhsh River (Table 8).

Conclusion

The necessity to establish the interstate commission on control of water quality of the Transboundary Rivers is proved. Comparative calculations of efficiency of a number of hydroelectric power stations are carried out. Multifunctional influence of these constructions on agroclimatic and ecological conditions of environment is specified.

References

1. Aitmatov I.T., Torgoev I.A. and Aleshin U.G. (2001). Water and steady development. Bishkek. Publ. Center FPOI, 25.
2. Chembarisov E.I. (2001). Modern hydrological problems of water resources of Central Asia and ways to solve them. Water and steady development. Bishkek. Publ. Center FPOI, 82.
3. Jalalov A.A. (2001). Ecological aspects of water resources management in the rivers: limiting and regulating mechanisms. Tashkent: ICWC Research Center. 24.

4. Murtazaev U I. Diss. Evolution of natural complexes of reservoirs of Tajikistan and their influence on adjoining Landscapes. Dushanbe, 2005, 322P.
5. Nurgisaev S.U. (2002). Social-economic and water situation in downstream of the Sir-Darya River. Coll. reports of Scientific Practical Conference “Water resources of Central Asia”. Tashkent. ICWC Research Center, 23.
6. Shirokov V M, Lopukh P.C. Features of development of the nature of small reservoirs (on the example of artificial reservoirs of Belarus). J. Geography and natural resources. 1985(1), 40-49.

THE DYNAMICS OF FLUCTUATION AMONG MAXIMUM WATER RUNOFFS OF SOME RIVERS IN ARMENIA

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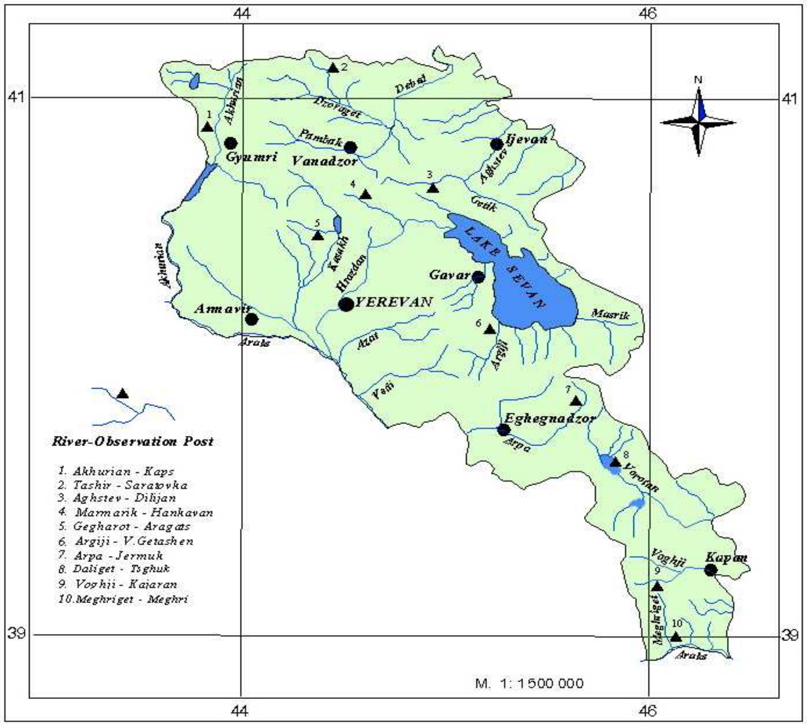
The 20th century was marked by global changes in the social, political and economic spheres. The state of the environment, including water bodies, changed as well.

The nature of these environmental changes is connected with the increase of greenhouse gas concentration in the atmosphere and with the growth of temperature of the sub-surface layer of the atmosphere. According to the data of IPCC, the perennial average annual air temperature on the Earth in the last century increased by 0,3-0,60C, and still keeps on growing; according to separate forecasts, temperature may rise by 5-60C by the end of XXI century (IPCC …, 1995; 1997; Climate Change… 2001, WCRP-107 …, 1999; WCRP-108 …, 1999).

The global aspects of overland moisture change are certainly reflected in the change of water resources even on small areas. Armenia is a small mountainous country distinguished by aridity and river scarcity. The present-day climate change may decrease restorable water resources and enhance aridity there, as well as potentially increase the frequency and intensity of disasters such as floods, droughts, and mud-flows. Given these possible conditions, the task to study and evaluate the changes in water resources of rivers becomes urgent.

This work is aimed to study and evaluate the dynamics of changes of 30-day maximum runoff with the case-study of some rivers in Armenia (Fig.1).



According to calculations, the 30-day maximum runoff considerably exceeds the calendar mean monthly runoff. With this respect, in conformity with the calculations of the maximum runoff, it is recommended to use the value of 30-day maximum (average for 30 days) water discharge rather than maximum mean monthly (calendar) value for the main characteristics.

The calculations show that 30-day maximum runoff is always bigger and the 30-day minimum runoff is smaller than the monthly calendar runoff (Vardanian, 2006).

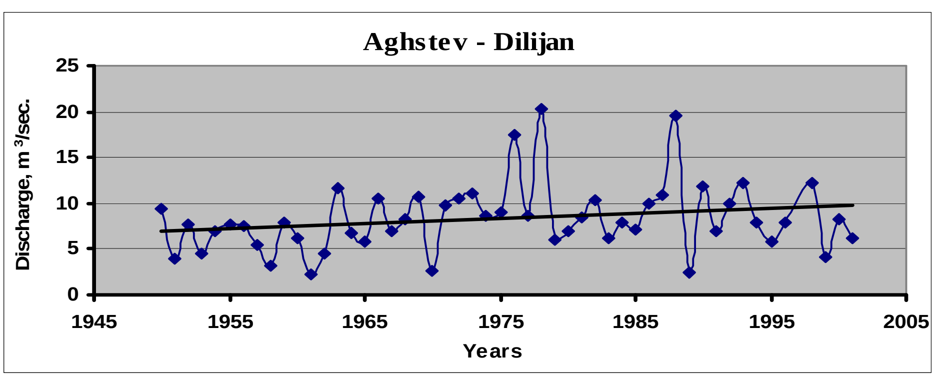
The main hydro-meteorological characteristics of the 30-day maximum runoff of some rivers in Armenia are presented in Table 1.

The area of the studied river basins (Table 1) varies from 40 (Gegharot) to 839 km2 (Akhurian). The mean altitude of watersheds varies from 1810 (Tashir) to 3100 m (Gegharot). The layer of precipitation on this territory is about 273 (Meghri) to 845 mm (Tsghuk). The mean annual air temperature alters within the limits of -2,60C (Aragats) and 14,20C (Meghri). Mean perennial water discharge changes within the limits of 0,96 (Gegharot) and 7,24 m3/sec (Akhurian).

Table 1. Hydro-Meteorological Characteristics of Water-Abundant Runoff of Some Rivers in Armenia

N, by the List on Fig.	River-Post	The Area of Watershed, km2	The Mean Height of the Watershed, m	Mean annual			30-day Maximum Discharge, m3/sec
				Water Discharge, m3/sec	Precipitation, mm	Air Temperature, 0C	
	Akhurian - Kaps	839	2710	7,24	566	4,5	19,1
	Tashir – Saratovka	450	1810	2,65	662	6,1	6,6
	Aghstev - Dilijan	303	2000	3,45	620	8,2	8,3
	Marmarik -Hankavan	94	2430	1,65	776	3,8	7,8
	Gegharot – Aragats	40	3100	0,96	802	-2,6	3,0
	Argiji – Getashen	366	2470	5,56	495	5,7	21,6
	Arpa – Jermuk	180	2790	5,33	741	4,7	18,5
	Daliget - Tsghuk	137	2780	1,50	845	3,0	5,1
	Voghji – Kajaran	120	2840	3,64	830	5,1	11,5
0	Meghriget - Meghri	274	2200	3,12	273	14,2	8,7

Now, let us see, what changes the perennial 30-day mean maximum runoff of some rivers in Armenia has undergone (Table 2, Fig. 2) during last 50 years (1950-2001) and why.



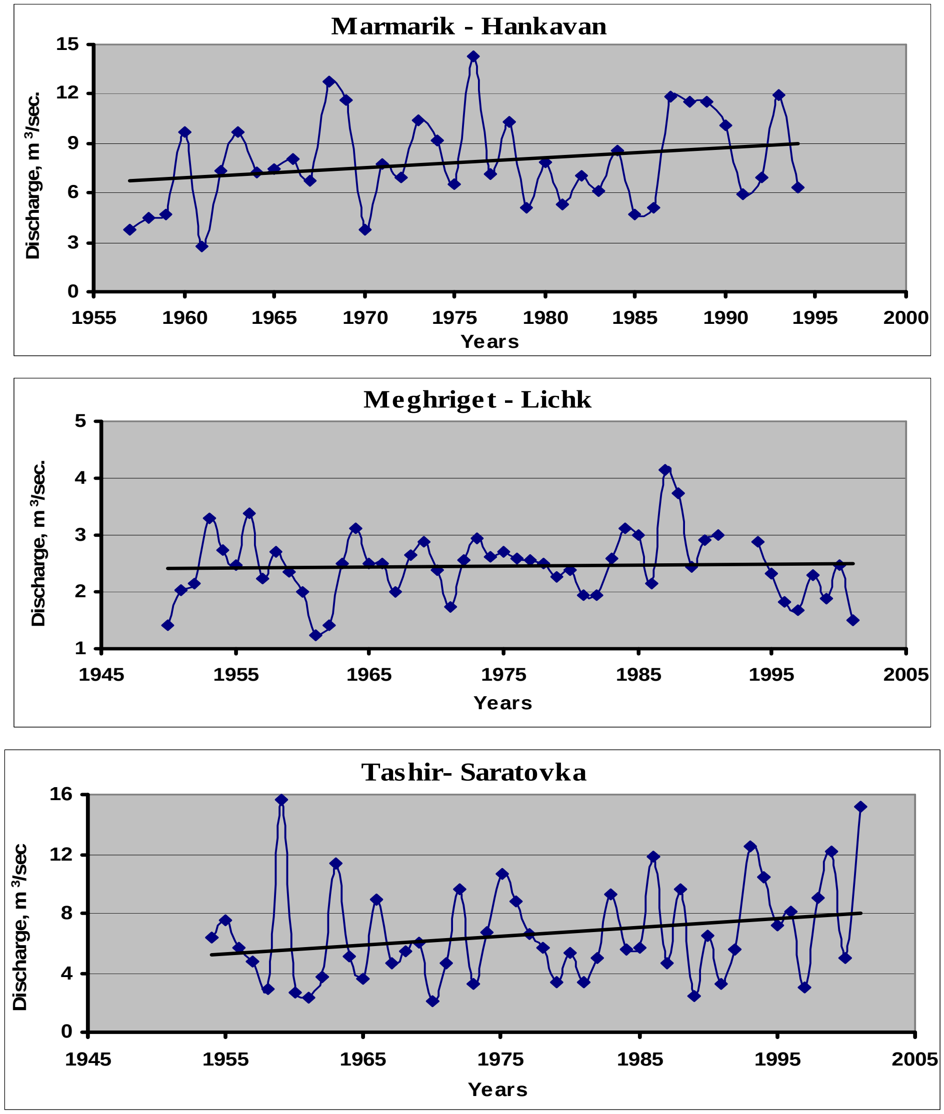


Fig. 2 Rivers which have a Tendency of Increase of 30-day Maximum Water Discharge

The change of the perennial 30-day mean maximum runoff is no the same for all the studied rivers (Fig. 2, Table 2).

In the range of perennial observations the tendency of runoff increase was observed for the rivers Aghstev, Marmarik, Meghriget and Tashir, and the tendency of decrease-fro the rivers Argiji, Arpa, Daliget, Voghji and Gegharot (Fig. 2, Table 2).

The biggest value of increase in the 30-day maximum runoff was identified in the Tashir river (Saratovka) – 20,2% (Table 2), while the smallest value was observed in the Meghriget river (Lichk) – 0,5%. If the latter one is taken as invariable, one can note that only in case of three rivers runoff increase was observed – about 14-20% (Table 2).

Table 2. The Change of 30-day Maximum Runoff of Some Rivers in Armenia

N, by Map (Fig. 1)	River-Post	Trend Equations	Correlation Coefficient, R	Discharge, m3/sec, (Average for 1950-2001-)	Change of Water Discharge, Qmax	
					m3/sec	%
2	Tashir – Saratovka	Q = 0,058T - 108,68	R = 0,24	6.64	1,34	20,2
3	Aghstev - Dilijan	Q = 0,058T - 106,81	R = 0,23	8,34	1,51	18,1
4	Marmarik - Hankavan	Q = 0,061T - 111,85	R = 0,24	7,85	1,14	14,5
5	Gegharot – Aragats	Q = -0,001T + 5,64	R = 0,02	3,02	-0,02	-0,6
6	Argiji – Getashen	Q = -0,077T + 174,52	R = 0,11	21,57	-1,26	-5,8
7	Arpa – Jermuk	Q = -0,082T + 181,11	R = 0,18	18,48	-1,65	-8,9
8	Daliget - Tsghuk	Q = -0,025T + 55,32	R = 0,15	5,12	-0,63	-12,3
9	Voghji – Kajaran	Q = -0,029T + 69,68	R = 0,14	11,46	-0,51	-5,3
10	Meghriget - Lichk	Q = 0,002T - 0,94	R = 0,04	2,45	0,01	0,5
	Total Runoff	Q = -0,286T + 653,71	R = 0,17	84,93	-4,11	-4,8

We believe, according to the testimony of the study, the increase of the 30-day maximum runoff in the selected basins is caused only by climatic factors, namely, by the increase of precipitation, while the other factors are derivatives and they only stimulated the runoff increase.

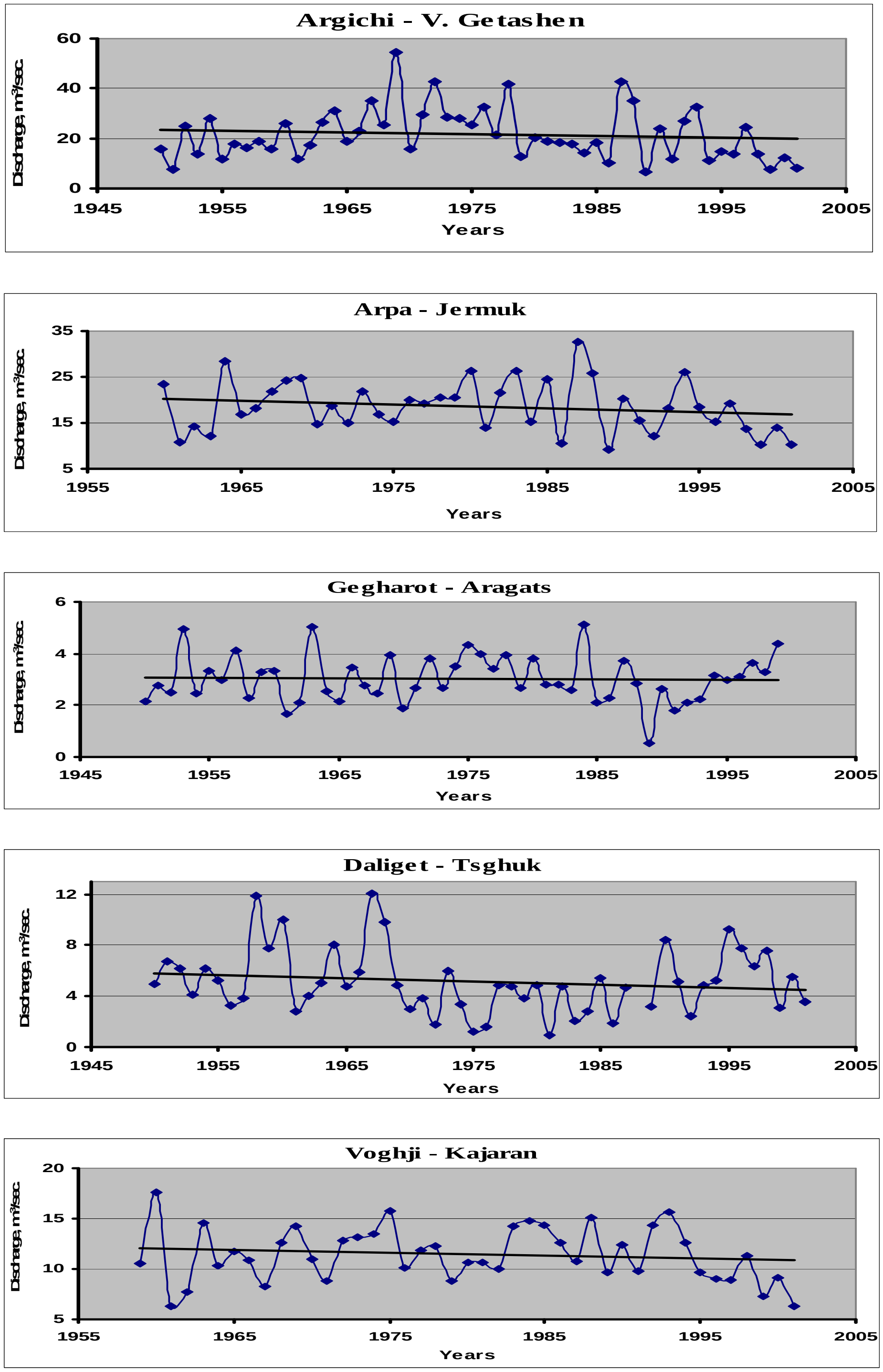


Fig. 3 Rivers which have a Tendency of Decrease of 30-day Maximum Water Discharge

The biggest value of decrease in the 30-day maximum runoff was identified in the Daliget river (Tsghuk) – 12,3%, while the smallest value, which can be taken as invariable was observed in the Gegharot river (Aragats) – 0,6% (Table 6.2). In case of the other rivers, the mean value of decrease has changed within the limits of 5-9% (Fig. 3, Table 2).

As is apparent in the afore-mentioned indicators, the change in the 30-day maximum runoff for some separate river basins does not create a holistic vision of the runoff change. With this respect, the study was carried out for the change in the total runoff for the same period of time (Fig. 4, Table 2).

Fig 4 and Table 2 show that the 30-day maximum total runoff рек of rivers has a tendency of decrease. According to calculations, with respect to the mean perennial 30-day maximum runoff, it has decreased by 4,8%. However, it is worth noting that this value of maximum runoff decrease (4,8%) has almost no significance for the economy, as it is considered to be a limitative runoff.

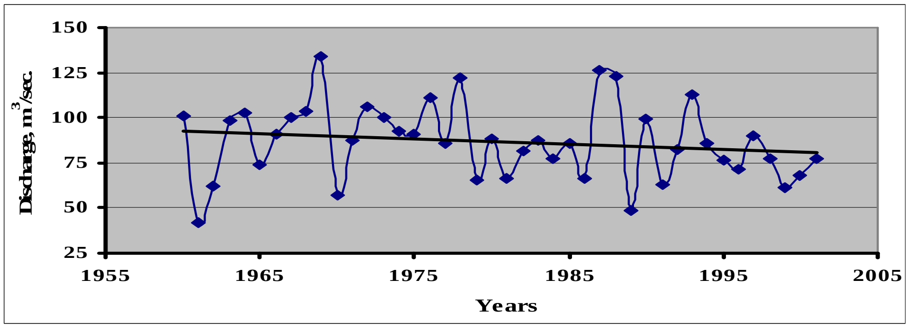


Fig. 4 The Changes of Total 30-day Maximum Runoff of Some Rivers

in Armenia (1950-2001)

If we compare the change of the 30-day maximum runoff with the minimum one (30-day summer-autumn and winter) for the same period of time, then we shall notice that in low water period there is a reverse tendency, that is, a minor increase (Vardanian, 2006). In other words, a tendency of equalization of seasonal runoffs of rivers was observed.

In case the change of the 30-day maximum runoff is compared with the mean annual total river runoff for the same period of time, it can be seen that the change of total runoff is also accompanied with its tendency to decrease, though, a slight decrease, by 1% (Vardanian, 2006). This circumstance also denotes that the perennial mean annual runoff of rivers in the Republic of Armenia strongly depends on the 30-day maximum runoff. The latter one is significant and it is not a coincidence that 60-70% of perennial mean annual runoff falls on the high-water season in rivers.

Thus, the research of the change of perennial 30-day mean maximum runoff on the selected parts of rivers showed that for some parts of river basins (4 areas) it has increased, while for the other parts (5 areas) it has decreased. The total maximum runoff also has a tendency to decrease, which composes about 4,8%.

References

1. Climate Change 2001. Impacts, Adaptation, and Vulnerability. Cambridge University Press, 2001.
2. IPCC: The Regional Program IPCC for Eastern Europe, 1997
3. IPCC European Regional Program 5; Regional Impacts of Climate Change, 1997
4. The Second Report of IPCC on Evaluation of Climate Change, 1995, 59 p. (in Russian)
5. Vardanian T. G. River Runoff in Armenia and the Assessment of its Change Under the Global Warming of Climate. Yerevan: Yerevan University Press, 2006, 176 p. (in Russian)
6. WCRP-107, COARE-98: Proceedings of a Conference on the TOGA Coupled Ocean-Atmosphere Response Experiment (COARE) Boulder, CO, USA, 7-14 July 1998 (WMO/TD-N 940), 1999, 416 p.
7. WCRP-108, Proceedings of the International Clivar Conference, Paris, France, 2-4 December 1998 (WMO/TD N 954), 1999, 257 p.

PRESENT-DAY SOLUTIONS TO THE ISSUE OF POLLUTION OF HYDRO-ECOSYSTEMS CAUSED BY TRANSPORT MEANS

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Abstract

For centuries, hydro-ecosystems have operated self-purifying qualities against water pollution. However, caused by rapid industrialization in 20th century, the anthropogenic overload undermined the balance of hydro-ecosystems on the planet and put new challenges and tasks for their rational use.

This paper discusses the environmental effects caused by transport-cause pollution and suggests two main solutions. They are: the improvement of monitoring systems aimed at protection of hydro-ecosystems and development of the multi-modal transport systems. In particular, the attention is drawn to regional multimodal transport systems aimed at establishment of a joint transportation infrastructure and in-country economic development.

Introduction

Before the 20th century the anthropogenic load on water resources was relatively insignificant, it did not affect the natural balance, and small changes, like pollution, could be "recovered" by means of self-rehabilitation and self-purification. At present, the ecological balance is destroyed to the extent that it is necessary to reconsider environmental policies and restore the balance of hydro-ecosystems.

The anthropogenic impact endangers the quantity and quality of water resources, causing changes in water balance, hydrological, hydro-chemical and hydro-biological regimes of the water bodies.

There are a number of factors which affect the quantitative and qualitative changes of water resources in any header. Among them are:

- water use for household and industrial needs;
- waste water;
- urbanisation;
- reservoir construction;
- irrigation and enrichment of arid lands with water;
- drainage, agro-melioration works and others.

1. Sources of pollution

Water resources can be contaminated in directly and indirectly. The direct sources are provided by factories, refineries, etc., while the indirect sources contaminate water bodies from soil and atmosphere, being in their turn polluted as a result of human activity.

There are different sources of water basins contamination. They are classified into several groups: mineral (sand, rock particles, clay particles, etc.), organic (plant remains, pollutants of animal and human origin etc.), bacterial, biological, industrial.

Pollution of water bodies is caused by industrial, agricultural and household wastes, as well as transport related emissions. Oil production, chemical, wood-processing and other wastes are the most dangerous industrial pollutants which have a negative impact on life in water basins. These pollutants appear as a result of not only careless attitude towards environment. In developing countries sewage systems are usually depreciated, with worn-out pipelines that cause additional leakage of the pollutants. In case of household and other recyclable wastes, the lack of recycling systems makes water bodies serve a dumping place.

The effects of pollution can vary; they may become considerable not only to the water bodies and unbalance the system, when the water bodies will be unable to sustain biodiversity. The alarming signal for us should be that endangering the environment is hazardous for human health. Contaminated water (and air) causes an increase in various respiratory diseases, allergies, oncological and other diseases. In countries with no medical insurance system and high poverty level, health issues can become acute especially for vulnerable groups of population.

1.1 Transport system as a pollution source

One of the man-caused factors which have a negative impact on environment, is the transport system, or, rather, its unbalanced use. Car-dominant transportation system pollutes the air, contaminates water resources, and affects biodiversity.

Road transport has been the dominating source of NOx emissions since 1970s, and contributes with 40% to the total emissions in 2005 [1]. This non-point pollution source contaminates water resources with fertilizers, pesticides, engine oil, rubber and metal deposits, and other pollutants into water bodies. Water quality is significantly deteriorated by marine oil spills, too.

Transport emissions have an adverse effect on human health, too. According to EPA (US Environmental protection Agency) In the 1996 National Toxics Inventory, vehicles like cars, trucks, and so on, release about 3 billion pounds of cancer-causing, hazardous air pollutants each year [2].

Within a period of years, Europe developed a ‘less polluting’ system of transport means and made its management more effective. Cleaner and more energy efficient vehicles, as well as elimination of obsolete vehicles from use are promoted to cut emissions. This, however, does not necessarily apply to some states in Asia, Latin America, Middle East and Africa, where less policy regulations are in place and Nitrogen oxides emissions are increasing [3].

2. Purification of water resources

The man cannot change (increase) the absolute amount of water resources, however, he can balance the amount by applying rational use of water and improving the quality of available water resources.

Water purification, which implies breakdown and removal of certain substances from it, is like a complex production, where waste water is the raw material and purified water is the final output.

As is well known, the application of methods of water purification depends of the nature and degree of pollution of waste water. These methods can vary from mechanic, physical-chemical to biological, which are currently replenished with new methods of phyto-technology (mainly used in rural areas). In industry, it is usually a combination of methods applied for better results.

To conserve water resources from pollution and exhaustion under conditions of intensification of water use, a complex of activities, which will ensure the appropriate condition of water bodies in accordance with the present legislation on water, are to be applied. The implementation of this complex, it requires solution of a number of scientific, technical, and financial problems:

to define norm setting of water quality;

to reduce the quantity of waste water;

to study the processes of self-purification in every single water basin and set a strict control over the process of purification of waste/sewage waters to be thrown off into water basins.

The issues of hydro-ecosystems require a new approach to their use and protection of water resources. To settle these issues, a number of measures and activities (including monitoring) are suggested:

to stop the overflow of waste water into the water basins;

to introduce zero /minimum/-emission technologies in industry;

introduce new technologies allowing to make some water-retaining industries into less water-retaining ones;

to reduce losses and water amount, consumed per unit of agricultural output, and others.

The implementation of these activities, that would protect water resources and prevent the hydro-ecosystems from degradation, requires considerable investments and state intervention for the solution of this issue.

3. Additional measures and new systems

3.1 Pollution monitoring system

Untreated or insufficiently treated sewage is the main cause of the pollution of water bodies. In some CIS states, the technologies applied in the plants are not efficient and do not meet modern requirements. Moreover, the treatment technologies used were based on practically free energy (both natural gas and electricity). Under present conditions, their use is extremely expensive and the use of existing water treatment facilities cannot be justified [4].

However, alongside the problem of obsolete treatment systems and sewage pipelines, there is another crucial process, that controls the quality of water bodies, that is the pollution monitoring system /for drinking, waste, environmental waters/ that must involve regular monitoring observations and systemic approaches.

Today, enhanced technology offers sophisticated equipment to monitor different types of pollution; however, not every country can afford these means. Yet, since water resources are interconnected, they do not recognize political or administrative borders, the issues of water pollution and conservation of water resources by application of various techniques must be carried out jointly, on regional and global levels. Such example is South Caucasus region where the states in the region have launched a river monitoring programme [5], aimed at solving the issues of in-country and transboundary river contamination, by increasing technical capabilities for monitoring, data management and communications among the states.

3.2 Regional multimodal transport

There are certain solutions aimed to balance transport use and minimize their environmentally unfriendly “status”. It is the initiation and use of multi-modal transport system. Multi-modalism is a priority for European transport policy. This policy must be pursued in developing states and countries with transit economies as well.

Multi-modal transport system is a system under control or ownership of one operator, with use of many transport means. The multi-modal system has a number of advantages, such as:

- faster transit of goods and time saving;
- less bureaucracy connected with documentations;
- dealing with one operator;
- reductions of costs, etc.

After collapse of the Soviet Union the economies of South Caucasus states were seriously damaged and are still in process of revitalization. It refers to transport system as well. Thus, formerly developed transport system in Armenia (rail, road, air) is presently overloaded with predominantly motor transport means. A number of steps have been already made for introducing more balanced transport system that would be more environmentally friendly and economy beneficial.

To proceed with these aims, the next step is to be made, that is to develop a multi-modal transport system. This step can be better achieved with joined forces of the other South Caucasus states. On the regional level, the establishment of a regional multi-modal transport infrastructure will enhance the economic development in the region and also provide joint solutions to the efforts for environmental protection, in particular that of hydro-ecosystems, mentioned before. The regional multi-modal system will create opportunities for the more effective use of services in road, rail air and water transport. To establish a multi-modal transport system on the regional level, it will be necessary to consider a number of activities, aimed at improvement of legislative, technical and information systems.

4. Conclusions

Today, hydro-ecosystems and their quality are highly dependent on the anthropogenic factor. At the same time, man actively uses water resources and any disbalance in them finds its reflection on people. There is one solution-to keep the hydro-ecosystems protected. As transport is one of the main pollutants of water bodies, there must be new approaches and solutions on how to make transport infrastructure environmentally more friendly.

The paper suggests a number of activities and techniques, singling out two solutions: to enhance the water monitoring systems and for some regions to make them on the regional level. And the second suggestion is to develop regional multi-modal transport systems for small and developing (with transition economies) states, for environmental protection of their common watersheds and also economic development in these regions.

References

1. Vestreng V. et al, Evolution of NOx emissions in Europe with focus on road transport control measures. Atmos. Chem. Phys., 9, 1503–1520, 2009. At www.atmos-chem-phys.net/9/1503/2009/
2. http://www.epa.gov/ttn/atw/nata/natsa1.html#summary
3. Naja M. et al, Ozone in background and photochemically aged air over central Europe: Analysis of long-term ozonesonde data from Hohenpeissenberg and Payerne, J. Geophys. Res., 108(D2), 4063, doi:10.1029/2002JD002477, 2003; Cofala, J., et al, Scenarios of global anthropogenic emissions of air pollutants and Methane until 2030, Atmos. Environ., 41, 8486–8499, 2007. In: Evolution of NOx emissions in Europe with focus on road transport control measures.
4. Environmental Monitoring And Reporting Countries Of Eastern Europe, the Caucasus And Central Asia: National Report on the State of the Environment in Armenia in 2002, At: http://www.unece.org/env/europe/monitoring/Armenia/en/Part%20I%20-%20Ch.3.pdf
5. http://www.kura-araks-natosfp.org/

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Ecological and water - related problems of hydropower development in Siberia and Altai

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The economic development of any country greatly depends on its power engineering that is presented by three major power generating capacities, i.e. thermal power plants (TPP), nuclear power plants (A-plant) and hydropower plants (HEPS). For Russia, the latter is the most suitable power source.

Russia ranks the second, and is inferior only to China in water-power potential, while by its efficiency it is behind the majority of the countries that develop power engineering. Moreover, Russia occupies a huge territory distinguished by different economic development. For instance, in the European part of Russia about 45 % of water-power potential as against 4 % in the Far East have been developed. The distribution of global energy capacity is also uneven: 40% falls on the European part, 40% - on Siberia, 35%- the Far East. Hence, in the Central European part of Russia the potentialities for the large-scale engineering have been practically exhausted but in Siberia, the Far East, in the northern Caucasus and in the west of the European part of Russia hydropower engineering has good prospects and can satisfy the forecasting demand in energy.

In view of engineering features, HEPSs have some advantages as compared to other sources of energy (e.g. TPPs and A-plants) because they don’t consume fuel or other non-recoverable resources.

The HEPS efficiency is independent of fuel availability and price. The growing HEPS power output leads to conservation of mineable resources including gas which steadily goes up in price on the world market.

High maneuverability is characteristic of HEPS: it takes around 10 minutes to achieve 100% operating power and even less time is required for its load-off. HEPS unit capacity varies from 100 up to 640 MW (e.g. Sayn-Shushenskaya HEPS), unlike other alternative power generating sources: to achieve a design condition for TPP, several hours are required; for A-plants it is prohibitive because the application of fluctuating loads is at variance with safety conditions. To achieve the design conditions at gas-turbine power plants having low capabilities, tens of minutes are required. Owing to high maneuverability, HEPS are irreplaceable in providing steady operation of power lines and the power supply system as a whole. Thus, HEPS allow the TPPs and A-plants to operate steadily or with gradually changing load, thus eliminating the electricity deficiency during rush hours.

High maneuverability of HEPS hydraulic units is ideal for using them as backup ones. Currently, 95% power reserves of Russia fall on HEPS.

In contrast to other types of energy sources, most HEPS have *a multipurpose assignment.* The HEPS reservoirs provide flood control, navigation, water supply, irrigation, etc.

The lack of oxygen combustion and carbon dioxide release by HEPS gives a good ecological effect which importance was specified in the “Kioto Protocol”. However, to evaluate its economic effect is hardly possible due to the improper legislation.

Any energy system is optimal if all types of power generating sources are available in the region. In Siberia and the Far East, by objective reasons, the specific weight of waterpower engineering in energy output is higher than the average one in Russia.

It should be noted that any large-scale hydraulic engineering constructions (especially high-

pressure HEPS on Siberian rivers) make an impact on the environment. When large and deep reservoirs are constructed in Siberia, the forecast of water state on the regulated river flows (i.e. in the reservoir and tail-water) is of great importance. For instance, in winter, with change in hydroicethermal regime in tail-races of high-pressure HEPSs, unfrozen patches of water are formed.

Temperature fluctuations and gaseous exchange in the river water make a negative effect on the river’s flora and fauna, and hence on its self-purification ability. All these effects should be assessed in advance, at the stage of studying ecological consequences of the hydroengineering project implementation.

Many typical water-economic problems related to high-pressure HEPS construction in Siberia were observed under the construction of the Evenki HEPS on r.Nizhnaya Tunguska with rated capacity of 12 mln.Kw, output- 46 b k W h. The HEPS construction in the scarcely populated part of Russia allows to use water-power resource of a river at maximum and to transmit the generated power to the European part of Russia and to the Far East.

The natural-economic peculiarities of the flooded area imply partial territory withdrawal of the river valley settled by the root population. In Siberia, in the course of reservoirs construction, specific problems caused by poor preparation of the reservoir floor to its filling, and the lack of forest data and clearing may occur.

The construction of the unique reservoir of 1200 km long on the main riverbed of r.Nizhnaya Tunguska with the design capacity of 409 km 3 under extremely severe climatic conditions generates specific problems which solution requires thorough scientific study associated with forecasting the ice-thermal regime in the reservoir and tail-race as well as water quality change in r.Nizhnaya Tunguska due to vast flooded areas covered with woody-shrubby vegetation.

To predict the ice-thermal processes, dissolved oxygen and admixture transport, water quality change in a deep slightly running water body (e.g. the Evenki reservoir), the methods of mathematical simulation (including the ones developed in IWEP SB RAS) were used [3,4].

The investigations done are the initial stage of works on forecasting the changes in Nizhnaya Tunguska water quality under the Evenki reservoir construction

The construction of plain HEPSs is another matter. The construction of the Novosibirsk HEPS and reservoir that brought to improvement of power and water supply of Novosibirsk city, including navigation on the Ob' is a striking example. However, typically all plain reservoirs are subject to marginal erosion, shore impoundment and deterioration of water self-purification. To prevent the negative processes, a set of special measures are undertaken.

Shortage of water also generates big problems: to forecast the reservoir's inflow, the climate change effects on the river runoff formation in the Upper Ob basin should be studied. When analyzing the natural-climatic factors, modern knowledge on the peculiarities of a hydrological cycle should be used. One of the key problems to be solved at the international level is working out the scientific fundamentals for a short-term forecasting of a river water regime to study probable extension of lead time and to improve the reliability of hydrological prediction.

The specificity of hydraulic engineering construction in the mountain regions accounts for both natural-climatic conditions and social-ecological importance of such territories. In this connection, it is of great interest the real and potential experience of Republic of Altai gained in hydraulic engineering construction (wind and solar energy, large- and small scale power engineering) subjected to permanent shortage of electricity that hampers social-economic recreational development of this region.

At present the Republic of Altai lacks the generating capacities except for the oldest beyond the Urals Chemal HEPS and the newly constructed small HEPS on Kairu and Tyunya rivers (near Balykcha and Dzhazator villages, respectively) which satisfy the needs only of the nearest settlements. The main volume of energy comes from Altai Krai suffering from power shortages.

The projects on hydropower development in the Republic of Altai are being considered since the last century and incorporated the construction of coordinated small HEPS on Biya and Katun rivers and the realization of a rather challenging project on the construction of the Katun HEPS with compensating Chemal HEPS. In the case that this project is implemented, of great importance is the forecast of environmental and social change under the effect of hydraulic structures including the evaluation of damage caused by landflood, change of water quality in reservoirs and transformation of floodlands in tail race as well as the influence of hydraulic engineering construction on natural-resource, ecological and socio-economic potential of the region. Once an Environmental Impact Assessment was conducted, the original project was improved and such topics as microclimate variation within the resort settlement of Chemal and the accumulation of toxic materials in reservoir were withdrawn. However, this project was not realized and currently the ordinary one on the construction of the Altaiskaya HEPS providing the use of natural runoff power is under consideration. It is expected that the dam height will be 50 m, the plant output – 140 MW, and mean annual power production will make up 0.85 b kWh. Since the river flow won't be regulated, only 50% of power demand of Republic of Altai will be satisfied during winter period, and in summer, the excess of energy can be sold to the neighboring regions and countries, in particular, Mongolia and China. The construction of more than 50 small HEPS on Altai rivers holds much promise. According to preliminary estimate of Krasnoyarskgidroproekt it is advantageous to use the hydroelectric potential of small rivers and their tributaries, namely, Peschanaya river (8 small HEPS), the Anuy (7 small HEPS), and the Charysh (11 small HEPS) [11].

In the context of transboundary aspect, the experience in the construction and operation of the tandem reservoir system on Irtysh river which changed significantly the hydrological regime of the river and its tributaries is of great interest. The study of water-related and ecological risks carried out currently by IWEP SB RAS on transboundary territories in the Irtysh basin reveals a number of claims of Russia to Kazakhstan on water withdrawal from the Irtysh (unreasonable volume and uncoordinated dates). Similar claims are laid by Russia and Kazakhstan on the one hand to China on the other.

Irtysh river is a very important source of fresh water for East and Central Kazakhstan. The Irtysh-Karaganda canal provides large cities and agricultural regions with drinking water. The flow from the upper part of the Irtysh-Kara-Irtysh (Black Irtysh) basin runs across China where about 9.0 km^3/year of river flow is formed. Until the present time China took up to 1.0-1.5 km^3/year; it is expected to increase the water withdrawal through the Black Irtysh-Karamai canal up to 4.0-5.0 km^3/year to provide the area of petroleum deposit and for other purposes. Then the Bukhtarma and Shul'bino reservoirs which experience water shortage during low water can remain without water. Difficult situation is observed in the Lower Irtysh (Russian part) where the flow reduction has caused serious problems in navigation and water quality in the river which is the only drinking water source for a million-strong city of Omsk.

Nowadays the international community deals with a number of projects on the improvement of the situation in the Irtysh basin. Kazakhstan discusses two projects providing water replenishment in the Irtysh on the one hand and dilution of industrial runoff on the other.

The first project proposes the diversion of Tikhaya river water to the Irtysh basin. In Kazakhstan, it is expected to make a pressure hydraulic tunnel 4.5 km in length and 3 m in diameter to the Bukhtarma river basin, and to construct the Belokatun'skaya HEPS of 1.25 b m^3 capacity at the point of water level difference. According to the preliminary estimates the HEPS construction cost will make up about 77 b tenge ($ 0.5 b), the designed capacity will be as large as 800 MW and the annual power production – 2.7 b kWh. In this case the power generation at the existing Upper Irtysh coordinated hydroelectric system increases by 660 b kWh that makes possible to restore the water balance throughout the whole river.

The second project concerns the diversion of Ak-Kaby and Kara-Kaby rivers which rise in Katon-Karagay region, run to China and after joining enter the Black Irtysh. The project is evaluated at around $1 billion. The tunnel will be as long as 20 km. It is expected to divert the river from the border and to direct it to the Back Irtysh just in the Kazakhstan part. It is the authors' opinion that "in this case the problem of water shortage will be settled".

At present the experts are active in the development of both projects [9]. However, it is assumed that the diversion of rivers will take place within the Katunsky biosphere reserve (Russia) and Katon-Karagaisky natural park (Kazakhstan) where any kind of construction even if it is environmentally sound one is forbidden.

The Russian part is involved in the consideration of a number of projects as well. The first one is connected with the construction of a dam to the south of Omsk city and a reservoir which will accumulate water during winter and high water periods and then replenish the Irtysh evenly to satisfy natural and economic demands. In June 2008, The Russian government approved the technical and economic assessment (TEA) of the construction of the low-pressure hydroelectric complexes in Omsk and Tyumen oblasts to settle the problem of water shortage in the Irtysh. It was planned to construct a small hydropower station and a road bridge by 2012, however, up to date no final decision has been made. Alternatively, it is proposed to do away with the dam and reservoir construction and to establish the artificial sills which allow the raising of water level at the sacrifice of flow rate reduction [12].

In this case a reinforced concrete structure is established on the river bottom; it supports the river runoff but doesn't block the flow. Here, the runoff velocity increases and the water level rises. However, one cannot anticipate high water level on a sill, therefore the establishment of a cascade of artificial sills is preferable. The construction of sills is performed step-by-step that is rather effective even at initial investments. Besides, the sills do not present extra obstacles in case of the runoff increase due to the increase of withdrawal or discharge in neighboring countries.

Here, the international cooperation of scientists and experts from Kazakhstan, China and Russia is very promising.

Large-scale hydropower engineering is closely connected with other important water-economic problems, in particular, the influence of large reservoirs on hydrological and climate conditions in the adjacent territories, abrasion of reservoir coastal zones, the construction of reservoirs in permafrost regions and the ones with high tectonic activity. The involvement of the available potential of international cooperation within AASA and IAP with due consideration for theoretical and practical experience in the forecast of environmental influence of large-scale hydropower engineering in Brazil, China, Canada, USA, Europe and Russia is of great importance.

References

1. Vasiliev O.F., Zinoviev A.T., Bocharov O.B. Mathematical modeling of hydrothermal processes in deep reservoirs // Hydraulic engineering construction. – 1991. - №7. – p. 3-5.

2. Vasiliev O.F., Zinoviev A.T., et al. Mathematical model of dissolved admixture transport within a "reservoir – flooded areas" system // Water resources. - 1993. - V. 20. – N 6. - p. 701 - 706.
3. Electronic library of educational resources [Electronic resource] - http://elib.altstu.ru/elib/books/Files/2000-02/25/pap_25.html
4. Kostarev S.V. How to help Irtysh to become a full-flowing river? An expert's opinion [Electronic resource]. http://omsk.yabloko.ru/news/index.phtml?id=673
5. Time for regions. In Omsk oblast, the construction of the largest in Siberia reservoir is expected [Electronic resource].: http://www.regtime.ru/owa/rt/rt_lenta.html?a_id=16603&c_id=49&r_id=6055

The Southeastern Anatolian Project (GAP)

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Abstract

The South-eastern Anatolia Project (GAP) seeks to increase the income levels and living standards of people living in the region by mobilizing and utilizing resources existing in this region and to contribute to nationwide goals of economic development and social stability. The GAP Region has a share of about 10 % in both the total population and geographical area of Turkey. Yet, 20 % of total irrigable land in Turkey is in this region and the region represents 28 % of Turkey's total hydraulic potential mainly with the rivers Euphrates (Firat) and Tigris (Dicle). The package included 22 dams, 19 hydraulic power plants and irrigation covering an area of 1.7 million hectares. With GAP Master Plan in 1989, the project transformed into integrated regional development effort also covering such diverse fields as rural and urban infrastructure, housing, transportation, communication, agricultural and industrial development, tourism, education and health. Projects for Human Development include multipurpose community centers for Women, Social Development Projects for Youth, Public Health Project, and Rural Development Project etc.

Key Words: Dams, Hydro-electric power plant, project for human development

Current situation and development of the GAP Project

The South-eastern Anatolia Project (GAP) seeks to uplift the income levels and living standards of people living in the region by mobilizing and utilizing resources existing in this region and to contribute nationwide goals of economic development and social stability.

The GAP Region has a share of about 10 % in both the total population and geographical area of Turkey (Fig 1). Yet, 20 % of total irrigable land in Turkey is in this region and the region represents 28 % of Turkey's total hydraulic potential mainly with the rivers Euphrates (Firat) and Tigris (Dicle).

Electricity Studies Administration (EIEI), founded in 1935, in 1936 started establishing flow inspection stations over Fırat, Keban and Kemaliye region. Similar stations were set up in 1945 over Dicle and Diyarbakir. The data and newly established (1954) State Hydraulic Works (DSI) planning were the important step to built set of dams on the Firat and the Dicle Rivers.

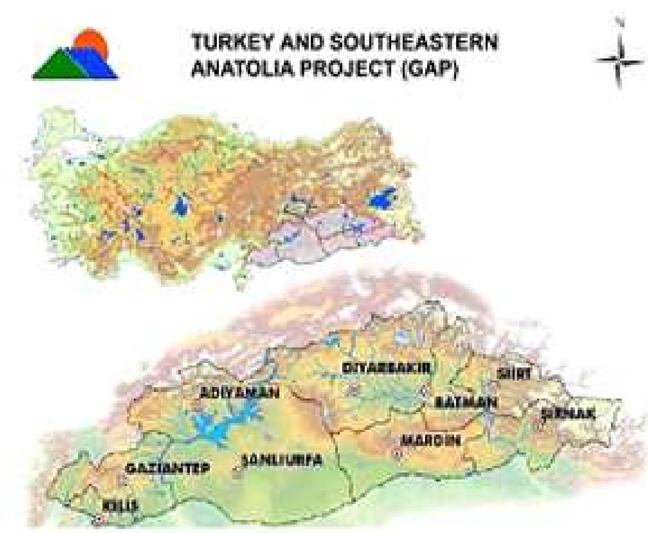

Fig. 1. Turkey and Southeastern Anatolia Project, GAP

	Turkey	GAP	GAP/Turkey
Total Area (km^2)	780.000	75.000	%9.7
Population (million)	70	6.8	%9.7

The cascade of dams on the Fırat River is shown in Fig 2. The construction of main body foundation of Keban dam started in 1966; it was put into service in 1974. It is one of the most important establishments with 1330 MW power plant, productivity of 6 TWh/year, and 14 billion m^3 of active storage (Fig3). Later Karakaya and Atatürk dams were built for the electricity production and irrigation purposes (Fig 4 and 5). Water taken from the reservoirs of both dams is used for gravity irrigation.

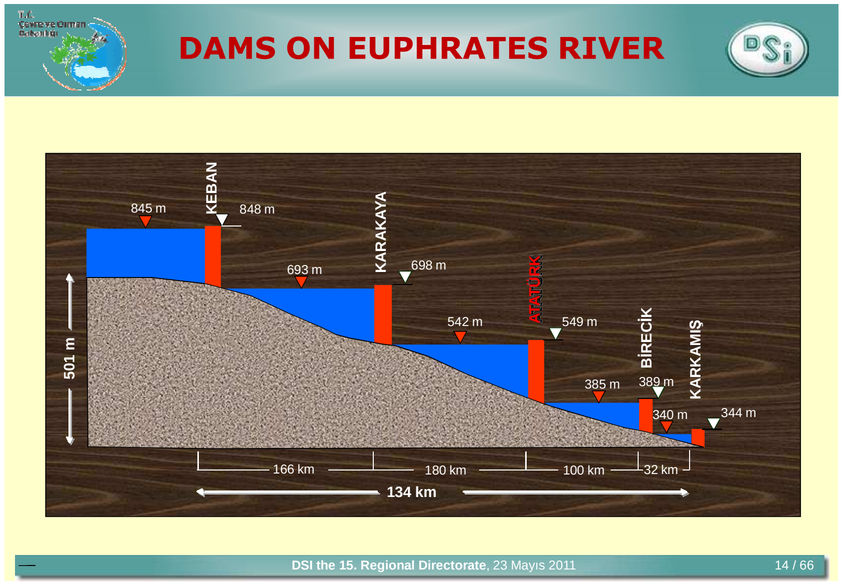

Fig. 2. Cascade of dams on the Firat River

Fig. 3. Keban Dam on the Firat River

In 1968 DSI started building dams on the Dicle River also, planning 20 dams of various dimensions and irrigation of 190 000 ha land; by means of 16 power plants having total 770 MW installed capacity, 3,9 TWh/year electric energy is produced (Fig 6).

Nowadays, The Southeastern Anatolian Project (or GAP) is not only water and soil sources development project, it is described as an integration development project affecting the economic and social life of the region. Tables 1 and 2 show projects and units at the Firat and Dicle river basins. Table 3 shows all the dams and hydro-electric power plants in operation and under construction. At the moment 21% of Turkey hydroelectric energy potential and 20% of irrigation potential were supplied from GAP.

RESERVOIR AREA : 26 800 ha

TYPE : Gravity Arch Dam

CREST LENGTH : 462 m

CREST ELEVATION : 698 m

HEIGHT (from thalweg) : 158 m

HEIGHT (from river bed) : 173 m

ANNUAL GENERATION : 7,5 billion kWh

Fig. 4. Karakaya Dam and HEPP

GAP guides the development of other sectors such as urban-rural infrastructure, agricultural substructure, transportation, industry, education, health, housing and tourism. This project covers all or some parts of Gaziantep, Adıyaman, Şanlıurfa, Diyarbakır, Mardin, Siirt, Batman, Şırnak and Kilis cities. According to the results of 2010 census, about 10% of Turkey population lives in these cities.

TYPE : Rockfill with clay core

CREST LENGTH : 1 664 m

CREST WIDTH : 15 m

CREST ELEVATION : 549,00 m

RESERVOIR AREA : 817 km2

HEIGHT (from river bed) : 169 m

VOLUME of EMBANKMENT: 84,5 million m3

ANNUAL GENERATION : 8,9 billion kWh

Fig. 5. Atatürk Dam and HEPP

DAMS ON TIGRIS RIVER

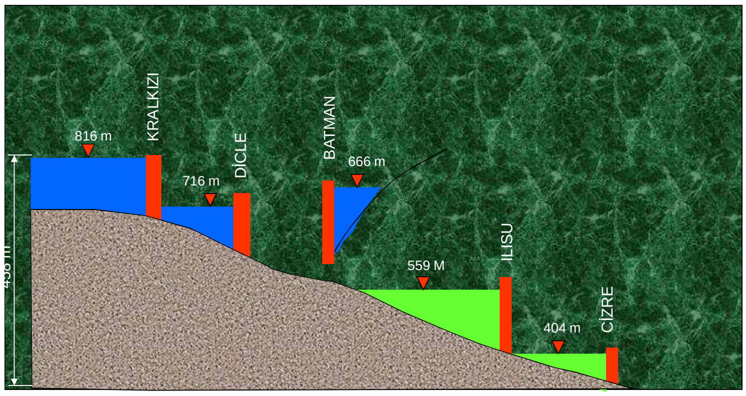

Fig. 6. Dams on the Dicle River

Table 1. Projects and units at Fırat Basin

EUPHRATES BASIN

N	Project and Unites	Installed Capacty (MW)	Energy Generation (GWh)	Irrigation Area (ha)
1	Karakaya Dam and HEPP	1 800	7 354	-
2	Lower Fırat Project	2 450	9 024	718 844
3	Border Fırat Project	852	3 168	-
4	Suruç – Yaylak project	-	-	113 136
5	Adıyaman Kahta Project	195	509	78 134
6	Adıyaman-Göksu-Araban Project	7	43	71 598
7	Gaziantep Project	-	-	144 064
Individual Projects		14,4	42	65 615
	TOPLAM	5 318,4	20 140	1 191 391

Table 2. Projects and units at Dicle Basin

TIGRIS BASIN

N	Project and Unites	Installed Capacty (MW)	Energy Generation (GWh)	Irrigation Area (ha)
1	Kralkızı – Dicle Project	204	444	130 159
2	Batman Project	198	483	37 351
3	Batman – Silvan Project	240	964	245 372
4	Garzan Project	90	315	60 000
5	Ilısu Project	1 200	3 833	-
6	Cizre Project	240	1 208	121 000
Individual Projects		-	-	35 773
	TOPLAM	2 172	7 247	629 655

Discharges of the Dicle and Firat rivers change excessively from year to year and from season to season and that caused big floods and droughts in all the basins (Turkey, Syria and Iraq) before the construction of dams in Turkey, but now they all are under control.

Water economy in GAP

Using limited water resources for different purposes out of irrigation and continuously increasing water demand for other purposes compel the conservation of water for the irrigation purpose. Requirement of long tunnels, conveyance canals and high altitude pumps to transmit water to irrigation area makes water economy obligatory in irrigation. Since water will be important in the following years, the necessity to use available water rationally has been observed. Due to the soil and topographic conditions, sprinkler irrigation was applied in Yaylak Project and Bozova Pumping Irrigation Project irrigated with water taken from Atatürk Reservoir by the means of Yaslıca Tunnel (Fig 7). As the network system equipped with high pressure pipes is operated according to the demand system, it was determined to design main canal with downstream controlled according to this operation system (Fig 8). Water level and discharge control or canal regulation are provided by tainted gates controlled electronically just near the gates.

Table 3. Dams and hydroelectric power plants at Fırat and Dicle Basins

DAMS				
DAMS IN OPERATION		***NAME***	ANNUAL ENERGY (GWh)	IRRIGATION LAND (ha)
	1	KARAKAYA DAM AND HEPP	7 354	-
	2	ATATURK DAM AND HEPP	8 900	882 000
	3	KRALKIZI DAM AND HEPP	146	
	4	DICLE DAM AND HEPP	298	130 159
	5	BATMAN DAM AND HEPP	483	37 350
	6	KARKAMIS DAM AND HEPP	652	-
	7	CAMGAZI DAM	-	8 000
	8	HANCAGIZ DAM	-	6 945
	9	CINAR-GOKSU DAM	-	4 234
	10	DERİK-DUMLUCA DAM	-	1 860
	11	HACIHIDIR DAM	-	2 080

	12	DEVEGEÇİDİ DAM	-	10 600
	13	BIRECIK DAM AND HEPP	2 516	107 901
	14	CAG CAG HEPP	42	-
	15	KAYACIK DAM		13 680
	16	SANLIURFA HEPP	124	-
	17	SEVE DAM	-	1 400
		TOTAL	20 515	1 204 809
UNDER CONSTRUCTIO N	1	ILISU DAM AND HEPP	3 833	-
	2	ERKENEK HEPP	43	-
		TOTAL	3 876	-

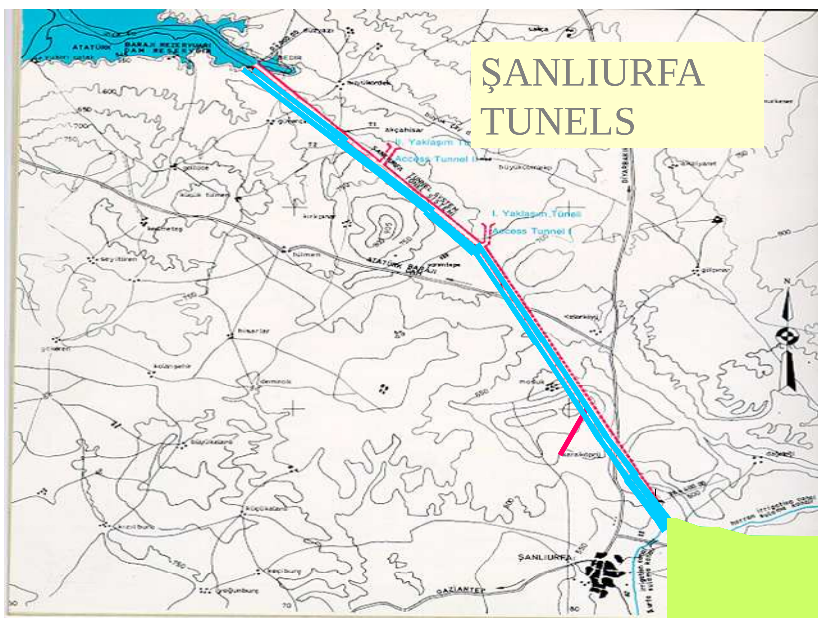

Fig. 7. Tunnels between Atatürk Dam and Şanlıurfa

TYPE : Circular Section

TUNNEL LENGTH : 26,4 km (2 units)

Tunnel Excav. Diameter : About 9,50 m

EXCAVAT. VOLUME : 3.00 hm3

CONCRETE VOLUME : 1,285 hm3

TOTAL DISCHARGE : 328 m3/s

Fig 8. Water Canals for agricultural purposes

Southeastern Anatolian Project: Sustainable Regional Development Model

Southeastern Anatolian Project (GAP) is a human centered regional development project targeting the full fledged socio-economic development of Southeastern Anatolia. As a project adopting the principle of sustainable development, GAP covers investments in such areas as rural and urban infrastructure, transportation, industry, education, health, housing, tourism and other sectors in addition to dams, hydraulic power plants and irrigation schemes on the rivers Euphrates and Tigris. The Project has the main challenge of substantially improving the life quality of the people and closing the development gap existing between this particular region and the other regions of the country. Thus, GAP is becoming a focus of attention for the world not only for its technical characteristics and physical magnitudes but also for its humanitarian and innovative approaches. The project started to bring benefits to people of the region by generating employment, raising income levels and expanding the service capacity of urban and rural centers. It was observed that farming services on land opened to irrigation have been developed by farmers, parallel to increased economic level of farmers. For this reason, by the means of Irrigation Unions founded on land opened to irrigation, it is possible to give information and guide farmers about development of farming services. After introducing irrigation, cotton, corn and wheat agriculture were started intensively on Harran Plain (Fig. 9). The tests done in firstly Research Institutes of Agriculture and Village Affairs Ministry, Çukurova and Harran Universities, showed that fruit trees (especially almond, plum, apricot, pomegranate) can be grown if irrigation is applied to region. DSI continues its research on land consolidation, development of farming service, pond fishing and organic agriculture on dam basins with Agriculture and Village Affairs Ministry and related organizations in a good relationship.

Fig. 9. Cotton field

In summary we can consider Southeastern Anatolian Project to be a project for Human Development providing multipurpose community centers, social development projects for youth, public health project, rural development project, beside irrigation and electric power

Hydropower in Bangladesh: Prospects of Regional Collaboration

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Introduction

Hydropower is an important component of renewable energy. Before we discuss aspects of use of hydropower, it would be prudent to present a comprehensive Energy Conversion Matrix as given below in Fig 1.

Energy Conversion Matrix

TO ↓ FROM →	ELECTROMAGNETIC	CHEMICAL	NUCLEAR	THERMAL	KINETIC (MECHANICAL)	ELECTRICAL	GRAVITATIONAL
ELECTRO MAGNETIC		Chemiluminescence (fireflies)	Gamma reactions (Co^{60} source) (A-bomb)	Thermal radiation (hot iron)	Accelerating charge (cyclotron) Phosphor*	Electromagnetic radiation* (TV transmitter Electroluminescence	Unknown
CHEMICAL	Photosynthesis (plants) Photochemistry (photographic film)		Radiation catalysis (hydrazine plant) Ionization (cloud chamber)	Boiling (water/steam) Dissociation	Dissociation by radiolysis	Electrolysis (production of aluminum) Battery charging	Unknown

NUCLEAR	Gamma-neutron reactions $Be^9+\gamma \rightarrow Be^8+\eta$	Unknown		Unknown	Unknown	Unknown	Unknown
THERMAL	Solar absorber (hot sidewalk)	Combustion (fire)	Fission (fuel element) Fusion		Friction (brake shoes)	Resistance-heating (electric stove)	Unknown
KINETIC	Radiometer Solar Cell*	Muscle	Radioactivity (alpha particles) A-bomb	Thermal expansion turbines) Internal combustion (engines)		Motors Electrostriction (sonar transmitter)	Falling objects
ELECTRICAL	Photoelectricity (light meter) Radio antenna Solar cell*	Fuel cell* Batteries*	Nuclear battery*	Thermoelectricity* Thermionics* Thermomagnetism* Ferroelectricity*	† MHD* Conventional generator		Unknown
GRAVITATIONAL	Unknown	Unknown	Unknown	Unknown	Rising objects (rockets)	Unknown	

Fig. 1

This Energy Conversion Matrix reflects the interdisciplinary nature of Energy transformation and focuses both renewable and non-renewable energy matrix elements. Hydropower is one such element realized in the transformation of kinetic energy of water into electric energy (Magnetohydrodynamics).

Hydropower in its different forms including that involved in agriculture has been as old as civilization itself. Its share in the production of electrical energy world wide has been mounting.

The use of hydropower as a percentage of total renewable energy used globally is shown in fig. 2. It was more than 63 percent in 2005. This number has further increased.

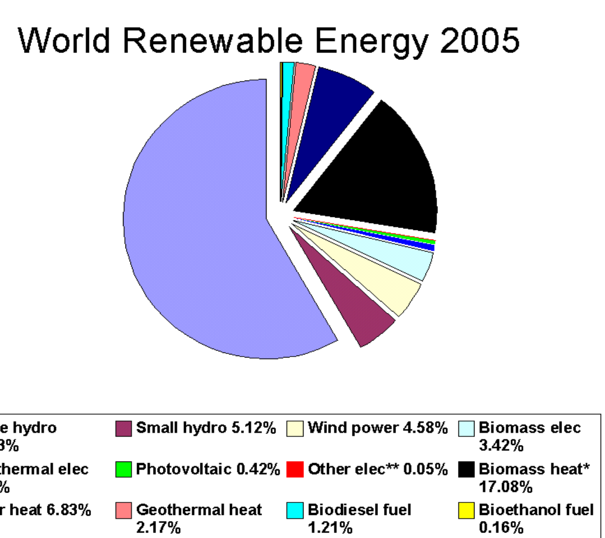

Fig. 2

Incidentally, it must be mentioned that the estimated renewable hydro energy potential is 460 billion kwh per year but at the present time less than 10 percent of this potential is used. It is interesting to note that while I talk of hydropower in Bangladesh, Kyrgyzstan accounts for 22 percent of the region's total hydro potential in managing water resources and energy production. The global hydro power is 675,000 MW, approximately 20% of the world's electricity. It is worthwhile noting that the percentage of hydropower in relation to total power production in Bangladesh is a mere 5%. However, since the power production is far below the existing and hidden demands, the percentage of hydropower will drop further with the fulfilment of energy needs form other sources.

2. Hydroelectric Power Plant in Bangladesh

The Hydroelectric Power Plant in Bangladesh started functioning in 1962.

The construction of the Kaptai dam and Karnafuli Multipurpose project started in 1957 with export credit / assistance administered by USAID to the then Pakistan. The Kaptai dam was supposed to provide 'benefits' in terms of hydropower, flood control, irrigation and drainage and navigation. It was commissioned in 1962. The Dam initially had two hydropower units with a total capacity of 80 MW. Currently, the dam has five units with a total capacity of 230 MW and it produces approximately 5% of the electricity in Bangladesh. The table below shows the basic features of the dam.

Table 1. Basic features of the Kaptai dam

Feature	Size/type
Body of the Dam	Earth

Length	670.6 m
Height	45.7 m
Crest width	7.6m
Maximum water level	33. 5 [110 feet above mean sea level (MSL)]
Minimum water level	20.1 m (66 feet MSL)
Capacity 33 m MSL	6477x 10 6 m3
Reservoir at 33 m MSL	777 km2
Spillway length	227 m
Maximum spillway discharge	16 000 cumecs
Installed capacity (five units)	230 MW

Plan for extension

The Bangladesh Power Development Board (PDB) has recently announced a plan to install two new hydropower units, 50 MW each, in the dam. These units are to be installed with financial assistance from Japan Bank of Investment Corporation (JBIC), in the form of a 30-year soft loan. According to the PDB officials, these new units will be operated using the excess water that is released through the spillway. And they can do it using the current rule curve. It has to be maintained that the current rule curve was last revised in 1981 before installing the third unit and the rule curve needs updating.

However, a social impact assessment (SIA) has been conducted which favours the implementation of the project in consultation with the local people.

2 (a) Some Social Problems Created Earlier by the Kaptai Dam

According to a study by Kibria1, an area of 655 sq km (Faisal and Pervin2) was flooded by the dam; 22,000 ha of cultivable land which was 40% of all such land in the CHT was inundated. Because of the reservoir 18,000 houses were submerged and 100,000 indigenous people were displaced ; 70% of these people were Chakma. The Rangamati town and the palace of the Chakma Raja (king) were also submerged. The majority of the displaced people which constituted 25% of the local population were rehabilitated on the upper reaches of the rivers Kasalong and Chengi during the early phases of the project. In reality, the displaced people, “environmental refugees” as they called moved to the low-lying areas of Langdu, Barkal and Bhagaichori which also went under water in 1962 with the filling up of the reservoir. This caused a second displacement of the people.

40,000 of the displaced people went to the Indian States of Mizoram, Tripura, Assam and Arunachal Pradesh and 20,000 went to Burma. Thus, there was an exodus of people which the Chakma people called Bara Parang (great Exodus). All Arunachal Pradesh Students’ Union (AAPSU) made systematic attempts to drive out the displaced people of Kaptai settled in Arunachal Pradesh. This they did despite the Indian Supreme Court directives against the drive (Chimni3 , 2000).

2 (b) Environmental problem

The reservoir submerged a vast area of vegetation with rich bio-diversity. The reservoir was home to a number of flora and fauna including many marine species. Platanista gangetica or the dolphin is an endangered species according to IUCN. These dolphins which have been reported from Kaptai reservoir are no longer observed. Thus because of the dam, an environmental price had to be paid. Further, silt is being gathered in the reservoir and a systematic study is yet to be undertaken of the loss of biodiversity and the degradation of the reservoir.

Small hydro

The Engineers of Power Development Board of Bangladesh made some studies with the help of Chinese experts for finding out possibilities for mini or micro hydro power utilization in Bangladesh. It was found out that small hydro projects will be economically viable if combined with an integrated project of flood control, irrigation, tourism etc.

12 sites which have some prospects for installing 2 Kw to 65 Kw micro hydro power plants have been identified in the hill districts of Chittagong. These sites are :

Nunchari (3KW) in Khagrachari, Chang-oo-Para (30KW), Liragaon (25KW), Bangchari (20KW), Kamal Chari (20KW), Monjai Para (7.5KW), Monjaipara (10KW) in Banderban, Thang Khrue Chara Mukh (30KW), Manikchari (2KW), Mitingachara (10KW) in Rangamati and Bamerchara (3KW) and Mohamaya Char (65KW) in Chittagong.

There has been a growing appreciation amongst the members of the public that the conversion efficiency from natural resources to electricity is 85% to 90% for hydropower compared to 20 to 30% for fossil fuels, nuclear and geothermal sources. There is a global demand for hydropower because of its minimal environmental impact except for land submergence under reservoir. Micro hydropower units are found to be cost effective with the possibility of providing an attractive means of rural electrification, power supply to irrigation, drainage pumps and cottage industries.

Sangu river:

Studies have shown that by constructing a dam on the river Sangu at Tarasa Chara location and building a reservoir with a surface area of 32,500 acres a capacity of 1900,000 acre-ft, power generation of about 82 MW at this site could become a possibility.

Matamuhuri river:

A compacted earth-filling dam is considered to be feasible at Champatoli over the Matamuhuri River with an installed capacity of 17,500 Kw.

Teesta Barrage project:

The Teesta Barrage project built in 1990 with regulating structure holds promise of generating 125 million kWh of electrical power. There are at least 19 potential sites of hydropower generation in the Teesta Barrage maintaining head difference of even one metre because of enormous discharge available here. At least for six months in a year around the monsoon season, power can be generated in these sites.

Ganges/Padma Barrage:

Bangladesh has a plan to construct Ganges/Padma Barrage to store a part of monsoon flow for use in dry season. This proposed barrage has a good potential for generating hydro power.

3. Regional Collaboration

So far we have discussed the hydropower situation in Bangladesh. With the addition of the units in the Kaptai hydro plants, there will be a scope of generating another 100 MW. The micro hydro plants which can be installed will act as sources of power in the hilly districts of Bangladesh. Altogether, the hydro potential in Bangladesh has a limited potential and attempts are being made to use it as far as possible.

There is, however, a far greater hydro potential in the neighboring countries of Bhutan and Nepal. The hydro electric installed capacity, as of 2006, has been 468 MW (5% of the total potential) without the one al Tala. The status of hydropower development of Bhutan, according to 2006 data can be summarized as follows:

Status of Hydropower Development in Bhutan

Hydro Plant	MW/GWh	Remarks
Chukha	336/1860	1986-88
Kurichhu	60/400	2001
Basochhu I	24/106	2001
Basochhu II	40/186	2004
Tala	1020/4866	Sept. 2006-Dec.2006
Mini/Micro	8.068/24	1967-2005
Total:	1488.068/7442	~5% of total

The total hydro plant potential of Bhutan is 30,000 MW of which 23,760 MW is economically feasible. The point about hydropower that needs to be mentioned while discussing

Bhutanese Hydropower is that hydropower plants can be of two types (a) Run of river plants (b) storage plants. Hydropower plants in Bhutan are mainly run of the river schemes. All major rivers in Bhutan flow through deep valleys. Thus, hydropower projects in Bhutan have had minimum environmental impact; there have been minimum and/or no displacement of people during in the Project Area. Thus there is no reason why the hydropower of Bhutan should not be thoroughly exploited especially when it is environmentally benign.

Next we talk of hydropower in Nepal. Talking of hydropower in Nepal, I feel tempted to recount a story. As President of Bangladesh-Nepal Friendship Association, I was leading a delegation to Nepal in 1975. We made a courtesy call on the Nepalese Prime Minister and during our discussion, the energy issue came up. Already, in the early seventies, the Oil Crisis had begun. The Prime Minister while talking of Nepalese topography said "Nepal is such a country that if you are riding on a horse on a mountain way, one of your feet will be brushing against the mountain and the other will be hanging in the air". This gave us a clear idea about the steepness of the mountains and the valleys. The interesting thing about Nepalese hydropower is that it contributes to 90 (ninety) percent of total energy generation. Whether it is a large hydro plant (>300 MW), medium plant (10-300 MW), small plant (1-10MW), micro plant (upto 1 MW), the Nepalese Govt emphasis has been to use hydropower to close the energy gap between urban and tribal areas.

Interestingly, talking of micro Hydropower Projects in Nepal, a recent study by Zaman, Chhetri and Tango[4] has shown that 95% of the hourly excess electrical energy generated in a micro hydro plant can be converted to H_2 through electrolysis with 75% conversion efficiency. Thus, the micro hydro plant may be considered as the most promising technology for small scale Hydrogen production. It is even more interesting to note that the first (and the lightest) element Hydrogen and the last (and the heaviest) naturally existing element Uranium in the Periodic table are both sources of energy.

It is worthwhile noting that the hydro-potentials of Bhutan and Nepal amount to almost 70,000 Magawat. Very little of this has been tapped (<5%). In view of the proximity of Nepal and Bhutan to Bangladesh, if would be quite in order to for these countries to have collaborative pacts of hydropower generation and utilization involving multi country funding and international finances if necessary. The vast potential of economically feasible hydropower, if utilized and shared between neighboring countries, will contribute to an accelerated economic development of all the countries.

India itself has a hydro potential of 84000 MW. But India's demand is also quite high in view of its huge population. India is recently wanting to set up Tipaimukh Dam for power production of 1500 MW at a site not far from the northern district of Sylhet in Bangladesh. This project has come under protest from within India and also from Bangladesh in view of the risk of dam failure and its impact on the Haor ecosystem. In spite of the excellent friendly relationship of Bangladesh and India, the water sharing issue between these countries has become a bone of contention. The sooner the water issue is resolved, the better it is for both the countries.

4. Conclusion

Hydropower is a site-specific issue and calls for people's participation both before and during implementation of the hydro project with due regard for environmental issues including earthquake consideration. The environmental impact would depend on whether the hydro plant is a run-of-river plant or whether it is a storage plant. The storage plant causes displacement of people which has to be handled with care and caution. Despite the fact that hydropower is a clean and cheap method of power production, the scope for hydropower generation is quite limited in Bangladesh because of topography. The tremendous untapped hydro potential in Bhutan and Nepal can be utilized and shared with Bangladesh. The Fellows of the Academies of Sciences in the region because of their high distinction in science and technology and their social image are expected to wield their intellectual power in prevailing upon the governments of the SAARC (South Asian Association for Regional Co-operation) countries to call for greater cooperation in the area of hydropower utilization.

One more interesting thing would be to form an association of hydro-engineers under the auspices of AASA. Kyrgyzstan which has also a great hydro prospect can take a lead in activating such a team of hydro-engineers and ecologists in Central Asia who can offer training and advice to the technical people in the countries of the region. This could act as a great platform for fostering further cooperation and understanding in the overall economic development of Central Asia.

References

1. Zakir Kibria, the Dam at Kaptaimukh in Bangladesh Proposed Extension Plan and Issues of (non) compliance, Dam and Development Project (DDP) Works " Addressing Existing Dams", June 14-16, 2004, United Nation Environmental Prgamme (UNEP, Nairobi, Kenya).
2. Faisal IM & Parveen Saila, " People versus Power, the Geopolitics of Kaptai Dam in Bangladesh" in Water Resources Development vol. 18, No. 1, p 197-208, 2002, Carfax Publishing.
3. Chimni, BS (ed), International Refugee Law: A Reader, Sage Publishing, 2000, New Delhi, India
4. M. S Zaman, A.B. Chhetri and M.S. Tango, Proceedings of the 2010 International Conference on Industrial Engineering and Operation Management, Dhaka, Bangladesh, January 9-10, 2010.

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Water and Energy: Issues and Solutions in the Indian Subcontinent

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Abstract

The Greater Asian Basin that includes Central Asia has acute water and energy scarcity which are intimately linked in myriad ways. The way people use water takes energy; the way modern society produces energy consumes water. In the United States, about 4 percent of power generation is used for water supply and treatment. In other parts of the world, the fraction of electricity produced that is utilized for some form of water delivery/extraction/purification is even higher. For example, in Northern Gujarat in India, as much as 58 percent of the electricity produced by UGVCL (the local utility that serves approximately 9 million people) is used to pump groundwater for agriculture. While India, (along with parts of China) are prime examples of regions that using electricity to simply pump limited groundwater, there are parts of the world where groundwater is already so depleted that governments find themselves forced to resort to far more energy intensive methods of obtaining fresh water. For example, governments from California to Israel to Saudi Arabia are turning to massive desalination projects as a holy grail to solve persistent water problems. But as a 2007 report by the California Public Utilities Commission pointed out, "Producing fresh water from sea water by desalination is a highly energy intensive process and should be utilized only when no other economical water supplies are available. According to the commission, Catalina Island, off the coast of Southern California, produces 25 percent of its fresh water from desalination–but that same desalination accounts for nearly 70 percent of the island's energy use. Generally desalination is so energy intensive that it does not pay off to use desalinated water for agriculture. The challenge of the energy-water nexus in a time of climate change and increasingly scarce resources is to design solutions that always take water, energy and the relationship between the two into account, and avoids single-focused, isolated and potentially counterproductive interventions. In order to establish resources base, a consistent and persistent competition over water and energy resources is anticipated in future between farming families and urban dwellers, environmental conservationists and industrialists, minorities living off natural resources and entrepreneurs for commercial gains. More than four billion people worldwide live in regions facing water and energy scarcity particular in the Indian Subcontinent where this is a particularly acute crisis. A huge percentage of people lack access to clean drinking water. Indian Subcontinent demand for water is growing at an alarming rate which is expected to overtake China's by 2050 when it reaches a staggering 3 billion. A rapidly growing economy and a large agricultural sector stretch supply of water even thinner. Meanwhile, region's supply of water is rapidly dwindling due primarily to mismanagement of water resources. Climate change is expected to exacerbate the problem by causing erratic and unpredictable weather, which could drastically diminish the supply of water coming from rainfall and glaciers. Region will face a slew of subsequent problems, such as food shortages, intrastate, and international conflict. Extremely poor management, unclear laws, government and institutionalized corruption, and industrial and human waste have caused this

water supply crunch and rendered what water is available practically useless due to the huge quantity of pollution. Nepal is one of the poorest nations in the world and is economically linked to

India because of its geographic situation. However, Nepal's water wealth is enormous. Several studies revealed that 89 sites within Nepal are potentially capable of producing 30 gigawatts of hydroelectric power to energy starved region. The initial feasibility studies on the Karnali project failed to take into account: the impact of this product on financial feasibility and its sociological impact on Nepal. Another issue of contention for Nepal was that during their negotiations, India denied or gave lip service to issues surrounding irrigation and flood control. The idea of a 'water war' between India and Pakistan is being deliberately drummed up. In this regard, Pakistan is likely to pursue the three strategies at national (within Pakistan), bilateral (with India) and international levels. Strategy 1: Blame India for Pakistan's Water problems Strategy 2: Object to each and every Indian Project Strategy 3: Internationalize the Water Issue and Replace 'Kashmir Issue' with 'Water Wars.' This paper will address and discuss the issues surrounding GAB's water and energy scarcity: demand and supply, management, pollution, impact of climate change, and solutions the governments may consider developing policies to alleviate the water and energy scarcity in the GAB.

Water issues play a crucial role in Central-South Asia, both in the quantity of water available and its quality. Access to clean drinking water is a major, though largely unmet, objective. While much of the region is experiencing water shortages, poor water management lies at the heart of many problems. Climate change — in the form of glacier melt, drought, rising temperatures, and changes to the monsoon cycle — will increasingly exacerbate water scarcity. Although the region's water challenges do not necessarily or inevitably lead to armed conflict, they increasingly threaten to undermine human security. Cooperation will be critical for the region to meet its water challenges in the years and decades ahead.

Inefficient water use plagues Central Asian agriculture and water use in the region is several times higher than in countries like Spain, Turkey or Egypt. Hydropower projects conflict with irrigation needs which, in the absence of regional agreements, could lead to transborder disputes.

Millions of Afghans are food insecure and these desperate conditions have triggered local-level conflicts over land and water. In Pakistan, a combination of rising temperatures and population growth could reduce water availability to a critically low level by 2020. Water pollution is a leading cause of death in both Pakistan and Afghanistan. Solutions must address efficient water use and international funding is urgently needed to improve agricultural production. Existing institutions can contribute to seeking solutions and promoting regional cooperation, especially if they engage with civil society.

Water issues play a crucial role in Central-South Asia, both in the quantity of water available and its quality. For the purposes of this brief, the region is defined as encompassing the Amu Darya and Indus water basins and their tributaries —Afghanistan and Pakistan in relation to their neighbours India, Tajikistan, Turkmenistan, and Uzbekistan. (See maps on pages 3 and 5.) Competing water use plans pose critical challenges under conditions of environmental degradation, demographic pressure and rising demand for water. Both within and among the riparian states, there is fierce competition between irrigated agriculture and energy generation (hydropower).

Access to clean drinking water is a major, though largely unmet, objective. While much of the region is arid or semi-arid, poor water and watershed management lie at the heart of many problems. Much of the region is already experiencing physical water shortages or approaching such a state. (See table below.)1 Climate change — in the form of glacier melt, drought and shifting precipitation patterns, rising temperatures, and changes to the monsoon cycle — will increasingly exacerbate water scarcity.

The region's water challenges do not necessarily or inevitably lead to armed conflict. Unalleviated, however, they increasingly threaten to undermine human security and to bring different communities and regions into dispute with each other. While there are some positive regional experiences in managing transboundary resources — the Indus Water Treaty between India and Pakistan most prominent among them — cooperative approaches have been sparse and institutional structures remain fragmented and weak. Yet cooperation will be critical for the region to meet its water challenges in the years and decades ahead.

Water Resources and Usage in Central and South Asia

	Precipitation (mm/year)	**Total Renewable Water Resources per Capita (m3/year) a**		**Dependency Ratio b** (%)	**Proportion of Renewable Water Resources Withdrawn C** (%)
	Long-term Avg	**1990**	**2006**		
Afghanistan	350	*5,135*	2,492	15	36
India	1,100	2,205	1,647	34	34
Pakistan	500	1,994	1,400	76	75
Tajikistan	700	2,896	2,407	17	75
Turkmenistan	150	6,363	*5,045*	97	100
Uzbekistan	200	2,344	1,868	77	116

a The sum of internal and external renewable water resources. It corresponds to the maximum theoretical yearly amount of water actually available for a country at a given moment.

b Water resources originating from outside the national territory**,** relative to total water resources.

c Water used for all purposes.

Some 178 million people in the densely-populated Indus basin inhabit an area of 1.1 million km2 *(145* people per km2). Recent studies estimate per capita water availability at around 1.000 m3 per year. Population size and density in the 535,000 km2 Amu Darya basin are much lower (21 million people; 33 people per km2). and water availability runs to more than 2,000 m3. Both basins have suffered heavy loss of original forests and the majority of the watershed areas.

Afghanistan Water Issue

Millions of Afghans are either seasonally or chronically food insecure. Beyond hunger, these desperate conditions have also triggered local-level conflicts. In an Oxfam survey in six provinces across Afghanistan, nearly half the respondents regarded land and water issues as major causes of disputes.

Water contamination in Afghanistan has risen to the level of a severe public health threat that sick- ens or kills people, owing to poor household and industrial waste management practices, and the lack of modern sanitation and sewage systems. A 2003 United Nations Environment Programme (UNEP) assessment concluded that "reliable access to a safe water supply is virtually non-existent in Afghanistan's urban areas." Access to safe water is estimated at no more than 12 to 23% of the urban population.3 Similarly, only one-third Afghans in urban areas have access to improved sanitation, and only one-tenth in rural areas. The nations sharing the Amu Darya are locked into seemingly irreconcilable sets of interests. Tajikistan and Afghanistan look to the Amu Darya for hydropower as well as irrigation.

Even though Afghanistan's proposals are far less ambitious than Tajikistan's, they nonetheless have aroused opposition from Turkmenistan and Uzbekistan. Afghanistan has not been included in any of the post-Soviet water management structures and institutions in Central Asia. There are no bilateral water agreements, and only Tajikistan has (since 2006) engaged in serious dialogue with Afghanistan.

Indus Watershed

The melting of the Hindu Kush-Karakorum-Himalaya glaciers will have serious consequences for hundreds of millions of people. The warming trend in these mountain ranges has been much greater than the global average. As a result of rising temperatures, more precipitation falls as rain instead of snow, leading to shrinking glaciers. Two thirds of the Himalayan glaciers are reported to be receding. Glaciers in Tajikistan have shrunk by a third in the second half of the 20th century. The Kolahoi, Indian-controlled Kashmir's biggest glacier, is melting faster than other Himalayan glaciers, from 11 km2 to 8.4 km2 over the past three decades. Kolahoi is the principal source of water for the Thelum River, which is the main source of water for agriculture in Pakistan's Punjab province. The Siachen glacier — site of an Indian-Pakistani military standoff for 25 years has shrunk to half its size. Glacier melt at first results in increased water flow in the summer months. The International Centre for Integrated Mountain Development (ICIMOD) — a regional knowledge development and learning centre — warns: "It is not unlikely that this will appear as a positive, comforting sign, deterring and delaying required emergency initiatives." However, receding and eventually disappearing high-altitude reservoirs of snow and ice will over time reduce downstream runoff, and increase its variability.9 As the water flow declines, it compromises hydropower generation. In the agricultural sector, the result is falling production of foodstuffs and commodities like cotton, which in turn may lead to growing poverty and social disparities, escalating rural-urban migration, and rising food prices in cities. There is also potential for conflict between up- and downstream states.

Climate change is also expected to cause significant changes to monsoon patterns and increase unpredictability. While much of South, East, and South-East Asia may see increased intensity of these storms and greater rainfall by century's end, for most parts of Pakistan and southeastern Afghanistan a reduction in precipitation of up to 20% is projected. Low-lying coastal areas such as the Indus delta will likely see an increase in the number and intensity of cyclones due to warmer seas. The resulting destructive storm surges and greater saltwater intrusion could drive migration from major coastal urban centers such as Karachi. Flooding is expected to increase across the Himalayas, as well as northern Pakistan and India.

India's – Energy Problems and issues:

India, along with many other developing countries and most Western countries, has been in the grip of the worst ever energy crisis since 1973 when oil-producing countries increased oil prices manifold. This price increase upset the economies of most of the advanced and developing countries as oil constitutes one of the basic ingredients of industrial base. Even though India's fuel needs are smaller than those of the advanced countries, the country's import bill for getting this limited quantity is now eating away a large chunk of its scarce foreign exchange resources. No wonder, the country is devoting greater attention to the development of alternate sources of energy.

If 1973 was the year when the Arabs had the Western world tumble over a barrel of oil, it was1974 which witnessed in the whole world a slowdown in production, growth and unprecedented pay and price rises. Interest rates reached new dizzy heights which prompted some skeptics to talk about a possible collapse of the world's banking and monetary systems. It was the year when gold came close to S 200 an ounce. The oil crisis which broke out in the late 1973, took a more moderate shape in 1974, than was initially feared, but it shattered the hopes of a quick economic recovery in most, countries. The four-fold increase in oil prices had a depressing effect on the pays and price increases in the developed world although their direct impact on the cost of living index \\it> generally limited to a few percentage points. As a result, the specter of hyperinflation still menacingly looms on the economic horizon of the world. The 15-year perspective plan for the development of coal, oil and power drawn up by the Fuel Policy Committee lays emphasis on the use of coal and suggests a total ban on the use of fuel oil by the, industry and elimination of naphtha as feedstock for fertilizers. In the switch-over to coal, the report cautions over-enthusiastic approach as some of the conversion schemes required heavy investment and the availability of oil might improve in the years, to come. In effect, it lowers down the targets of the projects being pursued by the Steel and Mines Ministry like conversion of coal to oil and coal gasification on a large scale. The report estimates crude reserves both off-shore and onshore in the country of about 128 million tonnes. It estimates that there is more oil reserve in Assam area (72 million tonnes) than in the Gujarat area (56 million tonnes). On power generation, the report suggested stepping up of hydro generation capacity from 13 million kwh at the end of the filth plan to 28 million kwh in 1980, nuclear power capacity from 1 million kwh to 8.6 million kwh and the thermal generation from 19.5 million kwh to 50 million kwh. It lays down" more emphasis on hydro generation and nuclear resources, particularly the development of thorium-plutonium line.

Based on the fechno-economic studies conducted jointly by ONGC and-the Soviet oil experts, the Commission has drawn up an ambitious programmer of exploration and production during the next five years and taken a perspective view of what should be done over the five-year period thereafter. The main thrust of the Commission in on-land exploration appears to lie in intensifying exploration in such promising areas as Tripura and Assam as well as in drilling, deep exploratory wells in Northern India, including West Bengal and Ganges Valley. The Commission is acquiring the capability to drill deep exploratory wells by obtaining suitable drilling rigs from Rumania and the U.S. The exploratory work-in Cauvery basin is also being strengthened by extending drilling places like Mandapani and by reinterpretation of all available geological and geophysical data. The best hopes towards self-sufficiency appear to lie off-shore. The results of the wells drilled on Bombay High are beginning to confirm these hopes. Surrounding the Bombay High is a number of peripheral structures whose prospects are enhanced by the discovery of oil in Bombay High.

The indigenous production of crude this year is estimated at 8.25 million tonnes as against 7.49 million tonnes of production in the previous year. India spends Rs. 1,124.87 crore for import of 1.4 million tonnes of crude and 2.9 million tonnes of petroleum products.

Power Shortage and the New Priorities : The shortage of electrical energy which has developed in some parts of the country during the last two years, has been retarding the rate of growth of the economy. Industrial production has, in particular, been affected. Experience would suggest that the sustained growth of the economy would require the availability of electrical power should always be somewhat ahead of demand. Power is upstream of most production activities and unless this lead is maintained, the economy would continue to be handicapped in its growth.

During the Fourth Plan period, it had been programmed that over 9 million kw of new generating capacity would be added. This target was realized only to the extent of 4.20 million kw. Naturally, an imbalance between demand and supply of electricity developed. This position became more difficult because of the inadequate monsoon rains in several of the important catchments feeding hydroelectric projects in 1972-73 and 1974-75. An analysis shows that, despite the failure of rains, the power demand could have been met if the Fourth Plan target of adding new capacity had been realized. The States which are most affected by power shortage today are Punjab, Haryana and Uttar Pradesh in the Northern region. Orissa in the eastern region, Karnataka, Tarnil Nadu and Andhra Pradesh in the Southern region, and Maharashtra in the Western region. The difficulties in Orissa and Maharashtra are the direct consequence of the poor monsoons in 1974. In the Northern region, the conditions of power shortage have been persisting for the past two years. In 1974-75,the Bhakra Project, which supplies electricity to Punjab and Haryana, has had the smallest inflows in its history, and the generation of power was only about 60 per cent of the previous year. In the Southern region, the main cause of the shortage in Karnataka is the fact that new capacity to meet the rapidly increasing loads has not been commissioned. In Tamil Nadu, besides inadequate capacity, the performance of ‘the Ennore Thermal Station is also not satisfactory. In addition, the difficulties in the mining of lignite at Neyveli have resulted in the underutilization of capacity in that state.

Pakistan – Strategy to Improve or Blame India

The 21st century was expected to be the century of economic and social development following the tumultuous 20th century which was dominated by the two world wars in its first half and the Cold War in the second. In the last decade of the 20th century that followed the end of the Cold War, there was speculation as to the process of change towards an age of peace and cooperation in the coming century that would also mark the beginning of the new millennium. The signs could not be regarded as promising as Indo-Pakistan relations deteriorated following the intensification of the movement for self-determination among the Kashmiri people. The extremist Hindu Party, BJP, rose to power in India and decided to go overtly nuclear by testing nuclear weapons in May 1998. Indian leaders then adopted an arrogant attitude towards Pakistan, with top BJP leaders demanding that Pakistan should vacate Azad Kashmir. Pakistan was compelled to conduct nuclear tests two weeks later to match India’s ability and gain strategic parity.

This development gave impetus to a dialogue to resolve the disputes between the two countries peacefully reflected in Prime Minister Atal Behari Vajpayee's bus journey to Lahore in early 1999. Though the Lahore Declaration announced a joint commitment to resolve their differences peacefully, the Kargil conflict in Kashmir virtually cancelled out the gains. It took two years to resume the dialogue at the Agra summit in July 2001. The events of 9/11 caused an interruption as India tried coercive diplomacy in 2001-2002 but the peace process started anew from January 2004, with all items of the composite dialogue being taken up. An additional water issue arose over the Baglihar Dam, which was referred to the World Bank in accordance with the Indus Water Treat. The decision on the Baglihar Dam issue announced by the expert named by the World Bank serves to underline the growing importance of energy and water issues between India and Pakistan. As the river Chenab had been allotted to Pakistan under the Indus Water Treaty of 1960, India is entitled to use its waters only to generate hydro-electricity. However, the design and construction of the projected dam at Baglihar were such that the storage of the water in the winter months could result in denial of water for irrigation to Pakistan. Traditional concepts of security had been concerned with threats to the independence of countries from major powers, or ambitious neighbors. The maintenance of adequate armed forces, equipped with the latest weapons, was considered a necessity. Since the end of the Second World War the national interests to be defended through diplomacy and the international system has come to include trade and economic interests for which freedom of the seas and other facilities have been developed over the years.

As the world's population has increased and there are growing demands on natural resources, particularly water and sources of energy, the limits of economic growth have been recognized along with the need to develop and sustain the essential ingredients for a rising standard of living all over the world. The industrial revolution gave its beneficiaries not only the capacity to increase their production but also the means to increase their military power so that they proceeded to acquire colonies as markets for their goods and as sources for raw materials during the 18th and 19th centuries.

The colonizing powers, located mostly in Europe, managed to reach agreement on their share in Asia, Africa and Latin America, However, late-comers like Germany manifested their dissatisfaction by waging wars. The two world wars in the first half of the 20th century compelled the establishment of the UN system to end the "scourge of war", and to foster economic and social development in all parts of the world. Though the Cold War limited any significant political gains by the rival super powers in the second half of the 20th century, most of the colonies won their independence and the UN agencies dealing with economic and social issues recorded significant gains. However, despite having lost their empires the developed countries kept increasing their wealth and share of the world's resources through their control of capital and technology, while most developing countries fell further behind.

As the disparity between the developed and developing countries grew, the larger problems of resource constraint began to make their presence felt owing to a combination of natural and man-made factors. Scarcity of water and energy had been forecast in the planet as a whole since the mid-20th century. The concept of sustainable development gradually began to preoccupy planners and economists as the attention of leaders and administrations alike turned to mobilizing natural resources to improve the life of their people. As the limits to the water supplies available for meeting competing demands were realized it began to be forecast that "future wars might well be fought over water resources". Asia, the continent containing over 60 per cent of the world's population, with 20 per cent each in China and the South Asian subcontinent, has potentially the most serious problem in this regard. It may be recalled that following independence in 1947, the issue of sharing the waters of the Indo-Gangetic water system arose and was resolved only through the good offices of the World Bank that promoted lengthy negotiations culminating in the Indus Waters Treaty of 1960.

This treaty was not viewed favorably by exponents of international law as it violated the principle of safeguarding the rights of lower riparians. India was able to press its case by taking the water resources of the Indus river system as a whole, and as there were canals from two eastern rivers, Ravi and Sutlej irrigating substantial areas in Pakistani Punjab, Pakistan had to construct major dams on the Indus (Tarbela) and Jhelum (Mangla) to transfer water to the Ravi and Sutlej.

While the Indus Waters Treaty has worked reasonably well India has been interfering with the waters of the three western rivers, on the plea that the people of occupied Kashmir have needs also. The fact that Kashmir is a disputed territory has not inhibited it from coming up with water and energy projects that have given rise to new items in the agenda of bilateral differences, such as Wullar Barrage, Baglihar dam, and most recently the Kishenganga project. In the emerging scenario, India has the ability to pressure Pakistan on water issues, but its long-term energy requirements require transit facilities through Pakistan for oil and gas pipelines from Iran and Central Asia.

As the concept of security now covers assured access to both water and energy resources, this demands a virtual transformation of Indo-Pakistan relations from one of confrontation to that of cooperation. Indeed, the increasingly powerful industrial elite in India is in favor of the integrated management of the water and energy resources of South Asia, and the adoption of a conciliatory and cooperative attitude, rather than an assertive one towards its neighbors. Both countries are stepping up their efforts to develop water resources, both for generating hydro-electric energy and for human consumption and irrigation. Pakistan's total hydro energy potential is 30,000MW of which only about 6,000MW have been developed. There is need for harmonious management of available resources of water and energy, and for Pakistan, it is imperative that the interest of Afghanistan is kept in view as its main river, the Kabul, is a tributary of the Indus. India would have to keep in view the interests of Nepal, Bhutan and Bangladesh.

Agriculture offers a livelihood for over 40% of Pakistan’s labour force and accounts for a quarter of GDP. Agriculture is also the dominant water user with 69% of the total, while industries use 23% and households the remaining 8%. Water from the Indus and its tributaries irrigate 80% of the country’s *21.5* million hectares of farmland. The upper reaches of the Indus are almost exclusively fed by glacier melt from the Himalayan and Karakorum ranges (on the borders with China and India), as well as the Hindu Kush (on the border with Afghanistan). The remainder — a little more than 10% - comes from (monsoon) rainfall.

Extensive irrigation in Pakistan and India places Indus water resources under heavy stress, with about 90% of the basin’s available water flow utilized. Overpumping and inefficient irrigation techniques have led to sharply declining groundwater levels, loss of wetlands and salinization of agricultural lands. Because of soaring, yet inefficient, agricultural and urban water use in Pun- jab, farming in the southern Sindh province is becoming precarious — stoking ethnic tensions. The flow of the Indus is no longer powerful enough year-round to prevent saltwater from the Arabian Sea from seeping inland. More than half a million hectares of arable land have been lost to seawater intrusion and salinization. In the future, sea-level rise will place coastal areas at increasing risk of inundation. Water availability will decline dramatically in coming years as a result of climate change. A combination of rising temperatures and population growth could reduce Pakistan’s per capita water availability to a critically low level ofjust 800 m3 annually by 2020. Highly unequal land distribution and water policies that benefit large wealthy farmers are behind growing rural poverty and migration to urban areas. According to a 2008 report, levels of hunger in Pakistan are “alarming.”5 The government’s decision to offer long-term farmland leases to foreign investors for export production threatens to intensif’ land and water problems. An estimated *40-55* million Pakistanis do not have access to safe drinking water, yet the government spends 47 times as much on the military budget as on water and sanitation. According to Unesco’s World Water Development Report, only 2% of Pakistan’s cities have wastewater treatment facilities; and less than 30% of wastewater receives treatment in these cities. Water pollution is the leading cause of death in Pakistan and causes 60% of infant mortality.

Sugarcane-based industries, tanneries, and the textile industry are the principal industrial water polluters, causing high levels of coliform, fluorites, iron, sulphur, and sulphates in drinking water. Untreated sewage from cities adds to the contamination. And in Punjab province, many people depend on contaminated irrigation water for domestic use.

Population growth and increasing urbanization and industrialization continue to drive up water demand for drinking, irrigation, and hydropower purposes. There are many internal water conflicts between vidual communities or provinces. But transborder issues have also posed vexing problems.

In the current phase, the US is backing India in developing nuclear power, while Pakistan would have to rely on China. There is a role for the great powers, including Japan and Russia, in transferring technology. Together with other challenges of the environment, including global warming, degradation caused by poverty, and desertification, the management of water and energy resources in overcrowded parts of the planet must assume a high priority if our economic and social goals are to be achieved. South Asian nations long beset by problems that demand global attention — poverty, poor health, and unrest — are increasingly places where solutions are being developed and where technology enables innovation, according to panelists examining the region's future.

Climate change presents many challenges to the region. Rising sea levels coupled with more intense and more frequent storms will affect densely populated, low-lying regions like those in Bangladesh. He suggested that surging waves and heavy rains will become more frequent, while melting glaciers will threaten drinking water for many in the region who rely on glacier-fed rivers.

trigger tensions between the two countries in the absence of an accord, especially given their unresolved, decades-long border dispute. Pakistan does, however, have an important agreement with India. The Indus Water Treaty, signed in 1960, divides the waters of the Indus and its eastern tributaries. India has exclusive use of the Ravi, Beas and Sutlej rivers, while the waters of the Indus itself, as well as those of the Jehlum and Chenab, were allocated to Pakistan. India is permitted some non-consumptive "run of the river" uses, including the generation of hydroelectric power, but the treaty barred the construction of storage facilities (dams or reservoirs).

A 2008 joint UNEP *I* Asian Institute of Technology report notes that the Indus Waters Treaty does not address "transboundary pollution of the water resources, which is a significant contributor to the vulnerability of the basin's freshwater resources. A number of contentious projects undertaken upstream, by India, in Kashmir — in response to growing water needs, falling groundwater tables and power shortages — have served as reminders that water disputes between the two neighbours are never far from the surface. They include the following:

Baglihar Hydroelectric Dam: Pakistan has objected to this dam on the Chenab River since India began construction in 1999. A 2005 World Bank adjudication requires that the dam can only be filled between June 21 and Aug 31, with Pakistan's prior consent, and specifies minimum river flows. But in 2008, India continued to fill the dam well into September, considerably reducing the Chenab's flow and causing crop damage. A World Bank tribunal subsequently asked India to lower the height of the dam.

• Kishanganga Hydroelectric Dam: The proposed 103 meter-high reservoir threatens to displace some 25,000 people. A channel connected to the reservoir would divert the Neelum river from Muzaffarabad, in Pakistani-controlled Kashmir, to Wullar Lake and the Jhelum river near Bandipur instead.

• Tulbul Navigation Project: India is considering reviving this project on Wullar Lake, which it first initiated in the 1980s but scrapped following objections from Pakistan. Pakistan fears that India could use Tulbul to disrupt its triple canal system (Upper Jhelum Canal, Upper Chenab Canal. and Lower Barn Doab Caial).

Rising demand and reduced availability of water make it increasingly important for India and Pakistan to improve their water management and ensure that diplomacy, rather than threat of force, governs their water relations.

Climate change will dramatically raise the water challenges in Central and South Asia through rising temperatures and drought, more variable rainfall and glacier melt, sea- level rise, as well as changes to the monsoon cycle. By the middle of the century, increasing temperatures and growing water stress may lead to a 30% reduction in crop yields in the region.

Bangladesh Issues:

Where is the space in Bangladesh to which you can move? One is not talking about the entire coast becoming submerged. But major impacts from weather events, coastal flooding — these become increasingly severe as sea level rises. Bangladesh national plan to fight climate change recognizes that the country's development can't follow the Western pattern. Innovation will be important in improving the lives of both Indian and Bangladesh's poorest citizens. One approach, aimed at the 400 million who don't have access to electricity, uses a solar lantern program to provide lighting in rural areas. Arsenic contamination is a major problem in both Nepal and Bangladesh. Prof. Shamsher Ali has an extended presentation on issue of Hydro Power in Bangladesh.

Water and Hydropower Resources of the Sarydjaz-Kumaryk River and Prospects of Their Use

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Kyrgyzstan and China are friendly neighboring states. Length of their common border is about 1100 km. Basins of four trans-boundary rivers are situated on the territory of these states; they are the Sarydjaz-Kumaryk, the Aksay-Toshgan, the Uzengikuush-Yuyshangusi and the Koksu-Kyzylsuu rivers (names of the rivers are given in Kyrgyz and Chinese versions), and they belong to the basin of the Tarim River (in China). Over 70% of their runoff is formed on the territory of Kyrgyzstan; all of it goes to China.

The most promising of these rivers (in hydropower development) is the Sarydjaz-Kumaryk River. Rational development, use and protection of its water resources play the most significant part in the socio-economic development of Kyrgyzstan and Xinjiang Uygur Autonomous Region (XUAR) of China. Currently the Sarydjaz river flow is virtually not in demand on the territory of Kyrgyzstan; in China it is mainly used for irrigation.

The Sarydjaz-Kumaryk River has great elevation changes, important precondition for its cascade development, and substantial hydropower potential. According to the forecast of experts in electricity market development, socio-economic development of Kyrgyzstan and XUAR in China will soon be based on increasing energy consumption. Therefore, joint development of water and hydropower resources of the Sarydjaz-Kumaryk River is a project of harmonious and mutually beneficial cooperation between peoples of the two countries, stimulating economic development and friendly neighborly relations.

In 1959 D. M. Mamatkanov, I.P. Druzhinina, B.G. Kovalenko and V.G. Shpak took part in scientific expedition of the Institute of Energy and Water Resources of the Academy of Sciences of the Kyrgyz Soviet Socialist Republic, meaning to study the Sarydjaz River and determine its water and hydropower resources. The feasibility of construction of hydropower plants on the Sarydjaz River was evaluated and dam locations were determined. It was found that the use of hydropower resources of the Sarydjaz River was favorable in terms of construction of high dams, as it would not require significant expenditures.

In 2006, scientists and experts of the Institute of Water Problems and Hydropower of the National Academy of Sciences of the Kyrgyz Republic, together with specialists of the Department of Water Economy of XUAR PRC, began to work out scientific and technical grounds for joint development of water and hydropower resources of the Sarydjaz River. The Kyrgyz workgroup was headed by D.M. Mamatkanov, the director of the Institute, academician of the National Academy of Sciences of the Kyrgyz Republic. O.D. Erdmann, L.V. Bazhanova, V. N. Shilo and V.A. Kuzmichenok, leading research specialists, work under supervision of D.M. Mamatkanov. The Chinese workgroup, headed by professor Deng Mingtszyan, the deputy head of the Department of Water Economy of XUAR, is represented by professor Wang Zhitze, the head of Hydro-meteorological and Water resources Department; professor Huang Chi, the deputy director of the Project-exploration and Research Academy of water economy and electricity; professor Anwar Kadyr, the deputy head of the Project and Planning Department of Water Economy and Electricity, and others. Together the workgroups developed coordination mechanisms for joint cooperation and proposed a project of comprehensive use of water resources of the river on mutually

advantageous terms. In Kyrgyzstan, realization of this project will stimulate the development of mineral resources in the basin of the Sarydjaz River and recreational resources in the Issyk-Kul lake basin and additional electric power supply for the Issyk-Kul region.

In order to speed up the development of water-power resources of the Sarydjaz-Kumaryk River, the Department of Water Economy of XUAR PRC has repeatedly sent its specialists in water management and hydroelectric power to Kyrgyzstan for scientific technical exchange of experience with scientists and specialists of IWPHP NAS KR. In September of 2006, both sides signed the Minutes of the negotiations on Kyrgyz-Chinese joint research works on development of water and hydropower resources of trans-boundary rivers. In April of 2007, they signed the Minutes of the negotiations between Kyrgyz and Chinese scientists and experts on joint investigation of the Sarydjaz River and the Issyk-Kul lake basins. In May of 2008, the sides signed the Memorandum on issues, concerning the joint investigation of the Sarydjaz River, design of the planned hydropower plants to develop hydropower potential of the river, as well as technical personnel exchange. In August of 2008, both parties organized a joint survey of the Sarydjaz-Kumaryk River, and in September of 2008, in Bishkek, they signed the Minutes on the joint Kyrgyz-Chinese Sarydjaz river survey report preparation. China Guodian Corporation provided financial support in organization of works and report preparation. Report on the integrated use of the trans-boundary Sarydjaz- Kumaryk River water resources is a result of joint work of the Kyrgyz and Chinese scientists and experts in the field of hydropower [2].

In order to specify the water resources of the Sarydjaz River basin, scientists and specialists of IWPHP NAS KR analyzed all the available data on meteorological observations, conducted earlier in the basin [1,4,5]. This work enabled us to estimate the current state of the water mode of the Sarydjaz-Kumaryk River and its main tributaries and to select the locations of HPP sites, as well as to perform approximate calculations of hydroelectric capacity (Table 1).

Table 1. Hydrographic characteristics of hydroelectric power plants (HPP) on the Sarydjaz River

№ of HPP	Location	Elevation mark of HPP, m	Elevation difference between HPP sites, m	Distance between HPPs, km	Slope between HPPs, ‰
	The Semenov glacier	3360			
1	Taldysuu	2580	780	90	0.008
2	Enylchek	2350	230	29	0.007
3	Akshyirak	2200	150	18	0,008
4	Kokshaal	1780	420	52	0.008

Several options of the HPPs' locations were considered. The first version implied construction of four hydroelectric power plants, located on the stem stream of the Sarydjaz River (Fig. 1) [2].

HPP-1 with supposed capacity of 43 MW constructed in the upper part of the Sarydjaz River, at the confluence of the right tributary – the Malaya Taldysu (Minor Taldysu) River. When constructing a dam with the height not exceeding 100 m, a channel reservoir with area of 11.8 km^2 and capacity of up to 210 million m^3 will be formed. The river backwater will be extended for 18 km.

HPP-2 with supposed capacity of 98 MW built below the confluence of the right tributary Uchkel into the Sarydjaz River. Dam height is 100 m, flooding area will be 18 km^2, and reservoir capacity will be about 840 million m^3. Backwater will be 20-22 km (to the mouth of the Enylchek River)

HPP-3 will be below the confluence of the right tributary Akshyirak. Here, to create additional pressure, it is possible to use the natural crook (loop) of the Sarydjaz River. Dam height will not exceed 100 m. The flooding area will be about 8.0 km^2, reservoir capacity - within 480 million m^3. Backwater will extend for 18 km, hydroelectric power plant's capacity will be about 116 MW.

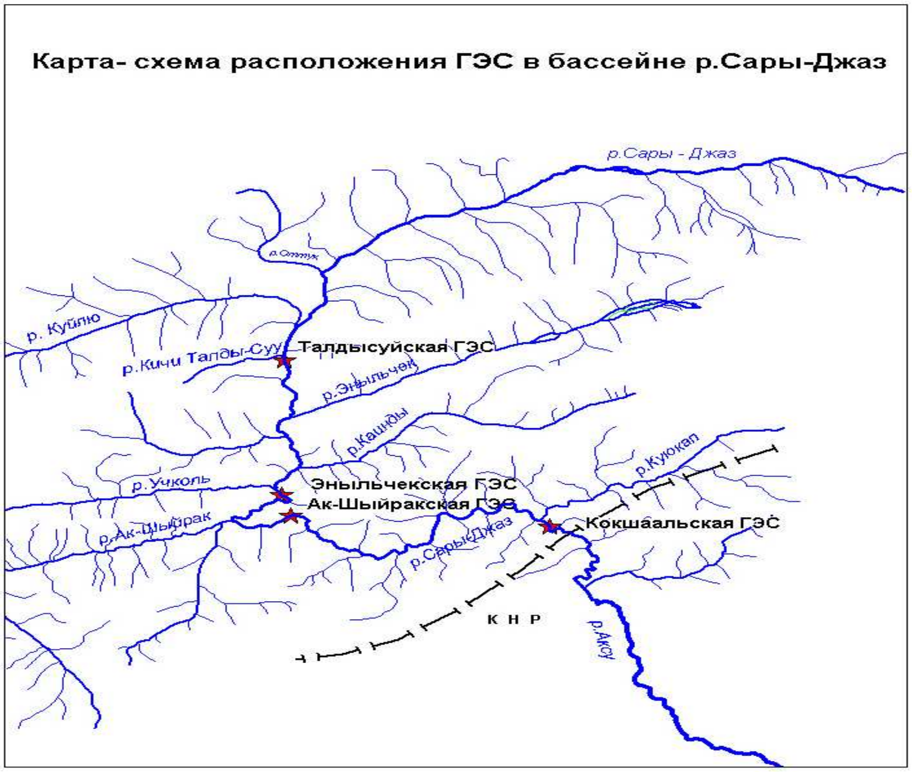

Fig. 1. Schematic map of location of the four power plants on the Sarydjaz River

HPP-4 can be constructed is in the ravine of the Kokshaal-Too ridge, below the influx of the left tributary Kuyukap, on the border with China. There is no need to create a large separate reservoir, as the HPP will work at the expense of the flow, regulated above. Capacity of HPP-4 will be more than 123 MW. Dam height will be 100 m, the flooding area - about 8.4 km^2, reservoir's capacity - within 600 million m^3. Backwater of the river will be 30 km (Table 2). Due to the small slopes of the Sarydjaz River channel, dam height is considered to be not more than 100 m.

It should be noted that during the process of filling-up of the channel reservoirs, a territory with total area of 46.2 km^2 will be flooded. The territory will include a highway, bridges, power transmission poles, sheep barns, pasture lands and areas suitable for irrigation. The village of Inylchek and mineral deposits will not be flooded.

Table 2 . Key indicators of the planned HPPs on the Sarydjaz River (Option I)

№ HPP	Location	Elevation point, m	Reservoir capacity, million m^3	Dam height, m	Average annual runoff m^3/s	Average annual runoff volume, km^3	Capacity, MW
1	Taldysuu	2580	210	100	44.2	1.39	43
2	Enylchek	2350	840	100	100	3.15	98
3	Akshyirak	2230	480	100	119	3.75	116
4	Kokshaal	1780	600	100	126	3.97	123
	Total						380

Another option was considered. After heightening the dam up to 270 m and discharge of water through the tunnel and subsequent increase of the head at the Akshyirak HPP, the dam of “Kokshaal” HPP can be heightened to 200 m.

This options considers construction of the Akshyirak HPP on the Sarydjaz river below the influx of the right tributary Akshyirak. The dam itself should be built 1 km below the confluence of the Akshyirak and the Sarydjaz River, with the water rise height of 225 m. This dam would create additional backwater of 148 m at the Akshyirak loop, which, in its turn, would bring the gross head of the Akshyirak HPP to 270 m. At the same time, capacity of the hydropower plant will be 315 MW. Length of the tunnel, connecting the loop, will be 1.9 km. The area of dam storage will be 33.1 km^2, the capacity - 2.87 km^3. Annual runoff volume in the alignment of the hydroelectric plant is 3.76 km^3, and the filling-up of the reservoir will take 2-2.5 years. The Inylchek village may be flooded at the maximum reservoir filling in this case.

Location of the "Kokshaal" HPP was planned to be below the influx of the left tributary Kuyukap, on the border with China. There will be no need to create a large own reservoir, because the HPP will work at the runoff, regulated above. Capacity of HPP can reach about 246 MW. Dam height will be 200 m with the flooded area of about 10.9 km^2, the volume of channel reservoir within 750 million m^3, and backwater of about 30 km. The second version considers the estimated total capacity of the two hydroelectric power stations on the lower section to be 561 MW (Table 3).

Table 3. Key indicators of potential hydroelectric power plants in the Sarydjaz river basin (Option II)

№ HPP	Location	Elevation point, m	Reservoir capacity, million m^3	Dam height, m	Average annual runoff m^3/s	Average annual runoff volume, km^3	Capacity, MW
1	Akshyirak	2230	2 860	270	119	3.76	315
2	Kokshaal	1780	750	200	126	3.97	246
	Total						561

After the joint Kyrgyz-Chinese expedition to the Sarydjaz river basin in 2008, Chinese experts suggested three options for location of HPPs on the Sarydjaz-Kumaryk River, both on the Kyrgyz territory and on the territory of XUAR PRC with gross installed capacity of 2,190 MW. Average long-term power generation of the four hydroelectric power plants will amount to 7.7 billion kilowatt-hours [3].

The first option: "High Dam of Dashisya" with five reservoirs and acascade of eight hydroelectric power plants: Taldysuy + Inylchek + Akshyirak + Kokshaal + Dashisya (with dam height of 251 m) + Syaoshisya + Tagak + Tumusyuk; two of them are multi-purpose hydro-systems.

The second option: "Medium-high dam of Akshyyrak” with four reservoirs and a cascade of seven hydroelectric power plants: Saralatash + Akshyirak (with dam height of 131 m) + Sarydjaz-Kumaryk + Dashisya (height of the dam - 198 m) + Syaoshisya + Tagak + Tumusyuk; three of them are multi-purpose hydro-systems. This option implies construction of the “Sarydjaz-Kumaryk” HPP both in Kyrgyzstan and in Chinka, with its dam and reservoir on the territory of Kyrgyzstan, and the “Kumaryk" hydroelectric power plant on the territory of XUAR PRC.

The third option: "High Dam of Akshyirak” with four reservoirs and a cascade of seven hydroelectric power plants: Saralatash + Akshyirak (with dam height of 168 m) + Sarydjaz-Kumaryk + Dashisya (dam height of 198 m) + Syaoshisya + Tagak + Tumusyuk; three of them are multi-purpose hydro-systems. This option, like the second option, implies construction of a dam and a reservoir on the territory of Kyrgyzstan, while the hydroelectric power plant “Kumaryk" will be located on the territory of XUAR PRC (Fig.2).

However, it should be noted that damage caused by potential flooding of the Inylchek village during construction of “Akshyirak” hydroelectric power plant was not taken into account.

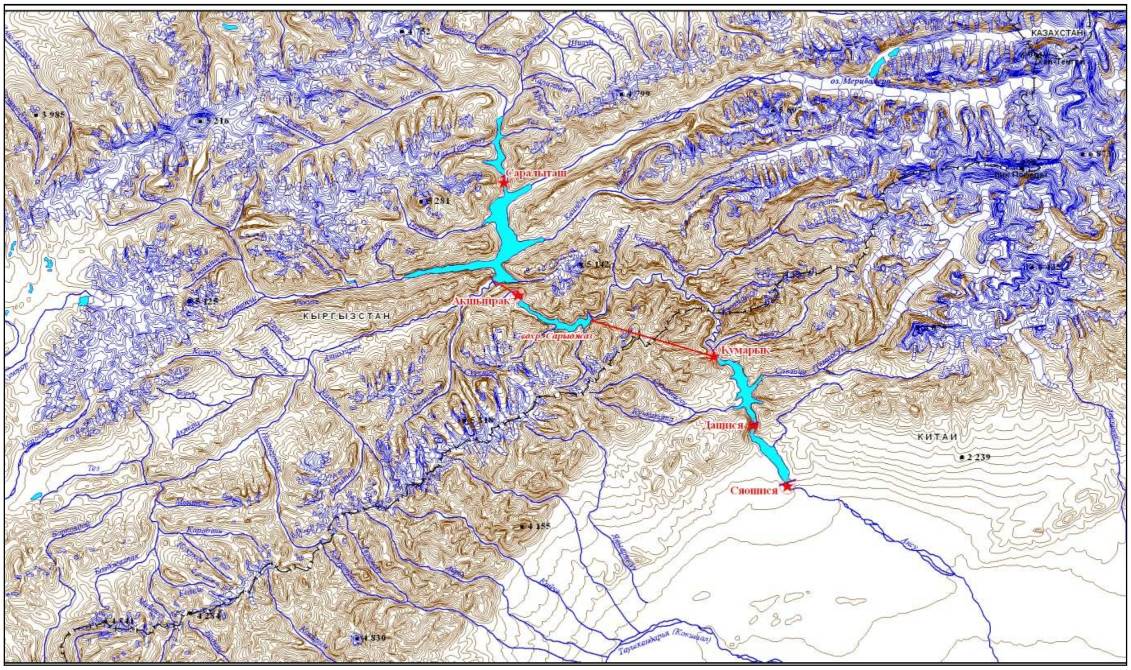

Fig. 2. Schematic map of the location of HPPs on the Sarydjaz River. The third option

After comparison of the estimated energy indicators, it was determined that the determined capacity of hydropower plants in the first, second and third options is 1,170, 1,830 and 2,190 MW; total firm capacity is 218.9, 348.2 and 547.9 MW; total average long-term value of annual output of electricity is 4.05, 6.45 and 7.71 billion kilowatt-hours, respectively. This comparison shows that the third option has the highest power indicators. Let’s look into it closer, as it is the most acceptable, beneficial and economically feasible option.

Construction of the “Saralatash” hydroelectric power plant and the main regulating reservoir for the following cascade plants is planned 11.5 km below the confluence of the Sarydzhaz River and its right tributary Kuylyu, in the Saralatash tract. The reservoir capacity will reach 311 million m^3 at the full water supply level of 2,680 m. The main task of this seasonal storage reservoir will be power generation.

The riverbed at the “Akshyirak” HPP dam site is narrow. Bottom contour of the reservoir is almost flat and represents the intermountain basin. Conditions of the reservoir basin are good. The reservoir capacity at the full water supply level (2,507 m) will be 1.0 billion m^3. It is a seasonal storage reservoir with the main tasks to produce electricity, to regulate the flood wave (especially in case of the Merzbacher Lake outburst), and an additional task to produce electricity for the cascade in the lower part of the river on the territory of Xinjiang.

At the "Dashisya" waterworks facility, the annual runoff volume is 4.92 km^3. The riverbed at the dam construction site is narrow; rocks on both sides are steep. This hydropower system will be situated on Chinese territory, 33 km away from the state border. It will serve as controlling facility for integrated flow use (irrigation, anti-flood measures, environmental protection, and electricity generation). The reservoir capacity at the full water supply level (elevation point - 1,655 m) will be 549 million m^3.

Results of calculations show that for “Akshyyrak", "Kumaryk" and "Dashisya" HPPs, specific investment per 1 kW is up to 1,267 U.S. dollars/kW, specific investment per 1 kWh. is 0.38 US dollars/kilowatt-hour. Economic performance of the "Saratalash" HPP is somewhat worse. Therefore, “Akshyirak", "Kumaryk” and "Dashisya” HPPs will be selected for the upcoming period as priority and economically feasible. Installed capacity of this cascade of hydropower stations amounts to 2,070 MW, annual electricity output is 7,348 billion kWh. The volume of investments for the coming period will amount to about 3 billion U.S. dollars. A preliminary economic assessment has shown that this option is effective, and its implementation is feasible. Implementation of this project will significantly influence the basin of the Sarydjaz-Kumaryk River and promote to the positive development of the entire region.

Conclusions

The comprehensive analysis and comparison of the three options of the cascade development show that the third option is the most effective one. It is characterized by higher power indicators, minimal investment in the project and a higher indicator of economic efficiency. Therefore, it is selected to be the working version of the cascade development of hydropower resources of the Sarydjaz-Kumaryk River.

References

1. Mamatkanov D.M., Bazhanova L.V., Romanovsky V.V. Water Resources of Kyrgyzstan at the present stage. Bishkek. Ilim. 2006.

2. Report on the results of joint Kyrgyz-Chinese expedition to the Sarydjaz River basin in 2008. Bishkek, 2009.

3. Report on the integrated use of the Sarydjaz-Kumaryk River resources. Bishkek-Urumqi. 2010.

4. Surface Water Resources of the USSR. Volume 14, issue 2. Central Asia. Basins of the Issyk-Kul lake, Chu, Talas, and Tarim rivers. Leningrad. Gidrometeoizdat. 1967.

5. Surface Water Resources of the USSR. Main hydrological characteristics. Volume 14. Central Asia. Basins of the Issyk-Kul lake and Chu. Talas and Tarim rivers. Leningrad. Gidrometeoizdat. 1967.

Renewable energy resources as a basis for social and economic development of rural regions

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The current development of countries and their successful scientific, technical and socioeconomic progress is not possible without the active use of energy resources.

The active use of traditional hydrocarbon fuel (gas, coal, oil) has shown that these resources can be exhausted within the next 30-50 years. In this regard, our search is for essentially new, alternative energy resources rather than those actually used.

Big hopes have been pinned on nuclear power development; however, major accidents at the Chernobyl and Fukushima nuclear plants have shown what catastrophic consequences this direction may have. Therefore, over the past years the scientists have been paying great attention to potential use of non-polluting, renewable energy sources.

The researches show that renewable energy sources (RES) have huge potential. It is enough to mention that the energy coming from the sun to the Earth within a year is 3.9·1024 J, which is 10,000 times more than the world’s annual demand for energy and much more than existing world's resources of hydrocarbon and nuclear fuel.

The use of renewable energy sources in the Central Asian region has its own specific characteristics and appears to have sufficient potential, and first of all, in terms of resolving socioeconomic problems of agricultural communities. The Central Asian countries are agrarian republics and the majority of their population (50-60%) lives in the countryside. Communities that live in these regions are most vulnerable from a power supply standpoint. As a rule, the poorest communities in the Central Asian countries are rural communities. The most effective and accessible way to resolve these power supply problems is to use renewable energy sources at a large scale. Factors that contribute to this include not only the remoteness of the majority of agricultural communities from the centralized power supply networks but also the huge potential of renewable energy sources, which are available as sunlight, the wind, flowing water and biomass.

This paper discusses the efficient use of renewable energy sources and provides an assessment of technical solutions to power supply problems of agricultural communities. The research results are used to develop methods and technologies that incorporate renewable energy sources. The paper outlines the results of practical application of various solar systems for heat supply, wind energy devices, micro-hydroelectric power stations and biogas plants to ensure electric power and heat supplies for remote rural communities.

The analysis of this experience and all results obtained enabled us to define and prioritize various energy sources depending on their potential and practical applicability.

The paper also considers legislative issues and development of a legal framework for the use of RES including issues related to training of engineering and highly skilled scientific personnel in the field. The objective barriers that prevent the accelerated use of renewable energy resources are identified, the ways to overcome those barriers for integration with the Central Asian countries are offered including joint solutions to problems of the large-scale use of renewable energy resources to resolve social and economic problems of rural community development.

Modeling Relationships between Water, Land and Energy Resources on the Earth and in Central Asia (Studies of Catastrophes and Engineering Aspects of Geonomy)

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Abstract

Engineering geonomy (EG) concept and methodology for identifying paleo-catastrophic formations on the Earth. Basic periodic internal and external types of movements shaping the world of slow and fast disasters on the Earth. Develop a multidisciplinary research geonomy models based on quantitative and qualitative conversion of thematic maps of the Earth and its sub-parts. Geological models are projected on the rotational axis of the Earth, which reveals the regularities of the lateral (latitude and longitude) and vertical (altitude and depth) distribution of different geonomy objects: 1) land, 2) water, 3) orogeny, 4) cryogeny, 5) glaciation, 6) distribution of energy systems, 7) desertification, 8) locations of electric power (hydro and nuclear) facilities, and other associated components of the environment (1-10).

Currently water on the Earth gives life to flora and fauna including mankind, and plays a crucial role in the geosphere. Water in its different forms occurs in hydro-, cryo-, bio-, seismo-, litho- and other spheres of our planet. Water covers up to 70% of the Earth's surface. The water cycle in nature is truly universal. The water conservation issue is always quite serious. Annual water consumption per capita is estimated at 2,600 m^3. For comparison: in Egypt it is 1200, in Sudan – 1100, in China, Syria and Israel – up to 450 $meters^3$. From 1960 to 1990 the area of irrigated land in Central Asia increased by 65%, the population grew from 14 million people to 50 million, and the need for water increased from 60 to 120 km^3 per year.

A significant portion of water resources occurs in the form of natural ice covering an area of 72.4 million km^2 on the upper part of the Earth's crust, which is more than a half of the total land surface. The volume is over 30 million km^3, which is about 70% of total volume of fresh water. It would take 700 years for all the rivers in the world to accumulate such volume of water. Water problems are not only lack or excess of water including water pollution issues but also various kinds of hazardous natural processes and phenomena caused by water in the form of tsunamis, landslides, floods, outbursts of mountain lakes, snow avalanches, and glacier collapses and movements.

Based on the above, "catastrophic" aspects are presented in the EG models below in this paper. Identified ENG laws reflect the response of structural and material composition of the

Earth to the major types of simultaneously occurring EG motions that take place each year and contribute to the formation of disasters on the Earth:

1. Usual Earth's orbital motion around the Sun;

2. Unusual internal orbital motion of the solid part of the Earth's liquid core;

3. Cyclic incremental impact of tidal waves on the geosphere which also raise and lower the Earth's surface due to the attraction of a) sun, b) moon, c) "parade" of planets.

In this case, hydrosphere, cryosphere, lithosphere and its constituent parts – tectonic blocks on which power facilities (hydroelectric, nuclear power plants) are built – undergo systematical strain stress, which causes geodynamics of tectonic movements, earthquakes and tsunamis.

In close association with the studies of catastrophes, EG aspects are used to develop a scientific interdisciplinary concept that includes:

1. Monthly rhythmical changes in the volume dynamics of the geological model of celestial bodies moving in orbit around the sun: a) external (Earth) and b) internal (solid core moving inside the liquid core of the planet (Fig. 1). For example, Figure 1 shows the EG model of the Earth's geological history research true volumetric shape of the Earth on the cards, the geoid and solid models, allowed the surviving of lower portions and raising the Earth's surface, the installation of six lines of impact of education on our planet. Geo-ages of the ancient collision occurred of paleo-Earth with such celestial bodies. Clashes catastrophic, resulting in an abrupt increase in the generalized planet. Currently, the central part of the planet's liquid core inside the orbit of its own annual 45-degree angle to the sun commits a turnover a year, six solid cores previously united with the earth of ancient planet. These solid six cores floating in its orbit inside the Earth's liquid core, periodically perturb all of the above posted geosphere, giving the masses and moments of tectonic and gravitational forces in the areas of co-homology contacts. A group of six became acquainted solid nucleus to cause the effect of co-homology in their places of contact with the surrounding geosphere. It is in the areas of contact pressure, solid core raised up area of the lower mantle and upstream geosphere layers. At the same time on the near-surface part of the crust due to the effect of co-homology is accretion of tectonic blocks with compression fractures and clamped. This activates processes of displacement and lifts groundwater levels. Surface water due to reduced permeability geofiltration environment conducive to increased resources and the growth of the elements associated with surface water. Simultaneously with the diametrically opposite side of the Earth the effect of co-homology, shows the processes of lowering the surface of the lower mantle in the liquid core, and the higher lying near-surface zone of the crust undergo tensile stresses and unloading of stored elastic energy. At the same time tectonic blocks included in the corresponding lithospheric plates moving apart repel each other, faults expands, it promotes penetration of groundwater into the depths of the bowels, and ground water lowering its level, while increasing resources and reserves in this environment, surface water, reducing its volume and resources, replenishing ground waters mitigate disaster risks from exposure to surface water.

During the winter period (perihelion in December) in the northern hemisphere (when summer begins in the southern hemisphere), the speed accelerates to 30.3 km/sec and the Earth most closely approaches the sun at a distance of 147 million km, which increases the mass and compresses the volume of the planet. In this case, water and land and energy resources in the northern hemisphere experience a tremendous stress. When the Earth is far away from the Sun (aphelion in June, at a distance of 152 million km), the mass of the planet decreases and the speed drops to 29 km/sec while the volume of the planet expands.

2. As divided into the geoid and specific boundaries of alternating 12 lithospheric plates, the following geo-wave processes and phenomena have been developed: a) divergent (within mid-oceanic ridges), b) convergent (within mountain structures), c) monovergent (southern and northern, western and eastern directions) (Fig. 2). The boundaries of lithospheric plates are active, especially in areas of multiple intersections while mid-oceanic ridges are constantly forming new area young basaltic crust.

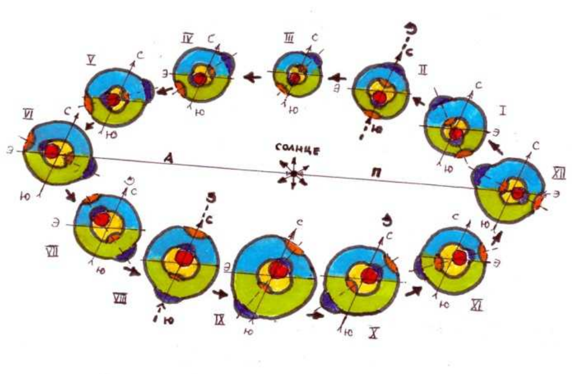


Fig. 1.

Fig. 2.

3. The EG model provides a paleo-space concept of the catastrophic formation of the Earth as a result of six largest collisions with such bodies, a timeframe which allows you to adjust the currently used essentially obsolete evolutionary geochronological scale (Fig. 3).

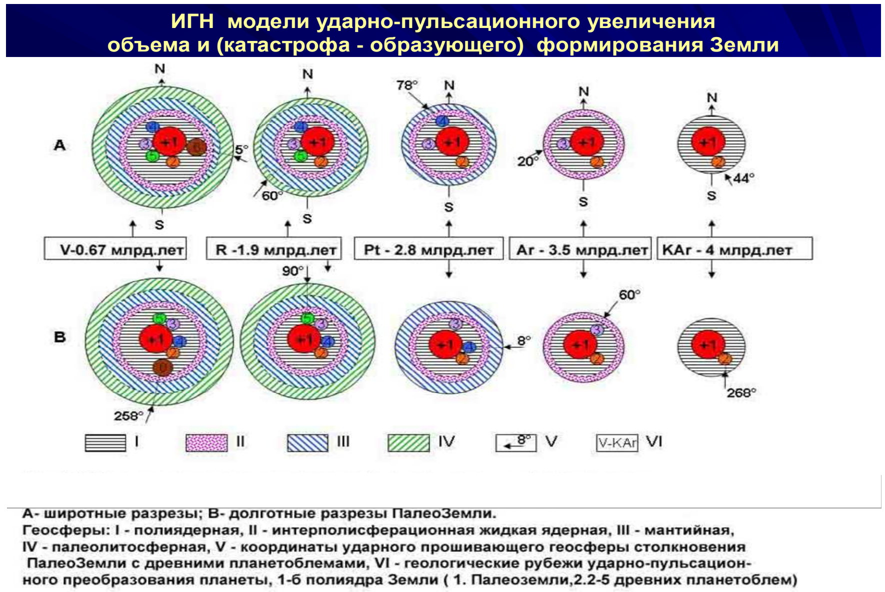


Fig. 3.

4. On converted into geons models of planetary levels, national, regional and local scale thematic maps for comparative research and synthesize uniform assessments, and establish regularities of changes in the environment shows the following IGS data: a) latitudinal distribution of large and deep earthquakes (Fig. 4), b) latitudinal distribution of hydroelectric power systems and nuclear power plants, b) distribution of the world population, c) latitudinal distribution of major earthquake-prone cities in the world, d) atmospheric precipitation, q) latitudinal distribution of water evaporation (Fig. 5). The peak distribution of hydropower facilities is at 37-38 degrees north latitude, i.e. natural environment is most favorable there for the development of hydropower facilities, and the peak distribution of nuclear power plants is at 48-50 degrees north latitude, i.e. natural environment is most favorable there for the development of nuclear power facilities. The regularities in the distribution of the most important hydrosphere components, namely precipitation and evaporation, show that safe and favorable conditions for enhancing the potential of resolving water, energy and land issues occur at 23-40 degrees north latitude. Geonomy models show minimum evaporation against increasing precipitation at 23-26 degrees N latitude. The minimum peak of evaporation geonom in the north hemisphere is closely and quasi-symmetrically correlated with the intersections of water and land geonoms of the Earth.

Apart from drinking water supply and agricultural uses, one of the fundamental components of integrated water use is hydropower. Based on the forecasts, the hydropower sector will account for about 8% of global water consumption. Water problems on the Earth are connected with each other through the uneven distribution of hydrological resources and uneven quality of water, particularly water used for drinking purposes. According to the forecasts, if the world population increases to 10 billion, it is expected that in the near future drinking water use will be 10 times less than the use of water for irrigation. Water use in different parts of the world is as follows: Asia – 56%, North America – 19.4%, Europe – 18.2% Africa – 3.1%, South America – 2.1%, Australia and South Pacific – 1.2%. In this case, total water consumption is 2,520 km^3 per year. According to statistics, in China the number of people without access to improved water sources reached 379 million in 2010, and over 200 million in 2009. The cost of water supply for 160 million people in the rural community in China totaled about US$ 6 billion ore US$37.5 per person.

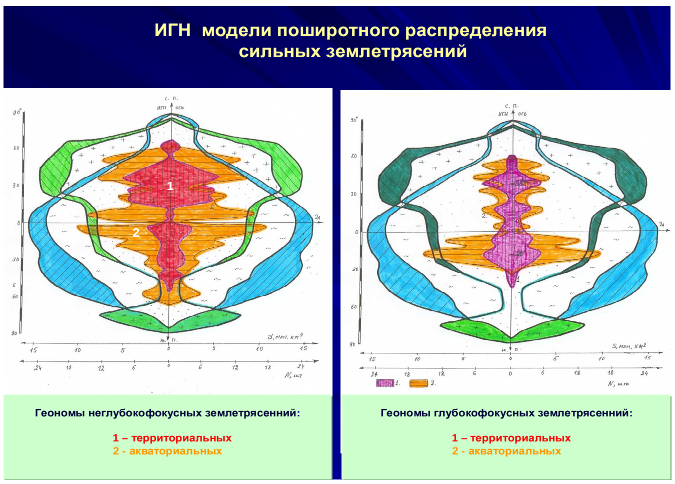


Fig. 4.

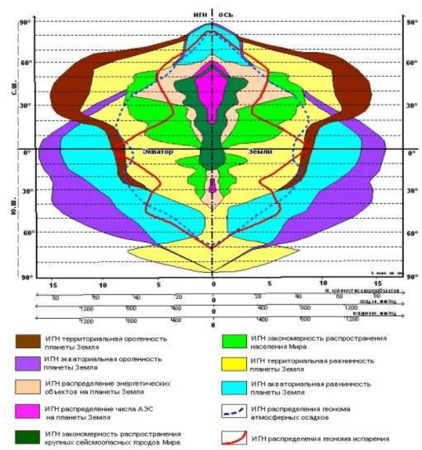


Fig. 5.

5. On the planetary EG models, the latitudinal distribution of a) glaciers, b) permafrost, c) sea ice (purple in winter, blue in summer) (Fig. 6) shows the patterns of maximum peaks of the investigated component to the Earth's cryosphere. The regional EG models (for the Eurasian continent) show the latitudinal distribution of a) number of earthquakes, b) earthquake-prone areas, c) mountains, and d) plains (Figure 7).

The interglacial time is divided into four epochs: two cold epochs with minimum temperatures 2900 - 2300 and 330 -125 years ago, and two warm epochs with maximum temperatures around 5000 - 3000 and 1000 - 800 years ago. The most recent cold paleo-climatic period was in 1435 - 1860 AD (lasted 425 years), and the most recent warmest period was in 985 - 1185 years BC (lasted 200 years).

According to Budyko M. I. (1977), gradual climate warming had been observed since 1880 and the maximum temperatures were reported around 1930, when the temperature in the northern hemisphere increased by 0.6 degrees Celsius as compared to the end of the 19th century.

Currently the Central Asian region comprises 21 countries and provides home to 3 billion people in the area of about 20 million km^2. For example, if the level of abstraction before 1960 did not exceed 50% of the total surface waterways in the Aral Sea region, from 1980 to 2000, total annual runoff reached 90%, and a reserve of 10% did not provide the criteria and resources for sustainable development. The efficiency of water use for irrigation is very low in the region and does not exceed 40-50%.

The Aral Sea Crisis. As a result of an increase in the irrigated area in the Aral Sea basin, which formerly covered an area of 2 million hectares (until 1950), and intensive development of up to 8 million hectares of land by 1989, the inflow of rivers of the Syr Darya River Basin into the Aral Sea stopped in the 1970-s and the inflow of the Amu Darya River into the sea decreased to 5 km^3 per year. The second largest water reservoir in the CIS and the fourth largest water reservoir in the world had a regional importance and total volume of 1,062 km^3 before this disaster. In 1989, the volume decreased 3 times to 354 km^3 as a result of artificial drainage. Each year up to 100 million tons of toxic salt and dust particles from the dry Aral Sea bottom, which is over 36,000 km^2, are carried by wind into adjacent Central Asian regions to a distance of first tens of kilometers. These salt and dust particles settle on glaciers and contribute to their melting and accelerated degradation.

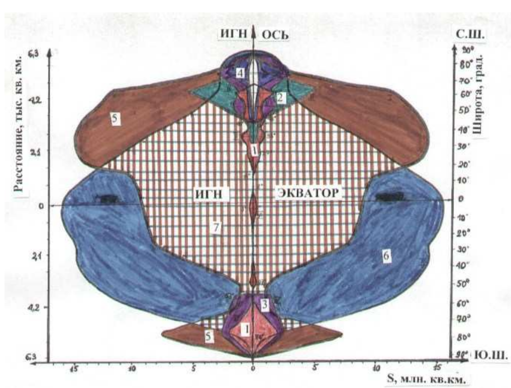
In the Aral Sea Basin, over 40% of the population in 2007 had no access to safe drinking water. In 15-20 years, if the current population growth rate continues, the percentage of people without access to safe drinking water may increase up to 70%.

Currently the annual withdrawals of surface and ground waters as a percentage of existing water resources and in relation to the Aral Sea Basin are as follows: Uzbekistan-100%, Turkmenistan-85%, Kyrgyzstan-40%, Kazakhstan-23%, Tajikistan-20%. Currently about 85% of water resources in Central Asia are concentrated in Tajikistan and Kyrgyzstan.

6. Transformation of thematic maps to show EG latitudinal and altitudinal distribution of glaciers in Kyrgyzstan (Fig.8 – lateral, 10 – vertical) and Tajikistan (Fig.9 – lateral, 11 – vertical). Geonomy models: a) mountain structures, b) intermountain valleys, and c) glaciers (ice).

In Kyrgyzstan and Tajikistan, there are huge water resources with hydropower potential estimated at over 554 billion kilowatt-hours.

Fresh water runoff in the Syr Darya and Amu Darya river basins is 150 km^3 per year.



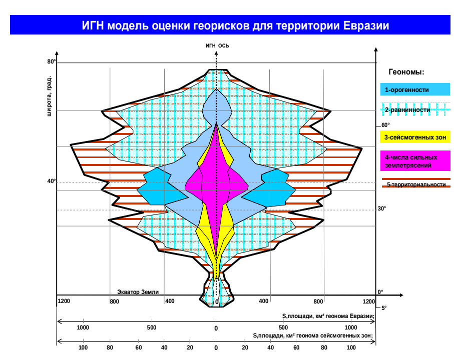


Fig.6 Fig.7

Up to 90% of runoff is used in agriculture for irrigation purposes and 10% are used by population and in industry. In the Kyrgyz Republic, the number of human settlements that do not have access to drinking water of standardized quality is around 1000.

Kyrgyzstan is a country that consists of the Tien Shan and Alay mountain systems, where 94.2% of the territory lies above 1000 m and 40.8% lies above 3000 m ASL. The climate is continental with sharp contrasts associated with high altitude zones. In Kyrgyzstan, there are 8,208 glaciers covering a total area of 8,100 km^2. Glaciers feed six river basins and are distributed in accordance with their area in the following descending order: 1) Sary-Jaz river basin – 33% of total glaciers in Kyrgyzstan, 2) Naryn river basin –17%, 3) mountains around Fergana Valley – 12%, 4) Kyzylsuu West river basin – 8%, 5) Issyk-Kul lake basin – 8%, 6) northern slope of the Kyrgyz Range – 5.8%.

Seven major glaciers have an area of 65 to 632 km^2 and a length of 11 to 60.5 km. Glacier degradation and climate change risk assessment model shows that glaciers in Kyrgyzstan have 3 maximums of glaciation genoms from north to south. Since the risk of glacier degradation of glaciers increases towards the south, it is likely that glaciers will melt and degrade in this direction. The EG model shows that glaciation maximums are confined to maximums of orogeny geonoms. For Kyrgyzstan, the northernmost glaciation maximum is located at about 42 degrees north latitude. The next maximum is located at 41 degrees. This one is the smallest of the three maximums. The third glaciation maximum is located at 39°30' north latitude. On the southern part of the EG model, it coincides with the orogeny geonom maximum.

International expeditions carried out together with the GFZ of Potsdam (Germany) over the last 3 years show that glaciers of the Kyrgyz Tien Shan including the largest ones, such as Inylchek, which is up to 60.5 km long, that cover a total area of 847.4 km^2. are susceptible to degradation. Based on follow-up theodolite surveys, the volume of glaciers in the ablation area has decreased 1.5-2.0 mm over 3 years, and the linear retreat has been from 25 m (Aksu Glacier) to 100 meters (Davidov Glacier - Ak-Shyirak Massif).

Tajikistan is a country that comprises the Tien-Shan, Alai and Pamir mountain systems with elevations ranging from 300 meters in the southern plain area to 7,495 meters at the Communism Peak in the eastern Pamir-Alai part of the country. According to Zabirov R. D. (1955), there are up to 1085 glaciers whose length is over 1.5 km and total area is 8,041 km^2. 16 glaciers had a length of over 16 km and the largest one – Fedchenko's glacier – was 70 km long and covered an area of 907 km^2. About 91% of glaciers occur in the Amu Darya river basin. According to the EG model, the distribution of glaciers throughout Tajikistan shows four preliminary maximums of glaciation geonoms. The biggest and broadest maximum of glaciation geonom is located in the northern part of the country at 38°30' to 39° north latitude and, like in Kyrgyzstan, correlates with the maximum orogeny geonom. The EG model (Figure 4) shows the altitude distribution of the following geonoms: 1) land, 2) glaciation extent in Tajikistan where the altitude distribution of glaciers is from 3 to over 6 km as compared to Kyrgyzstan. EG models (Figures 8-11) show that global or regional climate warming will reduce glaciers in area and volume in accordance with the established precise coordinates of the geonomy maximums.

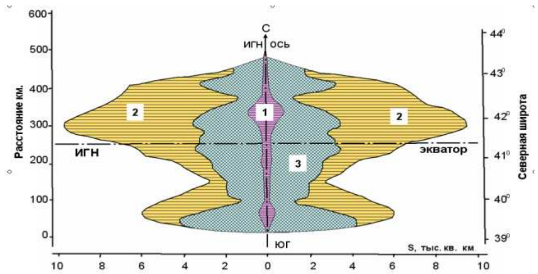


Рис.1 Инженерно – геономическая (ИГН) горизонтальная(латеральная) модель территории Кыргызского Тянь – Шаня и распределение геономов: 1 – оледененности, 2 – орогенности, 3 - долинности

Fig.8.

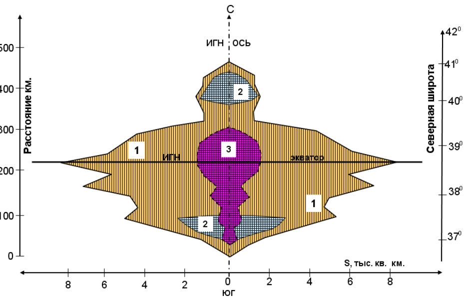


Рис.3 Инженерно – геономическая (ИГН) модель латерального поширотного распределения геономов для территорий Таджикистана : 1 –орогенности 2 – абсолютных отметок до 1км. (долинности), 3 – оледененности

Fig.9.

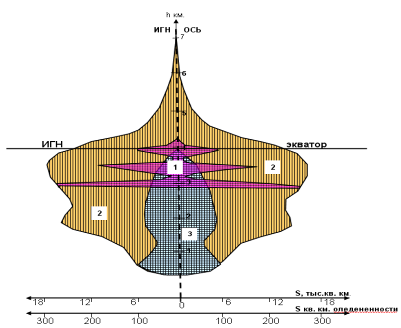


Рис.2 Инженерно – геономическая (ИГН) вертикально – высотная модель территории Кыргызского Тянь – Шаня и распределение геономов: 1 – оледененности, 2 – орогенности, 3 - долинности

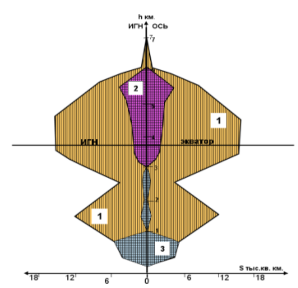


Рис.4 Инженерно – геономическая (ИГН) модель территории Таджикистана с высотным распределением геономов: 1 – территориальности, 2 – оледененности, 3 – долинности на примере Таджикистана

Fig. 10.

Fig. 11.

For a uniform approach to assessment of geohazards and forecasting and mapping of dangerous changes in the environment, there is a unified 12-point EG scale for classification of emergency situations of natural, technological, environmental and socio-biological origin (Fig. 12).

Conclusions

In practice and theory, when studying the relationships between water, land and energy sectors, it is necessary to use the developed engineering geonomy interdisciplinary concepts and methodologies.

Geonomy models of different scales constructed previously by recording the features and patterns of development of geo-system components allow unification on the basis of a 12-point EG scale to assess and forecast dangerous environmental changes.

ИНЖЕНЕРНО-ГЕОНОМИЧЕСКАЯ (ИГН)
УНИФИЦИРОВАННАЯ НОРМАТИВНАЯ ШКАЛА ОЦЕНКИ И ПРОГНОЗИРОВАНИЯ СТИХИИНЫХ БЕДСТВИИ

Табл.1

ИГН шкала / ИГН индикаторы	КАТЕГОРИИ УЯЗВИМОСТИ (КУ)											
	I. БЕДСТВИИ				II. КРИЗИСА				III. ДИСКАМФОРТА			
	СТЕПЕНИ РИСКА (С Р)											
	1. Катастрофически большая		2. Бедственно-большая		1. Кризисно-большая		2. Предельно-большая		1. Дискамфортно большая		2. Дискамфортно малая	
	УРОВНИ ОПАСНОСТИ (УО)											
	a. Катастро-фически высокий	в. Бедстве-нно высокий	c. Уничто-жающе высокий	d. Опусто-шительно высокий	a. Кризисно-высокий	в. Разруши-тельно высокий	c. Очень высокий	d. Высо-кий	a. Сред-ний	в. Уме-рен-ный	c. Низкий	d. Регистрируемо-низкий
	Универсальная шкала категорий стихийных бедствий (С Б) по Родкину М.В. и Шебалину Н.В.(1993) с изменениями и дополнениями Усупаева Ш.Э.(2009)..											
Название (С Б)	Всемир-ное	Межкон-тинен-тальное	Между-народ-ное	Межго-судар-ствен-ное	Нацио-нальное	Регио-нальное	Меж-район-ное	Район-ное	Меж-мест-ное	Мест-ное	Семейное	Индивидуально е
N,чел.- число погибших	от 301 млн. .до 3 млрд.	от 31 млн. до 300 млн.	от 3,1 млн. до 30 млн.	от 301 тыс. до 3,0 млн.	от 31 тыс. до 300 тыс.	от 3.1 тыс. до 30 тыс.	от 301 до 3 тыс.	От 31 до 300	от 3 до 30	от 1 до 3 (редко)	до 1 (редко)	жертв нет
Ц, долл. США ущербы при (медленных ЧС (цены 1991 года)	от 6 трлн. до 60 трлн.	от 601 млрд. до 6 трлн.	от 61 млрд. до 600 млрд.	от 6,1 млрд. до 60 млрд.	от 61 млн. до 6 млрд.	от 6 млн. до 60 млн.	от 601 тыс. до 6 млн.	От 6,1 тыс. до 600 тыс.	От 1001 до 6 тыс.	от 100 до 1000	От 250 до 100	менее 100
Ц, долл. США,	от 1,5	от 151	от 15,1	от 1,51	от 15,1	от 1,51	от	От	От	от 101	От	менее

Fig.12

References

1. Fundamentals of engineering geonomy and studies of catastrophes. (2006). Edited by Professor Sh.E.Usupaev. Bishkek. Univ Demi. 662 pages.

2. Lvovich M. I. (1986) Water and Life: (Water Resources. Transformation and protection). Thought. -254 pages.
3. Dmitreev A. A. (1987) Solar activity, weather and climate. Moscow. 48 p.
4. Hans-Ulrich Wetzel, Andreas Reigber, Andreas Richter, Wasili Michajlow "Gletschermonitoring und Gletscherseebruche am Jnyyltschik (Zentraler Tien-Shan) - Interpretation mit optischen und Radarsatellinen" (2005). Bishkek. 10 p. 4.
5. Usupaev Sh.E. Engineering geonomic forecasting model of radiation and energy disaster on planet Earth and its sub-parts. Proceedings of the CIS conference on 'Innovative nuclear power technologies in the 21st century. Objectives, selection criteria, development concept'. Moscow, 2001.
6. Usupaev Sh.E., Achkasov PV, "Engineering education geonomic paleo-catastrophe volume figures of the planets (for example, a geodesic globe). Proceedings of the International Conference on Surveying and Geoinformation Science held on October 18-19. Bishkek. 2007. Pp. 160-163
7. Usupaev Sh.E. Engineering and geonomy modeling methodology and assessment of geocryosphere risks of climate change on the Earth and its sub-parts. Collection of articles and reports of the scientific conference "Prospects for the use of hydropower resources of Tajikistan in the context of climate change." Dushanbe, 2009, pp. 59 - 63.
8. Y. P. Malyshkov, S. Yu. Malyshkov. Geophysical FIELDS AND VARIATIONS seismicity, THEIR POSSIBLE COMMUNICATION MOVEMENT OF THE EARTH outer core geology and geophysics, 2009, v. 50, #2, pp. 152-172
9. Usupaev Sh.E. Applied basic theory prediction of geohazards and handling of hazardous environmental changes. s.670 - 674. In: Monitoring, forecasting of hazardous processes and phenomena on the territory of the Kyrgyz Republic (Seventh Edition as amended), B.: MES KR, 2010, 753 pages.
10. Usupaev Sh.E. Fundamentals of engineering geonomic (EG), disaster forecasting methodology. Pages 682 - 683. Monitoring and forecasting of hazardous processes and phenomena in the Kyrgyz Republic (eights edition as amended), B.: MES KR, 2011, 718 pages.
11. Budyko MI (1977) Global ecology.-Moscow. Thought. P -328.

Mathematical-cartographic Modeling of **Water and Hydropower Resources inKyrgyzstan**

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An enhanced digital elevation model and a digital model of moisture characteristics in Kyrgyzstan, formed in increment of 500 meters, serve as a basis for modeling. Digital elevation model, except for the altitude of nodes of a regular mesh, also contains information about the angle of slope, exposure, mean surface curvature and the index of macro-slope orientation. Digital model of dampening contains the following characteristics for each node: average annual air temperature, annual amount of atmospheric precipitation, vaporization, evaporation, drain module and moisture. In addition we used digital models of snow cover characteristics, types of intra-annual precipitation distribution, climate changes in the second half of the twentieth century, as well as data files on the glaciers of Kyrgyzstan, formed on the basis of the Directory of glaciers of the USSR.

The above mentioned data can simulate condition of water and hydropower resources in Kyrgyzstan, or its chosen part, given the time of the original data. We've carried out the reconstruction of resources in the past, as well as modeling of their possible evolution in the future, taking into account certain climatic conditions. For example, the state of glaciation in Kyrgyzstan under different climatic conditions is simulated on the basis of statistic dependence of the firm line altitude on average summer air temperature and annual amount of precipitation on the territory of the Republic. Some of the used mathematical models were also developed for the territory of Kyrgyzstan. Almost in all the cases results of the modeling are presented in numerical, graphic and cartographic form.

Trans-Boundary Issues of Hydropower Industry in Kyrgyzstan

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Abstract

Available power of a country is characterized by the amount and capacity of electricity generated per person. In other technically advanced and economically developed countries, electricity production per person is only two-three times more than in Kyrgyzstan, where industrial organizations do not work and agriculture is in decline.

The Central Asian region is clearly divided into the countries, which are rich in water resources (Tajikistan and Kyrgyzstan) and the countries, dependent upon Tajikistan and Kyrgyzstan in terms of water supply (Uzbekistan, Turkmenistan and Kazakhstan).

The average annual water discharge from all the rivers, flowing on the territory of the Kyrgyz Republic, is about 1 500 m3/s. The main hydropower potential of the Kyrgyz Republic is the runoff of rivers, which originate in the Kyrgyz Republic. The Kyrgyz Republic faces a serious task to tackle poverty, and water resources are an important source of national economic development.

With all our hydropower abundance, we should consider not gross, but economic hydropower potential, which is 4 to 6 times less the gross one.

Export of electricity is the only source of funding fuel procurement for thermal power plants. Unregulated power consumption in 2005-2008 affected the gradual depletion of water supplies from conservation zone of the Toktogul reservoir to the dead storage level.

The power system of the Kyrgyz Republic, being isolated from the power systems of neighboring states is currently not energetically secured. Maximum load in the north is 1,900 million kW, while in the south it is 1000 million kW. Generation power plants are located in the south by 90%.

The Government of the Kyrgyz Republic has been choosing investors for construction of small, medium and large HPPs for several years.

Joint development of water and hydropower resources of the Sarydjaz-Kumaryk River is a project, proposed by IWPHP NAS KR, a project of harmonious and mutually beneficial cooperation between China and Kyrgyzstan. Chinese National Energy Corporation “Guodian" is ready to invest in cascade construction projects on Sarydjaz and Chu rivers.

Introduction

Electric energy is an index of technical and economic development of the country and human wellbeing.

Reliable and dynamically developing electric power industry enables a country to live comfortably in the present and to confidently plan its future, developing energy-intensive production, which significantly increases the competitiveness of the economy and is conducive to long-term investments.

Available power of a country is characterized by the amount and capacity of electricity generated per person.

Electricity production [1, 2] in some countries of the world, amount of electricity generated per person annually and power capacity per person are shown in Table 1.

Table 1 - Electricity Production Worldwide

#	Country	Electricity Production Million kWh/year	Population size, thous. people	Amount of electric power per person, kWh/year	Elecric power capacity per person, W/person
1	USA	4 110 000	310 233	13 248	1 512
2	China	3 451 000	1 330 141	2 594	296
3	Russia	1 040 000	139 390	7 461	852
4	Japan	957 000	126 804	7 546	861
5	India	723 800	1 173 108	617	70
6	Canada	620 700	33 760	18 380	2 098
7	Germany	593 400	82 283	7 212	823
10	Brazil	438 800	201 103	2 182	249
16	Australia	239 900	21 516	11 150	1 273
25	Norway	142 700	4 676	30 518	3 484
32	Pakistan	90 800	184 405	492	56

36	Kazakhstan	78 400	15 461	5 071	579
51	Uzbekistan	44 800	27 866	1 608	184
75	Tajikistan	16 100	7 487	2 150	245
76	Kyrgyzstan	14 500	5 363	2.703	308
77	Turkmenistan	15 500	4 941	3 137	358
108	Armenia	5 584	2 967	1 882	214
136	Laos	1 656	6 368	260	30
157	Mali	515	13 796	37	4
167	Afghanistan	285	29 121	10	1
189	Chad	100	10 543	10	1
211	Gaza Strip	0.065	1 604	0.04	-

In terms of electricity production, Kyrgyzstan ranks 76th out of 211 countries. Electricity produced per person in Kyrgyzstan is 11 times less than in Norway - the country, which occupies the first place in the world in this indicator. In other technically advanced and economically developed countries - Russia, Japan, France, Germany, Great Britain - electricity production per person is only two-three times more than in Kyrgyzstan, where industrial organizations do not work and agriculture is in decline.

Electric power industry in Central Asia

Central Asia has extremely uneven distribution of energy resources on its territory. Countries located in the lower part of the Amu Darya and Syr Darya rivers - Kazakhstan, Uzbekistan and Turkmenistan – are rich in oil and gas, and the Kyrgyz Republic and Tajikistan almost do not have it. The main energy resources of the countries of Central Asia [3] are shown in Table 2.

Country	Fossil fuel reserves, Million tons fuel equivalent					Hydropower capacity		
	Oil	Gas	Coal	Total	Per-cent	Billion kWh	Million tons fuel eq.	Per-cent
Kazakhstan	1,100	1500	24300	**26900**	77.4	**27**	2.3	5.2
Kyrgyz Republic	5.5	5	580	**591**	1.7	**163**	14.0	31.1
Tajikistan	1.7	5	500	**507**	1.5	**317**	27.3	60.5

Table 2 - Basic energy resources in Central Asia

Water resources in the states of Central Asia are distributed unevenly. Central Asian region is clearly divided into the countries, which are rich in water resources (Tajikistan and Kyrgyzstan) and the countries, dependent upon Tajikistan and Kyrgyzstan in terms of water flow (Uzbekistan, Turkmenistan and Kazakhstan). Kyrgyzstan controls the Syr Darya river basin, and Tajikistan controls the Amu Darya basin.

More than 25,000 streams and rivers flow on the territory of Kyrgyzstan, 73 rivers have the length of more than 50 km. Most of the rivers are of up to 50 km in length, and streams are of up to 10 km in length. The total length of all the rivers is more than 500 thousand kilometers. Density of river network in average is 2.5 km per km^2 [4].

The Syr Darya River is the first in length and the second in water content in Central Asia.

The length of the Syr Darya River is 3,019 km; its basin area is 219 thousand km^2. The main part (75.2%) of the Syr Darya runoff is formed on the territory of the Kyrgyz Republic, 15.2% - in Uzbekistan, 6.9% - in Kazakhstan and 2.7% - in Tajikistan.

The main tributaries of the Syr Darya River are the rivers of Naryn, Karadarya and Chatkal, which are formed in the Kyrgyz Republic. The main river in Kyrgyzstan is the Naryn River, which collects water from the territory of 53,000 km^2. The Naryn River takes its rise from the Kumtor River, originating at the altitude of 3,700 meters from the lake which is formed by melt water from the Petrov glacier. The Kumtor River, taking several tributaries, flows into the river of Bolshoi Naryn (Great Naryn), and after its confluence with the Malyi Naryn (Minor

Naryn) river, it forms the main river of Naryn. The average annual water flow of the Naryn River at the place, where it leaves the territory of Kyrgyzstan, amounts to 430 m^3/s.

The average monthly water consumption of the Naryn River (Uch-Terek village), of the Chu River (Kochkorka village) and of the Sarydjaz River with its tributaries Kuylyu and Akshiyrak are shown in Fig. 1.

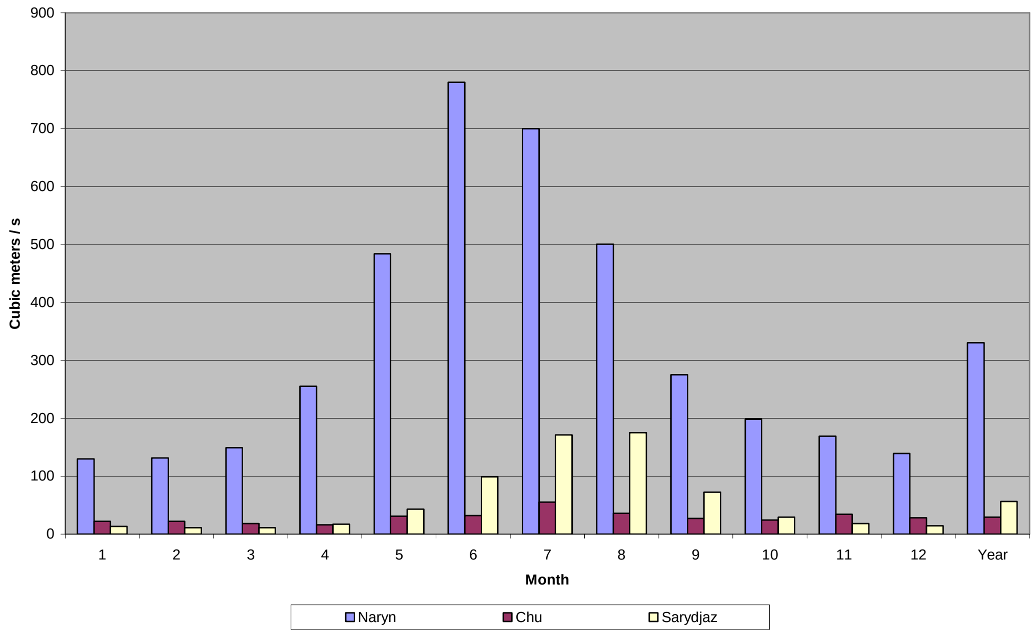

Figure1. The average monthly water consumption in Naryn, Chu, Sarydjaz rivers

Minor rivers and tributaries with discharge of up to 10 m^3/s are often fully taken to the irrigation channels. The average annual water consumption of all the rivers, flowing in the Kyrgyz Republic, is around 1,500 m^3/s.

The total average annual river runoff in Kyrgyzstan is about 50 km^3/year.

The main hydropower potential of the Kyrgyz Republic is the runoff of the rivers, which take their rise from the Kyrgyz Republic.

Irrigation and power operation modes of power plants are significantly different. Irrigation mode involves discharge of large amount of water in summer, when Uzbekistan and Kazakhstan need it for irrigation of their fields. Power operation mode means that power plants discharge large amount of water in winter, when the demand for electricity increases. Water reserves in the region are limited. Water is scarce for year-round operation in both modes. During the Soviet period, when energy complexes of the Central Asian republics and Kazakhstan were a part of a huge integral system, power plants operated in the irrigation mode, dropping the water in spring and summer, receiving in return gas, coal and fuel oil from other republics in winter. After the collapse of the Soviet Union, the situation changed, and all the calculations for energy consumption were oriented to market prices. Uzbekistan and Kazakhstan refused to pay for water used for irrigation, considering it as a common heritage of the region. Maintenance costs of power plants and reservoirs are covered by the Kyrgyz Republic and Tajikistan, which led to significant deterioration of their technical condition.

For the fault of its own fuel resources, as well as experiencing difficulties with their acquisition, the Kyrgyz Republic is planning to solve its energy problems by constructing a cascade of Kambarata power plants, which began during the Soviet period.

In January 2008, the Kyrgyz Republic resumed construction of the Kambarata-2, using its own resources. The Kyrgyz Republic cannot build Kambarata-1 at its own expense, and the project completion may possibly be implemented at the expense of Russian loans.

According to Uzbekistan, construction projects of hydropower stations in upper courses of major waterways should take into account the interests of all the states in the region and undergo a mandatory examination to assess their technological and environmental safety, as well as guarantee of the preservation of water balance. Uzbekistan considers Kambarata-1 project to be the most undesirable project for Uzbekistan.

Situation in water use is actually a reflection of a profound socio-ecological crisis, existing for a few decades. It exists due to the discrepancy between natural climatic resources of the region and the rapid increase in its population, as well as the unreasonable economic system. In 1960-2000, total amount of water intake in Central Asia has doubled. 90% of this water is used for agriculture.

The Kyrgyz Republic faces an acute task to tackle poverty, and water resources are our source of national economic development.

Hydropower resources of the Kyrgyz Republic were determined by the Academy of Sciences of the Kyrgyz SSR in 1960; in 1967, the Academy of Sciences of the USSR specified hydropower resources of the Kyrgyz Republic. In 1983-1985, KirNIOE developed a thematic map "Hydropower industry of the Kyrgyz SSR". The Institute of Water Problems and Hydropower of the National Academy of Sciences of the Kyrgyz Republic (IWPHP NAS KR) specified the main indicators of hydropower resources of rivers in the Kyrgyz Republic. Results of the studies [4, 5] are shown in Table 3.

Table 3 - Hydropower Resources of the Kyrgyz Republic

Organization	Known rivers, number	Hydropower potential					
		Gross		Technical		Economic	
		Capa-city, million kW	Power, Billion kWh/ year	Capa-city, million kW	Power, Billion kWh/ year	Capa-city, million kW	Power, Billion kWh/ year
Academy Kyrgyz SSR, 1960	180	14.9	130.3	-	-	-	-
Academy USSR, 1967	236	16.3	142.5	8.3	72.9	5.5	48
KirNIOE, 1986	252	18.6	162.5	11.3	99.2	6.3	55.2

With all our hydropower abundance, we should consider not the gross, but the economic hydropower potential, which is 4-6 times less than the gross one. Out of 45.5 billion kWh/year of the Economic hydropower capacity - about 20 billion kWh/year is currently used, developing up to 14 billion Wh/year of active hydropower at HPPs of the Kyrgyz Republic. Assume that existing and future hydropower plants in Kyrgyzstan may develop up to 30 billion kWh of active hydropower annually.

Water and energy modes of the Naryn cascade of HPPs

Average long-term runoff of the Naryn River in the period from 1910 to 1974 was 11.4 billion m^3. From 1975, when the Toktogul HPP was launched, to 2010, the average long-term runoff of the Naryn River amounted to 12.6 billion m^3.

Average annual water output from the Toktogul reservoir between 1975 and 1992 was 10.7 billion m^3, 7.7 billion m^3 out of which were produced during the period of growing irrigation needs. Since 1995, water in the Toktogul reservoir began to be used in the power mode - at an average annual production of about 14 billion m^3, water production for non-growing period accounted for 61%.

Water releases from the Toktogul Reservoir, regardless of electricity production, caused idle discharge of water in all cross-sections of the hydropower stations cascade.

Water release mode is continuously monitored and daily information is submitted to dispatcher services of JSC “National Electric Networks of Kyrgyzstan", "Energy" corporation, JSC "Power Plants". Unauthorized electricity supply volumes are not possible either. All data on cross-flow of electricity is fixed by metering tools in all the energy systems of the neighboring republics and is submitted to the customs authorities.

Electricity production in the Lower Naryn HPPs cascade is annually planned, taking into account energy consumption in the Republic, availability of water reserves, capacities of Bishkek and Osh Heating Power Plants, electricity export volume. Export of electricity is the sole source of funding fuel procurement for heating power plants.

Unregulated power consumption in 2005-2008 affected the gradual depletion of water supplies from conservation zone of the Toktogul reservoir to the dead storage level.

In 2010, for the second time over the operation years of the Toktogul waterworks, there was need for idle discharge. To avoid idle discharges during the growing season of 2010, it was necessary to ensure power export of about 3 billion kWh. Hydropower production at HPPs and Heating Power Plants in Kyrgyzstan and export of electricity from Kyrgyzstan for the period from 2000 to 2010 [6] are shown in Fig. 2.

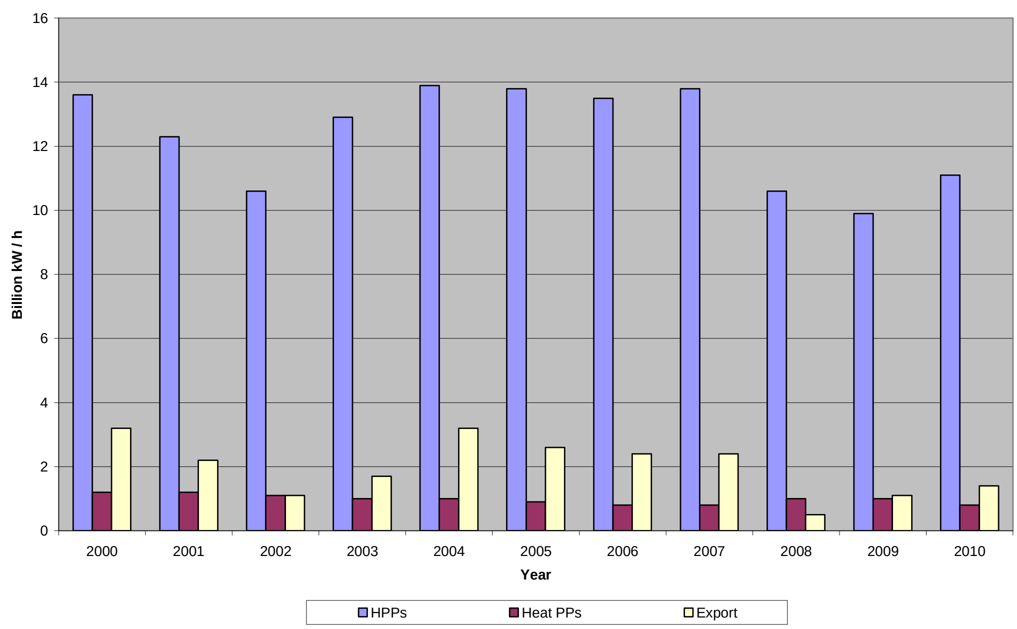

Fig. 2. Electricity production at hydropower plants and heating power plants

in Kyrgyzstan and export

Limitations on discharge capacity of trunk transmission lines, organization of open tendering and bureaucratic delays in electricity export prices approval at the Ministry of Energy led to idle discharges on the cascade of hydropower plants in August - September 2010.

In the energy system of Kyrgyzstan, there are problems with electricity supply for consumers. There is steady growth in power consumption, especially in the north of the Republic. The power system is geographically divided into the north one and the south one. They are connected by one high-voltage line of 500 kV. Maximum load in the north is 1,900 million kW, and in the south – 1,000 million kW. Generation power plants are located in the south by 90%.

Average daily consumption of electricity in the Republic is about 18 million kilowatt-hours in summer, and in winter it increases to 67 million kilowatt-hours/day [7]. Such an increase in electricity consumption is due to the use of electricity for cooking and heating.

Electric network with voltage of 500 and 220 kV in the north is loaded up to the highest notch in hours of maximum loads in winter.

The power system of the Kyrgyz Republic, being isolated from the power systems of neighboring states currently does not have energy security.

The Sarydjaz - Kumaryk River is a Kyrgyz-Chinese cross-border river. Part of this river (from its source to Kyrgyz-Chinese border) is called Sarydjaz, and on the territory of China to the mouth of the Aksu River it is called Kumaryk.

In the Kyrgyz Republic, the river has a length of 210 km, catchment area is 11,224 km^2, which amounts to 73.6% of the total catchment area of this river.

The length of the Kumaryk River in China is equal to 105 km, the catchment area is 4,027 km^2, which is 26.4% of the total catchment area. Total catchment area of the Sarydjaz-Kumaryk River is 15,251 km^2, the length of the river is 315 km.

The Sarydjaz-Kumaryk River, having significant water capacity, has large differences in elevation and substantial hydropower potential, which creates good preconditions for cascade hydropower resources development. Joint development of water and hydropower resources of the Sarydjaz-Kumaryk River is a project of harmonious and mutually beneficial cooperation between the two countries, stimulating economic development and good-neighborly relations [8].

Since 2006, scientists of IWPHP NAS Kyrgyzstan and XUAR PRC began to develop scientific and technical justification for joint development of water energy resources of the Sarydjaz River. As a result, coordination mechanisms of joint cooperation have been found, and a project of integrated use of the river water resources has been proposed, which will stimulate the development of mineral resources in the basin of the Sarydjaz River and recreational resources in the Issyk-Kul lake basin.

Joint development of hydropower potential in future will strengthen bilateral cooperation, develop economy of Kyrgyzstan and China, strengthen good neighborliness and cooperation between present and future generations of the two countries.

"Report on integrated use of water resources of the transboundary Sarydjaz-Kumaryk River", composed in 2010, is a result of generalization of Kyrgyz and Chinese scientists joint work.

IWPHP NAS KR proposed the Government of the Kyrgyz Republic to consider the report on the integrated use of water resources of the Sarydjaz-Kumaryk River, aiming at decision-making at the government level for further development in this direction. Chinese investors, represented by the China National Energy Corporation “Guodian", are ready to invest in this project today, as well as in the construction project of two hydroelectric power stations on the Chu River. Economic and social benefits for our Republic from these projects are obvious.

References

1. Electricity production in the countries of the world according to 2007-2009 data. www.iformatsiya.ru World countries.

2. The population of the world (2010) www.iformatsiya.ru World countries.

3. I.Kirsanov. Struggling for water Central Asia. – “Nezavisimyi obozrevatel’ stran sodrujestva” [Independent Explorer of the Commonwealth], #12, 2006.

4. D.M. Mamatkanov, L.V. Bazhanova, V.V. Romanovskaya. Water resources of Kyrgyzstan at the present stage. - Bishkek: Ilim, 2006. – 276 pp.

5. Energy Resources of the USSR. Hydropower resources. -M.: Science, 1967, 600pp.
6. The volume of electricity production and export for 2000 - 2010. Ministry of Energy of the Kyrgyz Republic. - Bishkek, 2011.

7. Specific features of the Kyrgyz power system. Ministry of Energy of the Kyrgyz Republic. - Bishkek, 2011.

8. On complex use of water resources of Sarydjaz – Kumaryk river basin. Report of the Department of Water Resources Economy XUAR CPR and IWP@HP NAS KR. - Bishkek - Urumqi, 2010. – 45pp.

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