The Regional Workshop
of the InterAcademy
Panel Water Program

Proceedings of the VI Regional Workshop "Water Resources and water use problems in Central Asia and the Caucasus"

July 10-13 2007

Barnaul 2008

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Materials presented interesting for water managers and research institutes involved in water-related issues study.

All papers are printed in author’s alteration.

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Address from the chairman of the IAP Water Programme

José Galizia Tundisi, Prof.
International Institute of Ecology,
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São Carlos, Brazil

I would like, first of all, to give a warm salute to all our friends and colleagues from the Siberian Branch of the Russian Academy of Sciences that organized and prepared a very important workshop on behalf of the IAP Water Programme.

As you know I am coordinating a very large-scale program on water resources management and integrated research and management in several different countries.

The workshop that you have prepared is a very important one, because it will discuss water issues and problems in countries of Central Asia and Caucasus with the participation of many Academies of Sciences. Therefore I would like to congratulate all of you for effort in organizing and participating in this conference.

Let me give you a brief introduction on the water problems that all of you know, but I would like to emphasize some of them. As you know, water of good quality and in sufficient quantity is important for the economic development, for the quality of life of the population, for the production of food, for recreation, for tourism, and for giving to the people better opportunities of employment and human development, in the best sense. Water of good quality has a very important also, social importance; therefore I would like to stress that your workshop that addresses several problems of water quality and quantity in your region is a very important one.

As we know, to solve all the problems of water scarcity, water quality, contamination, eutrophication and pollution, it is necessary a large-scale effort, worldwide effort, that will be based on scientific and technological development and the transference of this knowledge for the society, for the management systems. Therefore all proposals, the IAP Water Programme is to develop a strong component on innovation, research and capacity building around the world, in specialized centers that will be focal points for the network that we are developing.

At this point we have a network consisting of six countries: Brazil, Poland, Russia, Jordan, China and South Africa; and we have also Mexican Academy of Sciences and Argentinean Academy of Sciences preparing to enter this network.

We also have several large-scale global problems like climatic changes that are increasing the vulnerability of the water resources in many areas of the world. Therefore we have to address not only regional and local problems, but also global problems; for that we develop this network. Therefore we expect that your participation in this network will bring together not only scientists from Central Asia countries and the Caucasus, but will enhance our network in order to produce a large-scale movement of scientists, students, post-doctoral fellows that can be integrated in this network and exchange knowledge between ourselves, but not only between ourselves, especially with the management system. One of the key problems in the water resources management is the integration of what we know, the knowledge, the local, regional and global knowledge into programs of management that address not only global and regional problems, but local problems.

As you know, the contamination, pollution and the good water quality or bad water quality depends a lot on the watershed status and the use of the watershed as a unit to manage water. Many human activities that affect the water resources, underground or surface water resources are directed to the watershed uses and are related to the watershed uses. Impacts of large-scale on land uses, industrial impacts, domestic wastewater are all originated in the watershed and depended on the human activities. I urge you to discuss these issues in your regional basis and I see with satisfaction, that all the points that we have addressed, all the topics that we have addressed in our workshop, they cover very well the needs that are present needs and future needs for the water management: drinking water quality, quality of underground waters water, runoff and quality of runoff waters, and all the impacts of water degradation, on the economy and on the quality of life of your society.

We have a lot to learn with each other and I expect that after this workshop, the book that will be produced by our colleagues and friends from the Russian Academy of Sciences, the Siberian Branch of the Russian Academy of Sciences, the book will be useful to all of you, but also to all of us, of the network and the many other countries that are around the focal points, such as in Jordan, Poland, South Africa, China and Brazil.

I wish you a very successful workshop. I regret I am not being able to be with you. I was called by our President to interfere with some critical problems on water issues in Brazil; therefore I was unable to participate in this workshop as I wanted and wished since the beginning of our conversation with Dr. Zinoviev. I expect that your discussions, the presentation of papers and the book that will follow will be an excellent contribution to the IAP Water Programme.

Let me emphasize that the IAP Water Programme has a strong component on innovation, not only research and developments and innovation for research and development, but specially innovation in capacity building and I can see that your program encompasses specially this innovation characteristics of the IAP Water Programme.

I am especially happy that you are able to invite Government Officers and high-level managers to interact with scientists in this meeting, because this is a very important component of the IAP Water Programme.

Finally, I would like to wish you an excellent conference in Barnaul and I am sure that the contributions that we will produce, either the book or the discussions during the conference will be a very fundamental component of our workshop and will be a useful and a fundamental addition to all the participants of the network. Therefore, I would like once more to congratulate you on your effort and wish you a happy period in Barnaul.

Opening remarks

Marcos C. B. Scheuenstuhl, Dr.
Brazilian Academy of Sciences, Rio de Janeiro, Brazil

On behalf of Professor Jacob Palis, President of the Brazilian Academy of Sciences, and of Professor José Galizia Tundisi, Chair of the IAP Water Programme, I have the privilege to address this most distinguished audience. I should say that it is an honor to be among personalities such as Dr. Iakov Ishutin, vice-governor of Altay Krai; Prof. Igor Saldan, the head of Rospotrebnadzor, chief sanitary doctor of Altay Krai; Dr. Nikolai Tselishcev, Deputy of the Director of the Housing and Communal Services Department of Altai Krai; and Prof. Vinokurov Yuri Ivanovich, Director of the Institute of Water and Ecological Problems, of the Siberian Branch of the Russian Academy of Sciences. Naming Prof. Vinokurov, I would also like to mention Dr. Alexander Zinoviev, Head of the Laboratory of Hydrology and Geoinformatics, and Dr. Elena Mitrofanova, Scientific Secretary of this workshop, both from the Institute of Water and Ecological Problems, with whom we have been interacting directly since January of this year, when we started to discuss the organization of this meeting. I would like to acknowledge the representatives of the Science Academies of the region that are present at this workshop.

As I mention our Russian colleagues, I should not forget to express our gratitude to Academician Nikolai Dobretsov, Chairman of the Siberian Branch of the Russian Academy of Sciences and Vice-President of the Russian Academy of Sciences. Prof. Tundisi and myself met with Prof. Dobretsov in Korea, on October 2005, when we discussed the possibility of holding an IAP Water Programme workshop in Central Asia. At the time, not only he expressed his full support to the proposal, but also embraced the idea, putting us in contact with Prof. Vinokurov. The leadership and patronage of Prof. Dobretsov and Prof. Vinokurov were determinant to close the circuit and make it possible for us all to be here today.

In short, although our contact with the colleagues from Russia is relatively recent, dating only seven months, they have proven to be key partners for the regional building up of the IAP Water Programme. I here thank for this support, congratulating the teams of the Institute of Water and Ecological Problems and of the Siberian Branch of the Russian Academy of Sciences, which have been tireless in the organization of this event, making things easier for all and providing us such a generous hospitality in this magnificent country.

Having said this, in a few words I would now like to present a short background on the IAP Water Programme and on this specific workshop, organized by the Institute of Water and Ecological Problems of the Siberian Branch of the Russian Academy of Sciences. Considering that probably most of you are being introduced today to the InterAcademy Panel on International Issues (which is IAP), let me first say a few words on IAP and its programmes.

IAP is a global network, launched in 1993, with a current membership of 94 Science Academies from around the world. These include national Academies and Institutions, as well as regional and global associations of scientists. A number of other scientific organizations also participate in IAP meetings and activities as observers. Examples of these associations and organizations, in Asia, are the Association of Academies of Sciences in Asia (AASA) and the Federation of Asian Scientific Academies and Societies (FASAS).

IAP is headquartered in Trieste, Italy, and operates under the administrative umbrella of the Academy of Sciences for the Developing World (TWAS), formerly known as the Third World Academy of Sciences. IAP receives a substantial support from the Italian government that, in 2004, passed a permanent law providing a secure funding basis for the activities of the network. Additionally, member Academies also contribute to the programmatic activities of IAP. This workshop itself is a good example of this type of support, as the Siberian Branch of the Russian Academy of Sciences is not only kindly hosting us, but also supporting this meeting with local funds. And for this, on behalf of IAP and of the Brazilian Academy of Sciences, lead Academy to the Water Programme, I would like to thank our hosts.

IAP has as its primary goal to help member Academies work together to advise citizens and public officials on the scientific aspects of critical global issues. IAP is particularly interested in assisting young and small Academies achieve these goals, and through the communication links and networks created by its programmes and activities, help member Academies raise both their public profile among citizens and their influence among policy makers.

Science and the development of knowledge has always been an endeavor with international characteristics based on the close interaction between scientists of all nations. However, science and the benefits derived from it are far from being equally distributed and shared, especially considering the people living in the developing countries. IAP intends to serve as an instrument for the international scientific community to offer its contribution to the overcoming of this situation, which represents an enormous challenge for the achievement of sustainable development and of a more egalitarian world, where famine, poverty and lack of access to safe drinking water are no more characteristic marks.

As for the IAP Water Programme, evidently behind it is the concern on the emerging “water crisis” that threatens large parcels of the human population in many regions of the world. Today, about one-third of the world’s population is living under moderate or severe water stress, most notably in the Middle East and North Africa. One billion and three hundred million people lack access to adequate water supply and two billion people do not have access to adequate sanitation. Water pollution is continuing to cause millions of preventable deaths every year, especially among children. The challenges of this crisis require a vigorous scientific, technological and managerial action in order to use adequately and better the existing water supplies, to recover degraded surface and groundwater reserves, and to secure, for the future generations, the necessary water resources.

To cope with this problem, the Brazilian Academy of Sciences presented to the IAP Executive Committee the proposal of a new IAP programme on Capacity Building in Water Resources Management. This proposal was discussed within the Academies and at the 2003 IAP General Assembly, held in Mexico, the IAP Water Programme was established. Since then, 64 Academies of Sciences throughout the world have committed themselves with the building-up of this programme.

A long process of conceptual discussions and strategic planning has been covered and presently we are holding, here in Barnaul, the last of a set of six regional workshops that were planned to be held in 2006 and beginning of 2007. In June 2006, a first workshop was organized, in Beijing, by the Chinese Academy of Sciences, covering the East Asia and Pacific Region. The Americas held its regional workshop in July, in Guarulhos, São Paulo, under the auspices of the Brazilian Academy of Sciences. This was followed by the African workshop, held in August and hosted by the Academy of Sciences of South Africa, in Pretoria. In September, in Lodz, the Polish Academy of Sciences organized the fourth workshop, covering the European region. And last March 2007, the Royal Scientific Society of Jordan hosted the workshop for the Middle East and South Asia Region.

Basically, the objective of these workshops was to bring together high-level water researchers and managers to regionally discuss the major problems presently faced by water managers, and how can science contribute to the overcoming of these. Focusing the problems through a regional perspective, these workshops helped in the identification of specific and general demands, and in the building up of an agenda to the programme. Evidently these workshops also played a crucial role in the consolidation of the IAP Water Network.

As for the general objectives of the IAP Water Programme, I could summarize it as an effort, to be developed by the Science Academies of the world, focused on: (1) development of local capacity building in water management; (2) networking of water researchers and managers to help enhance water management capacity in the developing world; (3) improvement of policy and decision making processes; (4) increasing public awareness on the emerging water crisis; and (5) bringing to the table the major international water programmes and initiatives, to discuss complementary work and to avoid irrational duplication of efforts and funds.

A very important aspect of the IAP Water Programme is the proposed approach. Although the hydrological cycle makes all kind of water in the planet linked some way, traditionally surface and ground waters have not been viewed or managed as integrated units. The disconnection between policies and practices regarding the two main water compartment stems in part is due to the failure of professionals, both scientists and managers, in considering them as integrated units.

What happens in a watershed can have a big impact in the aquifers, qualitative and quantitatively. Pollution, for example, is nowadays the most serious human impact on water. An increasing variety of contaminants find its way into both surface and ground water supplies, especially in urban and industrialized areas. The chief pollutants come from point and non-point sources - such as landfills, sewage treatment lagoons; disposal pits; urban runoff; water from agricultural land treated with fertilizers and pesticides; as well as industrial sources. All of these contaminate both surface and groundwaters. Effective management will depend on a deep understanding of the processes regarding water and catchment issues.

In short, the present dichotomy regarding surface and groundwater issues can be advantageously treated by a watershed and integrated approach. At the same time, differently from how it has been in the past, management must be predictive, foreseeing the problems, and not only responding to them. And for this, the IAP Water Programme raises a new paradigm, proposing that water - both at and beneath the earth surface –

can and must be treated as an integrated unit. Hydrogeologists, limnologists, engineers and ecologists, among others, need to work together, upon cross-sectorial and regional approaches to management, in order to optimize investments, both human and financial, that will be essential if water is to continue playing its critical role in the natural functioning of the Earth, providing ecological, hydrological and economic services to humankind. This will demand from us innovative approaches at the research, management and capacity building levels.

Having said this, I shall stress that the dominion of knowledge is a necessary, but not a sufficient condition. The sustainable management of surface and groundwater resources will only be possible if scientists are able to bridge professional and cultural gaps among them. Similarly, if we are not successful in getting the best possible understanding and knowledge into the hands of managers, our effort will have been in vain.

As part of the framework for improving the development of human resources and the integration of research and management, the Water Programme proposes the implementation of International Training Centers, which will act as nuclei for training, development of new technologies and field facilities for case studies. These training centers are not necessarily new structures; they can be based on existing institutions and networks. These centers will be linked throughout a network that will provide a facility for exchange of programmes, scientific data, research information and training programmes. They will also stimulate, integrate and catalyze ongoing activities, fostering innovation.

The proposed international training centers will have the task to draw attention to the water problems of the world in an integrated approach. They will place together scientists and managers that will address the pressing problems of water supply and, at the same time, produce advanced scientific knowledge. These centers shall stimulate publications and enhance activities for public awareness. They will address managers and scientists in specialized training courses, working in cooperation with local universities and institutions. At the same time, these centers will be cooperating with other international centers worldwide, securing thus a network of high quality, which will stimulate advanced scientific research. The idea is to accelerate the development of partnerships between public and private institutions, integrating climatology, hydrology, hydrogeology, limnology, ecology and research, development, innovation and management.

One aspect that is important to recognize is that, presently, many international programmes and initiatives are already dealing with water issues, through a wide variety of approaches. From the IAP Water Programme's point of view, a major problem is the lack of integration among these, which leads to an inefficient duplication of efforts. This is caused by a focus on limited aspects of the problem, as well as too much disciplinary research, what impairs a systemic approach. What the IAP programme proposes represents an innovative approach and might represent a new step forward on water research and management. Benefiting from the prestige of the Science Academies, the intention is to call the table the major existing initiatives and discuss with these the importance of the adoption of a new paradigm to water management, and more collaborative work among the different programmes.

In conclusion, I would like to, again, thank and congratulate the Institute of Water and Ecological Problems of the Siberian Branch of the Russian Academy of Sciences for the organization of this workshop. I would also like to give a very special thanks to the Science Academies that came to this workshop. The active engagement of each one of the Academies is essential for the success of the IAP Water Programme. The challenge to be faced by this programme is enormous, but bigger is the responsibility that is put to the international scientific community in coping with problems that increasingly afflicts society. From the response that we are receiving, we are most confident that this programme will present an important and effective contribution that will add to other existing experiences. Via our joint effort, IAP will be bringing into action its commitment of bridging science with the pressing problems facing humanity, among which is the need to assure access to water both to the present and future generations. This is without question an important contribution towards the fulfillment of the UN Millennium goals.

Once I read a saying, based on the old African wisdom, which said something like: “The earth is not ours. It is a treasure we hold in trust for our descendants”. Well, let us hope that the discussions that we will hold in the next days help us pave the way for the building-up of a better future for those to whom we bear this treasure.

Thank you.

Session 1

Water resources formation in Central Asia and the Caucasus

Formation and use of water resources in Central Asia

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Abstract. The article analyzes the conditions of formation and use of water resources of the Aral Sea Basin Transboundary Rivers. A modern water resource management system is described. The problems related to water resource management in new conditions of development of the independent States of the Aral Sea Basin are also discussed. The issues related to ecological status of transboundary water entities and the ways on how to organize ecological management are analyzed. A new water-management strategy to improve the Aral Sea Basin water resource management is proposed.

Keywords: water resource management; transboundary water resources; Central Asia; water flow formation

1. Introduction

Water resources, as any other natural resource, represent not only an ecological category, but an important economic category. In Central Asia, water resources acquired this significance in ancient times, about 6 – 7 thousand years ago, along with the appearance of irrigated agriculture. At the beginning of 20th century, when the industrialization process (including construction) started in Central Asia, almost half of the river flow was utilized for irrigation. The process of allocation of water resources had been completed by the 1990 th. It is necessary to note that the process of allocation of water and energy resources of the rivers was performed in accordance with special programs (see, e.g., refs. [1-4]). The implementation of these programs resulted in utilization of entire water resources of the South area of the Aral Sea basin, and ultimately in the destruction of the Aral Sea as a morphological and ecological component of the region.

2. Formation of water resources and its role in economy

Prior to independence of the Central Asian states, the water management conditions in the region were characterized by data presented in Tables 1, 2 and 3.

Table 1

Water resources of river systems (in zones of formation, km^3/year [3- 8]

Item No	River name (river section line)	Runoff, coefficient of variation (Cv)	Runoff rate (or water resources at 50% flow probability)	Water resources at 90% flow probability
1.	Water runoff in upstream areas of the Amu Darya	0.14	65.9 (65.4)	54.4
1.1.	Including Pyanj (Downstream Pyanj)	0.12	33.1(32.9)	28.1
1.2.	Vahsh (Tutkaul)	0.14	19.9 (19.9)	16.4
1.3.	Kunduz(Askarhona)	0.23	3.50 (3.42)	2.50
1.4.	Kafirnigan	0.19	5.51 (5.41)	4.19
1.5.	Surkhandarya	0.19	3.67 (3.60)	2.80
1.6.	Sherabad	0.32	0.22 (0.22)	0.14
2.	Runoff in the rivers situated in the South-West of Uzbekistan		6.55 (6.48)	5.17
2.1.	Including Zeravshan	0.15	5.28 (5.24)	4.30
2.2.	Kashkadarya	0.26	1.27 (1.24)	0.87
3.	River runoff in Turkmenistan		2.77 (2.60)	1.35
3.1.	Including Murgab	0.29	1.54 (1.50)	1.0
3.2.	Tedjen	0.58	0.96 (0.86)	0.35
Total in the Large Amu Darya Basin (excluding North Afghanistan rivers which do not flow in)			75.2 (74.6)	60.9
4.	Water runoff in upstream areas of the Syr Darya		(25.56)	19.59
4.1.	Including Naryn (Uchkurgan)		(13.74)	9.9
4.2.	Karadarya (Kampyravat)		(3.76)	2.24
4.3.	Inflows in Fergana Valley		(8.06)	7.45
4.4.	Middle part rivers runoff		(9.3)	6.51
4.4.1.	Runoff from Golodnaya Steppe foothills		(0.6)	0.31
4.4.2.	Chakir river runoff		(8.7)	6.2
4.4.3.	Including Chirchik (Khodjikent)		(7.1)	4.8
5.	Water resources in the area of formation in relation to the section line of Chardarya (excluding runoff from Golodnaya Steppe foothills rivers)		(34.26)	25.8
6.	Arys and rivers of Karatau mountain ridge		(2.3)	1.5

7.	Total in the Large Syr Darya Basin		(37.2)	27.6
8.	Total in the Large Amu Darya and Syr Darya Basins		(112.4)	88.5
9.	Total in the large Amu Darya and Syr Darya rivers flowing into the Aral Sea		(100.11)	80.2

Table 2

Main indicators of water balance in the Amu Darya Basin

(area in thousand of hectares, water volume in cubic meters per year), [4-6]

Item No.	Indicators	Level in x 1990 г. According to "scheme …" (4. p.233)	Estimates of actual values in 1990 – year ~50% x) probability of water availability	Deviations (±)
1.	Available water resources (2/2.1+3+4)	72.5	74.5	+2.0
2.	River water resources	54.4	65.8	
2.1.	Including minimum flow	62.1		
3.	Ground water resources (output)	1.5		
4.	Return water resources	8.9	8.7	-0.2
5.	River water intake for irrigation	50.2	57.4	+7.2
6.	Internal use of return water for irrigation	10.5	2.7	-7.8
7.	Water intake for industrial and residential use	10.4	2.7	-7.7
8.	Discharge of return waters into local water intake units	9.8	9.3	-0.5
9.	Total water losses in river beds and water reservoirs	8.7	2.9	-5.8
10.	Water flushed into the Aral Sea through river beds	3.2	6.2	-3.0
11.	Irretrievable losses and withdrawal s (5+7+9)	69.3	65.7	-8.5
11.1.	Including irrigation agriculture (5-4)	41.3	62.4	+21.1
12.	Area of irrigated land	3514	3430	-134
12.1.	Irrigation norm – gross, m^3/hectare per year, ((5+6):12)	~17270	~17520	~+250
12.2.	Specific irretrievable losses, m^3/hectare per year, ((5-4):12)	~11750	~14200	~+2450
	excluding the Zeravshan River and Kashkadarya River basins			

Table 3
Main indicators of water balance in the Syr Darya Basin
(area in thousand of hectares, water volume – cubic meters per year),
[3, 5, 6]

Item No.	Indicators	Level in 1990г. According to "scheme …" (3. p. 233)	Estimates of actual values in 1990 – year ~50% probability of water availability	Deviations (±)
1.	Available water resources (2/2.1+3+4)	48.1	49.8	-1.7
2.	River water resources (90% probability of water availability)	27.6	34.3	-10.6
2.1.	Including minimum flow	33.0	33.0	-
3.	Ground water resources (output)	3.1	H.c	-
4.	Return water resources	12.0	15.5	+3.5
5.	River water intake for irrigation	36.6	40.9	+4.3
6.	Internal use of return water for irrigation	6.5	6.6	+0.1
7.	Water intake for industrial and residential use	2.1	2.4	+0.3
8.	Discharge of return waters into local water intake units	0.6	3.3	+2.7
9.	Total water losses in river beds and water reservoirs	3.8	4.0	+0.2
10.	Water flushed into the Aral Sea through river beds	2.9	2.0	-0.9
11.	Irretrievable losses and withdrawals (5+7+9)	42.5	47.3	+4.8
11.1.	Including irrigation agriculture (5-4)	24.6	25.4	+0.8
12.	Area of irrigated land	3094	2983	-91
12.1.	Irrigation norm – gross, m^3/hectare per year, ((5+6):12)	13930	15923	+1993
12.2.	Specific irretrievable losses, m^3/hectare per year, ((5-4):12)	7950	8515	-565

3. Ecological condition of waterways

At present the overall ecological consequences of water resources development in the region are assessed as negative and their main result is seen in the Aral Sea destruction. However, the economic consequences include a 2-3 time increase of the irrigated land and the hydroelectric resources development. It is evident, that in view of the demographic growth in the region, the social and economic consequences of the irrigation should not be assessed as completely negative.

It is better to refine everything once again and "separate the wheat from the chaff". But it is necessary to note an accuracy of the hydro-economic programs of that period: everything that happened, including the expected situation, time, initial scope, and other parameters of the runoff diversion, had been calculated beforehand practically with no mistakes. But the main shortcoming of this region's economy - high, unacceptable for arid zone expenditure of water, has not yet been overcome.

The formation of a state independence of Uzbekistan started in very complicated social, economic and ecological conditions. The condition of the water industry of the country, as well as the condition of all water consuming branches of economy, and the condition of its infrastructure was assessed as problematic and even critical.

Uzbekistan, as a part of Central Asia and one of the most arid regions of the world, by the time of gaining its independence used about 52-57% of its very limited water resources which were almost fully used in the economy. The existing significant shortage of water resources was aggravated with their exhaustion in water quality. This process is quite complicated, and it is accompanied by salinization and contamination of surface and ground waters. The most apparent process in the region is the process of water salinization that, according to its genesis, depends on the evaporative concentration. The evaporative concentration conjugating with mass exchange of the first type results in increase of mineralization of natural waters. In the Syr Darya River Basin these phenomena were observed during the 20th century, and, by the end of the last century, the average annual mineralization in the Syr Darya River at the Kayrakum reservoir outlet point was equal to 1.22±1.3 g/l, and the mean waters were practically unsuitable for drinking water supply.

In the Chirchik, water salinization processes practically reached the longitude of the city of Yangiyul where a mean water mineralization reached all allowable limits, and in the mouth it exceeded these limits In the Zeravshan, water salinization processes practically reached the river section line of the city of Khatyrchi, and rapidly approaching the Damkhodjinsk section line. The main water intake facilities of Navoi and Bukhara Oblast are now located downstream of this line.

For almost 50 years in the Kashkadarya river bed, the brackish tail water of Chimkurgan reservoir has been flowing. The same situation is arising in the downstream part of the Surkhandarya River.

In the downstream part of the Amu Darya River, in the section line of the Tuyamuyun reservoir the average annual mineralization of river water almost reached allowable limits, and in the mean waters it exceeded them. The mineralization of the Amu Darya River waters at the upstream outlet point is also increasing. However, it has not reached the maximum allowable limits.

The mineralization is increasing due to growing concentration of magnesium ions, sodium sulfates and sodium chlorides. According to these indicators and, also, to the total hardness, the water becomes unsuitable for drinking water supply and, very often, for irrigation too. Increased incidence rate of cholelithic and nephrolithiasis diseases to a considerable degree is related to an increase of total hardness of drinking water.

On the territory of Uzbekistan, there are various sources of natural water contamination including industry, power engineering, motor transport and other engineering services, mining and processing of minerals and hydrocarbon materials, farming industry, processing of products of plant cultivation and livestock farming, and housing and communal infrastructure related to “utilization” of various domestic wastes. Because of that, on the territory of Uzbekistan all types of natural water contamination are present: biological, chemical, radioactive, thermal and their complex combinations.

Bacterial contamination is frequently connected with pathogenic germs and viruses. Today’s situation of this kind of contamination is elevated and is characterized by the fact that almost all surface water supply sources require sterilization. The state of the ground water sources is also becoming a more complicated issue.

The chemical pollution becomes apparent much more in the water bodies of Uzbekistan from industrial, agricultural ones, and municipal sources. The water is contaminated with heavy metals, cyanides, thiocyanates, metabolites of pesticides, herbicides, and other ingredients the concentration of which is regulated by to the general- sanitary and organoleptic norms. There is an increase in radioactive water contamination, e.g., there is increase of uranium concentration in the Aral Sea Area where it reaches 104÷105 g/l.

Thermal water pollution results from the thermoelectric power stations with the direct cooling system and metal manufacturing premises.

Such effects as the Aral Sea degradation and degeneration of its ichthyofauna, changes of specific phyto- and animal plankton structure in downstream areas of large and average rivers of Amudarya, Surdaya, Zerafshan, Chirchik, and others are the results of complex combinations of depleting of water resources both in quantity and quality. For example, the reduction of fish that does not meet veterinary-sanitary requirements usually takes place in the return water lake-stores systems.

In general, it is necessary to take into account that a progressing pollutant concentration is accompanied by cumulative effects resulted in degeneracy of important biocenosis components.

4. Water management strategy

It is evident that there is a need to develop a water management strategy for the whole region and the states both included in the region and bordering with that region. Such a strategy should be a rational system of high priority (incorporating political, defense-strategic, economical, sanitary-hygienic, etc. components) purposes and technologies of prospective (and operative) water supply management of the countries (region), organization and control of water-consumption and water-use.

The strategy should also take into account natural, social-cultural, economical and technical-technological capacities and geopolitical conditions.

In the past, the strategy of water management activities, being an empirical generalization, was based on the social-cultural traditions of the region. Later during the soviet period the strategy was formed on the bases of various kinds of legislative and other normative acts. Nowadays, in compliance with provisions of the current law, the strategy is to be determined on a state (and, if necessary, on a national) level of management. The strategy defines the long-term social approaches and requirements to water as an essential life-supporting natural resource and as the habitat of many biological hydrocoles species, and, at the same time, as a potentially dangerous and harmful factor due to its nature. Moreover, in arid environments, the water management strategy functionally interconnects the structures of the economic and ecological security of the country.

The strategy is implemented (and simultaneously revised, corrected, etc.) through long-term planning of the water management activity in specific programs. The water management planning includes the theory and practical issues of water supply of the country (region); transition to optimal water-use and water-consumption, taking into account the regularities of forming and peculiarities of using of water resources; special measures for providing water supplying, water-use and water-consumption and preventing dangerous and harmful water related effects to public and environment. In addition, it is necessary to analyze the interconnections of the water management systems and complexes, and to forecast their technical-economical parameters; to formulate the requirements to the systems and services providing monitoring and control and to determine a structure and sequence of their activities. The water resources are to be distributed to the territorial-production complexes and water management complexes of the country (region) for social, ecological, sanitary needs. The protection of water against depletion, pollution and their ecological well-being rehabilitation is planned.

The main feature of contemporary water management is seen in its ecologization and in inclusion of economic mechanisms and legal regulations in the program implementation. In general, the water management program presents a new scientific and technical foundation and proposes solutions to problems of rational using and water conservation, and all spectra of issues related to effective use and conservation of the environment. The strategy realizes the provisions of water management doctrines and strategies developed by governmental and legislative bodies. If necessary, recommendations on improving of water relations are to be developed to take into account new data on water needs; availability of new technologies; water-use and water-consumption on the one hand, and on the other hand – ecological limits and imperatives. The water management program is to be reviewed and approved by the government of each country.

It is obvious that the water management programs shall proceed from the fact that the social-economic perspectives of the region's members are to be based on the regulations tested by the whole world community:

- sustainable increase in the common wealth can be achieved by implementing power and resources saving technologies and approaches, and minimizing of the production and service costs;
- restructuring of the countries' economies is directed on absorption of their own labor resources and development of a high technology manufactures, forming of new industries based on new water saving technologies, or waterless technologies, low-waste and no-waste technologies;
- ecologization of all spheres of production of material goods and vital functions of the society for conservation of biota diversity, the natural vector of ecotopic and biocoenotic selection, and, as a whole, the hygiene and quality of the entire environment.

In this situation, Uzbekistan should take into consideration three factors that are connected to the formation of quantity and quality of water in the intergovernmental relations on development of the water resources management strategy:

1. The natural river flow is formed out of Uzbekistan, mainly in the chain of mountains of the Tien Shan and the Pamir;
2. The main water reservoirs that transform the intrinsic regime of the river flow for household use needs and providing the water supplying stability are located outside of Uzbekistan;

3. Original water-management systems were designed to service water-management complexes for irrigation and power purposes, and the main regime of their functioning was to meet first the needs of irrigated farming at the expense of decreasing of power production. This is not profitable to the present owners of these hydro-facilities.

In the former Soviet Union, the mentioned above issues and following from them interrelations between the Aral Sea Area states were centrally regulated. Nowadays, when Uzbekistan became an independent state and international proprietor, there is an urgent need to regulate in the water relations regulation between the Aral Sea Basin states by the highest level international/legal authority. It is evident that it is in the national interests of all countries of the basin to define the regulation of the water-management systems functioning that could take into account the mutual economic and ecologic needs and benefits, and damages.

According to some forecasts, the issue of water supply of Uzbekistan could be aggravated, especially in the long-term perspective, of 2025-2030 due to global climate change. However, there also some “bright” forecasts. According to forecasting scenarios, the river flow changes could be reduced one third from its standard (about 32-38 cubic m/yr) level. This would reduce sharply the irrigation capacity of the water management systems, and, to a greater extent, taking into account the territorial location of Uzbekistan at the zone of transit and dissipation of the flow, it would have a strong affect on the water supply.

The current almost exhausted water resources and the possibility of negative changes in the river systems of the region require a radical change of the established approaches to water-use and water-consumption and overcoming of the Aral ecologic disaster.

Under these circumstances Uzbekistan should focus its strategy on saving the water economy in the all branches of the economy and especially in the irrigated agriculture that consumes more than 90% of water resources.

The rehabilitation of irrigative water presents an important element of water saving. High quality of irrigative water improves the harvest of cultivated crops, reduces the expenses for overflowing of used water from irrigated fields, affects positively on the adjacent natural and cultivated landscapes. However the issue of water quality management of the irrigation sources of large rivers does not have an ultimate scientific/objective solution. There are some approaches to river flow demineralization that are used in practice, but they can solve only special problems, and, very often, only temporarily. In Uzbekistan, the solution to the river flow demineralization issue is estimated to be equivalent to adding into the fund of irrigative farming from 200 to 500 thousand hectares.

A decisive component of water supply management is a reliable water supply. The demineralization of river water would greatly increase the water supply effectiveness. In addition to demineralization, in some regions of Uzbekistan the growing ecologic tension requires to use additional reprocessing facilities for water desalination and purification in order to meet the sanitary standards for water quality.

According to some forecasts, it is expected a decrease of the water flow in the region. In this situation it becomes necessary to utilize the groundwater. The way of current ground water use is difficult to characterize as a rational.

The shortage of water resources was the main cause of the Aral Sea problem. In view of an expected decrease of water flow in the region, the conservation and further restoration of the Aral Sea may be an unachievable objective. At the same time, there is a self consistent solution of the Aral Sea problem. Within the natural structure of Central Asia the Aral Sea used to perform the functions of the largest regional salt receiver. First of all it is necessary to restore this function of the Aral Sea. To do this it is necessary to stop salinization of natural and artificial waterways and reservoirs in the deltas of the Syr Darya and Amu Darya. This should significantly improve the ecologic situation in the Aral Sea Area and, along with activities aimed at demineralization of river waters, would positively affect on the productivity of irrigated lands in Karakalpakstan and Khorezm. The quality of irrigation water is becoming the determining factor of the environment rehabilitation.

5. Conclusion

The current and future hydro-economic and hydro-ecologic conditions in Uzbekistan are closely related to each other and very important to life-support of the population. It demands the development of the new water management program for Uzbekistan which is based on achievements of the world community.

Realization of strategic water management programs, as is known, occurs not in 1 – 2 year, but will require decades. Therefore it is needed already now to target scientific and design/research teams for development of mid- and long-term programs which could presented for approval by statesmen and community. Well-being of the community of the region, its social-economic and ecological security depends on the timely development of these programs and appropriate strategic decisions and measures taken by the states. It is out of question that the development and implementation of the water management program should be performed by each state of this region separately. Only joint intellectual and technological efforts and sharing of natural resources can justify the public expectations of prosperity, well-being and peace. This approach is justified by past experience and new achievements in the field of water resource management.

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Priority solutions of the water-resource problems in East Siberia

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Abstract. The territory of East Siberia is now being faced with eight main groups of problems, to resolve which requires a package of scientific, technical, economic and organizational measures: the drinking water supply problem whose high priority is defined by the Water Code of the RF; the water pollution problem; the problem of harmful effects of water; the problem of reservoirs, primarily of the Angara-Yenisei cascade; the problem of protection and management of the lakes' water resources, primarily Lake Baikal; the problem of water-protection zoning; the problems of sectoral water usage; and the problems of monitoring and supervising water usage and water-protection measures as well as relevant management. An important role in resolving these problems must be played by geosystem-water management approach.

Keywords: water resources; problems; basin approach; water management; Baikal; East Siberia; water protection

1. Introduction

Water has always held a most unique position on the globe, and in the 21st century it is becoming the vital resource of mankind. Furthermore, the water problems are becoming increasing complicated. The rates of pollution of the water environment are accelerated across the globe, and the quality of water used by the population is frequently poor, which leads to human health impairment. Our planet Earth is heading to a water crisis forming part of a degradation of the entire environment.

Russia is no exception in this regard. In spite of its generally huge water resources, a large number of Russia's territories are faced with serious problems relating to quantitative and, especially, qualitative water supply to the population and the economy. Even the dramatic setback in production in the 1990s has not led to some improvement of the situation. Many water bodies continue experiencing a high anthropogenic load. This is aggravated by wear and tear of the entire water-management infrastructure and a reduction of the water monitoring network, no commissioning of new capacities of pollution control facilities, and by other negative trends in water management and hydrometeorology which are mainly caused by financial stress.

East Siberia (together with Yakutia) is Russia's region having the greatest wealth of water resources: the river discharge makes up 41 % of Russia's total discharge; it is concentrated largely in the river systems of the Yenisei and Lena, the largest rivers in the country. These resources are of crucial importance in the economy of Siberia, and of the country in general: the production of hydropower is as much as 60 % against Russia's total figure, and the length of inland water ways is over 30 %; a prominent place in the region's production structure are occupied by water-intensive and energy-intensive metallurgical, chemical and petrochemical enterprises, and by paper and pulp industries. However, there is a host of problems as regards the state and utilization of the water resources in East Siberia.

2. The main water-resource problems

Eight groups of problems are identifiable, the solution of which requires a package of scientific, technical, economic and organizational measures.

2.1. The problem of drinking water supply

Its priority is defined in the Water Code of the RF. Its causes are: the non-standard quality of many water sources; actual wear and tear of water-supply lines and of the sewerage networks; shortage of water in some of the northern (because of total river freeze-up) and rural southern localities and on some urbanized territories; outdated water treatment techniques at the water intakes, and others. To ensure reliable, safe and continued drinking water supply calls for the combined utilization of surface water as well as groundwater by adhering to the non-depletion exploitation, implementation of state-of-the-art water treatment technology, replacement of worn-out networks, utmost water saving, as well as a further development of water bottling. A special task of hydrogeologists engaged in resolving the water supply problems implies giving a correct rationale to the amount of water of the necessary quality which could be taken from the aquifer within a calculated period without detriment to the environment (including groundwater itself) or, at least, how this detriment can be kept at a minimum through special measures.

2.2. The problem of water pollution

The current importance of resolving this problem is particularly vital for the Angara basin as well as to the drainage areas of many smaller rivers and lakes. It is rooted in the inadequately efficient purification of industrial, mining-industrial and household waste water, in the entry of pollutants with the dispersed runoff, and in some neglect of the decreased self-purification ability of the Siberian rivers. The most hazardous is pollution by heavy metals, oil products, and phenols, as well as pollution in terms of microbiologial and hydrobiological indices. This problem cannot be fully resolved only by improving the waste water purification systems – equally important is establishing order on drainage territories, strict observance the legally enforced regime of water management activity and of nature management restrictions on them, carrying out special-purpose rehabilitation measures, and the provision of cities and townships with storm sewerage. The strategy is to focus on the prevention of pollution, and on pure water saving in the course of technological re-equipment, including the replacement of water cooling by air cooling, and the introduction of water recycling in major enterprises.

2.3. The problem of harmful effects of water

To resolve it requires primarily perfecting the models explaining the mechanisms triggering and sustaining extreme hydrological phenomena, and the methods of forecasting them and calculating the possible damage.

Hazardous natural processes are occurring in the "hydrosphere – atmosphere", "hydrosphere – lithosphere" and "hydrosphere – glaciosphere" systems. According to the genesis, we suggest that three classes of hydrological hazard should be categorized: hydro-climatic, hydro-geological, and hydro-glaciological. For Russia there exist 15 main types of natural hydrological hazards. Hydro-climatic hazards: high-water floods, freshet floods, low-water periods, very heavy rains, and agitation on water bodies. Hydro-geological hazards: debris flows, sheetwash, galley erosion, channel erosion, and abrasion. Hydro-glaciological hazards: avalanches, ice and log jam-caused floods, icing phenomena, very heavy snowfall, and snow-drifts. An expert assessment and ranking of hydrological hazards has been made for the territory of East Siberia in 13 macro-basins. The most severe integral hazard is characteristic for the Upper-Yenisei, Upper-Angara, near-Baikal, and Selenga basins.

Floods present the greatest hazard. Floods in East Siberia are caused by high water in the spring (and in the spring and summer) and rain-induced high water in the summer-time; by a rise of the water levels in the case of log and ice jams; anthropogenic activity; and by wind-induced pileup and tides in the outlets of the rivers. A rise of the level in smaller rivers of East Siberia is frequently caused by the thawing of icing produced by freeze-up of the channels of these rivers. Floods are not infrequently caused by several factors simultaneously (high water and jams on the plain, the thawing of snow, and torrential rains in the cities). Archival and published data were used to make a retrospective analysis of the floods for the cities and townships of East Siberia in the 19^{th}-20^{th} centuries. Almost all large cities of the region were experiencing significant floods of a different genesis: Irkutsk at the Angara river was affected by jam- and high water-induced floods (a total of 32 cases); Yeniseisk (33), Krasnoyarsk (10), and Kyzyl (5) at the Yenisei river experienced high-water and jam-induced floods; Kirensk (19), and Yakutsk (15) at the Lena river were affected by log-induced floods; Abakan at the Abakan river (6) was affected by high water floods; Tulun at the Iya river (9), Nizhneudinsk at the Uda river (14) experienced high water floods, and Ulan-Ude at the Selenga river (5) was affected by high water and freshet floods.

For analyzing the recurrence rate, we selected moderate, strong and disastrous floods. A quantitative indicator of the flood onset is represented by a critical level at which water inundates the floodplain, inundating considerably agricultural lands and partly residential centers, which does correspond to a class of moderate floods. A total of over 1700 floods were recorded at hydraulic sites of the rivers in East Siberia for the period under review. The largest number of sites with floods is in the Lena basin which is also characterized by the largest number of floods. As far as the recurrence rate of the floods is concerned, the hydraulic sites are all divided into four groups (Table).

Table
Distribution of hydraulic sites according to flood recurrence rate

Basins	Recurrence rate of floods*, %			
	<30	30-50	51-70	>70
Yenisei	11/40	10/37	5/19	1 / 4
Angara	2/22	5/56	- / -	2/22
Lake Baikal	3/38	2/25	1/12	2/25
Lena, Yana, and Indigirka	18/42	11/26	7/16	7/16
East Siberia	34/39	28/30	13/15	12/16

* Numerator – number of hydraulic sites, denominator – % of the total number of hydraulic sites with floods.

It is our opinion that evidence for a global warming as a key cause for the increase of the number of disastrous floods is not conclusively proved. This means that attention is distracted from the really chief causes for the increase in disastrous floods, i.e. absence of a unified legislative system that must regulate intermittently and potentially inundated territories and no rigid and constant control and no adoption of timely measures to enhance reliability of all operating water-development works, and to improve the designing and construction systems for protection facilities.

Top priority tasks should include carrying out zoning of the valleys of major rivers that experience inundation at the time of floods, by identifying territories of the greatest risk, and by developing for them the package of engineering and non-engineering measures, including the arrangement of insurance. Of particularly vital importance for East Siberia is also the protection against glacial hazards: log jams and ice jams, avalanches, icing phenomena, etc.

2.4. The problem of reservoirs, primarily of the Angara-Yenisei cascade

It is a large-scale comprehensive problem involving a need to settle the conflicts between hydropower generation and other water users as well as to minimize the deleterious ecological consequences of their construction. In the first place it is urgently necessary to revise the "Regulations about the utilization of water resources" by focusing them on the comprehensive character of utilization by warranting safety of the population and the economic interests downstream, by delineating the technological zones of integrated hydro-schemes and approving documents on legal regulations of their economic exploitations, and by carrying out measures for the protection of the banks against abrasion. The decision to work out the new Regulation was taken as early as 2004, but their preparation is delayed. Furthermore, the development of the new "Regulations about the utilization of the water resources of the reservoirs of the Angara-Yenisei cascade" is based on traditional normative-directive as well as current economic principles and foundations. The significance of this problem implies that in the case of multi-purpose uses of the reservoirs, it is virtually unfeasible to fully meet the requirements of all stakeholders of the water management complex in all years and seasons. For that reason, in reality all regimes of utilization of water resources usually represent compromise solutions which inevitably infringe to a certain extent on the interests of some water users, typically energy users, as well as of the population, economic entities, and the natural environment.

Of particularly important significance is the development of the technique for forecasting the inflow rate into the reservoirs in order to improve the regime of high water passage, as well as for foreseeing the consequences of low water periods.

2.5. The problems of protection and utilization of the water resources of lakes, primarily Lake Baikal

The importance of this problem is determined, on course, by a special status of the unique lake. Lake Baikal is the oldest (25 mln years), deepest (1637 m) fresh-water lake in the world, storing 20 % of the fresh surface land water, a global resource of fresh water with a drinking quality. This resource is practically inexhaustible. If the influx of the rivers into Baikal terminates and if the mankind continues exhausting its bowl by supplying 1.5 l water per day to each human being, this reserve would last out for 6 thousand years.

According to Academician M.A. Grachev, the state of Baikal's water is steady-state rather than at equilibrium. The entry of pollutants and their treatment by Baikal's ecosystem are quite well balanced. Therefore, the concentration of the main dissolved substances in the lake is virtually constant at every depth and is the same in the Northern, Middle and Southern hollows of Baikal.

The influence on the ecosystem of Lake Baikal is exerted through the air, water and biological pathways. The main sources of influence are the industrial enterprises located within the lake's watershed basin and along its shores, some sections of the Trans-Siberian and Baikal-Amur railroads, agricultural enterprises in the Transbaikalia, as well as the aerial transfer from the Irkutsk-Cheremkhovo industrial center.

However, the results from international investigations, summarized in a monograph by the LIN SB RAS director Academician M.A. Grachev (2002), showed that the advanced sphistigated methods did not reveal any anthropogenic changes in the concentrations of principal ions, heavy metals, species composition of the phytoplankton in the lake's water. Although pesticides and organo-chlorine ecotoxicants were detected in Baikal (incidentally, as is the case with most of the other lakes in the world), but their concentrations are very low. Catches of Baikal omul fish fluctuate, but its population (about 20 thousand) is not threatened. The population of Baikalring seal is no less than 100 thousand, and it is also not doomed for extinction. Recently there emerged a hazard of biological pollution of Baikal: some bays and shallow water places were colonized by Amur sleeper (P. glenhi *Dybowski*), and by some other new fish species as well as by Canadian waterweed (Elodea canadensis Michx.). The hazard of the entry of rainbow trout (S. Gairdneri *Richardson*) was eliminated.

On the other hand, there are real local problems of pollution of Baikal's shore water areas. The territory of the core alone includes 152 communities with the population over 140 thousand. In the vicinity of settlements and ports in the summer time there are always increased concentrations of coliform bacteria, the indicator of untreated fecal waste water. In places of unorganized recreation, the shore is loaded with garbage. Near the water line, the disorderly construction of cottages, dachas, and small recreational facilities is underway, and natural landscapes are being disturbed. The operation regulations of water ships are systematically violated.

New threats are also emerging. Very much effort (by consolidating the contributions from scientific communities and public ecological movements, and after a personal intervention of the country's President) was directed in 2000 towards saving Baikal from the threat of the laying of the East Siberia –pacific oil pipeline along the lake's shore.

The priority measures on the protection of the great lake include: conversion of the Baikalsk paper and pulp integrated plant; updating of the list of the permitted kinds of activity and standards of influence; organization of collection of oil-containing water and waste from ships; completion of the construction of the pollution control facilities in the cities of Slyudyanka and Baikalsk; improvement of recreational activity on the shores and on the water surface; removal of solid waste on the shores; switch-over to gas fuel supply; improvement of the comprehensive monitoring system for scientific observations; and increase in Baikal water bottling.

2.6. The problem of water-protection zoning

Among other things, it involves improving the methods of delineating the boundaries of water-protection zones and coastal protective bands, with due regard for the characteristics of the hydrological regime of water bodies, inundation of their floodplains, the genesis of feeding, the character of channel processes, as well as regulation on these territories of the construction, recreation, and other activities.

2.7. The problems of sectoral water usage

There are a plethora of problems which were faced, as before, by the individual sectors of water management of East Siberia in the 21st century. For hydraulic power engineering, very challenging problems are the inadequately rational system of financial-economic interaction of the sector with regions (the questions relating to the more equitable allocation of hydropower rent, compensation of damage done by the construction of hydropower facilities, etc.); the need to optimize the operating conditions of the Angara-Yenisei cascade of hydropower electric stations, with due regard for the requirements of the other stakeholders of the water management complex, ecological restrictions, the changes in the operating conditions of the hydropower electric stations themselves; unsettled inter-regional water management relations in the case of exploiting – for hydropower generation purposes – the transboundary water bodies; and selection of the ecologically acceptable variant of the completion of the Boguchanskaya hydropower electric stations under construction now.

For the water transport at the present state, of the most current importance are the problems relating to low competitiveness of the river fleet as compared with the other kinds of transport, deterioration of the water ways, and a decrease in navigation safety. The problem of hydromelioration involves a drastic decrease (for the 1990s) in the area of irrigated and drained lands, and cessation of the construction of new melioration systems and of the reconstruction of existing ones. Fishery is experiencing a heavy crisis, and catches of fish dropped several times.

In practice, the departmental interests and isolated activity of water users is responsible not only for the absence of coordination of the measures but also for the joint creation of hazardous situations which are detrimental to the reliability of the facilities and sometimes lead to unjustified prohibitions of the particular measures, to the singling-out of the presumably positive role and priorities of a single water user to the detriment of the others, and to the disregard or neglect of the measures which are of benefit but are devoid of any clearly pronounced effect. Among them are the preferential consideration of the requirements of the power generation industries to the detriment of the other water users, although in some cases this would lead to negative consequences, especially downstream from the water development schemes. Only a comprehensive scientifically grounded approach in exploiting the water resources, based on taking proper account of the interaction of water management measures and channel processes, can ensure hydro-ecological safety and yield a real economic effect in their implementation.

2.8. The problems of monitoring and supervising water usage and water-protection activity as well as their management

The chief point in this case must involve the transition to the basin principle of water management, not nominally but actually, including via basin councils. The key taxonomic and computational unit is the river basin as a geosystem, because it has a powerful integrating factor, i.e. the water stream directed downward the slopes and along talwegs, and, most frequently, clearly-cut boundaries, or watersheds. Basins as integral entities that are structured hierarchically, closing many kinds of turnover of matter that are in isolation within orographic boundaries, hold promise as territorial cells not only in hydrology but also in nature management in general – for investigating the technogenesis, for natural-and-economic regionalization, for administrative regionalization, etc. It is necessary to optimize water monitoring operations, and more specifically, to increase the network density, especially in mountainous areas and on territories of new development, and to reconcile departmental networks according to the composition and techniques of observation. Of utmost importance is perfection of the economic and legal mechanism of water usage (by developing the system of rents, improving the economic evaluation of water potential, switching over to payment for water consumed by all users not only in terms of the amount of actually received water, promoting the competitive forms of meeting demands for water, etc.). It is necessary to stress the importance of improving coordination of territorial and sectoral management as well as combining the departmental information flows in electronic format.

3. Conclusion

In conditions of an economy in transition, the functioning of East Siberia's water management system was extremely adversely affected by the following financial-economic and organizational factors: instability of the performance and a deterioration of the financial standing of water consumers and water users; lack of interest of privatized enterprises in carrying out water-protection measures; imperfection of the economic mechanism in the water management system itself, and instability of the associated management system; an unsatisfactory degree of development of the legal and normative-methodological foundation; and an inadequate degree of coordination among regions, water management agencies, water consumers, and water users in the realm of management and joint utilization of water resources. Therefore, at this stage the emphasis ought to be on searching for ways of achieving the most painless adjustment of the water management sectors to the emergent economic conditions.

Water resources of Siberia: state and prospects for use

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Water is a major vitally important element of biosphere. Water resources available for Man, including lakes, rivers and mires make up only 0.3% of the total on the Earth and are the most vulnerable. By now the fresh water ecosystems as compared with the surface and oceanic ones have lost the quality of water and the diversity of hydrobionts (Shiklomanov, 1998).

The level of national water resources development is determined by the load index estimated as a percentage of the water used of the water resources available. The current and expected load indices in all Asia regions excepting the Asian part of Russia (Siberia and Far East) and South-East Asia are already exposed to high or mid-high stress. However, even the regions which do not experience the lack of water face serious problems in water quality.

The Asian part of Russia is one of the most favorable regions in Asia concerning the quality and quantity of fresh water resources. Ob-Irtysh basin is situated in the center of Eurasia and stretches from the mountain ridges of South Altai and Kuznetsk Alatau in the south to the Kara Sea in the north, and from the Urals watershed ridges in the west to the watershed of the Ob and Yenisei tributaries in the east. The basin area including the closed regions constitutes 12% of the country territory.

On the whole, Ob-Irtysh basin is rich in water resources; its average annual flow is 408 km^3. However, the distribution of water resources is not uniform. The distribution of water consumption in the regions within Ob-Irtysh basin is characterized as follows:

- minimal water consumption (< 100 m3/year): Republic of Altai;
- water consumption of 100-500 m3/year: Omsk, Kurgan, Tomsk oblasts, Khanty-Mansy and Yamalo-Nenets autonomous okrugs;
- water consumption of 500-1000 m3/year: Altai Krai, Novosibirsk and Chelyabinsk oblasts;
- maximal water consumption (>1000 m3/year): Kemerovo, Tyumen and Sverdlovsk oblasts.

The problem is dramatized by the irrational economic activity at the watershed that results in the anthropogenic change of the flow and the pollution of surface and underground water.

The change of watersheds caused by extensive plowing, overgrazing, deforestation, regulation of the small rivers flow results not only in the time redistribution of the surface streamflow but the progressive desertification of the steppe and forest-steppe zone in the basin. At the same time some regions of Ob-Irtysh basin are exposed to flooding and territory impoundment.

The industrial centers and urbanized areas contribute significantly to the pollution of the basin river system. For instance, during the snow melting period, 55 % – 65 % of pollutants enter the rivers from the urban territories which occupy about 3 % of the watershed territory.

Most water-ecological problems in Ob-Irtysh basin are of interregional character and can be solved only through the basin approach by all countries and administrative regions within the basin.

Water resources of Altai Krai are represented by surface and underground waters that serve as the sources for domestic and industrial water supply. The total runoff in Altai Krai rivers makes up 53.5 km^3/year.

The key problems of water economy in Altai Krai are the following:

- water supply deficit in the steppe zone;
- water objects pollution, in particular, small rivers, as a result of effluent discharge and high anthropogenic load on the watersheds primarily in water protection zones;
- low rate of production that doesn't meet the current environmental challenges;
- bad condition of hydraulic structures causing the risk of accidents;
- poor economic mechanism of water objects restoration and conservation, underinvestment to water economy;
- the lack of reasonable materials provided in the Water Code of the RF (water-management balance etc.);
- low level of dataware that doesn't meet the current requirements of water management.
- Prospects:
- assessment of water resources in Siberia (surface and underground waters);
- forecast of emergency situations;
- program-oriented approach to the assessment of water resources of Siberia;
- reuse of water;
- water and human health.

Session 2

Runoff transformation at watersheds under the global changes and anthropogenic impact

Water use problems in Charyshsky region of Altai Krai: current state, issues and prospects

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The problems of population supply with quality drinking water are not only topical at the turn of the XX century, but they also become more aggravated. They are manifested at all territorial levels, i.e. from global to local ones, and the tendency of their enhancement from the industrial regions and large settlements in the central part of the country to the peripheral regions is observed.

The global level is distinguished by the reduction of resources and quality of the available drinking water. It is associated with the environmental changes, quality loss in the underground and surface waters due to the industrial and sewage pollution of water objects, the increased withdrawal of underground and surface waters and the increasing of water consumption per head.

The federal level reflects as the nonuniform distribution of drinking water resources as the different development of water supply systems and the technological level in central and peripheral regions of Russia.

The regional level demonstrates the specific features of the previous two ones. They are enhanced due to the lack of financing of water-related activities that is most pronounced in the subsidized regions including Altai Krai..

The local level (some villages and rural boards) shows the most pressing issues that are often not considered at all because of the poor social-economic situation.

Based on the system approach to the solution of the complicated natural and industrial problems Institute for Water and Environmental Problems (IWEP SB RAS) studied the water-related issues in the Charyshsky region of Altai Krai that belongs to the perspective territories for the establishment of special economic zones of tourist-recreational type. The research done allowed us to evaluate the current water supply of each village and rural settlement in the region. The key water-related problems were ranked by the level of stress, and 4 stages for their solution were defined.

The Charyshsky administrative region is situated in the submountain-mountain south-east part of Altai Krai. Most of its territory occupies the medium and high mountains of Altai. The population lives mainly in low mountain regions.

The territory of the region is distinguished by complex geomorphology. The relief abounds in hills and ridges dissected by the Charysh river valley, its tributaries and gullies. The surface elevation is observed from north-west to south-east. The climate is sharply continental with warm wet summer and frosty winter. Strong interseasonal winds are frequent, and day and night temperature difference is observed all the year round. The average temperature in January is – 16 -17°C, and +16 +18°C in July. The frost-free period lasts for 115-120 days. The specified temperature for the coldest five-day period makes up 38°C. The soil freezes as deep as 0.8-1.2 m. The annual precipitation is 550-600 mm/year. The seismicity of the area is 8 points.

The Charyshsky region is characterized by the extended river system. The main river, the Charysh, extends to 80 km within the region; the largest tributaries are Inya, Tulata, Sentelek, Kumir, Belaya, Bashchelak and Sosnovka rivers.

The surface runoff is formed by snow water (49%), rain water (30%) and underground water (21%). The flood time lasts 20-30 days (May-June) when the water level raises up to 3-5 m and even up to 8 m if the melting is intensive. In the rainy period the water level is as high as 2 m for several days.

In low-flow period the water mineralization reaches 200-220 mg/l and decreases up to 20-100 mg/l during the flood time. The ionic composition of water is distinguished by a predominance of hydrocarbonates (42-36% of eq.) and calcium (30-28% of eq.); the water hardness in the course of year is 1-2 mg-eq./l.

Hydrogeologically, the Charyshsky region forms a part of the Altai-Sayan complex artesian basin, and its waters are represented by the fracture, fracture-vein, fracture-karst, deposit-block and the deposit ones. The underground water increment takes place due to the passing of precipitation through the zone of suspended water and shatter zones, filtration from the surface streams and the flow from the underlying aquifers of the bedrock.

Water intake proceeds mainly from sandy-gravel-pebble, sandy-loam and crushed stone sediments, and bedrocks as well.

By and large the Charyshsky region is favorable for the intake and use of underground water of good quality for domestic water supply of settlements.

The economic development of the region is different. The southern part is characterized by the poor land development, while the rest part of the territory shows high rural development and the most favorable living conditions for population.

The total population in the region is 14 898 people with the density of 2.2 people/km^2 (data available for 2002).

The economic development of the region is based on agriculture represented by the enterprises with different forms of property and mid-and small-scale farms where meat and dairy cattle raising prevails.

Recent trends are toward the development of maral-, reindeer-, and horse-breeding as well as the beekeeping.

The region is characterized by the developed logging and woodworking complexes engaged in the production of consumer goods. Food industry is represented by bread-making, cream- and cheese-making, and milk plants. The communal services, trade and catering are progressive as well.

On the whole, the region economy has a good potential to provide the population needs in full.

The water supply system in the region was formed in 70-80s of XX century. It was based on the current technology and local water resources. Nowadays the system is distinguished by the deterioration of technical equipment and water quality.

The assessment of the current water supply was carried out in each rural settlement. The water wells, their operating conditions and discharge, hygiene and sanitary conditions and water quality, water-supply networks, regulating reservoirs and their operating conditions as well as the general issues of water supply were analyzed.

Water supply in rural settlements is carried out due to underground waters which are drawned out by shaft wells and drive wells in rural settlements located in the river valleys.

Significant relief difference along with the complicated hydrogeological conditions, the dissection of the territory by rivers and their tributaries, and floods makes the establishment of different infrastructures in one, even small, settlement more difficult. Thus, due to short distances it is impossible to solve the problem of the construction of common water supply point and distributing water networks. Each rural settlement has 2-5 single water supply points.

The standard of construction of water supply systems in the region is low. Almost all water supply points are represented as the single wells of 20-80 m depth. The reserve wells are abandoned. The lack of regulating reservoirs causes the water shortage in water-supply systems and frequent irregularities. A great deal of water is lost due to the pipes leakage.

The farms are located in the outskirts and have the water-supply plants of their own. In some villages (Sentelek, Maly Bashchelak) the water from farms is delivered to the population. As a rule, the sites around the wells are covered by manure and litter, and the sanitary protection zones are not found.

Except for the Charyshskoye regional center, no sanitary control of the heads in water-supply wells and the first belt of the sanitary protection zone (SPZ) are observed in all settlements. The first belt of SPZ doesn’t meet the requirements anywhere, and the sites around the water supply plants and water reservoirs are in the insanitary conditions.

The water-pipe networks in all settlements are in bad condition.

The following major problems of water-supply system exploitation were revealed:

- significant relief difference;
- complicated geological and hydrogeological conditions;
- seasonal high water in rivers and their tributaries;
- near-surface ground water bedding;
- ice mounds and frost penetration in grounds;
- non-designed building;
- run duration of water-supply systems (worn out state);
- allocation of water supply plants below the pumping reservoirs;
- lack of isolation valves and automatic devices;
- lack of fire hydrants;
- absence of sanitary control zones;
- different diameters of networks and pipe material;
- severe pipe corrosion.

Nowadays the close control of consumable water in all settlements is nowhere to be seen. The water use rate includes the household water use, watering of the farmlands in summer and the needs of livestock. On the average, for each countryman there are 110 l/day of water.

Water supply of stock-farms is independent without any control of the water consumed.

Relying on the analysis of the current state of water supply in rural settlements, the major measures to improve the present-day unfavorable situation in the region were elaborated and the priority of activities in each settlement was set. They are as follows:

- construction of new wells, pumping stations, water towers, and standpipes;
- sampling and analysis of water from the available wells;
- construction of water conduits;
- reconstruction of the existing conduits;
- establishment of sanitary control zones;
- equipment of fire hydrants.

Two complex options for water economic problem solution were proposed.

The first one involves all measures on the improvement of water supply according to sanitary and ecological standards.

The second variant consists of an abbreviated list of top-priority measures to be carried out within the available local finances that partially eases the tense situation in the region.

Unfortunately, the peripheral regions characterized by the extensive agriculture, in particular, the Charyshsky region, the solution of water-related problems is impossible without the support of regional and national target programs. In this case the reconstruction and improvement of water supply system are of vital importance. Therefore, the water-related proposals and recommendations should be included in the Program for social and economic development of the Charyshsky region in Altai Krai and supported financially by Altai Krai administration.

THE ASSESSMENT OF WATER QUALITY OF SOME TRANSBOUNDARY RIVERS OF THE KURA-ARAKS BASIN

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Abstract. The research goal was to complexly assess the quality of water of some transboundary rivers of the South Caucasus. Initial materials were monthly monitoring data on Rivers Debed, Aghstev and Arpa for 2004-2006. As result of research a general characteristic of waters by basic ions was given. We indicated the impact sources and water quality formation factors, assessed the level of water pollution with heavy metal and gave their hydrogeochemical characteristic. The dynamics of variations in concentration of pollutants was also studied.
Keywords: Water quality; Heavy metals; Ions; Ore regions; Dynamics; Mineralization

INTRODUCTION

This article covers a complex research on the quality of waters of transboundary Rivers Aghstev, Debed, Arpa and highlights monitoring data obtained between 2004 and 2006 in the frame of an international NATO/OSCE project N977991 "South Caucasus River Monitoring" (2002-2008).

Fig.1.

Synchronous execution of the project in the three South Caucasian countries, identical up-to-date lab facilities, application of identical determination methods assure credibility and compatibility of data on surface waters. The essence of the research consists in the application of the obtained data for scientific interpretation and in the assessment of quality of waters of some transboundary rivers of the region.

Primary material were data on river water quality monitoring conducted on a monthly base for

1) **River Aghstev** on monitoring stations R.Aghstev-Fioletovo vil**.,** ***Ar-11*** (Armenia), R. Aghstev – the city of Ijevan, ***Ar-10*** (Armenia) and Aghstafachay, ***Az-3*** (Azerbaijan),
2) **River Debed with its tributary – River Pambak** on monitoring stations R.Pambak –Shirakamut vil., ***Ar-1*** (Armenia), R. Pambak – the city of Vanadzor, ***Ar-2*** (Armenia), R. Debed – Ayrum vil., ***Ar-3*** (Armenia), R. Khrami – Krasniy Most (Red Bridge), ***Ge-10*** (Georgia), R. Khrami, ***Az-1*** (Azerbaijan), River Kura**,** ***Az-2*** (Azerbaijan),
3) **River Arpa** on monitoring stations R.Arpa-Areni vil., ***Ar-6*** (Armenia), R. Arpachay, ***Az-9*** (Azerbaijan) (Fig.1).

Study methods

Samples were collected, conserved, transported and stored following international Standard Operational Procedures (SOPs) based on International Standard Organisation (ISO) standards [1]. We studied basic ions: Na, K, Mg, Ca, SO_4, Cl, HCO_3, CO_3, - and heavy metals (HMs): Cu, Mo, Zn, Ni, Mn, Cd, As, Hg, Co, Pb. HMs were analyzed on a device Aanalist 800 through the methods of atomic-absorption with graphite atomizer, and flame photometry. Ions were analyzed through spectrophotometric, flame photometric, complexometric, potentiometric and gravimetric methods. The analytes concentration was measured following the developed ISO-based SOPs [2, 3].

Results and discussions

Studying basic ions

River Debed. For the studies period total river water mineralization values varied 183.2 to 378.2 mg/L. Relatively high total mineralization values were common for summer, autumn, winter months as a consequence of a season-dependent decrease of river water discharge.

River Arpa. For the studied period total river water mineralization values varied 141.3 to 491.6 mg/L. Relatively low values established for spring were also common to the river waters. The observed inclination was linked to spring high water, when high discharge values correspond to low concentrations of the studied water ions.

High ion values in summer, the fall and winter resulted predominantly from underground feeding [8].

River Aghstev. For the studied period total river water mineralization values varied 173.4 to 468.4 mg/L. Annual river water mineralization showed inclination similar to that for River Arpa, justification logic being the same.

Consistent with the accepted classification [7] the waters of the studied rivers were characterised as predominantly hydro-carbonate.

Studying heavy metals

Studying the dynamics of HM contents in transboundary Rivers Debed, Arpa and Aghstev.

As a result of analysis of data on HMs for 2006, Cu, Cd, Cr, Ni, Mn, Zn were selected for further interpretation of the dynamics of their concentrations. The rest heavy metals represented no research interest from positions of the stated task, as for the studied period the dominating portion of their values did not reach MDL.

River Debed

On downstream river sections the dynamics of variations in HM contents was characterized as follows. Cu and Cd showed an inclination to an increase from st. Ar-1 towards st. Ge-10, this entailing from exploitation of ore deposits, and a slight decrease of the contents on. st. Az-2, this evidencing the absense of Cu and Cd pollution sources on the studied river section and the beginning of self-cleanup process. No notable variations were indicated for the dynamics of Cr and Ni contents except the observed peaks in the fall and winter months induced by typical season-dependent low water. Similarly to Cu, the concentrations of Mn and Zn were also increasing from Ar-1 towards Ar-3, which is explained by the impact of Alaverdi ore region and the presence of Cu and Zn in dominating industrial metals [4]. Due to high sorption activity Mn often plays a role of a “catcher” for other HMs. However changes in Eh and pH can induce changes in the process direction from dissolved phase sorption on hydroxides (which composition in turn is predetermined by the composition of dominating rocks) to their re-mobilization to dissolved phase [5]. This could probably explain similarity of tendencies in the contents dynamics. For downstream sections observed was a decrease of their concentrations linked to an active sorption process and co-sedimentation and thus water cleanup (Fig.2).

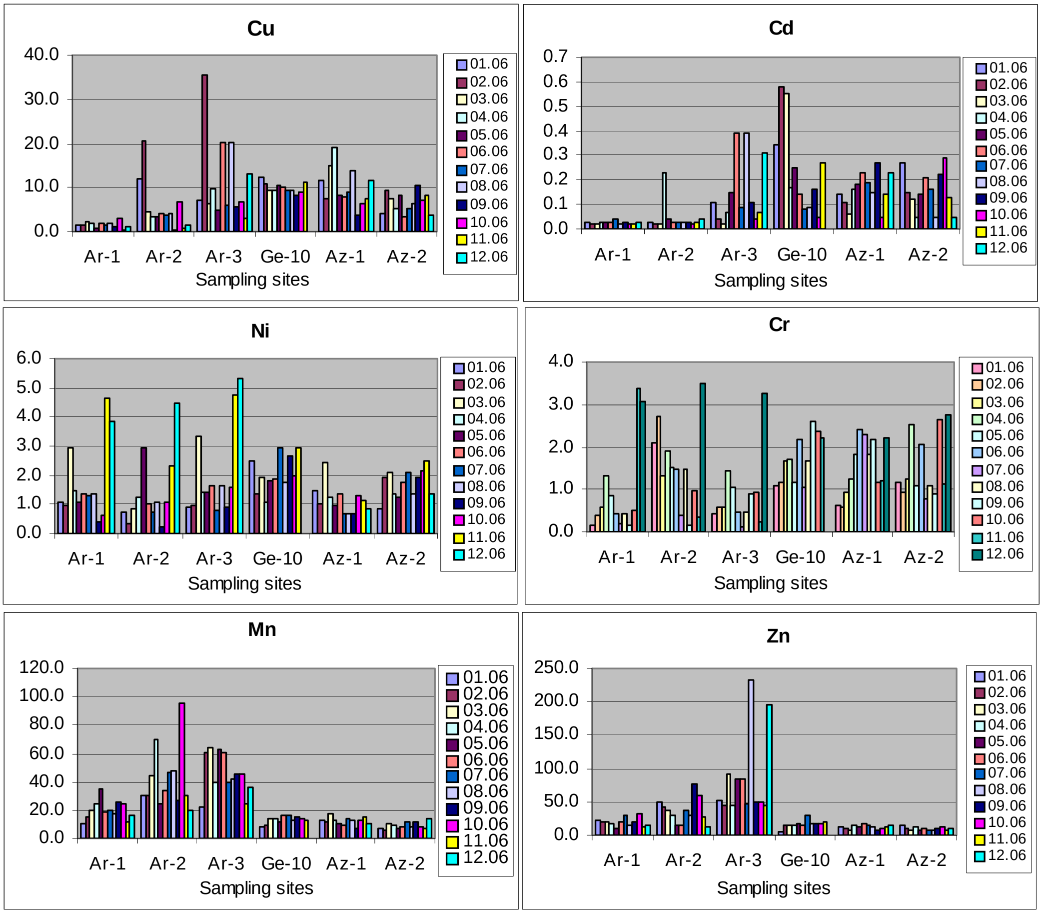

Fig. 2. The dynamics of HMs contents on Debed-Pambak river system, µg/l

River Arpa

High values of Cu, Mn and Zn in river water stepped from the impact of Vayotsdzor ore region [4]. Cr and Ni values on st.Ar-6 were low except those obtained for April when the observed high values resulted from soil washout from the watershed area, and for November-December – as a consequence of low-water period. On downstream st.Az-9 the values were even lower and reached MDL, thus proving the absence of pollution sources (Fig. 3).

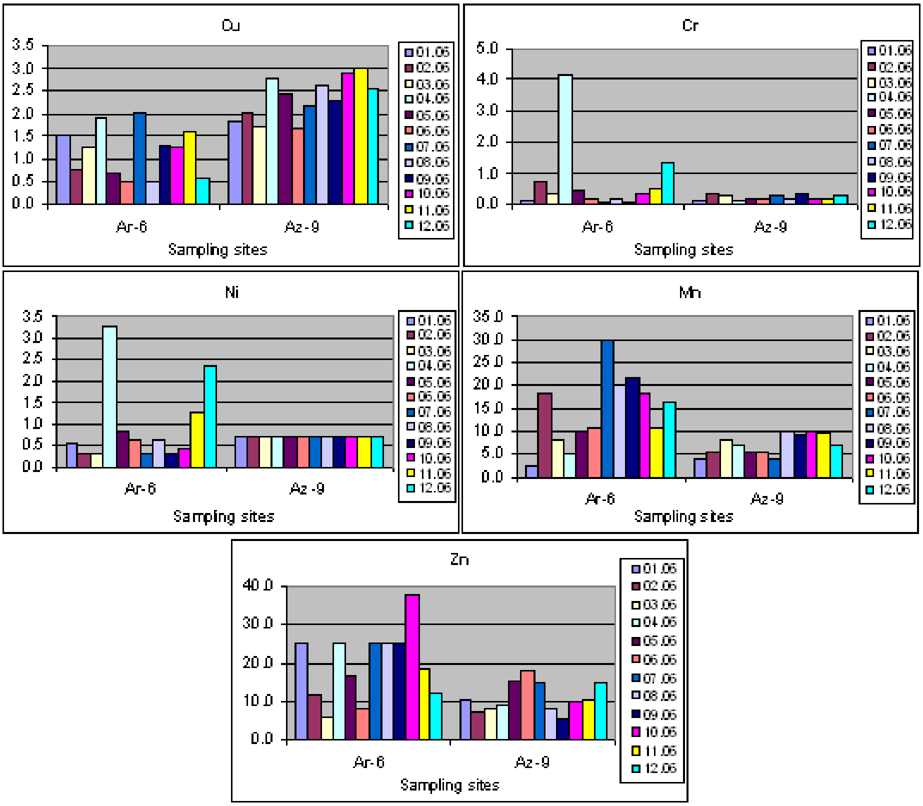

Fig. 3. The dynamics of HM contents on River Arpa for 2006, µg/l

River Aghstev

For the studied period the dynamics of Cu and Cd contents was characterized by relatively high values, this resulting from the impact of Ijevan ore region where small deposits of polymetallic ores are found at subordinate values of copper [4]. The changes in Cr and Ni contents were almost identical for sts. Ar-11 and Ar-10; for st.Az-3 Cr showed a sharp increase, and Ni – decreased. High stable contents of Mn common for the river are connected with manganese mineralization of sedimentary and hydrothermal genesis [4]. Decreasing contents of Zn are explained by sedimentation which favors a decrease of its concentration in water dissolved phase (Fig.4).

Sanitary and hygienic assessment of the level of river pollution by heavy metals indicated that the contents of the studied heavy metals were not excessive vs. MAC [6].

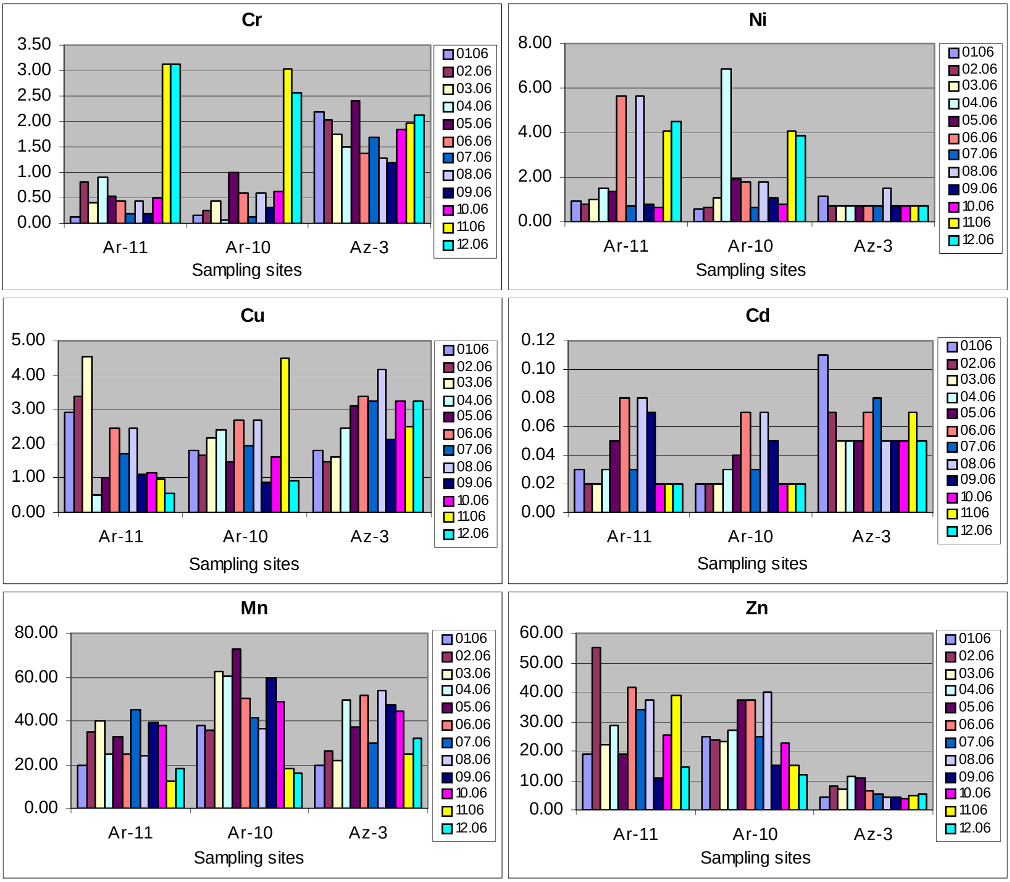

Fig.4. The dynamics of HM contents on River Aghstev for 2006, μg/l

Hydrogeochemical characteristic of the waters of Rivers Pambak, Debed, Aghastev and Arpa.

For the studied period, hydrogeochemical peculiarities of HMs contents in the river waters were investigated as well. We calculated qualitative and quantitative series of geochemical stream and summary indices of concentration (SIC) that represent the concentrations of elements standardized by background contents and calculated by a formula [9]

$$Z_c = \sum_{i=1}^{n} K_{c_i} - (n-1)$$

where n - the amount of chemical elements to be calculated; K_c – concentration coefficient.

The results of the analysis were as follows. For River Pambak, copper dominated in 2004 and 2005 and was replaced by cadmium in 2006. For River Debed copper was dominant during the entire studied period. In 2006 vs. 2005 min. a twofold increase of SIC was observed due to elevating coefficients of Cu, Cd, Zn concentrations (Tab.1).

Table 1

Qualitative geochemical series of HM for Rivers Pambak, Debed, Aghstev and Arpa

N	Monitoring stations	Qualitative series of geochemical flow	SIC
		2004	
St.2	r.Pambak - c. Vanadzor	$Cu_{(2.6)}$-$Cr_{(2.6)}$-$Cd_{(2.3)}$-$Mn_{(1,7)}$-$Mo_{(1,7)}$-$Zn_{(1,5)}$-$Ni_{(1,1)}$-$Hg_{(0,8)}$	**7.3**
St.3	r.Debed - v.Airum	$Cu_{(4,7)}$-$Cd_{(4,2)}$-$Zn_{(2,1)}$-$Mn_{(1,4)}$-$Ni_{(1,4)}$-$Cr_{(1,2)}$-$Hg_{(1)}$-$Mo_{(0,8)}$	**9.8**
St. 10	r. Agstev - c. Ijevan	$Cu_{(2,3)}$-$Mn_{(1,4)}$-$Cd_{(1,1)}$-$Hg_{(1)}$-$Ni_{(0,9)}$-$Cr_{(0,9)}$-$Zn_{(0,8)}$-$Mo_{(0,6)}$	**2.0**
St. 6	r. Arpa - v. Areni	$Cd_{(10,6)}$- $Cr_{(2,2)}$-$Mn_{(1,6)}$- $Zn_{(1,2)}$-$Hg_{(1,1)}$-$Mo_{(1)}$-$Cu_{(0,6)}$	**12.3**
		2005	
St.2	r.Pambak - c. Vanadzor	$Cu_{(5,5)}$-$Ni_{(1,8)}$-$Cr_{(1,4)}$-$Mn_{(1,3)}$- $Hg_{(1,3)}$-$Zn_{(1,2)}$-$Mo_{(0,9)}$-$Cd_{(0,4)}$	**6.8**
St.3	r.Debed - v.Airum	$Cu_{(5)}$-$Zn_{(1,7)}$-$Mn_{(1.3)}$-$Ni_{(1,2)}$-$Cr_{(1,2)}$-$Mo_{(1,1)}$-$Hg_{(1,1)}$-$Cd_{(1)}$	**6.6**
St. 10	r. Agstev - c. Ijevan	$Cu_{(2.3)}$-$Cd_{(1.3)}$-$Ni_{(1,2)}$-$Mn_{(1,2)}$-$Zn_{(1,1)}$-$Mo_{(0,9)}$-$Hg_{(0,7)}$-$Cr_{(0,6)}$	**2.3**
St. 6	r. Arpa - v. Areni	$Cr_{(12,5)}$- $Ni_{(4,2)}$- $Mo_{(1,8)}$-$Zn_{(1,2)}$-$Mn_{(1,2)}$-$Hg_{(1)}$-$Cd_{(0,8)}$-$Cu_{(0,6)}$	**16.3**
		2006	
St.2	r.Pambak - c. Vanadzor	$Cd_{(4,3)}$-$Cu_{(2.6)}$- $Mn_{(3,1)}$- $Zn_{(1,9)}$ $Cr_{(1,3)}$ $Mo_{(1,0)}$-$Hg_{(0,9)}$-$Ni_{(0,8)}$	**7.9**
St.3	r.Debed - v.Airum	$Cu_{(6,5)}$-$Cd_{(5,3)}$-$Zn_{(4,1)}$-$Mn_{(2,1)}$-$Ni_{(1,1)}$- $Mo_{(1,0)}$-$Hg_{(0,9)}$- $Cr_{(0,9)}$	**14.9**
St. 10	r. Agstev - c. Ijevan	$Mn_{(1,5)}$-$Cu_{(1,1)}$- $Hg_{(1)}$ - $Cd_{(0,9)}$- $Ni_{(0,9)}$- $Cr_{(0,9)}$-$Zn_{(0,8)}$-$Mo_{(0,7)}$	**0.8**
St. 6	r. Arpa - v. Areni	$Cr_{(12)}$- $Ni_{(1.6)}$- $Mo_{(1,1)}$-$Zn_{(0,9)}$-$Mn_{(0,7)}$-$Hg_{(1)}$-$Cd_{(0,7)}$-$Cu_{(0,7)}$	**11.7**

For River Aghstev Cu dominated the series in 2004 and 2005 and was replaced by Mn in 2006. Such a fact evidenced a prevailing impact of manganese ore upon formation of quantitative series of heavy metals in 2006 vs. previous years. The analysis of SIC for the studied period indicated a slight increase in 2005 vs. 2004 and a sharp drop in 2006.

To River Arpa common were geochemical series with high concentrations of Cd, Cr, Ni, Mo, Zn. Cd dominating in 2004 reflected a prevailing role of ore deposits located within the river basin. Domination of Cr and Ni in 2005 and 2006 was conditioned by a dominant factor of soil washout from the watershed. SIC showed an inclination to an increase in 2005 and substantial decrease in 2006 (Table 1).

Conclusion

The waters of the studied rivers are characterized as predominantly hydrocarbonate.

In river water heavy metal were indicated which contents were not excessive vs. MAC, this evidencing no strong pollution of the rivers. In the result of hydrogeochemical state assessment of the waters of Rivers Kura-Araks basin (Rivers Pambak, Debed, Aghstev), we indicated dominating heavy metals Cu, Cd, Mn which local geochemical background was characterized by relatively high values.

Thus, at the current stage of research a considerable role in water quality formation is given to exploited ore deposits and eroded zones of mineralization in ore regions. They enrich river waters by concentrations of chemical elements peculiar to natural geochemical landscape of the watershed.

Acknowledgement

A basic material for this article were the outcomes of a NATO/OSCE project N 977991 “South Caucasus River Monitoring” that include data provided by the Institute of Radiation Studies of the National Academy of Sciences of Azerbaijan.

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Biological assessment of ecological state of surface water in the Ob-Irtysh basin

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Rivers, lakes and reservoirs in Siberia are exposed to the effect of all factors associated with human activity, namely, urbanization, power generation and consumption, chemical, timber and mineral resource industry, oil and gas producing industry, mining and metallurgical enterprises. When the effect on water ecosystems is considered, a great variety of factors distinguished by the time of appearance, frequency, origin, conditions and nature, objects and the degree of influence should be taken into account.

The watershed of the Ob-Yrtysh basin makes up 15% of Russia. There are numerous water objects here and the whole spectrum of ecosystems of stagnant and flowing waters: rivers of different size; mountainous and steppe lakes of different size and salinity; small and large reservoirs, marshes (Fig. 1). The peculiarities of forming and functioning of the basin streams and reservoirs ecosystems are specified by diversity of natural conditions and character of vast territory use.

First investigations of aquatic ecosystems of the Ob basin were made in the 17th century. Necessity in making practical decisions on natural resource use in the region promoted and stimulated greatly such a research. For example, project on construction of hydropower station on Biya river gave rise to thorough studying of Teletskoye lake by State Hydrology Institute. In the 80th just this very lake attracted considerable interest again because of the need for giving ecological examination of Katun hydropower station project. Specialists from numerous institutes studied Katun river and its tributaries as well as Lake Teletskoye as analogue for future reservoir.

Long term complex research of Ob river and its basin for many years was made due to the project on Siberian rivers runoff redistribution including Nizhneobsk hydropower station and reservoir construction to solve the water supply problems of Kazakhstan and Central Asia.

Construction of Novosibirsk hydropower station in the 50 th gave impetus to carrying out investigations on the Ob, from Kamen-on-Ob up to Novosibirsk. Thus, Novosibirsk reservoir became the object under study for many years and to different specialists who investigated it as the reservoir of complex purpose including as a source of a water supply for Novosibirsk, as an ecosystem and as a model object for studying particular ecological communities and processes.

Design and construction of Krapivinsky dam (near Kemerovo) resulted in the 80th in great bulk of various data on Tom river.

Making prognosis on environment state changes as a result of construction and operating of Kansk-Achinsk fuel and energy complex (KAFEC) contributed to intensive complex investigations of rivers, lakes and reservoirs in Chulym river basin in the 70-80th.

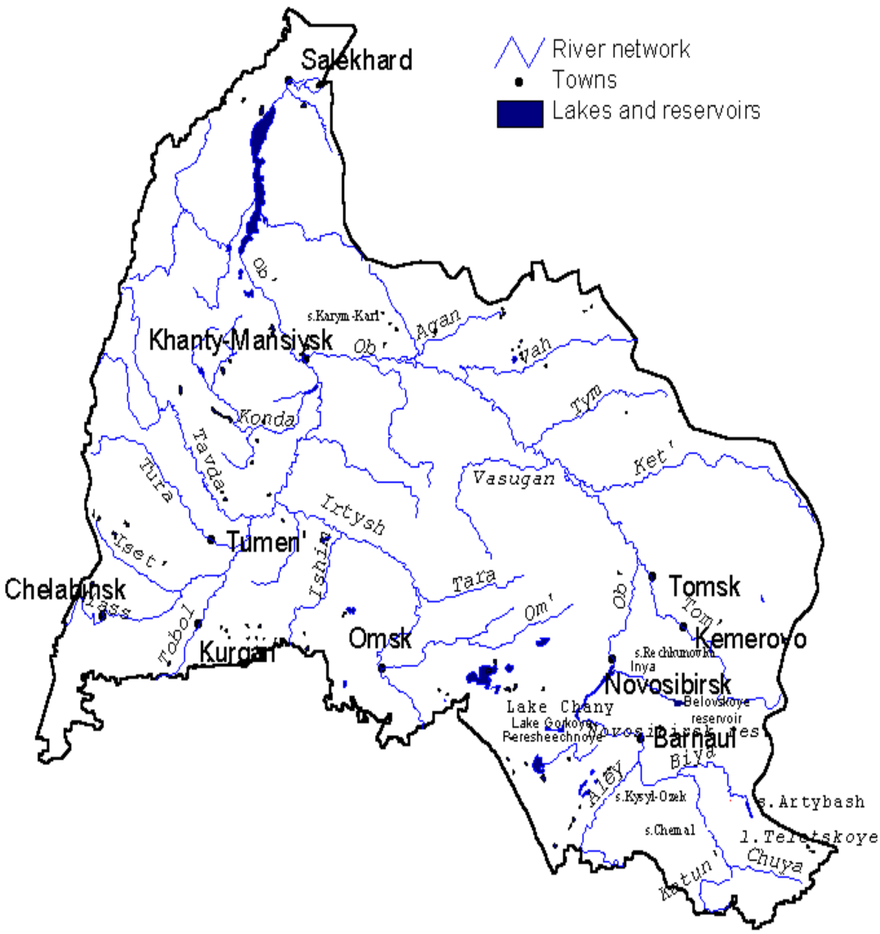

Fig. 1. The scheme of the Ob-Irtysh basin

Information and data on ecosystems of Alei River basin and Ob-Irtysh interfluvial area were used to assess nuclear tests after effects at Semipalatinsk Test Site.

Nowadays there is the need for assessment of aquatic ecosystems of Mid and Lower Ob as well as Tom River state and prognoses for their change since level of river waters contamination by petroleum products is rather high.

Water objects of West Siberia were always of great concern to researchers because of the region’s stagnant and flowing waters use for fishing and recreational (including treatment) purposes as well. Natural prerequisites for human morbidity especially aggravated by anthropogenic factors are one more reason for carrying out research.

Ecosystem diversity is one of the biological diversity levels which is based on the study results of diversity at genetic and species levels as well as on the data on conditions diversity for forming and functioning biological systems. It is suggested to refer a number of different habitats, biotic communities and ecological processes to ecosystem diversity (Mc Neely et all., 1990) by means of ecosystem typification on the basis of their ecotypes which are more conservative and stable than biocenoses (Rysin, 1995).

Investigations carried out by the Laboratory of Aquatic Ecology of IWEP SB RAS are aimed at the substantiation of principles, the development of theory and practical recommendations for ecological monitoring in the Ob-Irtysh basin. The research includes the study of biodiversity characteristics as the basis of ecosystems stability at different levels of biological systems organization, i.e. from the sub cellular to the ecosystem ones (Fig. 2).

At the sub cellular level, the chromosomes of the animal larvae and the meristem cells of the grass germs are studied. At the species level, the taxonomic composition and number of algae, Protozoa (free living infusorians), invertebrates, higher plants and fish are investigated. To differentiate aquatic ecosystems with respect to biological and system features diversity of taxonomic composition; information structure complexity; completeness and balance of trophic structure of biocenoses; intensity of energy and substances fluxes with estimating of relative share of allochthonous and autochthonous organic matter, degree of their transformation and accumulation; level of trophicity; distribution of typical life-time of biocenosis elements and dynamics of abiotic factors; rate and direction (tendency) of communities evolution (succession), biocenosis and the ecosystem on the whole are used.

Long-term observations of composition, structure, functioning and succession of the basin aquatic ecosystems of different types, in particular, the lakes of the upstream Ob - Lake Teletskoye (large, deep, fresh, oligotrophic), the lakes of steppe and forest-steppe zone in the south of the Ob-Irtysh interfluves: Lake Gor'koye-Peresheechnoye (medium-size, shallow, fresh, eutrophic), Lake Bol'shoye Yarovoye (large, shallow, hyperhaline, eutrophic), Lake Bol'shoye Gor'koye (small, shallow, mesohaline, mesotrophic), Lake Chany (large, shallow, hyperhaline, mesotrophic-eutrophic), Lake Kulundinskoye (large, shallow, hyperhaline, mesotrophic), Lake Kuchuk (small, shallow, hyperhaline, mesotrophic) were carried out.

Let us consider typological features of composition structure functioning and succession of the Ob basin aquatic ecosystems taking as an example the Ob itself in the part from mountainous tributaries up to Karym-Kary settlement.

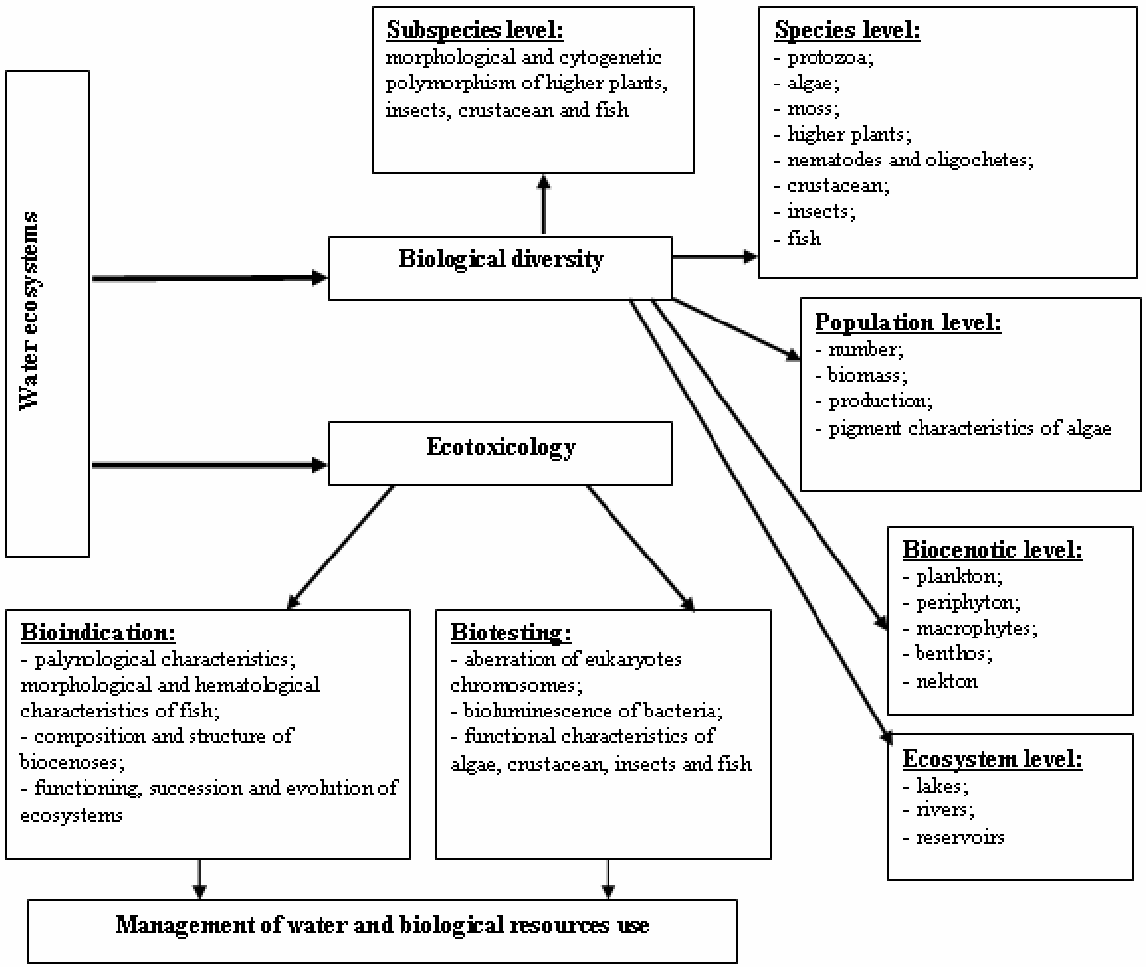

Fig. 2. The structure of the study of ecosystem biodiversity and the assessment of water objects ecological state

Rivers are considered to be the most dynamic component of Hydrosphere since changes of river bed waters are registered in the average every 11 days (L'vovich, 1986). Rivers as the system of removal of water and wind erosion products as well as wastes from the territory redistribute anthropogenic load within geo- and hydrosystems. As this takes place, in addition to standard classification of rivers by sites on morphological features (upper, middle, lower) it is suggested to consider changes of substances' flows, fluxes of energy and information, succession of river biocenoses and genesis of water quality along the stream. If we broaden the trophicity notion as the basis for limnetic system classification, oligo-, meso- and eutrophic sites could be detected in the river. Trophicity change as a characteristic for living organisms development level, intensity of substances and energy fluxes along the river takes place due to natural reasons but its significant shift towards as increase (in case of entering allochthonous organic and biogenic substances) as decrease (due to toxic substances and pollutants coming to the river) can be observed. Self-purification potential of the river is followed by trophicity.

Heterogeneity of features and the greatest changes in chemical composition of water downstream the river occurs when the river crosses different geographical zones, i.e. rivers running in meridianal direction (Alekin, 1970). One glowing example of such a river is the main water way of West Siberia – Ob River. Its ecosystem is subjected to intensive anthropogenic load factors increasing in the direction from the source towards the river mouth.

Natural and anthropogenic factors determining the ecosystem features and water quality in the ecologically different sites of the Ob river system (from the source to Karym-Kary settlement) including Katun and Biya rivers and the tributaries of the first order – small rivers (the Barnaulka, Cheremshanka and Losikha) and medium-size rivers (the Charysh, Alei, Chumysh, Inya, Tom', Chulym) as well as the large (Novosibirsk) and small (Gilevskoye, Sklyuikhinskoye, Belovskoye and Bereshskoye) reservoirs were defined.

The Ob site situated upper of Novosibirsk reservoir is typically flat but its ecosystem (which is considered complete on biotic communities content) is influenced by mountainous Katun and Biya rivers which form the Ob. Average monthly water temperatures are maximum in June and don't exceed 19.2°C. Investigations made there in 1989 and 1993 showed various phytoplankton (179 species) occurrence with predominance of green, diatom and to lesser degree blue-green algae and essential fluctuations in number (9.4-501 th.cells/l) and biomass (0.03-1.1 mg/l) downstream the river. The maximum values for biomass were registered in the mouth part of Biya river (near Biya town) and Chroomonas acuta dinophite algae - one of dominants of Teletskoye Lake was found. Species of algae belong to β-mesosaprobic ones. Approximately 50 species with predominance of Rotiferia wheel animalcules under maximum values of total number - up to 91.4 th.smpl./m^3 and biomass - up to 1.817 g/m^3 were revealed in zooplankton (Kirillov et al, 1997).

One of the methods for investigation of spatial-temporal heterogeneity of living organisms distribution and revealing of integral changes in the river and watershed area under influence of natural processes and anthropogenic load is phytoplankton pigments concentration studying. Seasonal, annual dynamics and distribution of major photosynthetic pigment of phytoplankton along the Ob were studied (Kirillova et al., 2000).

As for annual aspect trophic status of the upper Ob is stable one. Content of "a" chlorophyll varied within 2.9-51.2 mg/m^3. In August-September, 1999 in the course of complex experiments water sampling was made on the river site from the Tom river up to Irtysh river mouth and the content of "a" chlorophyll was within 2.9-51.2 mg/m^3 which differed little from the content obtained during studying of phytoplankton photosynthetic pigments near Barnaul in the period of low water in previous years: 14.2 and 13.0 mg/m^3, respectively.

Its minimum was registered in July lower Krasny Yar settlement and maximum - in August at the site situated lower the Tom river mouth. The Kruskall-Vallis nonparametrical criterium for comparison of several independent samplings was used to characterise spatial distribution and temporal dynamics of "a" chlorophyll and other photosynthetic pigments for analysis of the data obtained in July and August (Zaks, 1976). Analysis of calculations showed that for 95% of confidential interval reliable differences between single points of sampling in July were absent. Considerable differences between the river banks and water ways and 0-1 m horizons were not found as under assessment of mid stream tributaries effects on "a" chlorophyll content in the Ob river waters. As for temporal aspect, increase in pigment characteristics values was marked in August as compared with ones in July under 1-5% level of importance. Sharp fluctuations of "a" chlorophyll concentrations, practically by 5 times, were registered at the water surface of water way in the course of investigations carried out in the 3d decade of August - first decade of September, 1999 at the site of Mid and Low Ob river.

The highest values for "a" chlorophyll concentration were observed lower the Tom River nearby Bragino and Karym-Kary settlements; the least values were marked in tributaries mouths and near Nizhnevartovsk (Fig. 3). Reliable differences between 3 points on cross section for all sites studied during this period weren't revealed. Differences in content of key photosynthetic pigment in Mid Ob tributaries and main river bed (namely, in the Tom waters near the mouth average on section value (15.4±1.5 mg/m^3) was less ($p<0.05$) than appropriate indices upstream (24.0±2.5 mg/m^3) and downstream (42.9±4.2 mg/m^3) from the Tom inflow) were distinct in the fall period of water mass cooling.

Similar differences were found under comparison of mean concentration in Chulym River waters and the upper/lower parts of main river bed sites. Difference between the value of considered property in tributary water (18.1±1.5 mg/m^3) and the point situated upstream the Ob (22.6±0.95 mg/m^3) is less expressed. In spatial distribution the tendency toward smoothing the gradients of "a" chlorophyll concentration along the stream and on cross-section of sites was observed that was explained by slowing down of water movements as the floodplain broadened and relief slope decreased in north direction as well as by influence of vast well-developed lowland.

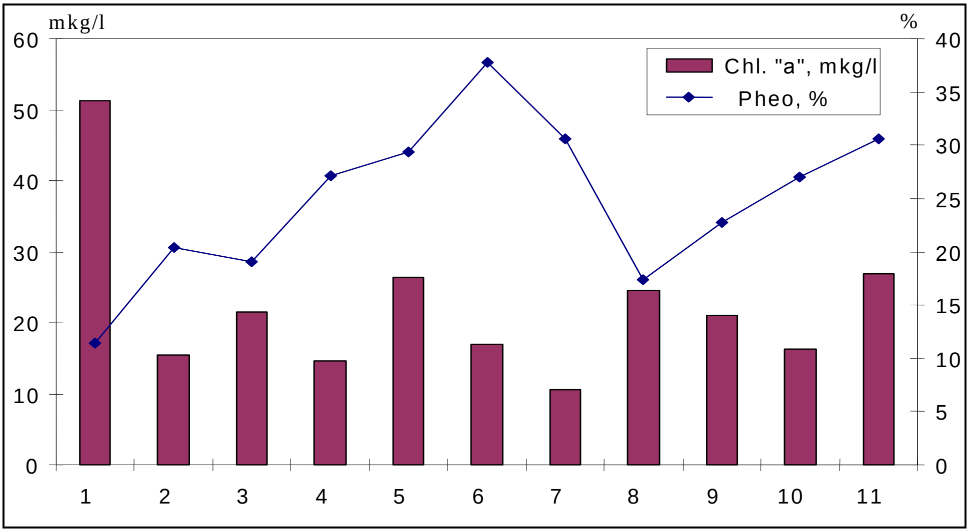

Fig. 3. Heterogeneity of "a" chlorophyll and pheopigments content along the stream of Ob river in August 1998.

Point of water sampling: 1 – lower the Tom river mouth, 2 – lower Krasny Yar, 3 – upper the Chulym river mouth, 4 – the Chulym river mouth, 5 – lower the Chulym river mouth, 6 – upper Nizhnevartovsk, 7 – lower Nizhnevartovsk, 8 – upper the Irtysh river, 9 - the Irtysh river mouth, 10 – lower the Irtysh river mouth, 11 – near Karym-Kary settlement

It is found that trophic status of the river increases from oligotrophic one in the mid stream and stays the same in downstreams under local changes in the regions of large settlements and tributaries mainly due to biogenic load and petroleum pollution. Seasonal dynamics of "a" chlorophyll is associated with hydrologic cycles phases and hydrometeorological peculiarities of the year.

The priority of natural factors in the formation and functioning of water ecosystems under short local change of biocenoses characteristics and surface water quality exposed to the influence of large industrial centers and single industrial objects has been defined.

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Session 3

The problems of quality drinking water supply of population

Water resources of Central Asia and their current use

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Central Asia covers the territory of 4 mln. km^2 with population of 57 mln. people (data available for 2003).

It should be noted that the Region never stopped in its development: irrigated farming (from the ancient times - a major trend in water resources use) is evidence of this fact. Another example is power engineering initiated and rapidly developed since the 20s of the last century.

Irrigation goes back to VI-VII BC, while its stormy development – to 60-90s of XX century when the USSR existed. Such a development brought to the expansion of irrigated territories up to 9 мln. ha. It is felt that it was a grandiose experiment on human intervention into nature and its processes. Nowadays, irrigation development in this Region has ceased.

Power engineering, that was absolutely new advanced industry for the Region, started its rapid development in the 30s. Total capacity of all HES constructed in the region in 30-90s of XX century made up almost 40 mln. Kw.

Actually, water power resources have been currently developed just by 5-10%.

Unfortunately, all these impressive results had negative effects, i.e. ecological imbalance in the region (the Aral Sea and the Aral region), increased soil salinity and desertification, degradation of water quality. By the 70s, water resources of Syr Darya river were practically exhausted that turned out to be a global ecological problem for this region.

The situation didn’t occur as a result of mistakes and miscalculations of specialists; in the USSR, the schemes of water resources use were developed and specified over and over again on the scientific base by numerous design and research institutes involved. These schemes were thoroughly examined at all levels, including the Republican one. The hydrologic budget (calculated, grounded and predicted by those specialists) is still used- that is evidence of the qualitative job made in the 70s by the involved organizations.

Thus, the problem arose because it was extremely complicated one related with profound and different changes in all social-economic spheres. In addition, the human belief in man’s power over nature was too strong.

Moreover, the demographic situation in the region became critical: for the 75 years of the Soviet regime the population of Tajik Republic increased more than 6 times; the same situation was observed in other Republics that couldn’t but influence on the development of these Republics.

In 1991, after the USSR disintegration, the problems of water power resources in the region became more complicated.

In the period of the USSR existence, the key criteria were maximization of common benefits and economies of integration. It was quite reasonable to construct reservoirs and HESs in mountain regions (Tajik and Kyrgyz Republics) distinguished by large resources, higher water resources efficiency and less flooding areas, while thermal power plants (TPP) were constructed mostly in low reaches (Kazakhstan, Uzbekistan, Turkmenistan), situated nearby the industrial centers and deposits of mineral oil. Also, the decision on agricultural production, including irrigation in rivers' valleys (with fertile lands) of Kazakhstan, Uzbekistan, Turkmenistan, was made.

That time the imbalance in some regions development was not a problem, because mutual supply of energy resources, agricultural and industrial products was practiced.

As soon as former USSR Republics became independent, they immediately put their national interests in the forefront, thus making the problems critical. As a matter of fact, wise heads of all 5 Central Asian Republics got together in Alma-Ata and Nukuss and reached the agreement to maintain the former terms of economic management for the transition period. It allowed to prevent conflicts on water –energy resources in the Region.

Clearly, this approach is not applicable now, since it aggravates and accumulates the contradictions. The Republics of Central Asia interpret the notion of water-energy resources conservation in different ways, e.g. Kazakhstan and Uzbekistan including Turkmenistan (i.e. the Amu Darya river basin) interpret it solely as the operating conditions of water-economic and power objects situated in the river basin, while Kyrgyzstan and Tajikistan - as all types of compensations.

This paper discusses the problems of joint use of water resources by the example of the most stressed basin of the region where all water resources have been exhausted, i.e. the Syr Darya one. This problem is a unique and extremely complicated one that requires the thorough revision of current methods in economic, political, social, ecological, futurological and other spheres.

At the same time, the world experience shows that all differences existing between our republics may cause not only contradictions but serve as a base for cooperation and interrelation.

The reached agreements on the joint use of water-energy resources of the Syr-Darya river basin and their practical implementation show good results, however, it's only the beginning of a hard and long-term work.

The agreement on the regulation of transboundary water in the Syr-Darya river basin among 4 Central Asia countries reached in 1998 is the basic one that is of framework character. It can start working under market conditions in full, if the relations among countries would be commercialized, like it is made in the energy sector.

Peculiarities of state registration of drinking and mineral water in Altai Krai

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The idea of state registration of product innovation was first introduced in the Federal Law "On quality and safety of foodstuffs" of 02.01.2000 No. 29 – ФЗ.

In line with art.10 new foodstuffs, materials and goods produced in the Russian Federation; foodstuffs, materials and goods imported by the Russian Federation for the first time are subject to registration.

The state registration of foodstuffs, materials and goods includes the following:

- the examination of submitted by a maker or a provider the proper documents on the conditions of production or delivery of foodstuffs, materials and goods, and results of tests made on request;
- the enrollment of foodstuffs, materials and goods as well as their makers and providers in the State register of foodstuffs, materials and goods allowed for production or import and selling on the territory of the Russian Federation;
- the issuance of the state registration certificate of foodstuffs, materials and goods.

It should be noted that for the first time a notion “The state register of foodstuffs, materials and goods permitted for production or import and selling on the territory of the Russian Federation” was legally introduced.

The law prohibits the registration of some foodstuffs, materials and goods under the same product name as well as a multiple registration of the same foodstuffs, materials and goods under the same or different product names.

To implement the Federal Law No. 29 – ФЗ, the RF Governmental Regulation of 21.12.2000 No.988 “On state registration of new foodstuffs, materials and goods” was passed. First, it was proposed to start the process of state registration from 2001, but later another date was fixed, i.e. 01.01.2004.

The Order of Ministry of Health of 15.08.2001 No 324 "On state registration of certain potentially hazardous products and some products imported to the Russian Federation for the first time" defined the procedure of state registration, list of documents and the statement form.

Initially the territorial organs of the State Sanitary-Epidemiologic Supervision were not authorized to make the registration of product innovation including drinking and mineral water.

According to the Order of National Service for supervision of consumers’ protection and human welfare of 18.06.2004 No 2 "On state registration of products, materials and medicine" this mission was assigned to the Department on state registration and licensing for human welfare (Moscow city).

A new stage in the implementation of state registration of new products including water and mineral waters started on 15.04.2005 when the Order of National Service for supervision of consumers' protection and human welfare of 21.03.2005 No 363 "On state registration of products, matters and medicine by territorial departments of Rospotrepnadzor" was issued.

All issues concerning the procedure of state registration of products, the list of documents required for expertise and the expert's report for decision making on the state registration in Altai Krai are regulated by the Order of Territorial Department of Rospotrebnadzor and the Center for Hygiene and Epidemiology in Altai Krai of 19.12.2005 No 243/420 "On certification of state registration of products".

In Altai Krai the mineral waters "Serebryany Klyuch" from Biisk region and "Altaiskaya" from Zav'yalovsky region were the first to be explored and bottled up (1995-1998).

At that time, however, the territorial centers for sanitary-and-epidemiologic supervision were not entrusted to examine the technical documents, and hence the hygienic and sanitary-and-epidemiologic reports for these mineral waters were given by the Department of State Sanitary-and-Epidemiologic Supervision (Moscow).

Currently, in Altai Krai, there are 29 enterprises producing 26 names of drinking water of the first class of 0.2-1 g/l mineralization and 12 names of mineral water only three of which have mineralization exceeding 1 g/l.

A great quantity of drinking water from the underground sources the quality of which meets the requirements of Sanitary Regulations and Standards 2.1.4.1074-01 "Drinking water. Hygienic quality specifications of water from the centralized system of drinking water supply. Quality control" is bottled, and the quality of the finished product meets the requirements of Sanitary Regulations and Standards 2.1.4.1116-02 "Drinking water. Hygienic requirements to the quality of bottled water. Quality control".

Besides, the drinking water from the local sources of centralized water supply serves as a primary product for the production of nonalcoholic beverages (the "colored" ones). Almost all drinking waters of different chemical composition including the ones corresponding to Sanitary Regulations and Standards 2.1.4.1074-01 "Drinking water" by hygienic regulations are purified with reverse osmosis systems.

It would appear reasonable that drinking waters and beverages based on them show no biological adequacy.

The expert opinion for such waters is given by Tomsk Research Institute for Balneology and Physiotherapy of the Federal Agency on Public Health and Social Development of the Russian Federation.

According to these reports and in terms of the criteria of mineral waters evaluation established by Ministry of Public Health of the RF (МУ No 2000/34 "Classification of mineral waters and therapeutic muds for certification") the underground well water refers to the " drinking table waters of hydrocarbonate class of calcium subgroup" or "natural drinking table waters".

The document mentioned determines the criteria of "natural drinking table waters", however, they do not agree with those of the State Standard 13273-88 "Treatment and treatment-table drinking waters. Specification".

In our opinion the most reasonable is the Yu. Rakhmanin's classification of the bottled water by the salt content, and the ways of its production and use, i.e. >1 g/l for mineral water and <1 g/l for drinking water.

The use of the term “drinking” for all waters with <1 g/l mineralization will make it possible to regulate the approval of technical documents, to arrange its production and to avoid the purposeful consumer fraud.

The first state registration of drinking water was certified on March 27, 2006 since the previously given sanitary-and-epidemiologic reports were still valid in line with the current legislation.

During the period from March 27, 2006 to April 1, 2007 the Department of Rospotrebnadzor in Altai Krai issued only 18 certificates including 13 for drinking waters and 5 for mineral ones.

The implementation of state registration of drinking and mineral waters at the Department of Rospotrebnadzor in Altai Krai allowed the regulation of expertise, the improvement of laboratory examination of the bottled drinking water according to Sanitary Regulations and Standards, and saving of costs for drinking and mineral water production.

Current state of water in Lake Baikal according to chemical and sanitary-bacteriological characteristics

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Nowadays, when anthropogenic effect is increasing, determination of safe indices of water bodies which are used by the population as a source of drinking water supply is of great importance. Lake Baikal, one of the unique natural objects, is the largest source of drinking water and a site of the World Heritage.

Water in Lake Baikal is of low mineralization. The sum of concentrations of major ions makes up about 100 mg/l. The concentration of major ions is constant within the whole water column. The range of concentration of Na^{+}, Ca^{2+}, Mg^{2+}, HCO_3^{-}, SO_4^{2-} is mainly limited ± 5 %. There is a significantly larger statistic error in determination of K^{+} and Cl^{-} the concentration of which is rather low. The stability of ionic composition of Baikal water is stipulated by insignificant amount of annual water flows in comparison with the volume of lake water masses, similarity of mean chemical composition of lake water with that of flowing waters into the lake, as well as compared to the intensive water exchange in the lake.

The mean concentration of major ions in the lake and in some basins is represented in Table.

The lake water is well saturated with oxygen. Its concentration in near-bottom layers is not lower that 75% of saturation. Nutrients which serve as one of indices of water quality are in small amount.

In the upper dynamically active zone (up to 200-300 m) the distribution of oxygen and nutrients changes considerably in different seasons depending on temperature regime, level of phytoplankton development and intensity of vertical mixing (see Fig.). In the deep zone below 200-300 m with lowered dynamic activity, the temporal changeability is low. In the near-bottom zone – 100-200 m from the bottom, the changeability of concentration of elements increases due to the effect of deep convection and near-slope circulation. In spring and autumn, the concentration of nutrients decreases, while the concentration of oxygen rises. Within some basins of the lake heterogeneities of distribution of concentrations of oxygen and nutrients are connected with two main factors: vertical shifts of water masses within horizontal currents and processes at the front of thermal bars.

Table

Mean concentration of major ions in water of Lake Baikal, mg/l

Ion	Southern Baikal	Central Baikal	Northern Baikal	The whole lake	The whole lake according to [K.K. Falkner et. al., 1991]
HCO_3^-	66.29±1.76	66.68±1.55	65.72±1.39	66.35±1.64	64.12±1.09
SO_4^{2-}	5.20±0.14	5.21±0.16	5.20±0.12	5.20±0.13	5.5 ± 0.18
Cl^-	0.43±0.02	0.43±0.03	0.43±0.02	0.43±0.03	0.4 ±0.02
Ca^{2+}	16.42±0.36	16.52±0.40	16.30±0.33	16.40±0.39	16.1± 0.1
Mg^{2+}	3.03±0.06	3.02±0.08	3.04±0.05	3.03±0.07	3.1± 0.03
Na^+	3.31±0.08	3.37±0.10	3.32±0.12	3.34±0.11	3.6 ± 0.14
K^+	1.01±0.06	1.02±0.06	1.03±0.04	1.02±0.06	0.9± 0.01

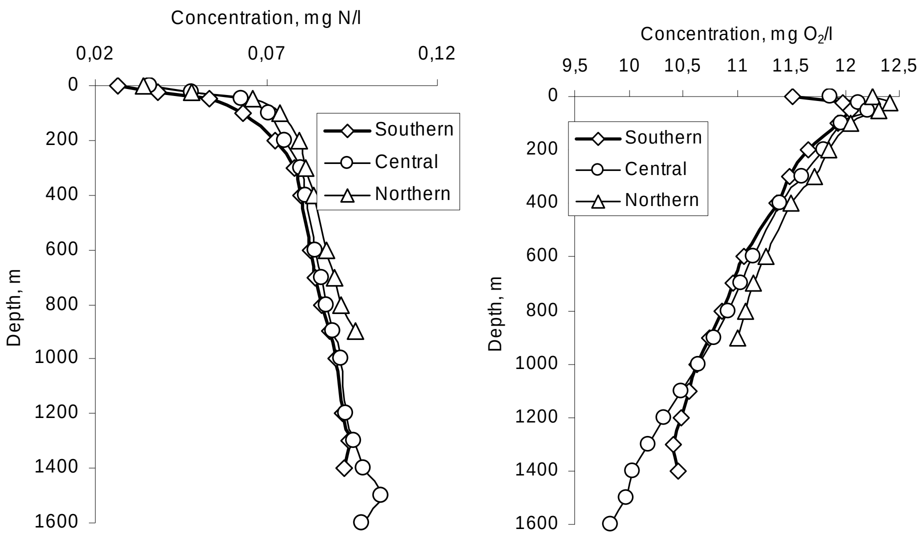

Fig. Vertical distribution of concentration of nitrates and oxygen in different parts of Lake Baikal. Seasonal and spatial changeability of concentrations of nutrients and oxygen is caused by biological processes and dynamics of water masses of the lake

The results of studies of sanitary-bacteriological characteristics of the lake water show that the abundance of heterotrophic bacteria in deep layers of the lake varies within tens of cells per ml. Surface waters do not always meet the requirements on water quality. There is a high abundance of microorganisms of this group in the littoral zone of the lake in the vicinity of settlements.

Self-purification of waters from nutrients and pathogenic bacteria which enter the lake with different flows is considered on the example of the Pokhabikha River. The source of the river pollution is waste waters of town Slyudyanka.

The effect of waste waters on the water quality of the Pokhabikha River is observed in all the chemical and sanitary-bacteriological parameters: oxygen, mineral nitrogen, phosphorus, organic matter, total microbial number, and abundance of coli bacteria. Bacteria were found in big amounts in the river opposite and below the discharge of waste waters where the concentration of ammonium and nitrite nitrogen and phosphates exceed the maximum permissible concentration. According to chemical and sanitary-bacteriological indices, the water quality in the area where flows run into the river is characterized as polluted and dirty. The number of microorganisms of studied groups is decreasing in the near-shore zone of the lake. The impact of sewage is almost absent at a distance of 350 m off the Pokhabikha River mouth. The number of saprophyte bacteria, the total microbial number and total abundance of microorganisms are characteristic of open waters of Lake Baikal. According to chemical parameters, the effect of waste waters on the water composition has not been observed even in the near-shore zone of Lake Baikal. This is evidence of powerful mechanisms of self-purification of Baikal waters.

Chemical and sanitary-bacteriological evaluation of deep waters of Lake Baikal during all the seasons of observation shows that the water quality is regarded as pure and very pure. According to existing standards, it may be used as drinking water without appropriate treatment.

Session 4

Natural water pollution, the issues of water sewage and treatment

Drinking water supply in Altai Krai and practical steps in supply of population with quality standard water

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Despite some problems, a number of measures on the reformation, modernization and reconstruction of housing objects were taken in Altai Krai in 2006. A considerable body of work on the capital and current repair of water supply and drainage objects was performed owing to the budgetary funds obtained from the authorities and enterprises.

In Altai Krai 1141 settlements have the centralized water supply. Basically water supply is carried out due to underground sources as well as from Alei and Ob rivers. The annual water supply of population makes up more than 182.9 mln. m^3.

Because of the dilapidation of most of water supply constructions the accident rate is rather high that results in the increase of non-productive water loss and a lot of appeals from the population about the service quality.

The introduction of modern economical technologies as well as the capital renewals in water supply and drainage systems is of strategic importance for the enterprises.

In 2006, the complex perfection of operation of water-supply constructions aimed at the improving of the services given and at the saving of material and financial resources and energy was carried out.

The reconstruction of filter No.3 at the old water supply point and No. 7, 5, 1 at the new one including the introduction of air-water flushing and the use of the “burnt rock” filter was implemented in Barnaul city.

Because of the need for optimization of the operation of the pumping plants the new pumping equipment was installed.

The variable-frequency electric drives were placed at the 1st and 8th artesian water supply points; this made it possible to save the energy that accounts 35% of the general costs of the enterprise.

The implementation of high-pressure fluid cleaner HD 19/180 allowed the improvement of pipe cleaning and the reduction of time for work performance.

The following new equipment was put into operation:

- the correlation leak detector "Enigma" which allows the precision detection of the fault point in the pressure pipes;
- the route detector "Metrotech" which makes it possible to determine the site and depth of occurrence of underground pipeline 150 m long without earth works;

- the pressure recorder "PraimLog" (4 devices) which makes the round-the-clock reading of the real pressure in the pipe possible (the measuring interval is 5 min.).

In Rubtsovsk town the operating costs were reduced considerably due to the introduction of technological innovations. The optimal scheme of the use of the pumping equipment for the filling of the emergency source of water supply, Skluikhinsk reservoir, was implemented giving the saving of 1.13 mln. rbl. The automatic system for power saving that allows to save 3.6 mln. rbl. has been put into operation.

The works on the replacement of the drainage filters by the polymer system were carried out. It made it possible to increase the capacity of the treatment plant by 20% and to supply the population with 62 th. m^3 of water per day instead of 50 th. m^3.

Due to the application of the new accounting systems and technological innovations the cost reduction by 14.4 mln. rbl. is expected.

To provide the perfect water supply in Biisk town a number of works was performed at water pipes. More than 12.5 mln. rbl. of the internal funds of enterprises were spent for reconstruction and capital and running repair. The filter medium was replaced in 4 filters at the deironing station of the local water supply point.

In 2006, the work on the improvement of water supply in Slavgorod town was well-directed. All in all, about 6 mln. rbl. were invested to improve the operation of water supply objects.

The reconstruction of the water supply point and the construction of the station of the 2nd, two reservoirs of drinking water of 500 m^3 each and the distributing networks was performed (total 3.3 mln. rbl.).

The “Chern” units for neutralization of drinking at two water supply points in different parts of the town water were purchased and installed.

The issues of water supply points’ modernization and the reconstruction of water-supply in Aleisk, Belokurikha, Novoaltaisk and Yarovoye towns are resolved in an organized way.

In Aleisk town the production of water-pumps and reinforced concrete slabs to cover the network and technological wells was serialized.

In Zarinsk town 1.6 mln. rbl. were invested to provide the perfect operation of waterworks that resulted in the considerable improvement of water supply of a number of districts.

Owing to the planned character of works carried out at the water supply objects the drinking water conforms to the accepted standards.

Last year 38 thousand water meters were installed in Altai Krai.

A lot of issues regarding the active group water pipes do call for resolution.

The enterprise “Altai Agency of Water Networks” (the Charysh group water pipe) has more than 1 000 km of water-supply networks at its disposal. The water quality meets all the sanitary and hygiene standards, and it supplies 6 regions and Aleisk town. However, no development of distributing networks as well as the reconstruction of the active ones and their protection from electrochemical corrosion has been noted recently. The Rubtsovsk and Blagoveshchensk water pipes are a special case because they are unfinished, and the functioning conduits lack the cathode protection and work at full stretch.

The capacity of group pipe lines allows the water supply of several settlements even without development. Nevertheless, we construct new single wells distinguished by the lack of water and develop the networks in another direction instead of the settlements' connection to the group water supply systems.

To solve the problems of equipment deterioration, the introduction of resource-saving technologies, efficient and rational management of enterprises providing the housing and communal services the Resolution "On approval of regional target program "Modernization of Housing and Communal Complex in Altai Krai for 2007-2010" was adopted.

The program envisages the common technical policy in providing high-quality housing and communal services including the replacement of manufacturing equipment by the perfect one and the liquidation of the key assets deterioration.

To improve water quality the target program "Supply of Altai Krai with drinking water for 2007-2010" is being elaborated. The program envisages the measures on the supply of settlements with quality standard water, the installation of local systems for water treatment, modernization of water wells, water towers and water-supply networks.

The key objectives of the program implementation are as follows:

- the increase in release of standard quality water via the construction of local systems for water treatment of 636 th. m3 capacity;
- the provision of 275 settlements with standard quality drinking water;
- the 5.6 % reduction of water-supply networks and constructions' deterioration through the reconstruction and the construction of the new ones;
- the provision of extra 220 th. people with standard quality water.
- The 4-year goals are the following:
- the development and installation of 79 modular package units for the source water treatment at water sources and the points of drinking water distribution;
- the replacement and repair of 67 water towers;
- the repair and drilling of 156 wells;
- the construction and reconstruction of 568 km long water-supply networks;
- the exploration of drinking water in 14 settlements;
- the purchase of 39 units of specialized transport for drinking water transportation to 14 settlements.

The program will be implemented by stages during 2007-2010.

The first stage (2007) includes the development, construction and reconstruction of water-supply systems as well as the exploration of underground water for drinking consumption. The funds in the amount of 130 mln. rbl. from the Krai budget will be allocated.

The second stage (2008) assumes the development and installation of the systems for local water treatment in the settlements distinguished by acute deficit of drinking water, continuation of the construction and reconstruction of water-supply systems, exploration of underground drinking water. The investment will make up 279 mln. rubles.

The third stage (2009-2010) calls for the development of the explored reserves of the underground drinking water, the development and construction of new water supply points and treatment plants, the equipment of the points of water treatment and distribution, the delivery of water to the population by specialized transport, drilling of wells, replacement of networks and water towers, and the continuation of exploration of underground drinking water.

It is expected to invest 805 mln. rubles.

In 2007 the reconstruction of water supply networks will take place in 3 towns and 24 settlements. The total investment will make up 271.2 mln.rbl. including 130 mln.rbl. from the Krai budget.

Besides, the regional target program “Development of mineral-raw material base in Altai Krai” envisages the survey of underground drinking water in 5 settlements and Barnaul city as well. The amount of financing from the Krai budget is 9.8 mln, rubles.

The second stage of the program implementation assumes the following activity in 146 settlements and 4 towns:

- the project work in 71 rural settlements with total investment of 13.4 mln. rbl.;
- the installation of 5 water treatment stations at water supply points – 4 mln. rbl.;
- the equipment of points of pure drinking water distribution in 24 rural settlements – 176 mln. rbl.
- the well repair work in 31 settlements – 4.65 mln. rbl.;
- the drilling of new wells in 48 settlements – 16.5 mln. rbl.;
- the repair of water towers in 14 settlements – 2.8 mln. rbl.;
- the replacement of water towers in 21 settlements – 13.1 mln. rbl.;
- the replacement of the out of repair water pipes with the polymer ones – 115.3 mln. rbl.;
- the construction of water supply systems of polymer pipes in 18 rural settlements and 4 towns – 222.3 mln. rbl.;
- the survey in 10 rural settlements and Barnaul city – 13.8 mln. rbl.;
- the provision of 14 rural settlements with the specialized transport – 6 mln. rbl.

The total investment is expected to be 487.0 mln. rbl. including 2719.5 mln. rbl. from the Krai budget.

The third stage of the program realization will involve the works to be carried out according to the proposals of the local authorities and the works carried out at the first and second stages of the program implementation. The total financing of the program will make up 1346.3 mln. rbl. including 805.5 mln. rbl. from the Krai budget.

However, in spite of the notable improvements in water supply of population, a number of problems still call for the solution. These are the following:

- insufficient financing of project work;
- slow modernization of water supply objects;
- limited financing of the objects of housing and communal services.

The study of soil water moisture retrieval using remote sensing method

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Deficit of water is a key problem in a semi-arid area of the northwest China. This article mainly deals with studies of different levels of degraded Vegetation. Aiming at the topic of regional water deficit, the soil water moisture retrieval method for remote sensing data preprocessing, and improvement of regional water deficit monitoring using remote sensing was developed.

This research has introduced a vegetation water synthetical index (VTWSI) using parameters extracted from remote sensing data vegetation index, normalized difference water index and vegetation component temperature that can be used to inverse vegetation water content using remote sensing monitoring of evapotranspiration at sub-pixel level combined with the field measurement and meteorological data. Taking into account the relation between leaf area index and vegetation geometrical roughness, a leaf area index is introduced to compute the vegetation geometrical roughness so that the algorithm computing the sensible heat flux can be improved. The surface water deficit index (SWDD) is extracted using actual and potential evapotranspiration to study the regional water deficit condition. The regional soil water content is then assessed.

More attention has been paid to the vegetation water content in monitoring regional water deficit and ravages of drought, but it is not enough to concern only vegetation water content. Thus, this article presents the remote sensing quantitative formula of regional water deficit using genetic plan based on surface water deficit index, surface soil water content and vegetation water content. The result shows that the quantitative formula is ideal in comparison of modeled and true values. For vegetation area, the quantitative formula considers not only the soil water but also the vegetation water. It can be used to study surface water deficit, and to improve the method of regional water deficit monitoring using remote sensing.

Parameters, such as land surface temperature, vegetation/soil component temperatures, albedo, leaf area index and vegetation coverage etc., are inversed quantitatively using MODIS data as the input of the model. To meet the need of dual-layer evapotranspiration model, this study adopts genetic algorithm to inverse component temperatures using two infrared bands of MODIS data, which can provide more accurate parameters for land surface energy balance and evapotranspiration study. The main physical bases and assumptions of these models are also discussed in this paper. Finally, we will discuss the application of these models for crop monitoring and water management, present potentialities and limits and future remote sensing tools.

Application of innovation water treatment technologies for natural resources conservation

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Steady development of any territory is impossible without its strategic potential, i.e. water resources. In West Siberia, surface waters entering mostly from Ob river and its tributaries-play a leading role in the maintenance of the national economy. However, Ob water quality varies from "slightly polluted" up to "extremely polluted" nearby large industrial centers or oil fields that threatens to as the population health, as the steady development of West Siberia.

The Ob is polluted by oil products and phenols, nitrogen substances, compounds of copper, iron, zinc and chrome. Often, manifold excess of maximum permissible concentrations on various compounds (including heavy metals discharged by enterprises with sewage) is observed.

Currently, about fifty legal points of sewage discharge do exist in Altai Krai; as this takes place, 60 % of sewage discharged into the Ob fall on the effluents treated to standard quality, 11 % are poorly ones, 27 % doesn’t require any treatment, while approximately 2 % of the sewage are not subjected to treatment at all (Fig. 1). The majority of sewage is discharged by industrial enterprises.

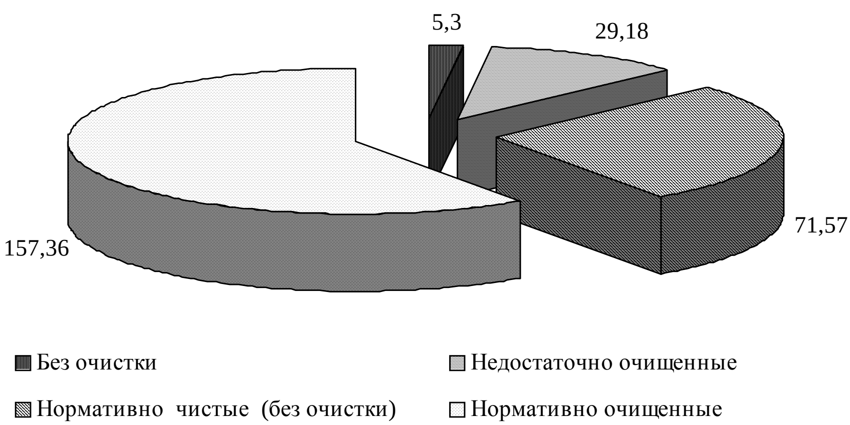

Fig. 1. Structure of water sewage in Altai Krai for 2005, mln. m^3

To solve the problem of water pollution, the development and introduction of alternative ecologically safe technological processes and production based on water and reagents reuse are required. Current operating sewage systems carry out collection, transportation, and appropriate water treatment. Undoubtedly, sewage treatment should be efficient, i.e. the residual pollutant concentrations must not exceed the maximum permissible concentration (MPC) that in its turn inevitably calls for large capital and operating costs. Development of the systems of recycling water supply and consecutive water use gives 20-25 times reduction in water consumption and sewage volume, thus bringing down costs of water preparation as well.

Expenses for the closed manufacture construction depend mostly on the production techniques used and the efficiency of local treatment.

The effluents from enterprises of black and nonferrous metallurgy, chemical and galvanic industry containing heavy metal ions, oil products and suspended substances cause the most hazardous for reservoirs water contamination. Even small in volume discharges of these extremely toxic waters constitute a serious ecological menace to water objects.

At present, concentrations of some heavy metals in many rivers of Russia essentially exceed the natural background. More that 20 th. t. of iron and zinc, 0.2 th. t. of copper and other metals are discharged annually.

Oil pollution destroys natural biochemical processes and brings to oxygen depletion needed for oxidation of organic substances. The rate of oil products accumulation as a result of industrial impact is much higher than the natural biodegradation one.

Suspensions are one of major pollutants of industrial sewage and surface waters. They worsen not only the water quality, but also adversely affect on stream movement, pipelines material state, the operation of the hydraulic equipment and lock valves.

Despite of a variety of techniques for sewage treatment (from heavy metal ions, suspensions and oil products) many enterprises face the challenge of the up-to-date equipment availability.

It is well-known that the most widespread and efficient water treatment methods are the sorption ones, because they are easy to operate and maintain, highly effective and easily automated. However, often high costs of sorption materials and the equipment setup make enterprises not to consider all these advantages.

The transition from traditional to innovation water treatment technologies can greatly reduce treatment costs and shorten the pay-off period of the equipment, and may serve as a solution of the problems mentioned above.

For example, as for adsorption equipment, one of the perspective approaches is based on the application of spatially set devices with regular packing planar sorption materials (so-called " active filters "). Such materials allow us to achieve higher efficiency of sewage treatment as compared with the traditional ones and, what is more important, to save energy and cut materials consumption. Besides, sometimes complex technologies are much more efficient and don’t require toxic reagents application.

The optimal placement of adsorbing material prevents from reduction of diffuse and thermal resistance of a working layer and mechanical energy losses caused by hydro-and aerodynamic resistance at adsorption and regeneration.

Active filters, activated by chemical reagents (by adsorption or catalitically), are distinguished by high compactness and low material consumption.

Granulated adsorbents are working elements of the majority of industrial devices. To create extremely efficient adsorber, the development of new adsorbents with filtration, granule-metric and structural properties are required.

The integrated systems assume the concurrent use of several types of adsorbents (granulated, planar, fiber) for absorption of various chemical toxic substances (e.g., hydrophilic and hydrophobic).

The use of composite materials made of natural mineral has good prospects.

For example, bentonitic clays of high ion – exchange and sorption properties may be such a sorbate. The basic component of bentonite is a complex mineral montmorillonite, able to exchange ions in the solution and crystal lattice.

The purpose of our research is to develop water treatment technology using the new filter-sorption and composite materials. We study the possibility to apply the mineral basalt fibres both in pure state and combined with bentonitic clay for water treatment from various pollutants (oil products, iron (III), suspended matters, and ions of heavy metals). As a result of physical modeling of filtration process a crucially new way of water treatment consisting in water passing through the layer of the free-distributed mineral cotton was proposed.

The results of research carried out with the model solutions let us propose the above-given method as the one for water treatment from the pollutants mentioned. The experimental evidence supports the high treatment efficiency, i.e. it is 95-100 % for iron (III) ions, 98-100 % for suspended matters, and 80-90 % for oil products.

To treat the sewage containing the ions of heavy metals the application of composite material, namely, the basalt fibre with bentonitic clay is under study. It showed itself to good advantage under water treatment from lead, zinc and chrome (VI) ions; this makes it rather promising to be used as the ion-exchange material with internal frame of mineral fibre.

New composite material technology includes the specific processing of basalt fibre with bentonitic clay suspension. As a result, new material based on basalt basis was obtained (“Bentosorb”).

The application of the technology of basalt fibre matrix modification enlarges significantly the available sorption bentonitic surface and improves the reinforcement and broaching of all its components that creates the uniform structure with highly-developed and catalyst-active surface.

To study the dynamic exchange capacity of «Bentosorb» by ion Cr6 + a number of laboratory experiments using the activated bentonite (bentonite and basalt fibre are in the ratio 1:3) was carried out. The sorption-ion-changing material obtained was loaded into the filtering module with 6 cm thick layer. The model solution of 0.5; 2.5; and 5 mg/l concentrations was allowed to pass through the column at the rate of 1 m/h. The samples were taken in every 2 litres of the model solution passed; as this took place, the filtration time (τ) was recorded and the concentration of metals’ ions (C) was estimated by photocolorimetry with diphenylcarbazide.

Fig. 2 presents the graphic dependence of treatment efficiency on the specific chrome (VI) solution passed at the rate of 1 km/h and different solution concentration.

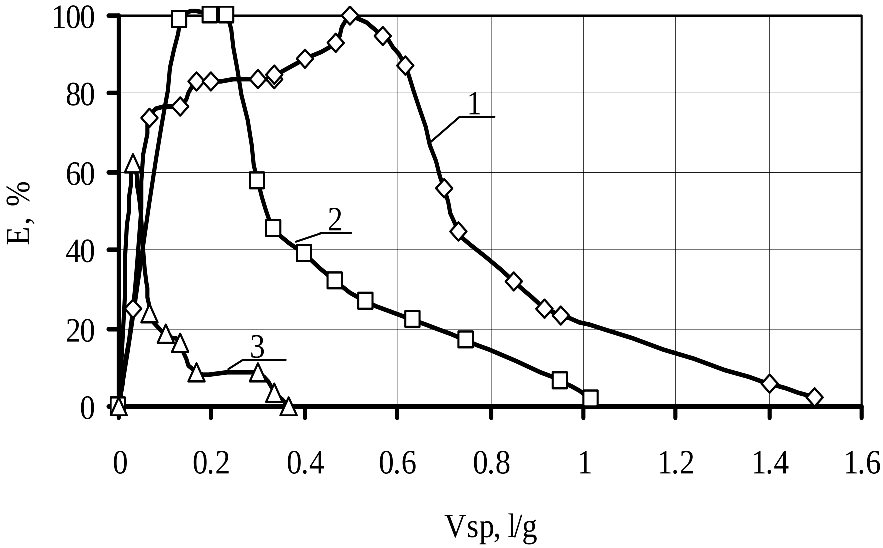

Fig. 2. Dependence of treatment efficiency (E) of chrome-containing water on specific volume of solution (Vsp) using "Bentosorb". Concentration of Cr (VI) in stock solution: 1 – 0.5 mg/l; 2 – 2.5 mg/l; 3 - 5 mg/l

The data obtained show that the highest treatment efficiency (from 80 % up to 99 %) was observed when the initial concentration of the solution was 0.5 mg/l and the volume of the filtered water was in the range from 0.15 to 0.65 liters. At 2.5 mg/l concentration the high efficiency of treatment (99 %) takes place only at small specific volume of the water passed (0.25 l/g), and it does not exceed 62 % at the initial 5 mg/l concentration.

To conduct the experiments on the simultaneous treatment of lead- and chrome-containing waste waters in dynamic conditions the sorption-ion-changing material "Bentosorb" was put into the column with diameter of 30 mm and 1.5 cm thick layer. The model solution with 2 mg/l chrome (VI) concentration and 2 mg/l lead concentration was allowed to pass through the column at the rate of 2 km/h. The sampling was carried out in every 0.5 litres of the filtered water. The results of the experiments are given in Fig. 3.

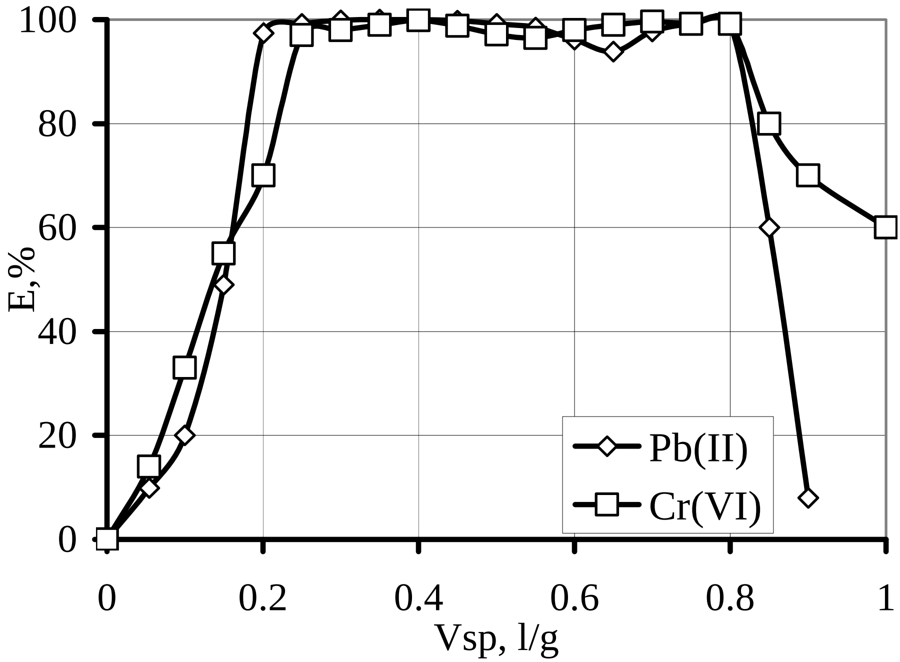

Fig. 3. Dependence of the efficiency (E) of water treatment from Pb2 + and Cr6 + ions with «Bentosorb» on the solution volume (Vsp)

As Fig. 3 suggests, the efficiency of water treatment from Pb2 + and Cr6 + ions in the range of the filtered water between 0.2 and 0.8 litres is as high as 97-99 %. Furthermore, the efficiency decreases since the dynamic capacity of a sorbent is likely to be reached.

The sorbents obtained can be referred to nanomaterials as the length of montmorillonite clasters sorbed on the basalt fibre is 1.4 nanometers. During the hydration in water the extended surface of colloidal bentonite particles is achieved due to their small diameter that varies from several microns to tens of angstroms. Because of such dispersion the mineral is characterized by large exchange capacity - 100 mg·equivalent/100 g of dry mineral and more.

The studies carried out let us to draw the conclusion regarding the prospects of application of new sorbents for treatment of water discharged from the iron, nonferrous, chemical and plating plants.

High sorbtion capacity and catalyst-active surface of basalt fibres modified by bentonitic clays allow their use as filters in the devices for sewage treatment.

High treatment efficiency and low cost of the material obtained will promote its introduction at different enterprises.

Thus, the application of new materials providing high treatment efficiency and low cost promote the reduction in the high-toxic substances discharge and the improvement of water resources environment.

Session 5

Water management in Central Asia and the Caucasus

Bridging water research, innovation and management: enhancing global water management capacity

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Abstract. The present water crisis has many components: excessive and inadequate use, contamination and increasing demand. To cope with these problems there is an increasing need for better management, based in research and innovation. In order to bridge water research, innovation and management in all continents a global water network, based on the Science Academies of the world and on International Training Centers, is being proposed by IAP. This network will develop a programme focused on research and capacity building for water management, thus contributing to the improvement of management practices, promoting integrated and predictive approaches, with optimization of multiple uses of water. This initiative will have an ecological, economical and social impact.

Keywords: Water Management; Water Research; Innovation; Capacity Building; Integrated Water Resources Management; Water Crisis

1. Introduction and background

At the beginning of the XXI Century there is a water crisis, which is a consequence of a long history of excessive and inadequate use, pollution and contamination, and increasing demand. There are several demands and multiple uses of water, with growing withdrawals of surface and ground water reserves. The increasing urbanization produced a rising demand for freshwater in very large quantities. In the next 20 years the rate of urbanization will continue to grow. By the year 2025, there will be 30 mega-cities with more than 8 million inhabitants and 500 cities of 1 million inhabitants. To supply clean and adequate water to these cities is a scientific, technological and managerial challenge.

Water in the planet exists in the atmosphere, on the earth’s surface and beneath it. However, at any given time, only 0.001% of the planet’s water is located in the atmosphere. The overwhelming majority is placed on both surface and ground water reserves. Hydrologically, wherever precipitation falls, the natural shape of the land gathers the runoff into lakes, streams and rivers constituting the watersheds. Watersheds integrate the surface water run-off of an entire drainage basin and they are vital to human civilizations, playing a critical role as sources of water, food, hydropower, recreational amenities, and transportation routes. Although great quantities of fresh surface water are present in many large watersheds, often extending across one or more international boundaries and providing the largest parcel of the water consumed in the world, the great majority of the earth's liquid fresh water is located beneath the surface.

Ground water has been used by humans since the beginning of civilization, however until less than a century ago, consumption was limited only to near-surface water. With the fast advance in technology, deep ground water is now extracted on a large scale. As a counterpart, in the last decades, especially in arid and semi-arid areas and in big cities around the world, the aquifer over-abstraction is producing rapid lowering of the potenciometric surface and water levels, increasing pumping costs and decreasing yields. Another problem resulting from the ground water over exploitation is an irreversible dewatering and compaction of the sediments resulting in subsidence and other geotechnical problems, as happening in places as Mexico City, Venice and Bangkok.

Multiple uses of both surface and ground water are increasing and many local and regional authorities now consider water as a basic asset for development (Gerick, 1993). On the other hand, degradation of water bodies by human activities may undermine their abilities to provide water ecosystem and economic services, potentially imposing enormous environmental and socio-economic losses.

Although the hydrological cycle makes all kind of water in the planet linked some way, traditionally surface and ground waters have not been viewed or managed as integrated units. The disconnection between policies and practices regarding the two main water compartment stems, in part is due to the failure of professionals (both scientists and managers) in considering them as integrated units, thus disregarding their interdependence. What happens in a watershed can have a profound impact in the aquifers, qualitative and quantitatively. Pollution, for example, is nowadays the most serious human impact on water. An increasing variety of contaminants is finding its way into both surface and ground water supplies, especially in urban and industrialized areas. The chief pollutants, as waste disposal sites, point and non-point sources (as landfills; sewage treatment lagoons; disposal pits; urban runoff and water from agricultural land treated with fertilizers and pesticides) have several sources, contaminating both surface and ground waters. Effective management will depend on a deep understanding of the processes regarding water (e.g., water regime, aquifer recharge, water quality) and catchment issues (e.g., land uses, terrestrial inputs).

The present dichotomy regarding surface and ground water issues can be advantageously treated by an integrated holistic approach, considering that there is a common source of problems (pollution, over-extraction, over-commitment), although subsequently resulting on different processes (eutrophication, contamination) and symptoms (excessive production, toxicity, salinization). Sustainable management on surface and ground water resources will not be possible unless scientists can bridge professional and cultural gaps, getting the best possible understanding and knowledge into the hands of managers.

The IAP Water Programme raises a new paradigm, proposing that water - both at and beneath the earth surface - can be treated as an integrated unit. Hydrogeologists, limnologists, engineers and ecologists, among others, need to work together, upon cross-sectorial and regional approaches to management, in order to optimize investments (both human and money resources) that will be essential if water is to continue playing its critical role in the natural functioning of the Earth, providing ecological, hydrological and economic services to humankind. Innovative approaches at both the research, management and capacity building levels are needed in order to accomplish the Millennium Goals proposals.

2. Water resources and development

Water of good quality is the basis for economic development and growth in the quality of life. Development also brings as a consequence increasing pressure from the multiple uses of water. Therefore it is necessary an adequate scientific and managerial approach to deal with this problem. Costs of water supply and water treatment will increase with development, therefore it is necessary to educate people in good practices, provide

cheaper techniques for water treatment and promote conservation of clean natural sources of water. Irrigation will play an important role in this XXI Century and the control of quality of irrigated water will be a basic need for many countries and regions.

Industrial development needs water and to promote industrial growth, incentives for saving water and treating effluents are necessary. Management instruments such as the implementation of legal and institutional framework are necessary to protect water supplies and to regulate its use (Meybeck et al, 1990).

The medium-size cities of several countries in the world (towns of 50.000 to 200.000 inhabitants) are now facing a water crisis due to contamination of the supply sources and the discharge of untreated sewage downstream. This is also aggravated due to the disposition of solid waste, which is always located in the watersheds far away from the cities, affecting the water supply of other urban regions downstream (Lee, 1992).

3. Proposal

In order to cope with these problems it is necessary to improve programs of water conservation, water management, wastewater treatment, control of eutrophication and contamination, and to develop a strong international scientific and technical capability based on research, development and innovation. Managerial capacity has to be improved and research & development to enhance management is essential. As development progresses, there is a permanent need to improve and further increase capacity building, including on this process researchers, water resources managers and water technicians. A strong link has to be developed between researchers, technicians and managers in order to improve management programs and to promote an integrated, predictive and ecosystem approach, or in other words, a watershed approach. Agenda 21 is very clear in the need for capacity building, human resources development and innovation.

3.1. International centers for research, development, innovation and capacity building

> *"Many Governments will need to assign a high priority to their capacity-building efforts towards institution-building, legislation and human resources development. National efforts in this regard need to be supported by international, regional and national external support agencies, and by the non-governmental community, including the private sector.* "
>
> **Agenda 21**

As part of the framework for improving the development of human resources and the integration of innovation, research and management, it is necessary to implement centers for development of these activities, which will act as nuclei for development of new technologies, research, capacity building and field facilities for case studies. These are not necessarily new structures, but can be based on existing centers and networks.

These centers will be linked throughout a network that will provide a facility for exchange of programmes, scientific data, research information and training programmes. Centers will emphasize the integrated management of atmospheric, surface and ground waters. These will also stimulate, integrate and catalyze ongoing activities, fostering innovation.

3.2 The need for international centers in water resources management

Capacity building facilities for advanced training at the specialist level, integrated to a network of institutions, are scarce in many regions of the world, although they are extremely necessary. Several programs for training at MSc and Ph.D. level emphasize local problems, but it is necessary to expand the scope of these programs and place them into the context of a larger reality, considered from a comparative perspective. An International Center in Water Resources Management will provide a forum for permanent discussion, preparation of case studies, and integration of research & management in a global perspective. Besides the regional context, the international centers will have visitors from many countries from industrialized regions, young PhDs. and managers that will interact in a productive and creative atmosphere, stimulated by the international environment and the existing facilities for research, field work, and access to specialized literature. Such a concentrated facility is lacking at present. It is necessary the articulation of researchers, laboratories and libraries to stimulate a programme of high-level teaching and research. Existing local/regional infrastructure for water resources research & management can provide undoubtedly the necessary scholarly and applied atmosphere necessary for productive work.

International centers will have the task to draw attention to the water problems of the world in an integrated approach. They will place together scientists and managers that will address the pressing problems of water supply and, at the same time, produce advanced scientific knowledge. These centers shall stimulate publications and enhance activities for public awareness. They will address managers and scientists in specialized training modules, working in cooperation with local and regional universities. At the same time, such centers will be cooperating with other international centers worldwide, securing thus a network of high quality, which will stimulate advanced scientific research of top quality. This programme will accelerate the development of partnerships between public and private institutions, integrating water resources development & management (Tundisi and Straskraba, 1995).

4. Objectives of an International Center

- To develop a focus on innovation, research & development and capacity building in water resources and related issues, control, management and treatment of water, including technologies for watershed (surface and groundwater) management and remediation and recovery.

- To promote and maintain a permanent advanced training activity in water resources management in order to improve regional standards of training and enhance the preparation of qualified human resources in these fields of expertise. This advanced capacity building programme will have a strong scientific and technological basis.

- To establish a network of collaborating institutions in the world, in order to utilize the best existing capacity and to provide the best quality training based research on development & innovation for scientists, managers and technicians. This network will also be extremely useful and fundamental for exchange of scientists, managers and decision makers.

- To develop new approaches, mechanisms and techniques of capacity building, at technical and scientific levels, integrating research approaches and innovation in water resources.

- To prepare researchers, technicians and water resources managers with the best qualifications in order to meet the growing demands for human resources in scientific research and water resources management.

- To provide opportunity for a permanent exchange of qualified personal.

It is clear that each International Center will add more activities and emphasize regional/local priorities to this focus. Training programmes will have emphasis on comparative studies, fieldwork, practical lectures, intensive use of field facilities and demonstration of water management problems. Training modules will be designed in order to promote an integration of science with management, providing the trainees with the best technological and scientific tools to develop research and management.

Staff will be recruited in the local expertise and a number of invited visiting scientists will be incorporated at each training activity. This will enhance the quality of the programme and will stimulate the development of joint research projects, with a network of professionals, training fellows and institutions.

5. Focus of the international centers: research and development in water management

In order to provide a solid scientific and technological background for the international centers, it is necessary to provide a focus on research and innovation development. This focus will enhance the performance and the role of the centers and will promote the necessary systemic approach to the problem of research and water management. The systemic approach will enhance the watershed as a unit of research and management and can address problems of water quantity and quality, integrating atmospheric, surface and ground waters at several spatial and time scales.

6. Examples

The prevention of eutrophication and the restoration of eutrophic lakes and aquifer contamination by nutrients require proper planning and management of associated watersheds. Therefore, sound management strategies require an understanding of the relationship between nutrient sources and degrees of contamination.

The watershed - a physical unit with a hydrologically integrated ecosystem - has been adopted as a unit for integrating research & monitoring and for managing and administering water resources. Integrated management should be adaptive, producing new ideas and tools, and can only be achieved with local participation and political and managerial support. Education at all levels plays a fundamental role.

> *"Enhance national water resource assessment capabilities and measurement networks and establish water resource information systems that enable people to understand the options available for sustainable urban, industrial, domestic and agricultural development in combination with environmental conservation. "*
>
> **Agenda 21**

7. Developments in 2006

During 2006 the IAP Water Programme organized four regional workshops: Brazil (Americas), Poland (Europe), China (East Asia & Pacific) and South Africa (Africa). Another workshop was organized in 2007 in Jordan (Middle East &¨South Asia) These were a venue for discussion of local and regional priorities and helped in the planning of the future steps for the programme. The workshop in Altai (Central Asia) is the last of a set of six regional workshops, organized to launch the IAP Water Programme globally.

In the near future, the programme propose the organization of capacity building courses that will have emphasis on local/ regional problems, providing managers with capabilities to face challenges such as:

new technologies for water treatment (at lower costs); new technologies for conservation of water sources; integration of multiple uses in management; inclusion of predictive mechanisms in management; inclusion of the management at the watershed level; implementation of new and participative mechanisms for the administration and governance of the watersheds; groundwater management: new technologies and approaches; advances in the monitoring and evaluation of surface and ground waters; use of remote sensing for watershed management; use of geographical information systems for watershed management, among others.

A meeting in Trieste was carried out in May 2007, with the participation of the Academies that have hosted the regional workshops, in order to appraise the accomplishments and to discuss the next steps, aggregating new ideas to the project. An international symposium on “Bridging Water Research, Innovation and Management: Enhancing Global Water Management Capacity” is also being planned for the second semester of 2007.

Fig. 1. International Centers and Focal Points for integrating a network of research and capacity building for managers

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CENTRAL ASIA: THE PROBLEM OF COOPERATION IN THE FIELD OF WATER AND MINERAL ENERGY RESOURCES USE

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Abstract. Central Asia is full of rich natural resources that, when used effectively and efficiently, could be a basis for stable development of the national economies and considerable improvement of well-being of the people inhabiting the region. However, these natural potentials, namely waters and mineral energy resources, have become subjects of the longstanding confrontation between water-dependent Kazakhstan and Uzbekistan and their energy-poor neighbours, Kyrgyzstan and Tajikistan. One-sided perceptions of political and economic realities, expressed in increase of export prices for energy resources to practically market levels and unwillingness to revise the outdated Soviet principles of water allocation, prevent the Central Asian countries from reaching a compromise settlement acceptable for all parties involved. The last 15 years of independence have demonstrated that a solution of the existing disputes seems to be unlikely without (i) new regional water and energy strategy, (ii) sharing operation and maintenance costs associated with the Toktogul facilities and (iii) introduction of the developed compensation schemes.

Keywords: Central Asia; transboundary waters; mineral energy resources; regional water and energy strategy; sharing O&M costs associated with the Toktogul facilities

In terms of natural resources availability, Central Asia has an adequate potential for stable economic development and growth. Indeed, the region is known worldwide for its rich deposits of carbon-containing mineral resources and considerable reserves of freshwater. For instance, about 4.4 % of world proved gas reserves and 7.7 % of world oil and coal deposits are located within its territory (World Resources Institute, 2005). Freshwater reserves of Kyrgyzstan alone make up 43 % of reserves of the Eurasian continent (Information Portal …, 2007), and the country's hydropotential is estimated to be 245 bln. kWh (Mamatkanov D. et al., 2006). If hydropower capabilities of another mountain country, namely Tajikistan, are taken into account, then the cumulative potential of the entire region will increase by more than two times.

In spite of such a generous gift of nature, statistics and information provided by international financial institutions indicate that all Central Asian countries are amongst either lower-middle income or low-income economies of the developing world (World Bank, 2005). Thus, for example, GNI per capita in Kazakhstan and Turkmenistan fluctuates within a range of \$ 876 – \$ 3.465; these two countries are considered lower-middle income economies. Kyrgyzstan, Tajikistan and Uzbekistan in turn belong to developing countries with low-income levels coming to $ 875 or even less. Other socio-economic indicators, including ratios of external debt to gross national income, poverty rates and life expectancy levels, do not impress and warn of generally alarming situation (World Bank, 2006). So what are those obstacles that prevent the countries, intertwined by geography and the historical past, from using natural potentials to change the actual state of affairs for the better?

Recent analytical reports mention non-constructive competition and unwillingness to consider interests and needs of each other as the main reasons of such deplorable situation in the region. Of course, it would be an exaggeration to maintain that a notion of “cooperation” is totally extrinsic to the interstate interactions. The growing positive dynamics between countries-exporters of the Central Asian energy resources could be an example of cooperative spirits and attitudes: Kazakhstan, Turkmenistan and Uzbekistan, with the direct involvement of Russia, conduct active consultations on establishment of a new energy alliance. Unfortunately, when it comes to the Central Asian waters, such unanimity and desire to work together can be hardly observed. The absence of a viable regional water and energy strategy, which could replace outdated approaches to water resources use, development and management, is a representative example of non-cooperative moods amongst the neighbours.

Defects of approaches of the Soviet period and their incompatibility with new political and economic realities have been repeatedly mentioned during signing of different interstate agreements, including the 1992 Almaty Water Treaty. The signatories of this Treaty agreed to adhere to the previous principles of water allocation until new regional and national strategies were developed. Such step was made to maintain stability within Central Asia and the signed Treaty, provisional by its nature, should become a flexible basis for further multilateral cooperation. Unfortunately, the current situation with water and energy resources demonstrates that nothing is more persistent than something temporary. 15 years have already passed but water and energy issues have remained unsettled. Provisions of many documents emphasizing the need for "a general strategy for water allocation and efficient water use" (The Programme of Actions …, 1994) or "economic methods of management in water and energy resource use" (Bishkek Declaration..., 1996) "have remained on paper and have never been put into practice in full measure" (Shalpykova, 2002).

As was the case during the Soviet Union, the upstream riparians of the Aral sea basin, namely Kyrgyzstan and Tajikistan, continue to supply 70 % of water resources to downstream neighbours and use less than 20 % for their own needs. As a result, these two countries have the lowest indicators of specific water consumption and specific irrigated areas. In other words, the Soviet principles, aimed at restraining irrigated agriculture in upper reaches of Syr Darya and Amu Darya, are still in force in Central Asia. The information given in Table 1 illustrates the discriminatory nature of the previous decisions and provides quite clear explanations of the existing disagreements between the co-riparians, which are not parts of a single state any more.

Table 1
Specific Water Consumption and Specific Irrigated Area

Country	Specific Water Consumption, m^3 per person	Specific Irrigated Area, ha per person
Upper riparian country		
Kyrgyzstan	1371	0.14
Tajikistan	1841	0.12
Lower riparian country		
Kazakhstan	1943	0.3
Turkmenistan	4044	0.41
Uzbekistan	2596	0.19

Such uneasy situation with the regional natural resources is aggravated by the firm unwillingness of the lower riparian countries to share costs associated with maintenance and operation of water facilities that primarily serve the needs of those, who are downstream. Under such circumstances, upper riparian Kyrgyzstan is forced to spend its budget funds not just for maintenance and operation works, but also for measures related to stable water supply, regulation and monitoring. By doing so, Kyrgyzstan, despite its annual losses estimated at tens of millions of U.S. dollars, continues to supply water. Put differently, the country meets its obligations under the 1992 Water Treaty and subsidizes, voluntary or not, the production of water-consuming crops (cotton and rice) in downstream Uzbekistan and Kazakhstan. The firm unwillingness to revise the outdated principles of water allocation has already led to a situation, where unsolved water and energy issues adversely affect state interactions and become "second only to Islamic extremism" in the interstate agenda (International Crisis Group, 2002).

Undoubtedly, the lower co-riparians are aware of both the importance of the above mentioned problems and the need for their prompt solution to preserve stability and security in the region. They do understand everything but continue to ignore links between water and energy issues. Instead of working together to develop mutually acceptable solutions, some of these countries take steps to get greater water independence (construction of reservoirs) and conduct active PR campaigns about "hydroegoism" and "water trade" to discredit viewpoints of their upstream neighbours.

The situation in the Aral sea basin resembles, in many ways, the current state of affairs in the Blue Nile river basin. For more than 50 years, a lower riparian, Egypt, which has considerable military strength, economic might and authority in the Arab world, has been successful in keeping water preferences inherited from the British rule. As of today, nothing, nor uncoordinated protests by upstream Ethiopia and midstream Sudan, no admonitions by international donors, has been able to change the existing state of affairs. Egypt keeps insisting on provisions of the 1959 Agreement for Full Utilization of the Nile Water, which was signed with the British-controlled Sudan and "did not take into account any claims of the other riparian states [of the White and Blue Nile river basins] … nor … their future needs" (Elhance, A., 1999). Chronic political instability in upstream countries (Rwanda, Kongo, Ethiopia) and the lack of coordination between them act in favour of "aggressive, but highly vulnerable" (Elhance, A., 1999) Egypt.

Hopefully, the Central Asian countries will not need a half of century to realize a non-constructive and dangerous nature of the existing approaches towards issues of natural resources use, development and management. It is obvious that a further lack of good will, neglect of interests of others and shady PR campaigns about "hydroegoism" and "water trade" will push all the co-riparians towards a threshold, behind which there is nothing but poverty, bloodshed and chaos. The Nile river basin could demonstrate possible scenarios for “the ethnically heterogeneous … water-stressed” environment of Central Asia (Chait, E., 1999). It is the right time, after 15 years of independence, to ask a question: When will ALL countries of the region get equal rights to use their own natural resources … not only oil and gas, but also waters? Why are the upstream riparians deprived of a right to say, using words and style of Russian President Putin, "…we have no obligation to provide … subsidies to other countries’ economies … No one else does this, and so why are we expected to do it?" (Transcripts of the Press Conference of President Putin with the Russian and Foreign Media, February 2007).

So what are those possible ways that could help the co-ripariand to settle the existing interstate disagreements? Before answering this question, it is worthwhile to mention once again the most urgent problems that require a constructive approach and immediate actions. As of today, issues of the outdated interstate water allocation developed during the Soviet period, the existing imbalance of state priorities with regard to the Toktogul reservoir and the lack of economic mechanisms are amongst the most salient topics in interstate relations. These problems are solvable, and if all the parties involved are genuinely serious about solving the natural resources disputes for the common good, stability and prosperity of the whole region, it is crucial to:

1. Start joint works on development of a new regional water and energy strategy.
2. Accept principles of cost sharing.
3. Put in force the developed compensatory schemes associated with the Toktogul facilities.

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Cartographic analysis as a tool of environmental monitoring (water objects of the upper Ob basin as a case study)

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It is well-known that natural waters possess the real-energetic and environment-forming properties; one can hardly imagine human life and economy development without this valuable resource. Indeed, water objects are considered as water resources essential in production and other human activities. On the other hand, "water resources" is associated with "water problems" that arise when water objects don't meet the recreation and economic requirements. A variety of problems (e.g. water supply, irrigation, water pollution) are caused by economical activity and just contradictory measures implemented on the water objects and their watersheds. Any complex of nature protection measures developed for any territory puts an emphasis on water resources conservation. The ecological monitoring of water objects is a part of the state environmental monitoring net. Mapping, mostly geoinformation one, is used as a tool for data processing and making spatial analysis. Mapping and GIS allow as to analyze and reflect, as to interpret cartographic data when modeling the ecological state of water objects. The goals and objectives of the water-ecological mapping includes: collection, analysis and representation of data on ecological state of water objects and their watersheds, natural and anthropogenic factors of aquatic systems formation and operation, transformation impact on natural and social-economic systems, activities on protection and liquidation of adverse water-ecological processes.

When creating maps, the primary attention is given to analyzing and mapping of interrelations among water objects features, natural factors, population and economy, while simultaneously developing trends of thematic mapping, such as ecological-hydrological and hydro-ecological ones, are focused on hydrological characteristics of aquatic systems, mapping of the structure and functional regularities, including the interference of biotic and abiotic components, the relation with external natural and anthropogenic factors. River basins and administrative-territorial systems serve as the cartographical units.

Currently, a wide range of the techniques on water-ecological mapping are available. However, there is an urgent need in the development of the methodically coordinated technique for water-ecological mapping at different territorial levels to analyze the influence of natural-anthropogenic factors on surface water quality.

At present, the developed technique allows to make a complex spatial analysis of water-ecological situation at regional and local levels using the geoinformation-cartographic method. To develop the technique, the works by A.V.Vysochenko, N.I. Alekseevsky, N.I.Koronkevich, V.V.Maslennikova, E.P.Ovcharova, V.A.Scornyakov, N.I. Khrisanov, B.A.Novakovsky, A.N. Chumachenko, V.Novotny etc. were used.

The regional water-ecological mapping is aimed at presentation of surface water pollution level using as hydrochemical observation data, as the spatial analysis of factors that determine the surface water quality. The regional mapping is a preparatory stage for local studies that makes it possible to consider not individual sources of pollution, but their interaction and distribution throughout the territory; to reveal ecologically unfavorable areas that in its turn allows to define the local objects to be mapped.

One of the objectives of the local water-ecological mapping is the analysis of a water-ecological situation in the urban territories. It involves mapping of water quality (including surface drinking water), as well as point and non-point sources of pollution; establishment of relations between the surface water quality and the pollutants entry to water objects and their catchments from different sources. The regional mapping involves the construction of a set of mid-scale water – ecological maps with the use of ArcView software. This cartographic method was based on the structural-functional algorithm (Fig. 1) that consists of 5 stages [Vedikhina, 2007]:

I. Selection of territorial operational mapping units

To select the territorial operational mapping units the landscape-ecological and the basin approaches are used. The object of mapping in the landscape-ecological approach is geosystems of different ranks, while in the basin approach- water objects and watersheds of different order. The combination of these approaches makes it possible to define cartographic units, the most acceptable in water-ecological studies. The lacustrine-river systems of the Upper Ob and Ob-Irtysh interfluve situated within the boundaries of Altai Krai serve as the object of regional mapping.

II. Preparation of digital cartographic base

Major physical-geographic and social – economic objects, the sites for monitoring surface water quality, “points” of sewage discharge are displayed on the electronic map that acts as the basis for further thematic mapping.

III. Construction of base “address” maps

The base “address” map is a digital cartographic base with a proper attributive geodata one. Construction of base “address” maps involves 1) collection and processing of source data on surface water quality as well as natural-anthropogenic conditions for water objects pollution formation and attributive geodata tables creation; 2) binding of the electronic base with cartographic one.

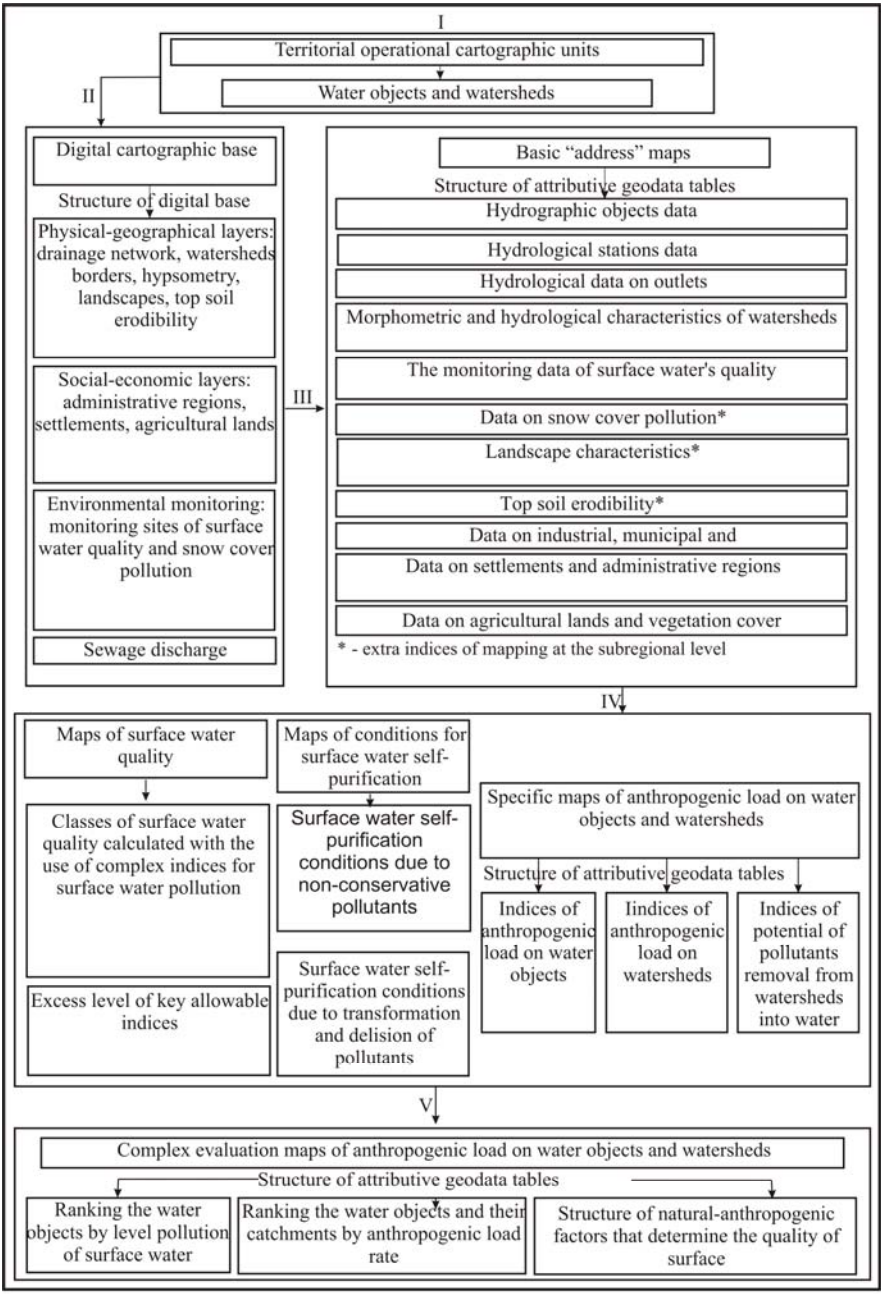

Fig. 1. Structural algorithm for water-ecological mapping.
The major stages of the algorithm for water-ecological mapping: I. selection of territorial operational mapping units; II. preparation of digital cartographic base; III. construction of the base "address" map; IV. construction of specific inventory and estimation maps; V. construction of an integrated estimation map.

IV. Construction of specific inventory and estimation maps

The constructed maps are grouped as follows:

Maps of surface water quality (present the classes of surface water quality using a complex index and MAC excess by some indices).

Maps of water self-purification (reflect the conditions of self-purification due to transformation and dilution of pollutants).

Specific maps of anthropogenic load on water objects and their catchments (include inventory and evaluation layers. The inventory layers represent quantitative analytical indices, while estimation layers- ranking the territory by anthropogenic load on water objects and their catchments as well as potential of pollutants removal from the territory into water objects. To rank the basins by some indices, the cluster analysis with the use of "Statistica" software should be made).

V. Construction of the integrated estimation map

To construct the integrated map, a set of indices that reflect direct and indirect anthropogenic load on surface water, natural conditions for pollutants removal from the territories into water objects and surface water self-purification were used (Table). Due to this set of indices the cluster groups of water objects and their watersheds ranked by anthropogenic load are defined. To assess the level of surface water pollution, the joint spatial analysis of surface water quality maps constructed by the State Environmental Monitoring Net data (SEMN) and the information layer reflecting the anthropogenic load on water objects and their watersheds was performed. Along with the assessment of pollution level, the integrated maps allow to identify key types of pollution sources that is of great importance under planning the water protection activities.

Table

Evaluation indices of anthropogenic load on water objects and their catchments as well as potential of pollutants removal from the territory into water objects

Indices of anthropogenic load on lacustrine-river systems
Sewage dilution coefficient for representative waste water volumes* (industrial and municipal sewage discharges directly effecting on the water objects)
Load indices on watershed due to industrial, municipal and agricultural sewage discharge to a settling tank, fields of filtration and irrigation, storage, unregulated discharge
Industrial sewage discharge (conditional m^3/km^2 of the watershed)
Municipal sewage discharge (conditional m^3/km^2 of the watershed)
Sewage discharge from the cattle breeding farms(conditional m^3/km^2 of the watershed)
Sewage discharge from rural settlements(conditional m^3/km^2 of the watershed)
Agricultural sewage discharge (conditional m^3/km^2 of the watershed)
Indices of agrarian territory transformation and pollutant entry from the atmosphere
Snow cover pollution summary indices **
Specific pest-killers application (introduced to arable lands, t/km^2)
Specific mineral fertilizers application (introduced to arable lands, t/km^2)
Specific organic fertilizers application (introduced to arable lands, t/km^2)

Indices of pollutants removal from a catchment to water objects
Surface run-off unit discharge
River net density **
Landscape situation at the geochemical interfacing rang**
Top-soil erodibility **
Extent of forests (%)

Note:

* Conditional sewage volumes (Sbvu) discharged from different sources are calculated using a formula: *Sbvu = Sbvoch • R*, where: *Sbvoch* – sewage volumes with regard to a treatment *level* ; *R* – reduction coefficient. *Sbvoch = 5 • Sbvbo+Sbvno+0.2 • Sbvuch*, where *Sbvbo, Sbvno, Sbvuch* – annual sewage volumes: crude wastewater, treated insufficiently and conditionally treated waters (including the ones treated in line with standards and norms), correspondingly. Reduction coefficients are calculated depending on the enterprise's risk (according to Sanitary Standards of 2.2.1/2.1.1.1031-01).

** Extra indices of the regional mapping

The integrated map analysis provides the grouping of basins by different anthropogenic load and surface water pollution (Fig. 2)

Rivers Alei, Barnaulka, Kuchuk, a closed drainage area are referred to the group of water objects and their watersheds distinguished by extremely high level of anthropogenic load. Here, the largest industrial, communal and agricultural sources of surface water pollution are situated. The potential of pollutants removal varies from mean - low (by various indices and for different territories) up to high ones. The level of local and background (especially at the increased potential of pollutants removal) transformation of surface water quality is the highest in Altai Krai. The rate of surface water pollution corresponds to IV class (i.e. polluted water).

In contrast, rivers Charysh, Maralikha, Nenya, etc. are referred to the group of water objects and their watersheds with low and extremely low level of anthropogenic load. Note, in spite of favorable natural conditions for geochemical pollutants migration within the system "watershed-river", the load remains minimal by all indices. The level of surface water pollution is the lowest as well (I and II classes of water quality).

Mapping at the local level involves a selection of structural-functional blocks similar to the ones at the regional level. At present, the structure of two blocks of maps have been prepared, i.e. address-inventory and evaluation maps (assessment of surface and drinking water quality). These blocks allow us to make sanitary-hygiene assessment of surface and drinking water quality in certain settlements; as this takes place, major hydrochemical and bacteriological data are used, and main sources of water pollution are mapped.

The address-inventory block includes physical-geographical and social-economic objects; the sites of surface and drinking water quality monitoring; points of surface water intake; sites of industrial sewage discharge; treatment plants; water protection zones.

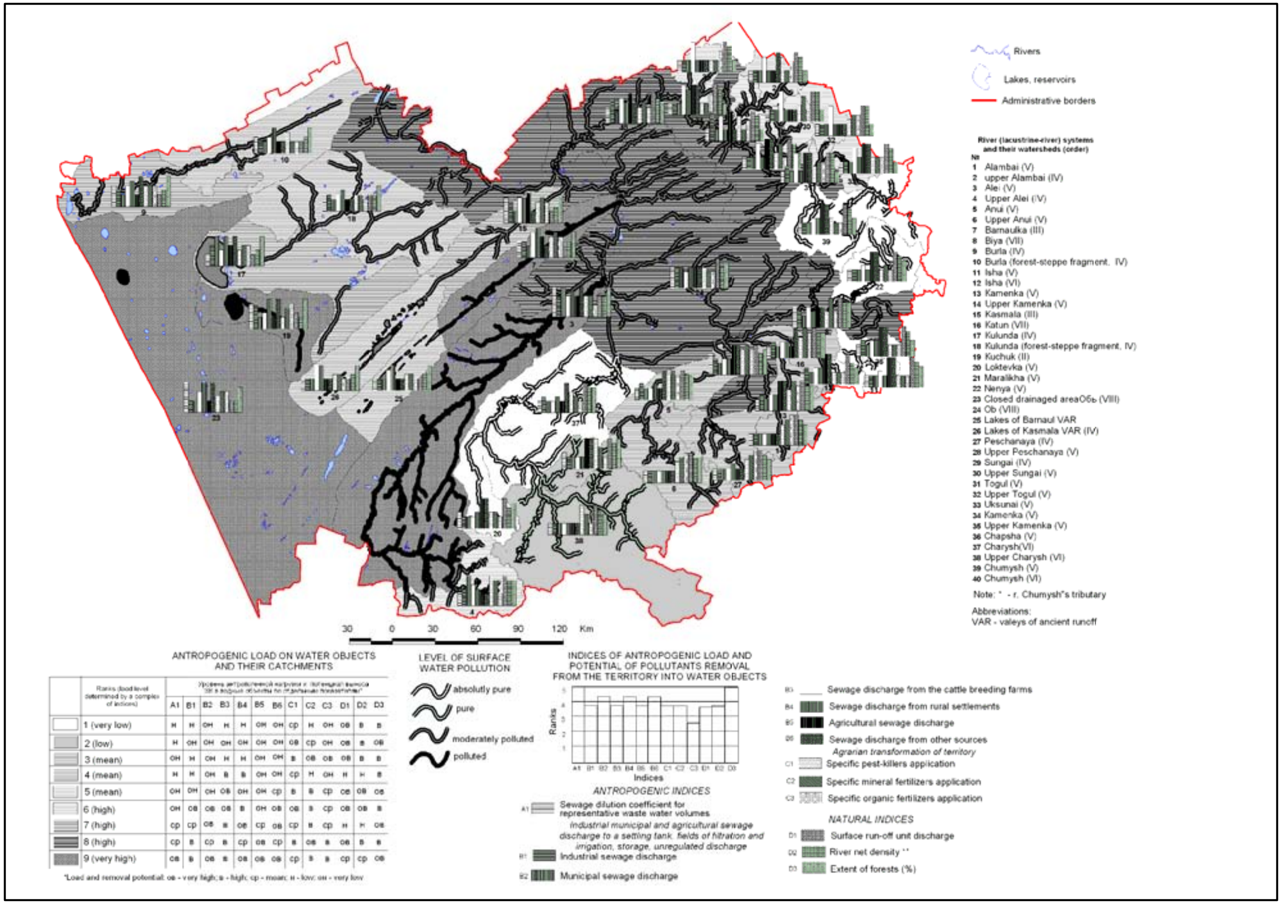

Fig.2. The integrated estimation map

The block of surface and surface drinking water evaluation consists of two layers: the first includes a versatility indicator (complex index) of surface water pollution that was developed in the F.F. Erisman Hygiene Institute [Novikov, 1984], the second one - the specific hydrochemical and bacteriological indices. A versatility indicator is applied for making the hygienic classification of water objects used for domestic and drinking water supply and recreation purposes by 4 criteria (organoleptic, sanitary, sanitary-toxicological, epidemiological) that act as limiting factors.

Based on the complex evaluation, 5 pollution levels for each limiting hazard factor is defined; in addition, social-hygienic recommendations for population how to exploit the reservoir are given.

To avoid superfluous evaluation formalization, multiplication factor for maximum allowable concentrations (MAC) for some hydrochemical and bacteriological indices are used.

The proposed maps were included into the "Maps of pollution level of surface and surface drinking water of Barnaul city" [Vedikhina, 2006] (Fig. 3). ArcView 3.2 software, survey data obtained by Hygiene and Sanitary Center of Altai Krai for the period 2001-2004, 2 -TP Vodkhoz statistical data on industrial discharges for 2000-2003 and the Project on water protection zones establishment in Barnaul city [Project…, 2002] were used for the map construction.

The created maps show that the highest level of pollution is observed in Barnaulka river and its tributaries, i.e. rivers Pivovarka, Vlasikha and a creek Sukhoi Log that is caused by urban surface runoff, storm discharge from refueling stations, parking lots, garage complexes, roads, dumps, sanitary sewage from a private sector. The situation with Ob river is much better; its deterioration (especially bacteriological one) is observed in the place of Barnaulka r. inflow. Along with Barnaulka r., the key polluters are municipal treatment facilities (MTF) which discharge untreated or undertreated sewage water into the Ob.

Thus, non-point pollution is a major contributor to surface water contamination in the vicinity of Barnaul city.

In general, the quality of water entered the water supply net meets the bacteriological standards, though it exceeds residual chlorine and cadmium indices.

The prepared set of mid- and large-scale water-ecological maps may serve as a basis for planning water protection activities to reduce anthropogenic load by some factors (taking into account the territorial combination) and to smooth the impact on surface water. To work out the water protection measures for certain enterprises and diffusion sources of pollution in detail, the application of the large-scale maps is recommended.

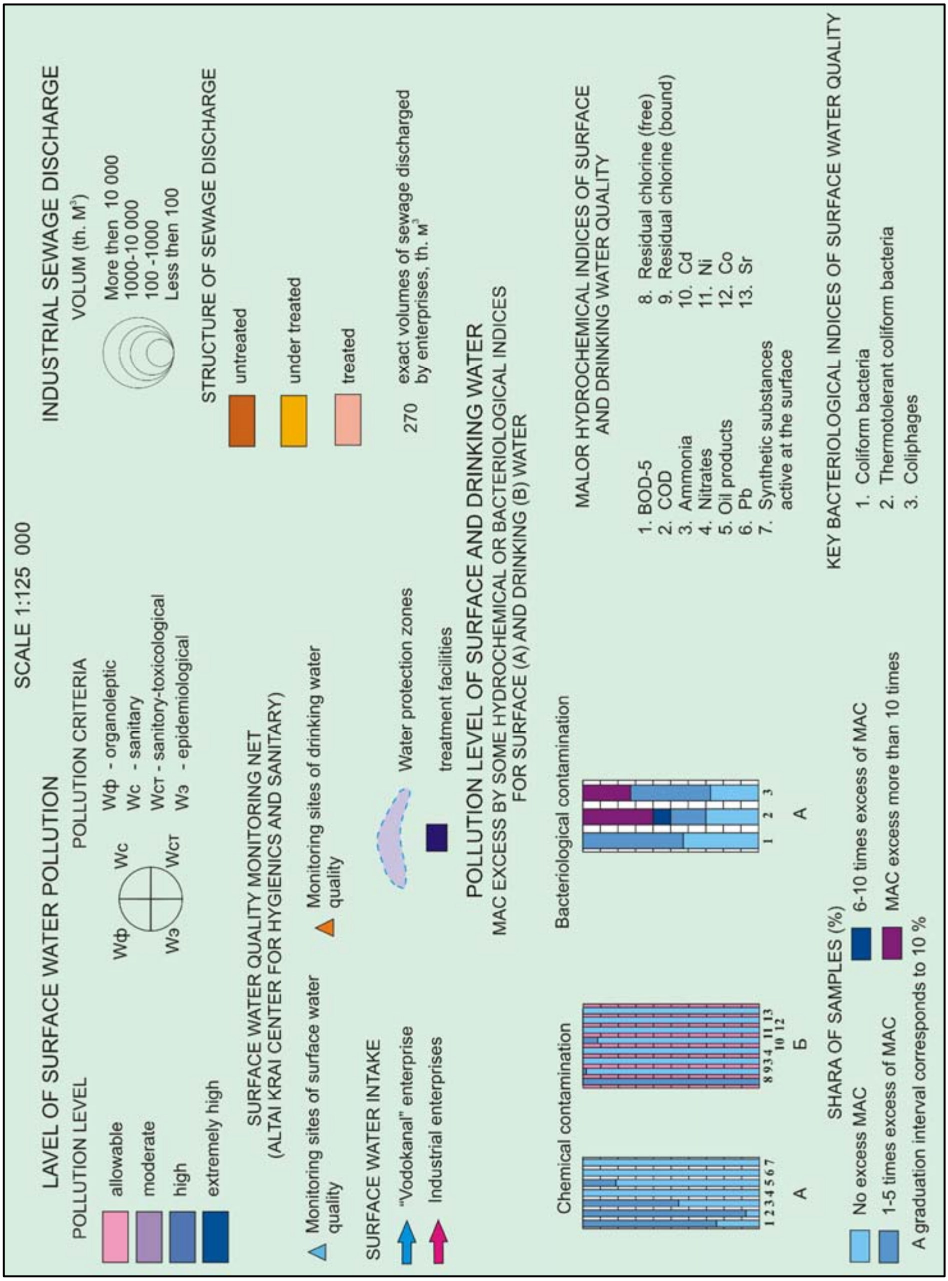

Fig. 3. Maps of pollution level of surface and surface drinking water of Barnaul city" [Vedikhina, 2006]

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Problems of water resources management in the Republic of Kazakhstan, interrelations of hydro power and water industries

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Kazakhstan surface water resources make 100.5 bln. m^3, and only half of them are formed within the territory of the country. Glaciers are the main source of rivers alimentation. By water supply Kazakhstan ranks one of the last amongst CIS countries and specific water supply makes 37 thousand m^3/km^2.

Total installed capacity of Kazakhstan power plants made 18.572 MW in 2006 and used hydropower potential amounted to 2.248 MW or 12 % of total installed capacity. Major hydropower plants (HPPs) in Kazakhstan are the Irtysh HPPs cascade, including:

- Bukhtarma HPP,
- Ust-Kamenogorsk HPP,
- Shulbinsk HPP,
- Kapshagai HPP on the Ili River,
- Shardarinsk HPP on the Syrdarya River.

Water Code of the Republic of Kazakhstan approved in 2003 is the principal legislative document for water resources management in Kazakhstan. Article 33 says that state management of water resources inventory use is carried out by authorized body – the Committee for Water Resources of the Ministry of Agriculture of the Republic of Kazakhstan. Main water consumers are:

- domestic water consumption of settlements and cities,
- industry,
- agriculture and fish industry.

Hydropower and water transport are main water users and are subject to developed regime of utilization of specific water resources stream. However, according to Law on Electric Power Industry, the System Operator, KEGOC (Kazakhstan Electricity Grid Operating Company), “is involved in development of HPPs’ operating regime inclusive of their water-economic balances and operating regime of the Unified Power System of the Republic of Kazakhstan” (Article 10.14), and has a right to operationally amend approved schedules of water consumption via hydro systems employing HPPs’ emergency reserve during blackout elimination.

Considering that substantial proportion of water resources relate to transboundary streams, the water resources management is carried out with due account for rules of the International Water Law.

Water and water-power resources of Kazakhstan are not evenly distributed over its territory, which may be conditionally divided into four regions (Fig. 1).

Eastern Zone – in the basin of the Irtysh River including its main tributaries: Bukhtarma, Uba, Ulba, Kurchum, Kaljir.

Southeast Zone – in the basin of the Ili River fed by the rivers flowing from the Zailissky Alatau Mountains (Kaskelen, Aksai, Turgen, Chilik and Charyn) and in the basin of the eastern Balkhash and the group of Alakol lakes fed by the rivers flowing from the Jungar Alatau Mountains (Koksu-Karatal, Sarkand, Aksu, Lepsy and Tentek).

Southern Zone – in the basins of the Syrdarya, Talass and Chu Rivers.

North, Central and West Kazakhstan – basins of the Nura, Sarysu, Ural, Tobol and Talass Rivers.

Fig. 1.

According to KazGIDRO JSC data – economically feasible hydropower potential makes about 30 bln. kWh, among this 7.5 bln. kWh account for small HPPs with capacity of up to 10 MW and 22.5 bln. kWh – HPPs with capacity over 10 MW. Major part of this potential (about 90 %) is attributable to East-Kazakhstan, Almaty, South-Kazakhstan and Zhambyl Oblasts. However, only 5% of hydro electric resources are used at small HPPs and about 30 % – at medium-sized HPPs.

From power-producing perspective, North-East Kazakhstan is energy surplus region because major heat and hydropower plants are located there, and South Kazakhstan is energy deficit region. The situation became complicated during outage of electricity transmission line of North-South transit, when power supply to Southern Zone of Kazakhstan has to be coordinated with vegetation watering in the basin of the Syrdarya River.

In 1990 Kazakhstan peak consumption amounted to 100.4 bln. kWh and decline in generation and consumption was evidenced until 1999, however during the last years the situation had changed. In 2006, power generation in Kazakhstan amounted to 71.56 bln. kWh, including 7.74 bln. kWh (or 11%) produced by HPPs.

After long time period the construction of Moinak HPP on the Charyn River with capacity of up to 300 MW has been resumed in 2006, construction of Kerboulak HPP on the Ili River with capacity of 49.5 MW and Boulak HPP on the Irtysh River with capacity of 68 MW is in the long view. Construction of smaller HPPs, in particular in southern energy deficit areas of Kazakhstan is a very promising trend in hydropower development. In accordance with Concept of Hydropower Development until 2015 approved by the government of the Republic of Kazakhstan, it is expected that the amount of power generated by HPPs inclusive of the commissioning of new facilities will make 10 bln. kWh in 2010.

Irtysh HPPs cascade is located on the Irtysh River (Fig. 2). This is a transboundary stream, which begins in the territory of China and known as Black Irtysh it flows into Lake Zaissan included now into Bukhtarma Water Reservoir, which is one of the largest reservoirs in the world. The length of reservoir is over 600 km.

he cascade includes Bukhtarma HPP with carry-over storage, Ust-Kamenogorsk HPP (counter-regulator of Bukhtarma HPP) with storage for regulation of stream flow and Shulbinsk HPP with seasonal storage. Total installed capacity of the cascade is 1.708 MW. Bukhtarma HPP is of major importance because it is the main counter-regulator of the cascade and it is involved in multi-annual and unrestricted daily regulation.

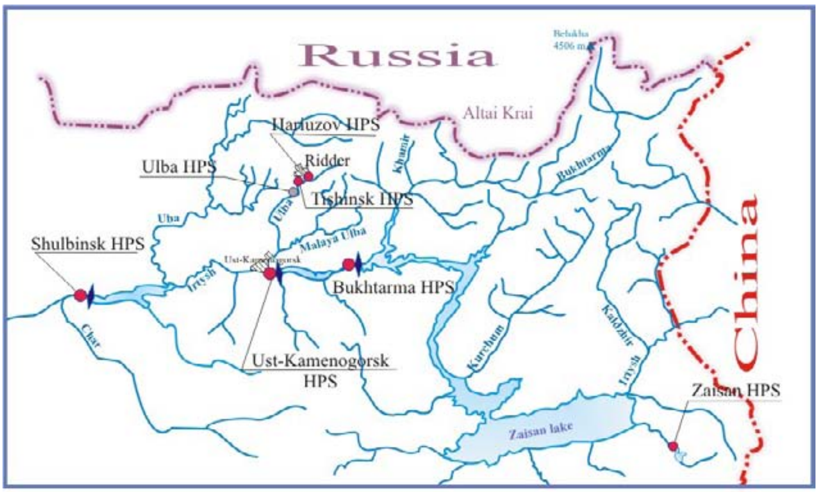

Fig. 2.

Ecosystem, hydropower and navigation make conflict demands to regime of stream flow. The Rules of Utilization of Water Resources of the Irtysh Cascade of Reservoirs are the only one governing document for all water utilization system parties. The Rules set out regime of use of water resources of the Irtysh River for the purpose of preserving water ecosystem and ecological balance of biotopes in the flood plain and specify boundary conditions, which meet the requirements of their multipurpose use with due account for the period of navigation.

For water transport purposes, according to the Rules, it is necessary to maintain the navigable levels of the river, predicted levels of reservoirs water balances, carry out discharges into downstream of Ust-Kamenogorsk and Shulbinsk Water Reservoirs.

For ecosystem purposes, protective discharge from Shulbinsk Water Reservoir should be carried out in accordance with the Rules and dispatch schedule. Discharge is carried out by the decision of the governmental water-economic committee at the end of April and beginning of May each year. Given that water supply makes 75% by the number of continuous years, the volume of discharge amounts to 5.4 km^3 with duration of 20 days.

For fish industry purposes, the Rules set out restrictions for fluctuations of levels of Bukhtarma and Shulbinsk Water Reservoirs and specify limit values of water flow and level during spawning and environmental discharge.

Irtysh Basin Authority exercises control over cascade based on the Rules and develops water economy balance for the current year. National Dispatch Centre of the System Operator exercises operating control over regime of power generation, transmission and consumption of the HPPs cascade within the approved balance.

Following restructuring of the electric power industry, HPPs of the Irtysh cascade were placed into trust. Bukhtarma HPP is long leased by Kaztsink JSC and Ust-Kamenogorsk and Shulbinsk HPPs are operated by AES Corporation (USA) under 20-year concession agreement. This affects electric power industry because HPPs ownership by different companies makes difficult to agree the cascade operation, in particular of Bukhtarma HPP and its counter-regulator – Ust-Kamenogorsk HPP.

To maintain conditions in the middle reach of the Irtysh River close to natural floods and with the view to preserve biological productivity and habitat for flora and fauna of the flood-plain, which has a status of State Wildlife Area, environmental discharge from Shulbinsk Water Reservoir is carried out annually. Discharge calculations are a sum of channel inflow of Bukhtarma-Shulbinsk HPP section, discharge of Shulbinsk Water Reservoir and compensating water flow of Bukhtarma HPP. Duration of the basic phase of the discharge by water flows from 2.000 to 3.500 m^3/s is 15 - 24 days depending on the water supply of channel inflow.

Considering that during discharge, the volume of Shulbinsk Water Reservoir is drawn down up to dead storage level, hydropower units start operating inefficiently with low water head. Unit discharge i.e. volume of water required for generation of 1 kWh of electric power is increased from 10 % at Ust-Kamenogorsk HPP to 60 % at Shulbinsk HPP. Actually, lost generation because of outspent water makes in average about 100 mln. kWh per each discharge or approximately 2 mln. US dollars. However, this collision is rather conventional because hydropower being the main water user is governed by set rules for utilization of the Irtysh water resources and during discharges the regime of water resources utilization is entirely subject to environmental objectives.

On the other hand the existing restrictions for fluctuations of level in the downstream of Shulbinsk HPP prevent from using its total available capacity during peak loads. This situation may be changed by leveling irregular regime of discharges of Shulbinsk HPP into a regular regime of discharges of underlying small water reservoir for week and daily regulation. Construction of such counter-regulator – Boulak HPP with capacity of 68 MW and mean annual generation of 350 mln. kWh is also provided for by the Concept for Hydropower Development. Feasibility study of Boulak HPP construction has been developed in 1994 even initial volume of excavation works has been made. In 2007, feasibility study has been revised taking into account new conditions. The project disadvantage is the cost of reservoir bed clearing, which makes about one-third of total amount and costs related to engineering protection of several villages and relocation of residential population from flooded area. Moreover, this HPP is located in energy surplus northern zone of Kazakhstan thus its construction is in the long-term.

Considering that Irtysh is a transboundary stream, everything related to utilization of its water resources affect interests of three countries – China, Kazakhstan and Russia. In 1992, Agreement on co-operation of transboundary rivers protection and utilization has been signed between governments of the Republic of Kazakhstan and the Russian Federation, in 2002 - People's Republic of China.

Irrigated areas (~ 200 thousand ha) were formed early in the 19th century and first half of the 20th century, about 1 km^3 of water was used to irrigate these areas. In the second half of the 20th century in the coastal zone of the Black Irtysh River about 100 thousand ha were developed and new irrigation systems were built, old irrigation systems with annual water consumption of 1 km^3 were redeveloped. Thus, in the upper part of the Irtysh River, which is on the territory of China there about 300 thousand ha of irrigated land (exclusive of Karamai area) and total water consumption makes 2.0 km^3/year. About 9 km^3/year goes now on the territory of Kazakhstan and 8.0÷8.2 km^3 of water will be available in 2010 after development of Karamai area.

Another multi-purpose hydro system is 364-MW Kapshagai HPP, the facilities include carry-over storage. Almaty Oblast suffers severe deficit of electric power and energy, particularly during winter-autumn period with steady growth of electric power consumption up to 10% annually. While HPPs are meant for generation of peak power, the Kapshagai HPP is very rarely involved in power control because of the existing limits of water level fluctuations in the downstream of the Ili River. Now the deficit may be covered either by purchasing deficient power in Kyrgyzstan or by involving Zhambyl GRES. Due to use of high cost gas and mazut, the price of electric power produced by Zhambyl GRES is non-competitive; this necessitates allocation of government subsidies.

The only one main document governing the regime of water resources utilization of Kapshagai Reservoir are the Rules of Kapshagai Water Reservoir Operation for the Period of Initial Impounding and Normal Operation, which were developed in 1979. HPPs' technical characteristics, water consumers' profile, operational environment and businesses' departmental identity have recently changed. To increase reliability of power supply to Almaty Oblast consumers in case of emergency outage of 500 kV OHTL, the generator load automation has been installed at Kapshagai HPP; activation of the device results in short-range fluctuations of discharges into downstream reach, which is prohibited by the Rules. It necessary to revise the existing rules for the Ili River water resources utilization, which would meet the needs of the age and would satisfy the requirements of all basin water consumers, however correspondence on this issue was not a success.

Construction project of Kerboulak counter-regulator, which is 23 km lower Kapshagai HPP power site, has been developed to eliminate the existing restrictions and optimize operation of Kapshagai HPP (Fig. 3). Construction of water reservoir for week and daily regulation with net capacity of 20 mln. m^3 will enable to re-regulate unevenness of discharges in the downstream reach and bring regime of the river to natural, lift restrictions regarding unevenness of Kapshagai HPP discharges and will make it possible to use HPP's available capacity to cover peak loads. Commissioning of Kerboulak HPP is planned in 2010 (optimum alternative).

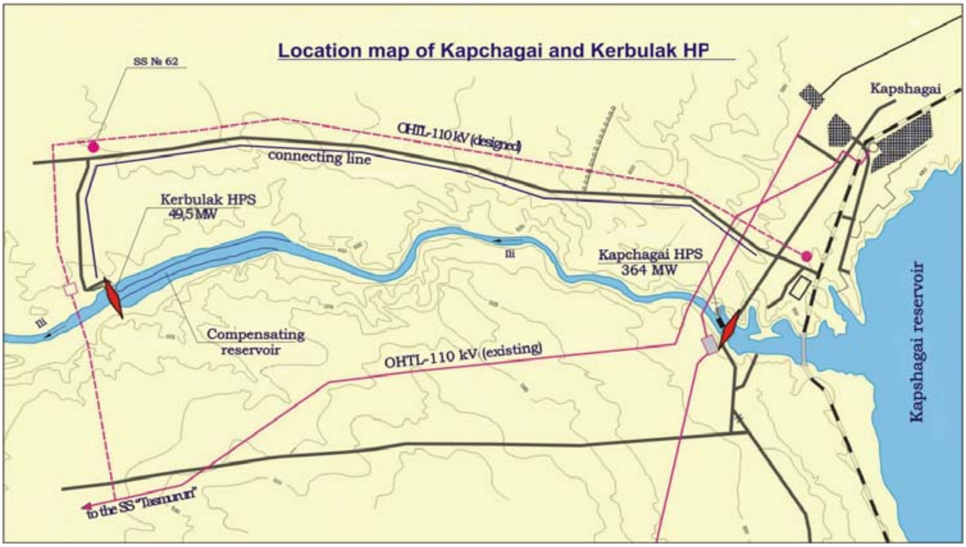

Fig. 3

It worth to be mentioned that the first River Basin Council – advisory body under Basin Authority consisting of heads of local government boards and representatives of water consumers has been set on the territory of the Balkhash-Alakol Water Basin. Representatives of public non-governmental organizations may be also included into the Basin Council. The Basin Council considers live issues regarding utilization and protection of water resources inventory, makes suggestions and recommendations for the Basin Agreement parties.

100-MW Shardarinsk HPP on the Syrdarya River is another major hydro system in Kazakhstan and, regrettably the most conflict during the last years because it is the bottom step of the Naryn-Syrdarya HPPs cascade and its tributary is defined to a great extent by the operating regime of the overlying water reservoirs, primarily by the Toktogul carry-over storage.

The Syrdarya River is formed by the confluence of the Naryn and Karadarya Rivers in the eastern part of the Fergana Valley. From this point to influx to the Aral Sea, the Syrdarya River has a length of 2.137 km among them 1.700 km is on the territory of Kazakhstan. The Syrdarya River flows into the Northern Aral Sea, dividing into numerous channels outside Kazalinsk city and flowing over the territories of Kyrgyzstan, Uzbekistan, Tajikistan and Kazakhstan. The River is extensively used in the economical activity.

The whole Naryn-Syrdarya HPPs cascade has been designed and planned for ensuring irrigated lands in the upper, mid and lower reach of the Syrdarya River by agricultural water, and until 1991 it was operated in the irrigation mode, i.e. maximum water flow was during summer period and minimum water flow - during winter period. Shortage of electric power in Kyrgyzstan during winter period was covered by integrated power system of Central Asia and surplus of electric power during summer was also consumed there. Primary energy resources were also supplied to Kyrgyzstan.

After 1991, supply of primary energy resources to the Kyrgyz Republic decreased, own production of fuel dropped and electric power was used for heating, hot-water supply and domestic needs, following this the operating regime of Toktogul Water Reservoir changed into the energy regime and consumption of electric power in Kyrgyzstan increased by 30 % during the last 12 years.

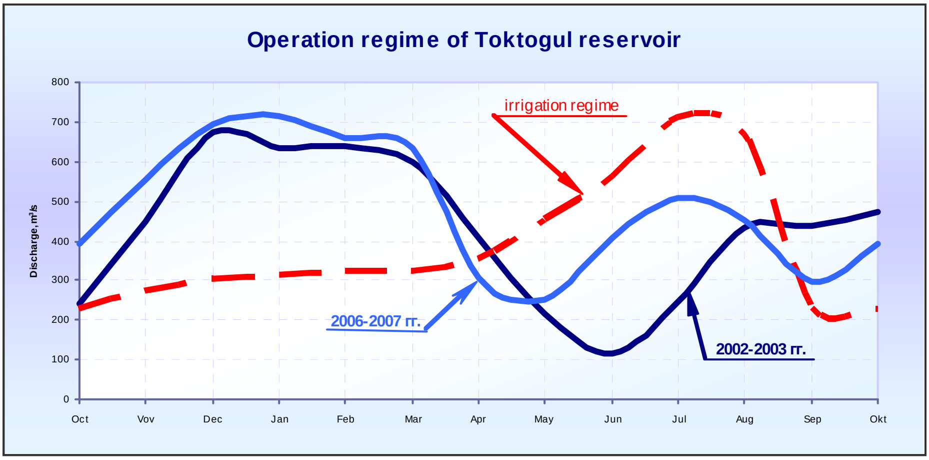

Fig. 4.

Since mid of the 90-s, to solve the problem of water supply to irrigated lands during vegetation period, intergovernmental minutes of meetings (MoM) are signed annually. Kazakhstan and Uzbekistan, as set by the MoMs, receive electric power from Kyrgyzstan during vegetation period, which was generated due to increased discharge of water, and supply primary energy resources in return. However, the basin hydropower resources are not sufficient for operation of the Naryn cascade in the irrigation mode during summer and in the energy mode during winter, this can result in drawdown of the water reservoir below dead storage level and disruption of irrigation works during low-flow period.

The problem of harmonised operating regime of the Naryn cascade is also a concern for power engineers because during outage of North-South Transit OHTL in summer and stoppage of Zhambyl GRES, the deficit of electric power and energy is covered by electric power supplies from Kyrgyzstan.

Along with the shortage of water during summer months the problem of overflowing the Shardarinsk Water Reservoir during winter and summer has blown up. Large inflow of water during autumn and winter months and limited discharge capacity of the lower bed reach of the Syrdarya River result in impoundment of the reservoir already in January with water surplus to be released into Arnasai Depression.

Arnasai hydro system, being a part of Shardarinsk Water Reservoir facilities has been designed as a flood-discharge outlet for high-water years. However in 2001-2002, Uzbekistan constructed hydraulic engineering facilities 5 km away from the Arnasai dam by setting backwater to the Arnasai hydro system and, therefore significantly reducing its discharge capacity from 2.100 to 900 m^3/s. Increased winter discharges during complicated icing conditions result in a sharp rise of the water-level, degradation and destruction of hydraulic engineering facilities and highways and flood of vast territories.

In 2005-2006, there were taken certain actions with the view to prevent emergency situations. To safely discharge winter water-flows, reduce release of water into Arnasai Depression and resume sustainability of Shardarinsk and Arnasai dams and within the Project - Syrdarya River Training and Northern Aral Sea Preservation the actions, reducing the risk of emergency situations in the lower reach of the Syrdarya River, were taken. There were constructed protection dams 49 km in length, the river-bed in the potential flooded area was cutoff, Aitek, Kazalinsk and Kyzylorda hydro systems were put into operation, lower slope of the Arnasai dam was reinforced. Completion of construction works at a closure structure – Aklak hydro system will enable to increase the channel capacity from 60 to 400 m^3/s at this section during winter period.

Work on signing the long-term framework agreement and signing of annual inter-governmental minutes of meetings between the state governments of the Naryn-Syrdarya Basin, which stipulate mutual obligations regarding supplies of electric power, water and fuel resources, water reservoir levels by the end of vegetation period and discharge from reservoirs during inter-vegetation, give us a hope that a hard but so necessary dialogue between our countries will go on and vitally important issues of energy and water supply will be resolved in a balanced and reasonable manner to maximally satisfy the interests of all water consumers of this large region.

Integrated water resources management of the Xinjiang toward effective water governance

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Xinjiang Uigur Autonomous Region (Xinjiang), located at northwestern China, is characterized by arid climate and water scarcity. The rapid population growth and irrigation agriculture enlargement along with irrational water utilization have aggravated the regional water scarcity and posed great threat to natural ecosystems in Xinjiang during the second half of 20 century. The serious imbalance between socio-economic development and ecological protection has resulted in the escalating conflicts among stakeholders, low water utilization efficiency and environmental degradation, which is restricting local sustainability and also exerting great negative influence to larger region of northwest China. It represents the governmental failures in water resources development and management in arid regions and adds uncertainties to further implementation of the National Strategy of Extensive Development of China West. It is acknowledged that an integrated water resources management approach is the key to harmonize socio-economic development and ecological protection in Xinjiang, in particular effective water governance is absolutely necessary.

The article first reviews the existing water management paradigm and major issues in Xinjiang. The inappropriate legal and institutional framework is approved a critical impediment. Then the emerging paradigm is analyzed and the Tarim River basin is taken as a typical case to demonstrate its applicability and validity. At last, the article suggests a new basin-wide approach to the integrated water resources management of the Xinjiang, incorporating four basic elements of good water governance. The lessons learned could provide a good example for other regions under similar condition.

Integrated water management based on the decision support system "Hydromanager"

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1. Introduction

Integral water-economic system (WES) is a management framework in water-economic complex. It includes nature-anthropogenic complex of interrelated natural objects and technogenic structures (for river runoff regulation, water treatment etc.). Water-economic systems have considerable territorial boundaries and are characterized by complex connections with other sectors of the country economy.

The optimality criterion for water-economic activity of an enterprise-water user may be its maximum net profit after all payments for water use. This optimum is achieved in dependence on level of financing of water protective measures from all sources. On the other hand, water use in basin scale must be characterized by minimal level of water pollution in control sections of the river network.

It means, that search for optimal choice is reduced to search for most effective set of "rules of the game", i.e. administrative-economic mechanism of water use in river basin.

The process of management decision elaboration in WES is very complex; it affects many economic objects and population. That accounts for necessity of special automated decision support system (DSS), which is a set of software products, combined by unified methodology of optimal choice.

As example the DSS "Hydromanager" allows comparing various hypothetical variants of administrative-economic mechanism of water use in case of their realization according to of forecasted level of natural water pollution. It is done on the basis of use of real input data about water-economic complex and assumption that all water users act in their own economic interests.

Water users may be influenced by means of norms change and differentiated rates of payments for various levels of different contaminants pollution and also by special management mechanisms, e.g. address support or licensing. Having calculation methods of inputs and feedback between environmental and economic components, one can choose the best "rules of the game" in accordance with their influence on water quality in a river basin.

The DSS "Hydromanager" basis is systems approach, simulation and optimization methods and GIS-technologies. Its application for the Nete river basin (Belgium) and the Upper Ob-river basin in the Altai administrative region (RF) is presented. Fig. 1 demonstrates the Upper Ob and the Nete river basin.

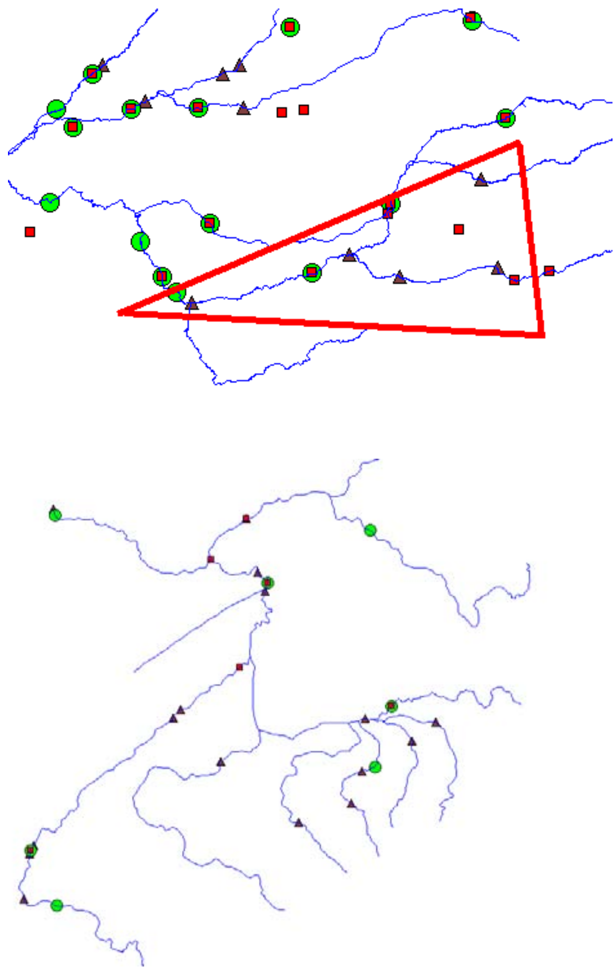

Fig. 1. The river basins of Nete (above) and the Upper Ob (below)

The DSS "Hydromanager" is an original product of the group of scientists under the leadership of Professor A.Tskhay (Altai State Technical University, RF) [Tskhay et al, 1996]. In 1997 this investigation was awarded the Tison Award of the International Association of Hydrological Sciences, uniting about three thousand scientists from more than fifty countries.

The implementation of "Water quality management information tool for rivers basins based on environmental and economic consideration" project of INTAS scientific program, Commission of European communities was started in 2002 by researchers from Austria (University of National Resources, Vienna), Belgium (Free University, Brussels), Russia (ASTU, Barnaul and Russian Research Institute for Integrated Water Management and Protection, Ekaterinburg) and France (Ecole des Mines, Paris).

In this project the application of the adapted DSS "Hydromanager" to the water use conditions in the countries of European Union by the example of the Nete river basin running in Flanders (Belgian region) as well as of the Upper Ob in Altai Krai, Russia is expected.

Nowadays the procedure of water use in Russia is the following. At the beginning of the year every enterprise must provide the basin authority with the list of water protective measures specifying their effectiveness (i.e. decrease values for every contaminant pollution) and costs. In case an enterprise does not submit the list, in accordance with the law the basin authority may veto the enterprise's activity. After that the problem of financing of water protective measures is solved.

In the absence of special DSS it is impossible to rank various measures according to their environmental significance. That is why decisions concerning water protective activities often leave much to be desired.

Let us call administrative center of the river basin establishing "rules of the game", accumulating payments for water use and investing them in water protective measures - the "basin authority".

It is assumed, that at every stage water users choose actions to maximize their net profit. This assumption makes it possible to forecast water users' behavior and to get closed definitions of simulation and optimization problems under consideration.

The geoinformation system is elaborated for support of management decisions on the base of regional economic mechanism.

The economic-ecological model for enterprise - typical water user - was developed in accordance with present normative basis for estimation of point sources of pollution. Then the method of integer optimization and the production functions approach are used for decision of this problem.

2. Input data

When dealing with DSS "Hydromanager", a large volume of input data are required to obtain adequate modeling outcome. These data should describe river hydrology and hydrochemistry as well as ecological - economical characteristics of enterprises located in the basin. Hence, the process of data preparation for working with "Hydromanager" is rather complicated and laborious that involves the performance of the following sequence of steps:

1. Forming of the enterprises' list with indication what rivers they are situated on;
2. Forming of all rivers basin list with indication of water discharges and levels;
3. Ranking of all rivers according to amount of discharge;
4. Selection of rivers from the basin to be considered (all rivers where enterprises are located and those rivers which discharges are higher than the ones of the rivers where the enterprises are situated)
5. Classification of chosen rivers by large and small ones;
6. Forming of the list of pollutants to be considered;
7. Collection of data on large rivers (hydrology and hydrochemistry);
8. Collection of data on small rivers (hydrology and hydrochemistry);
9. Collection of data on enterprises;

3. Distribution for water protection resources

One of the optimization measures is competitive investment. In doing so the lack of feedback, i.e. ranking of the activities proposed by their efficiency on the basin scale, is a deterrent.

For these purposes the developed DSS "Hydromanager" will include the model of water quality that makes it possible to forecast the pollutant distribution in the river network using data on specific conditions in the basin.

Thereafter a decision maker gets the list of measures on water quality improvement in the river basin. Such a list, for instance, can be received on special inquiry from the enterprises-polluters. For simplicity from here on it is assumed that the measures undertaken are independent of the results of waste effect.

Thereupon the list of concurrent introduction of the measures proposed is made up. In this case all degenerated cases (for example, when total planned decrease of pollution exceeds the actual one) should be cut off.

Using the computer-aided procedure the resultant values of emissions are set for each version. This enables the mathematical setting of the problem of water quality formating in river basin to be enclosed.

Thereupon the pollution distribution in river basin is estimated for each version within DSS "Hydromanager".

Having defined the criterion of water quality on the basin scale that depends on the decision maker's priorities the ranking of all possible investments is made. Thus, one can choose the best way for the limited financial assets to be used.

For instance, one can take, as the assessment criterion, the following integral index, relevant in view of the EU regulations [Directive, 2000]:

$$Cr_j = \sum_{i,k} \left(\frac{C_{ik}^j}{P_i} \right) \xrightarrow[j]{} \min , \qquad (1)$$

where i – number of contaminant, P_i – maximum permissible concentration of i-th contaminant, C_{ik}^j – concentration of i-th contaminant in k-th point after implementation of j-th variant of measures.

When the results obtained are estimated a decision maker chooses the most effective variant of spending the limited assets for water protection.

4. Water quality model

Main assumptions for the model are the following:

- the flow in river beds is steady;
- point and diffuse emissions are given;
- river flow is quasi-one-dimensional with limitations allowing the flow simulation using Sen-Venan equations;

- river-beds have non-prismatic profile;
- chemical processes in rivers are simulated by equilibrium reactions;
- river processes don't influence the flow of tributaries.

A comprehensive description of mathematical model of water quality for the Ob-basin is given in [Tskhay, 1995]. However, the structure of the source information for the Nete basin defined the necessity of model equations' modification.

In this case the equations' set takes the following form:

$$\left(1-\frac{Q^2\cdot B}{g\cdot w^3}\right)\cdot\frac{w}{2}\cdot\frac{dw^2}{dx}-\left(i_0-\frac{\partial h}{\partial x}\right)\cdot B\cdot w^2=-B\cdot\left(\frac{q\cdot Q}{g}+\frac{Q}{C^2R}\right) \tag{2}$$

$$q=\frac{dQ}{dx} \tag{3}$$

$$\frac{d\left(Q\cdot C_j\right)}{dx}=\frac{d}{dx}\left(E\cdot w\cdot\frac{dC_j}{dx}\right)+w\cdot H_j+G_j\ , \tag{4}$$

where Q - water discharge, m^3/s;
B - width of free surface of the current, m;
g - acceleration of gravity, m/s^2;
w - area of the current cross-section, m^2;
x - longitudinal co-ordinate along river-bed, m;
i_0 - bottom slope;
h - river depth, m;
q - channel inflow per unit of length, m^2/s;
C -Shezi coefficient calculated by Manning equation:

$$C=\frac{1}{n}\cdot R^{1.3\sqrt{n}}\text{, with dimension } m^{0.5}\cdot s, \tag{5}$$

where n - channel roughness; R - hydraulic mean depth, m:

$$R=\frac{w}{X}\ ,$$

where X - wetted perimeter, m:

$$X=b(x,0)+2\cdot\int_0^h\sqrt{1+\left(0.5\cdot\frac{\partial b}{\partial z}\right)^2}dz\ , \tag{6}$$

where $b(x,z)$ – river width distance z from the bottom, *m*;
C_j - concentration of the j-th chemical compound, g/m^3;
$j\in[1..N]$, N - number of components;

$$E=\beta\cdot h\cdot\sqrt{g}\cdot\frac{u}{C}$$

(Elder representation for longitudinal dispersion coefficient), m^2/s;

$u = \frac{Q}{w}$ – mean velocity of the current in the cross-section, m/s;

H_j - term characterizing the non-conservation of the j-th compound under consideration, g/m^3·s;

G_j - track load per unit of current length, characteristics of non-point sources of pollution, g/m·s.

Chemical components include the following: BOD_5, oxygen deficiency, suspended matter, COD, ammonium, nitrites, nitrates and phosphates that are related to each other in reactions of chemical compounds transformation.

Value H_j in (4) is defined by the first-order reaction with non-conservation coefficients K_j. Then

$$H_j = -K_j \cdot C_j \text{, for j=3, 4, 8;} \tag{7}$$

$$\begin{aligned} H_1 &= -(K_1 + K_3) \cdot C_1, \\ H_2 &= -K_2 \cdot C_2 + K_1 \cdot C_1 + P_1 \cdot K_5 \cdot C_5 + \\ &+ P_2 \cdot K_6 \cdot C_6 + J \cdot \frac{B}{w}, \end{aligned} \tag{8}$$

where K_3 - sedimentation coefficient; P_1 and P_2 - count coefficients of oxygen loss under nitrification; J - density of oxygen flow caused by the absorption by bottom sediments and photosynthesis.

In estimation of nitrogen compounds transformation (j=5÷7) the following scheme of nitrification is used:

$$\begin{aligned} H_5 &= -K_5 \cdot C_5 + P_3 \cdot K_4 \cdot C_4, \\ H_6 &= -K_6 \cdot C_6 + K_5 \cdot C_5, \\ H_7 &= -K_7 \cdot C_7 + K_6 \cdot C_6 \end{aligned} \tag{9}$$

where P_3 - count coefficient for ammonification process.

Hydrological conditions dependence of transformation coefficients is given at j=3, 4,…,7 as $K_j = K_{0j} u^{\theta_j} h^{\theta_j^h}$ is determined at the model parameterization. Values P_j are defined according to the actual stoichiometric ratios.

Boundary conditions are of the form:

$$\omega(x_{k_j}) = \omega_{k_j}, \qquad C_j(x_0) = C_{oj}, \qquad \frac{dC_j}{dx}(x_l) = 0 \tag{10}$$

Here x_0 and x_l - inlet and outlet of the simulated part of the river, respectively.

With the tributary (point sources of pollution) characterized by a constant rate during the estimated period, the concentration in the point of tributary inflow is calculated as follows:

$$C_{if} = \frac{C_{is} \cdot Q_s + C_{ia} \cdot Q_a}{Q_s + Q_a} \tag{11}$$

Here C_{ia} and Q_a - the content of *i*-compound and water discharge in the tributary. Index "*f*" is the parameter below the point of tributary inflow, and "*s*" - the parameter above the point of the tributary inflow.

Value G_{Jth} can be defined as:

$$G_j = C_j \cdot q\,, \tag{12}$$

where C_j - the content of *j*-th compound in water characterized by lateral inflow discharge q (if $q<0$, then $C_{jb}=C_j$).

To estimate the emissions from the diffuse sources of pollution the Behrendt - Bohme method [Behrendt et al, 1992] is used.

Water temperature has a pronounced effect on the processes that occur in the river. A simple assumption T=const is considered for a period under modeling.

To perform the numerical solution of the task a network by x: $\{x_i\}$, i = [0...L] (L is a maximal network node) is introduced on which such net variables as q_i, w_i, C_i, etc. are found. If the river has any tributaries, the task first is solved (2)-(4) for each tributary. If these have tributaries, the task is solved for the second-order tributaries, and so on. Finally, the rivers with the lack of tributaries are found.

The known experimental data for river stations is tabulated depth h dependence of river-bed width B. It is assumed that river-bed section between two measured depths is trapezium in shape. In this case the sectional area at the given depth can be calculated by the following formula:

$$\omega = \frac{1}{2}\sum_{i=1}^{k}(h_i - h_{i-1})\cdot(B_i + B_{i-1}) + (h - h_k)\cdot\left(B_k + \frac{(B_{k+1} - B_k)\cdot(h - h_k)}{2(h_{k+1} - h_k)}\right). \tag{13}$$

When only one value of width and depth is given, the river section is anticipated to be a triangle in form.

To calculate the flow area between sections a linear interpolation is used.

5. Calibration of water quality model

For equations' characterization the analytical solution of differential equations in approximation of the uniform flow motion in the river-bed with a constant profile and in neglect of longitudinal dispersion (it is acceptable for water objects with shallow depth and high current velocity) is used.

To perform calibration the following data are necessary:

- on river-bed morphometry (length of the part for which calibration is performed; area of the current cross-section given as a relationship between current width and depth);
- on hydrological regime of water (pollutant concentration, water temperature and discharge, current velocity) in two test sections (measurement in the downstream section is performed with regard to the time during which water from the upstream section reaches the downstream one).

The following parameters should be minimal between the upstream and downstream test sections: distance; the number of point emissions; change in river-bed morphometry (cross-section area, discharge rate) and current velocity as well.

If these requirements are not satisfied great discrepancy between calculated values and actual data is observed. If the model parameters should be more precise and the basic data do not meet the requirements mentioned above, specific extra investigations (establishment of temporary stations for water quality control) are carried out.

The process of model calibration can be divided into stages related to the definition of the following: auxiliary quantities associated with the river-bed morphometry; pollutant concentration in lateral inflow and coefficients of non-conservation for each pollutant.

The distance from the river-bed to calibration sections (observation stations) is measured. With these values the distance from the mouth to the midpoint between calibration sections is determined.

In the sections that are upstream and downstream the nearest ones to this point and show the data on the river-bed morphometry the area of the current cross-section and sections-to-river-bed distance are measured.

Based on the values obtained the dependence of the variation of the area of current cross-section in reference point is determined with linear interpolation

$$F(x^*, w^*) = \beta \cdot F_i^*(w^*) + (1-\beta) \cdot F_{i+1}^*(w^*)\,, \qquad (14)$$

where $\beta = \dfrac{x_{i+1} - x^*}{x_{i+1} - x_i}$,

x^* - distance from reference point to river-bed,

x_{i+1} – distance from river-bed to the section above reference point,

x_i – distance from river-bed to the section below reference point,

F_{i+1} – area of the cross-section in the section above reference point,

F_i – area of the cross-section in the section below reference point,

This area is considered to be constant on the whole calibration part of the river and is used in further calculations.

6. Procedure for efficiency estimation of investments in water protective activities

Functional sensitivity of water quality criterion to fluctuations of discharge volumes by enterprises-pollutants is of great importance for the analysis of efficiency of activities on discharge reduction. Costly and laborious measures that result in reduction of one component discharge are not always effective. In this connection the effect of water treatment technologies introduction on river water quality is significant since it makes possible to rank the arrangements on cost effectiveness at the initial stage of their design.

For the sake of convenience and clearness of the analysis, the level of dependence of criterion value on discharge reduction is presented as diagrams. But before constructing the diagrams let us define enterprises which discharges impact on ecological situation to a greater extent and let us reveal the most significant for enterprises pollutants. If discharges of any enterprise are insignificant, this enterprise should be excluded from consideration at this very stage

As for the Nete basin, 3 large enterprises, namely RWZI GEEL, RWZI WESTERLO and BP CHEMBEL, correspondingly R_1, R_2, R_3, discharge directly into the river site under study. Their discharge volumes are practically comparable with each other and are to be considered by all components included into the criterion. The components subject to consideration are BOD, Suspended matter, COD, NH_4, NO_2 и NO3.

As for the Upper Ob basin, the situation here is much more complicated. Direct discharges into the river are made by 28 large enterprises. Clear that not all of them impact on the ecological situation of the water object drastically. Hence we should define the greatest enterprises-pollutants till the beginning of discharge reduction modeling.

On the basis of the analysis of size of dumps the list has been made of 8 enterprises (Barnaul-Gorvodokanal, «Barnaultransmash», Biyskaya TEC-2, Biyskiy oleumniy zavod, Biyskaya TEC-1, Biyskvodokanal, Kamen Vodokanal, Hlopchatobumazhniy kombinat Barnaul) and polluting components (BOD, Suspended matter, NH_4, NO_2, Synthetical surface-active matter, Mineral oils, Phenol, Chlorine, Sulphate, Lindane) reduction of dumps on which is modeled. The strongest influence on an ecological condition of river pool is rendered with dumps of enterprise "Barnaul-Gorvodokanal".

Calculations have been made for each enterprise and with gradual reduction of components' discharges from 100% up to 0% with a 10% step.

These dependencies are linear and are presented in tables and in graphical form as well. They demonstrate that the most effective will be measures on COD and Ammonia discharge for R_2, COD for R_3 and R_1. Hence at the reduction of COD discharge by 80% at R_2 the criterion will be equal to 3.162, the reduction of Ammonia discharge by 80% will show the criterion value of 3.168. Similar reduction of COD discharge from R_1 and R_3 by 80% will result in criterion lowering up to 3.142 and 3.115, correspondingly.

Thus, with simulation we have defined the priority lines to reduce industrial discharges, and the measures to be implemented will contribute to environment improvement. They are presented in Fig. 2.

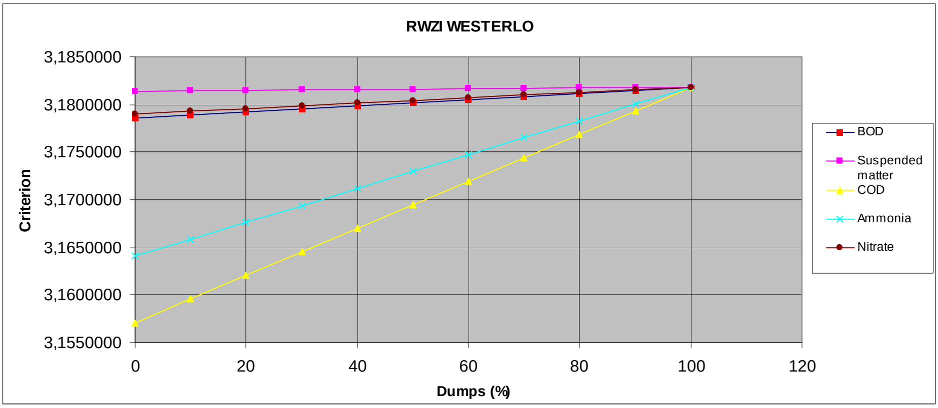

Fig. 2. Comparative criterion dependence on discharges from R_2

Similar calculations were made for the Upper Ob. Modeling was carried out on the enterprises and pollutants specified before. The most significant dependences are resulted on Fig. 3.

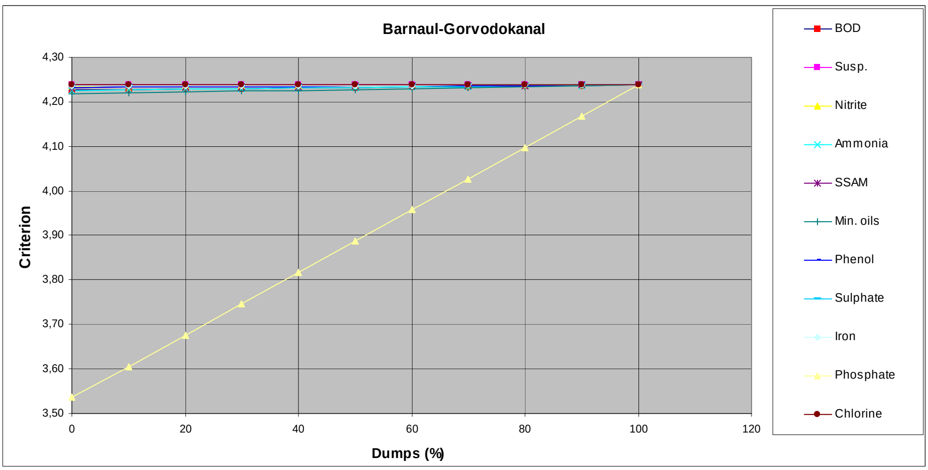

Fig. 3. Comparative criterion dependence on discharges from Barnaul-Gorvodokanal

The graphs show the criterion change under the reduction of the most considerable discharges from the enterprises located within the Upper Ob basin. Measures on the reduction of discharge from Barnaul-Gorvodokanal are expected to be the most effective. As this takes place the reduction of Phosphate discharge will contribute to environmental improvement to a greater extent than the reduction of any other discharge. While making a decision on the measures to be taken the reduction of Phosphate and Mineral oils discharge from Barnaul-Gorvodokanal should be of should have priority.

7. Procedure for efficiency estimation of investments in water protective activities

Let us consider the procedure for efficiency estimation of investments in water protective activities using actual data on the Upper Ob basin in Altai Krai.

Waste water discharge is observed at 35 large enterprises of Altai Krai among which 6 enterprises are main polluters. Respective measures can be put into effect at each enterprise resulting in the reduction of charges and, hence, in the lowering of quality criterion in control point.

All measures implemented are assessed and influence the discharge reduction. These data are given in Table 1. All the measures can be carried out singly or in combination. It should be noted that simultaneous implementation will result in large inputs. There is no doubt that the most expensive measure is the most effective one.

As an example of efficiency estimation of their implementation and decision making on investment advisability we refer to the simulation of 5 enterprises and the change of Cr criterion in control point. The list of measures specified for simulation is shown in Table 1.

Pollution rate (column “Value”) shows the times of pollution reduction after measures implementation. In other words, before measures “Collect wastes from coagulating bathes” carried out at the “Kombinat himicheskih volokon” the discharge of Mineral oils makes up 0.06976 g/s, and on completion of measures implementation it will be 0.85 times smaller and will constitute 0.06976*0.85 =0.059296 g/s.

Table 1

Characteristic of measures

Enterprise	Measure	Cost	Contaminant	Value
Kombinat himicheskih volokon	Collect wastes from coagulating bathes	100	Mineral oils	0.85
Kombinat himicheskih volokon	Implement the scheme of dye collection	15	Suspended matter	0.95
Biyskvodokanal	Capital repairs of mechanical grates	513.9	Mineral oils	0.98
Biyskvodokanal	Capital repairs of primary and secondary settlers	335.2	Suspended matter	0.9
			BOD	0.9
			Synthetical surface-active matter	0.8
Barnaul-Gorvodokanal	Build treatment facilities for industrial waste waters and storm precipitations	98948	Mineral oils	0.75
			BOD	0.7

The change of assessment criterion of water quality upon completion of measures implementation and simultaneous introduction is represented in Table 2.

Table 2

Water quality criterion under different measures implementation (as the criterion increases)

ID	Total Cost	Criterion	Measures
31	99912.1	4.229576792	Collect wastes from coagulating bathes; Implement the scheme of dye collection; Capital repairs of mechanical grates; Capital repairs of primary and secondary settlers; Build treatment facilities for industrial waste waters and storm precipitations
29	99897.1	4.229576905	Collect wastes from coagulating bathes; Capital repairs of mechanical grates; Capital repairs of primary and secondary settlers; Build treatment facilities for industrial waste waters and storm precipitations
…	…	…	…
2	15	4.238338187	Implement the scheme of dye collection
0	0	4.2383383	-

Thus, with this Table 2 a Decision Maker can take an option in favor of one or another measure based on water quality criterion and implementation value. There is no doubt that the most expensive measure is the most effective one. However, under the lack of financial resources and to exclude the ineffective measures the procedure of interest is of immeasurable service.

Further, using the scenario approach the procedure was tested in West Europe conditions, particularly, the Grote Neet as a case study.

Data of hydrological observations (discharge, level and concentration measured at monitoring stations) carried out in the average 2001 were taken as the basis for natural conditions scenario. Calculations assumed that waste water is discharged by two large water-supply plants and one industrial enterprise. Basic data on real discharge present mean annual pollutants concentration and the total discharge as well. That is why the estimation of change of pollutant concentration in the river-bed and criterion value in control point following the discharge reduction was of great interest.

Basic data on real discharge present mean annual pollutants concentration and the total discharge as well.

Criterion value is calculated in the Grote Neet river station at the monitoring station No. 73. The calculation was made before and after measure implementation on polluting discharge reduction. In the control point before measures the efficiency criterion is Cr = 3.182.

Let us consider the situation of nature protective measures implementation at the given water-supply enterprises leading to the pollutants discharge reduction. Suppose that measure M1 was carried out at R_1, and M_2 was implemented at R_2. Each measure has its own value that is taken into account under efficiency estimation of investments (the value of M_1 is \$50 000, and M_2 costs \$700 000). Coefficients of discharge rate change due to the measures implemented are shown in Table 3.

Table 3
Coefficients of discharge rate change after measures implementation

Contaminant	Coefficient of discharge rate change at RWZI WESTRLO (C_1)	Coefficient of discharge rate change at RWZI GEEL (C_2)
BOD (kg/m^3)	1	0.7
O_2 (kg/m^3)	1	1
Susp. (kg/m^3)	1	1
COD (kg/m^3)	0.25	0.1
NH_4 (kg/m^3)	0.1	1
NO_2 (kg/m^3)	1	0.3
NO_3 (kg/m^3)	1	0.15
SSAM (kg/m^3)	1	1

Coefficients of discharge reduction C_1 and C_2 show the change of earlier discharges as a result of measures implementation. For instance, the value of C_2=0.1 for COD discharge at R_1 means that implementation of measure M_2 at the given enterprise will result in tenfold discharge reduction. In a similar manner, C1=0.25 for COD discharge at R_2 demonstrates a 25% discharge reduction.

Measures M_1 and M_2 can be carried out singly or in combination. It should be noted that simultaneous implementation will result in larger inputs. To estimate the implementation efficiency and advisability of investments the simulation was carried out and the change of criterion Cr in control point was defined.

The change of estimation criterion of water quality after M_1 and M_2 implementation and simultaneous introduction is given in Table 4. The first line shows the value before the measure implementation, and the last one – after their simultaneous implementation.

Table 4
Water quality criterion at different measures

Measures	Criterion
0	3.182
M_1	3.147
M_2	3.136
M_1+M_2	3.102

Thus, the lowest criterion value and, hence, the best water quality is achieved after implementation of measure M_2 at R_1. Carrying out of measure M_1 at R_2 will improve the ecological situation as well, and what is more, it is much cheaper. Their simultaneous implementation will decrease the criterion to a greater extent than realization of one measure. Hence, in this case the more expensive strategy implying the implementation of both measures is more effective minimizing the criterion value. Nevertheless, when making a decision on implementation of one or another measure one should take into consideration the financial possibilities. Besides, the decrease of any one pollutant can be of critical importance under the decision making. For instance, in our example measure M_2 will add greatly to water quality in total pollutants. However, if we pursue the goal to decrease NH_4 content, then the strategy M_1 would be preferable or a combination of M_1+M_2 should be implemented on condition that sufficient financing is available.

This example demonstrates the attractiveness of the model application to specific conditions of the basin when the efficiency of investments is estimated.

Conclusion

Implementation of DSS "Hydromanager" in water protection in the region can promote the improvement of ecological conditions in the river basin. The availability of such a scheme of water quality control worked out with due regard for specific features of the region allows the investments to be maximum effective for improvement of the environmental situation.

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The water supply problems and the role of innovations in supply of the Altai Krai population with quality drinking water under current economic conditions

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Water with its unique physical and chemical properties has a crucial influence on human life. Indeed, in the advanced countries, the increased water pollution caused by rapid industrial development is sui generic an indicator of the environment state; in poor countries this problem is critical as well because of little attention given to the water treatment problems. The polluted water is a real source of diseases for growing population inhabiting the settlements with limited water consumption.

The role of water sources in the formation of ecological comfort of population has been proved. The delivery of necessary chemical and biological components to a human organism occurs via drinking water and food products. Drinking water provides daily 20% of all vital microelements, vitamins and other components.

One of the major trends in "Altaivodproject" activity is quality standard water supply of rural settlements. To satisfy the demands for drinking and municipal water in Altai Krai, ground waters are used; prospected and affirmed water resources make up 617.2 th m^3/day; of them only 72.2 th m^3/day falls on drinking water. Such a low water development is caused by water inadequacy to sanitary standards (2.1.4.1074-01 "Drinking water. Hygienic requirements to water quality for the centralized drinking water-supply systems. Quality control"). The ground water resources are unevenly distributed within the territory of Altai Krai. For example, 23 administrative regions of Altai Krai have no prospected reserves of ground water, suitable for drinking.

Generally, these are western steppe regions, i.e. Kluchevsky, Baevsky, Yegoryevsky, Rodinsky, Khabarsky with population of 1000 in 14 settlements (23.9 th.people). Here, the absence of the centralized watersupply system is caused by the unavailability of quality drinking water sources, therefore root population has to use the water of 3 g/dm^3 mineralization, with chloride and chloride-sulfate residuals, the increased iron concentration (up to 8 mg/dm^3) and the decreased fluorine content (up to 0.5 mg/dm^3) from the water supply wells. All in all, in 190 Altai villages and settlements with population of 95 th.people the water supply system is not available.

In some regions (Talmensky, Zavyalovsky, Loktevsky) ground waters are contaminated by heavy metals and other components of toxic substances.

In the 70s of the last century, the development and construction of some group conduits (the Charyshsky one with productivity of 170 th. m^3/per day was the largest) to supply the villages with drinking water of high quality were undertaken. At present, the decline in water consumption accompanied by 1 m^3 water net cost increase and water quality deterioration in the end water-supply points is observed. The absence of the Program on rural areas development in Altai Krai, water pumping over vast territories, low performance potential caused by lack of financing, technical equipment and facilities are major factors that made the situation critical.

Moreover, along with the issues of the centralized water supply, the problem of ubiquitous absence of collecting (sewage) systems - that brings to microbiological deterioration of ground water horizons- is still urgent. Insufficient municipal sewage treatment brings to pollution of the surface intake sources, i.e. rivers Alei and Ob.

This clearly demonstrates that the problems of water supply and water intake should be solved jointly.

Another pressing problem is a proper maintenance of sanitary zones around the water supply sources. Nowadays, about 40% of rural intake wells are out of order; being not tamped they cause the underwater pollution.

In general, drinking water quality more or less meets the sanitary standards approximately in 10 regions (Altaisky, Krasnogorsky, Soltonsky, Smolensky, Sovetsky, Soloneshensky and partially Zarinsky).

Bearing in mind the present-day economic situation, to solve the problem of drinking water supply in Altai Krai (mostly in settlements and villages with population of 500-1000 people) is possible by means of special treatment of water in small amounts, intended solely for drinking purposes, since currently the material resources for water treatment are not available.

To optimize economically the ways of water treatment according to demands, all settlements should be divided pro rata the number of residents. To provide water supply in the settlements with population up to 100 persons, the best option is the delivery of drinking water by vehicles; note, such a water will be 1.5-2 as cheaper as a bottled one.

To provide water supply in the settlements with population up to 1 000 residents, it’s reasonable to establish the sites for water intake and portable packages filling, just near the water supply point. Generally, building costs of a treatment station (with 8 m^3/day productivity) doesn’t exceed the ones spent for water tower construction. (1 mln. rbls.)

For settlements with population up to 10 000 it’s advantageous to construct treatment units in the centre of a village powering them from domestic water-pipes and making treatment under the indices of the source water (such an experience does exist in the settlement Stepnoye Ozero). This option is 2-2.5 times as efficient as the standard water supply scheme.

Provision of rural settlements with the sewage systems (especially in settlements where the centralized water supply systems operate already or are to be constructed in the near future) is the essential step towards the improvement of general sanitary and ecological state as well as the prevention of further pollution of the near-surface waters and surface water sources.

The following conclusion suggests itself: to improve water supply, most and foremost, the inventory of rural water-supply systems with further working out the program on perfection of quality water supply in rural settlements should be done.

Undoubtedly, the program under consideration should be a part of the programs on social-economic development of Altai Krai:

- public health;
- social-economic development of villages;
- reforming of housing and communal services;
- slum dwelling elimination, etc.

The problem of financing the “Drinking water” program should be solved at the cost of the program itself and the expense items of the programs mentioned above, since these programs pursue the same goals, i.e. improvement of the population’s well-being, health and gene pool.

The program on water supply improvement elaborated on the basis of the system analysis of current situation with drinking water supply and water resources availability should be focused on working out a set of target activities and the financial resources required for maintenance of water supply systems in workable and proper hygiene and sanitary conditions. Also, the emphasis should be put on further development of public water supply and water intake for the period of 25 years. The legal base must be determined and presented in the program. In addition, the program should have supposedly 3 implementation stages.

The first stage should envisage the restoration and reconstruction of the existing worn water- supply systems and the equipment, the cultivation of cautious attitude of the population towards water as exhaustible sources and the advocacy of ideas on the importance of quality drinking water for human health.

A great stress should be given to the water quality, the introduction of modular and membrane treatment systems and the prospecting the underground water resources, maybe not considerable but meeting the world standards requirements.

In the course of the third program phase, it is proposed to implement further development of the water supply systems and to introduce the “third tap” into the housing communal services, i.e. drinking water treatment by means of nanofiltration membranes. Nowadays, nanofiltration is the most perspective and unique technology applied for drinking water post-treatment. This advanced technology has a great future because of a steady decline in cost of drinking water treatment. In addition, it is an extremely important trend in the research of sewage post-treatment.

These are the prospects for further development of water supply systems in Altai Krai.

Computer simulation of stream processes to increase water intake on Altai Krai rivers

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Abstract. Mathematical modeling of river bed deformation processes is one of the more difficult problems of the river hydraulic. The necessity of such investigations is explained by existence in immediate proximity to the rivers of settlements, communication nets, agricultural lands and other objects of the human activities, including surface water supply points. Among of negative results of the river bed deformations are the redistribution of the river streams, erosion of the river shores, shallowing of the navigable parts of the rivers. In this paper the using of the computer models of the river bed deformation processes is discussed and some results of numerical modeling of such processes on the sites of rivers Ob and Charysh near the water supply points are presented. These data may be use for water management purposes.

Keywords: surface water supply, riverbed deformation model stream processes, water management, computer modeling, Ob river, West Siberia, Altai Krai

Introduction

The efficiency of measures on riverbed regulation and riverbed evolution management to a great extent depends on how these activities correlate with the river regime and how they take into account the riverbed evolution for the specific natural situation. Combination of up-to-date techniques of mathematical modeling with GIS-technologies makes it possible to do thorough investigations of riverbed evolution using the available information (morphological, hydrological, etc.) on specific objects by means of creation of the computer-based model for studying the processes on specific river sections. The computer-based model of riverbed evolution includes a planned model of a river flow, a model of sediment transport and bottom deformation as well as a digital elevation model (DEM) of a river valley section.

The objects and the investigation tasks

The stable water supply of Barnaul city.The problem of safe operation of the Barnaulsky water supply points is caused by the critical geomorphological situation due to the negative riverbed evolution near Barnaul city. Nowadays because of sedimentation processes the water intake point No. 1 is practically out of order. The problem is very serious for the municipal water intake point No. 2 too. If the trend of riverbed evolution on this site of Ob river will be the same, in some years the water intake point No. 2 providing by drinking water the most of the townspeople and industrial enterprises can be found in the accident condition.

Barnaulsky surface water intake point No. 2 is located below of the top of the Verhne-Erestinskay bend (see Fig. 1).

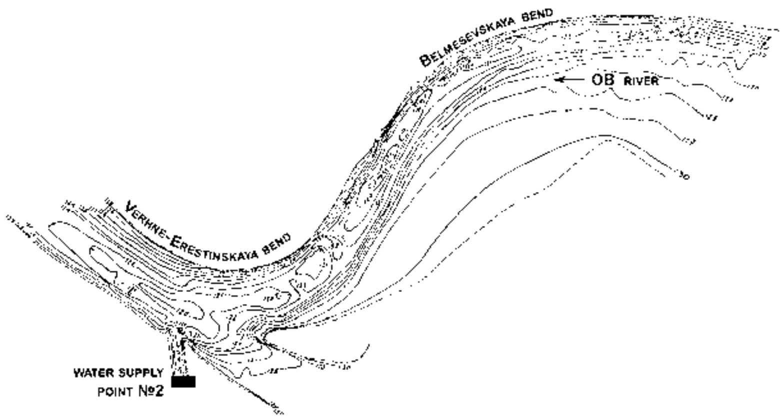

Fig. 1. The riverbed map of the Ob river section near water intake point No. 2. September 2002. The mark of water line is 130.17 m BS

The upper wing of the bend is oriented practically on normal to the left native bank. Dynamic axis of the water stream goes near the left bank only below water supply point and all approaches to water intake point are located in whirlpool zone in where the very intensive sedimentation processes are observed. The sediment accumulation in this zone is negative factor for stability of water supply of the Barnaul city.

The negative hydromorfological situation on the Charysh river. The Charyshsky common water pipe was constructed to supply several regions in the steppe zone of Altai Krai and Aleisk town by drinking water. These regions are short of underground and surface water of good quality. Water wells of the Charyshsky common water pipe are located on the right bank of Charysh river.

When the Charyshsky common water pipe was constructed, the water discharge of the Pravy Charysh near the water wells had 40% of the total discharge of Charysh river in summer-fall low-flow period. In recent years, the Pravy Charysh has been dying off causes the decrease of discharge and water deterioration in the wells of the Charysh common water pipe line.

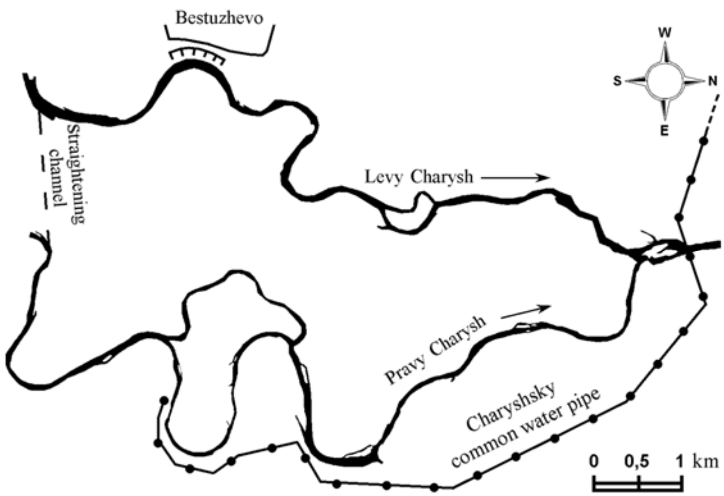

Fig. 2. The scheme of the Charysh river site near Charyshsky common water pipe line

To solve these problems the proposal of the partial runoff diversion from the Levy Charysh to Pravy Charysh along the straightening channel connecting both rivers upstream Bestuzhevo settlement as well as the Pravy Charysh dredging was made (Fig. 2).

To estimate the efficiency of engineering decisions proposed it is necessary to:

- estimate the carrying capacity of the modified Pravy Charysh channel under different discharge;
- estimate possible deformation of the Pravy Charysh channel and its retrogression and silting resistance;
- estimate the resistance of the straightening channel to erosion and silting.

Computer-based models

The computer-based model of riverbed evolution processes on Ob river at the water intake point No. 2 includes a two-dimensional plain model of the river flow, the model of sediment transport and bed deformation, and the digital elevation model (DEM) of the river valley section [Zinoviev et al, 2006]. The calculations show that the model demonstrates correctly the hydraulic effects observed, in particular, the formation of the whirlpool zones and the position of the flow dynamic axis. The values of the river flow velocity are in accordance with the field data too.

Mathematical model of plain flow in the open riverbed. The flow averaged over the depth is considered in the area the configuration of which can change in time, for example, as a result of the water level rise or dropdown. The set of governing equations is the following:

$$
\begin{aligned}
&\frac{\partial hu}{\partial t}+\frac{\partial huu}{\partial x}+\frac{\partial huv}{\partial y}=-ghi_x-gh\frac{\partial(h+\delta)}{\partial x}+\frac{\partial}{\partial t}hK_x\frac{\partial u}{\partial x}+\\
&+\frac{\partial}{\partial y}hK_y\frac{\partial u}{\partial y}+\tau_x-r|\bar{u}|u,\\
&\frac{\partial hv}{\partial t}+\frac{\partial huv}{\partial x}+\frac{\partial hvv}{\partial y}=-ghi_y-gh\frac{\partial(h+\delta)}{\partial y}+\frac{\partial}{\partial x}hK_x\frac{\partial v}{\partial x}+\\
&+\frac{\partial}{\partial y}hK_y\frac{\partial v}{\partial y}+\tau_y-r|\bar{u}|v\\
&\frac{\partial h}{\partial t}+\frac{\partial uh}{\partial x}+\frac{\partial vh}{\partial y}=R_a-I\ ,
\end{aligned}
\tag{1}
$$

where u, v – components of the flow velocity along axes x, y; h – flow depth; τ_x, τ_y - wind stresses ; r – bed friction coefficient; $|\bar{u}|$ - flow velocity module; K_x, K_y – turbulent mixing coefficients; R_a, I – source and sink intensity (i.e. precipitation and evaporation); i_x, i_y , - gentle downstream slopes in directions x, y.

It should be noted that equations (1) have one remarkable feature. Unlike the other well-known plain flow models [Brekhovskikh et al, 2000] these equations do not imply the assumption of small amplitude for water level fluctuations. That gives a possibility to describe such processes as the flood wave propagation along the dry land.

The boundary conditions setting should be defined according to the morphological characteristics of waterway and water exchange. The conditions of non-passing and friction are set at lateral boundaries if $(x, y)\in\Gamma$

$$
K\frac{\partial u_s}{\partial n}=-c_u|\bar{u}|u_s\ ,\ u_n=0\ , \tag{2}
$$

where Γ – area's boundary; n – external normal to the boundary Γ; u_n, u_s – normal and tangent components of the horizontal velocity vector; c_u – bank resistance coefficient. In case of the "open gate" boundaries flow discharges $Q^{(x)}$, $Q^{(y)}$ should be known at the given cross-sections.

$$
hu=Q^{(x)},\ \ hv=Q^{(y)} \tag{3}
$$

or the turbulent flow must be defined:

$$
hK\frac{\partial u}{\partial n}=hK\frac{\partial v}{\partial n}=0\ . \tag{4}
$$

The semi-empirical (k-ε)-model is used to describe the turbulence.

Mathematical model for sediment transport. In order to calculate the riverbed evolution the two-dimensional sediment continuity equation is added to equations (1)-(4):

$$
(1-p)\frac{\partial z}{\partial t}+\frac{\partial Q_x}{\partial x}+\frac{\partial Q_y}{\partial y}=0\ , \tag{5}
$$

where x, y – spatial coordinates; t - time; z –bed elevation; p – sediment porosity; Q_x, Q_y – sediment transport rate components.

The bed shear stress is determined as

$$\tau_b = -\lambda|\bar{u}|\bar{u}, \quad \lambda_b = gn_b^2 h^{-1/3}, \tag{6}$$

in which λ_b – bed friction factor; n_b – overall channel roughness; g – gravity acceleration.

Also, a relationship between the flow parameters and the sediment transport rate should be introduced. In these studies we have used Engelund-Hansen's formula for the total sediment transport rate (suspended load and bed load) [Engelund et al, 1967; Van Rijn, 1989]

$$q = \frac{0.05|\bar{u}|^5}{(s-1)\sqrt{g}\,d_{50}C^3}, \ ([q] = m^2/s), \tag{7}$$

where q – total sediment transport rate; u – depth averaged flow velocity, m/s; $s=\rho_s/\rho$ – sediment specific density (taken 2.65 for the quartz send); ρ_s – sediment density (taken 2650 kg/m^3 for the quartz send); ρ – water density, kg/m^3; g – gravity acceleration, m/s^2; C – overall Chezy coefficient, m$^{0.5}$/s.

Numerical realization. The system of governing equations (1)-(5) is solved numerically using an implicit conservative finite-difference scheme with irregular spatial grid. This approach allows a good numerical stability especially for long simulation time. Various GIS applications and tools have been widely used to prepare digital terrain data for the study sites and to visualize intermediate and final results.

Mathematical model of narrow and long water stream in open riverbed. To describe the hydrological regime of the Charysh site under study a one-dimensional mathematical model based on the equations set for the unsteady flow in the open channel (Saint Venant's equations) was used. The model allows the calculation of mean flow velocity and free water level in particular sites of the watercourse.

System of Saint Venant's equations for this case study is the following [Atavin et al, 1993]:

$$\frac{\partial \omega}{\partial t} + \frac{\partial Q}{\partial x} = q, \tag{8}$$

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}\left(\frac{Q^2}{\omega}\right) + g\omega\left(\frac{\partial z}{\partial x} + \frac{Q|Q|}{K^2}\right) = 0, \tag{9}$$

where ω – cross-section area; Q – water discharge; q – lateral discharge along the axis of flow; z – water surface elevation; K - discharge module; g – gravity acceleration; x – longitudinal coordinate; t – time.

We define ω as $\omega(x,z) = \int_{z_0(x)}^{z} b(x,\xi)d\xi$, where $b(x,\xi)$ is the river width at ξ level in cross-section with x coordinate; $z_0(x)$ is the bottom bed level.

According to upper definitions $i=dz_0/dx$ is the bottom bed slope; $u=Q/\omega$ is the mean velocity over cross-section.

The discharge module is defined as $K = \omega C\sqrt{R}$, where $R=\omega/\chi$ is the hydraulic radius; χ is the wetted perimeter; $C=C(R)$ is the Chezy coefficient approximated by the Manning formula $C=(1/n)\cdot R^{1/6}$.

Boundary and initial conditions for equations (8)-(9) are defined in the following way:

$$Q=Q(t) \text{ at } x=0, \tag{10}$$

$$\partial Q/\partial t + (u+a)\,\partial Q/\partial x = 0 \text{ at } x=L, \tag{11}$$

$$\frac{\partial z}{\partial x} + \frac{Q|Q|}{K^2} = 0 \text{ at } t=0, \tag{12}$$

where $a=(g\cdot\omega/B)^{1/2}$; B is the river width at the water surface elevation.

In branchy systems of free surface streams the conjugation conditions in inner points are defined by the conditions that in inner points the sums of input disharges Q_{in} and output discharges Q_{out} are equal to zero and the levels of free surface coincide with each other.

System of equations (8)-(9) with the boundary and initial conditions (10)-(12) is solved numerically with using the explicit two-step McCormack's scheme.

The plain stream structure necessary for the reliable estimation of the channel resistance to retrogression was worked out with using the M.A.Velikanov's plain section method. To calculate the channel deformation the hydraulic model was supplemented with the equations describing the sediment transport, their balance and deformation of the river-bed level in each single jet.

The essence of the method consists of dividing of the stream on defined number of elementary jets with the same discharges, i.e. $Q = Kq$, where K is the number of jet and q is the discharge of jet.

In the defined cross-section the boundaries of the elementary jets are calculated from the equation:

$$\frac{k}{K}Q = \left(\frac{\sqrt{I}}{n}\right)\cdot\int_0^{y_k} h^{5/3}dy\,, \tag{13}$$

where Q is the total stream discharge; I is the slope of water surface; n is the roughness coefficient; y is the transversal coordinate; $h(y)$ is the depth; K is the total number of elementary jets; k is the current number of elementary jet.

For k jet the mean velocity u_k and the mean depth h_k are defined as

$$u_k = q/w_k, \tag{14}$$

$$h_k = w_k/b_k, \tag{15}$$

where w_k is the square of the alive cross-section of k elementary jet; b_k is the width of k jet.

By connecting the boundaries or centers of the same elementary jet we can build the stream lines of the river flow.

To calculate the riverbed deformations the hydraulic model was added by equations describing transport and balance of sediments and level evolution of river bottom within elementary jets.

The discharge of riverbed forming sediments through the cross-section within k jet q_k is calculated according Engelund-Hansen formula [Englund at al, 1967]:

$$q_k = b_k \frac{0.05 u_k^5}{(s-1)\sqrt{g} d_{50} C^3}, \quad C = \frac{h_k^{1/6}}{n}, \tag{16}$$

where u_k, b_k, h_k are velocity, width and mean depth k jet at cross-section; $s=\rho_s/\rho$ is the specific density of sediments; ρ_s is the sediment density; ρ is the water density; g is the gravity acceleration; d_{50} is the median size of sediments; C is the local Cshazy coefficient.

In this case the total discharge of sediments through the cross-section will be evidently the following:

$$q = \sum_{1}^{K} q_k \ . \tag{17}$$

If we know the sediment discharges through the defined cross-sections we can estimate the mean velocity of riverbed deformations between neighboring cross-sections for each elementary jet on the base of the sediment transport equation [Zinoviev et al, 2007]:

$$\left(\frac{dz}{dt}\right)_{i,i+1} = \frac{q_i - q_{i+1}}{S_{i,i+1}(1-p)}, \tag{18}$$

where q_i and q_{i+1} are the sediment discharges at two neighboring cross-sections i and $i+1$; $S_{i,i+1}$ is the square of riverbed bottom between these cross-sections; p is the porosity coefficient equal 0.4.

To estimate the non-erosion velocities for considered site of the Charysh river and the straigtening channel the V.N. Goncharov’s formula was used:

$$u_н = 1.248\sqrt{g}\left(\frac{d_{50}}{d_{95}}\right)^{0.2} \left(d_{50} + 0.0014\right)^{0.3} \tag{19}$$

where $u_н$ is the non-erosion velocity; h is the depth; d_{50} and d_{95} are the typical diameters of riverbed sediments which were determined with using the averaged grain-size composition curve.

THE RESULTS OF NUMERICAL SIMULATION

The results for Ob river. On Fig. 3 the digital depth map of the site of Ob river (a) with resolution 10 x 10 m is presented. The water discharge value Q=1320 m^3/s agrees with the fall one. The maximal river depth on the considered river site equals 11.2 m. Here the fragment of the computation net (b) is shown too.

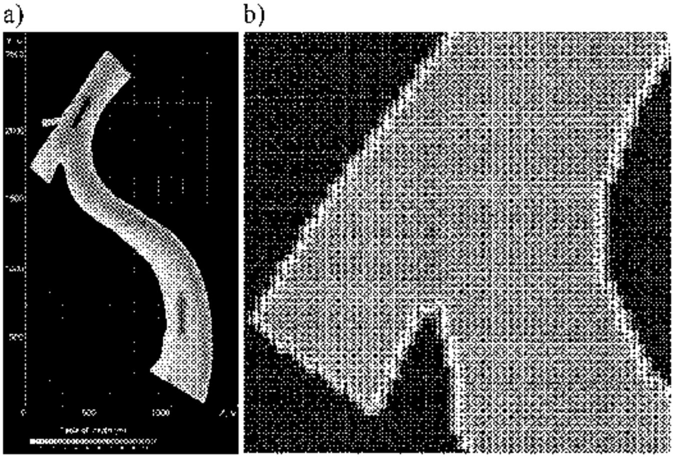

Fig. 3. The depth map of Ob river near the water intake point N 2 (a) and the fragment of computation net (b)

The results of the numerical modeling of the stream structure under discharge Q=1320 m^3/s are presented on the Fig. 4.

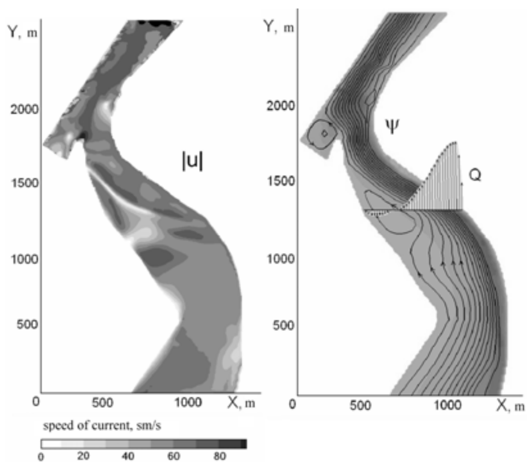

Fig. 4. The field of the stream velocities (|u|) and the stream functions (Ψ) on the part of Ob river nearby water intake point No. 2. Q=1320 m^3/s

As can see on Fig. 4 the computer-based model correctly reproduces hydraulic effects mentioned above in particular the forming of whirlpool zone at water supply point and the location of dynamic axis of water stream. Quantitative values of the calculated velocities are also in according with field data.

If the comprehensive data on the composition of the bed forming sediments and the sediment discharge on the upper boundary of the site under study are available the model will make it possible to get the detailed picture of the sediment transport and local bed deformation under different hydrological situations at the municipal water supply points.

The results for Charysh river. For validation of computer-based model reproducing riverbed processes in the right arm (Pravy Charysh) of Charysh river near Charyshsky common water pipe the numerical calculations of the hydraulic regime were fulfilled. The water discharge was equal 115 m^3/s. The observed morphometric data for definition of riverbed geometry were used. The calculations showed the calculated surface water level doesn't exceed bank lines. It correlates with observed data.

As mentioned above the principle solution of stable functioning of Cshryshsky water pipe must be based on increasing of water discharge in the right arm of Charysh river.

Thereto the complex of hydrotechnical measures must be realized. It includes the building of bottom-deepen slip with width 20 m along the site of right arm (Pravy Charysh) and straighting channel between two arms (see Fig. 2). The building of this channel will provide the transfer of additional water quantity from the left arm (Levy Charysh) to the right one.

The fulfilled calculations have confirmed a new geometry of riverbed of the right arm will give a opportunity to pass the water discharges within 200 m^3/s. With using the numerical modeling were specified the straighting channel parameters for which water discharge capacity of the channel will be 60 m^3/s. The calculations showed that channel reconstruction of the right arm will diminish the vertical riverbed deformations. When the straightening channel resistance to erosion and silting was estimated, it was found that under the assumed discharge the average flow velocity was lower than the non-eroding one for mean characteristics of the bed forming sediments.

Conclusions

The results presented above shows computer-based models developed can be not only successfully applied to assess riverbed dynamics in a variety of hydraulic and morphological conditions near water supply points. Besides, the models can be used to assess the efficiency of engineering activities for elimination of negative hydrological situations. The using of these models may be very useful for scientific support of the water management solutions.

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Integrated water resources mangement in the Jordan Rift Valley, Palestine

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Abstract. The Lower Jordan River Valley is a place of extreme water scarcity and constitutes an overexploited closed river basin. There is no surface runoff leaving the area and the water level of the Dead Sea as the final sink has already dropped in fifty years by more than 20 m as a result. The only means of introducing new, usable volumes of water to the area are water imports or reduction of evapotranspiration. Wastewater reuse and desalinisation will increase the amount of usable water but not affect the water balance in total. Increasing the amount of managed aquifer recharge (MAR) would be beneficial to the water availability of the region by reducing evapotranspiration. Dams and reservoirs which have been installed at the outlet of major wadis provide additional groundwater recharge but are characterised by high evaporation losses and progressive silting. Due to fast hydraulic reactions and short residence time of contaminants in the aquifer system, karstic aquifers are particularly vulnerable to contamination. Careful site selection must take place. At this point, major targets for managed aquifer recharge schemes could be the alluvial fan aquifers on both sides as well the carbonate aquifers west of the groundwater divide to the desert basin.

Keywords: water resources, Palestine, artificial recharge, managed aquifer recharge

1. Introduction and study area

Integrated Water resources management includes all water resources of the Lower Jordan River, namely ground water, waste water, saline water, and flood water into an integrated management concept. These issues are explored with a series of test sites along both sides of the Jordan valley. Test sites are planned for infiltration of reclaimed wastewater, infiltration of water from flash floods, infiltration of urban surface runoff and irrigation of agricultural area with treated sewage. The test sites are embedded into several water balance studies and finally, a numerical groundwater flow model will be constructed for the entire Lower Jordan Valley. Information is integrated into a decision support framework (DSS). The DSS is based on the DPSIR approach (Drivers, Pressures, State, Impact, Response).

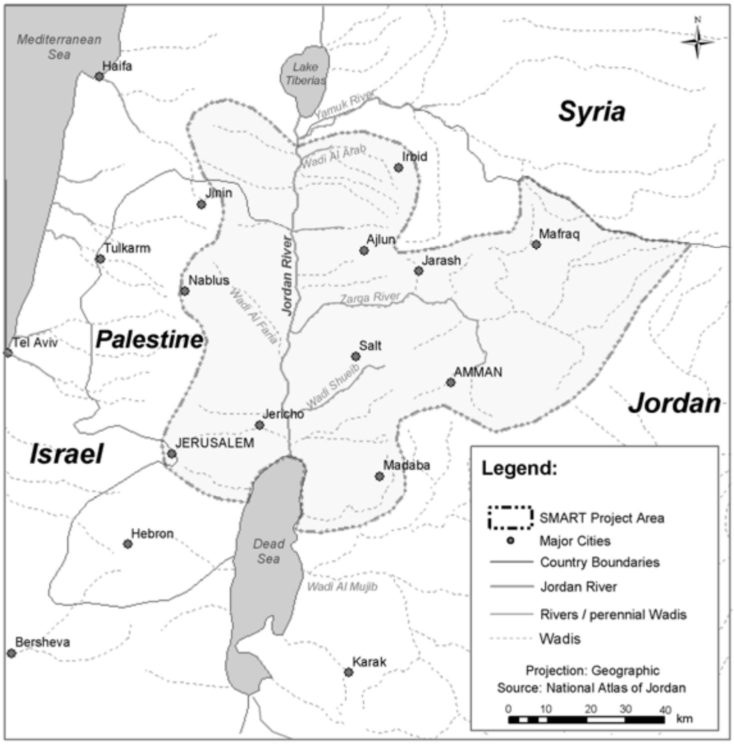
The investigation area covers the Lower Jordan River Valley and reaches from the southern shores of the Sea of Galilee (Lake Tiberias) down to the northern part of the Dead Sea (Fig. 1a). It comprises an area of about 8000 km^2. The dominating tectonic element of the Jordan River Valley is the Dead Sea Transform (DST) a segment of the East African – Red Sea Rift System. At the northern shores of the Dead Sea the valley floor is at ca. -400 m below sea level whereas the surrounding highlands reach on average 800 m above sea level. The Jordan River flows along the valley from Lake Tiberias in the north to the Dead Sea in the south. The waters of the Jordan River are an extremely important resource to the dry lands of the area and are a bone of contention between Lebanon, Syria, Jordan, Israel and the Palestinians.

2. Water resources status in the Lower Jordan River Basin (LJRB)

2.1. General situation in a closed basin

The study area constitutes a closed river basin with a pronounced water deficit. A progressive closure of the basin means in this case that almost no water is left to be mobilized and used while demand, notably in urban areas, keeps increasing (Venot, Molle et al., 2006). Figure 1b lists the key elements in the anthropogenic modified water cycle of the LJRB. The final sinks of water in the LJRB are evaporation and water exports, there is no surplus water running to the open sea. The area is characterised by severe water scarcity. Figure 2 shows the Schematic Hydrogelogical Profile of the Lower Jordan Valley. Aquifers are seriously overexploited and groundwater levels have been dropping during the last decades. As a result, the surface area of the sea has already shrunk by one-third, springs around the sea are drying up and sinkholes (areas of severe land subsidence) are forming, threatening historical sites and infrastructure.

Water quality of surface water is deteriorating due both due to reduction in natural flow volumes but also due to the many known and unknown releases of sewage into surface water. The situation is pronounced at the Lower Jordan River, whose waters were also historically more saline than the waters north of the Sea of Galilee (Like Tiberias) and of lower quality (Nissenbaum, 1969 in Farber et al., 2005). While flows of untreated wastewater in the wadis obviously constitute a pollution hazard, they still provide an augmentation of the Lower Jordan River baseflow.



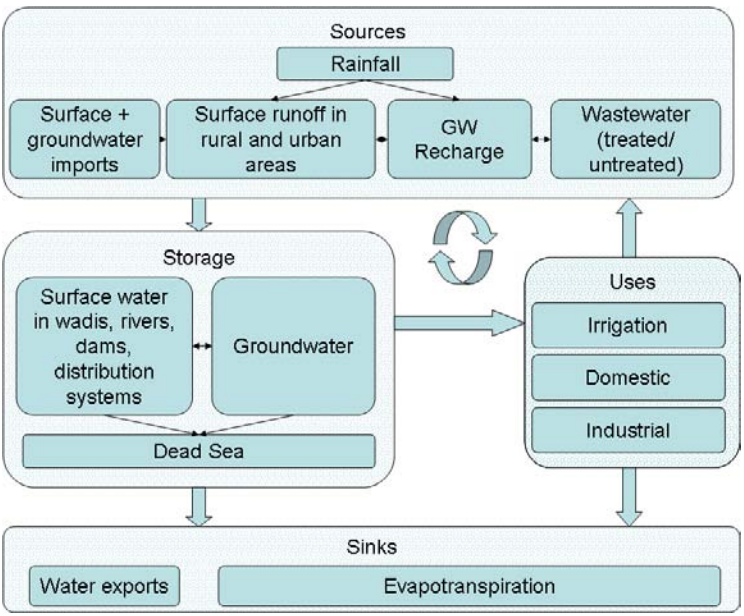


Fig. 1. (a) Surface watershed of the Lower Jordan River Basin excluding Syrian parts;
(b) Key elements of the water cycle in a closed river basin: the case of the lower Jordan River

2.2. Groundwater

As groundwater is the major source of drinking water in the Lower Jordan River basin, hydrogeological aspects exert a dominant influence on the water management. Especially on the west bank, groundwater is the most important source of fresh water supply in the area. The tectonically and sedimentologically complex setting in the LJRB produces a large number of local and regional aquifers. While major lithostratigraphic units were mapped in the region, hydrodynamic connections between aquifers and the borders of subsurface drainage basins are still a research topic. The various local aquifers may be grouped into three major aquifer systems:

1. Tertiary-Quaternary Shallow Aquifer System: Alluvial aquifers are present at the floor of the Jordan Valley and the fans of the incoming wadis, where the alluvium is in contact with the aquifers of Upper Cretaceous age (Ailjun series). The alluvial aquifer extends from the northern shore of the Dead Sea in the south to the downstream part of the Yarmouk River in the north. The thickness of the alluvium in the Jordan Valley varies from zero along the eastern boundary to about 750 m in the deepest part of the basin near the Jordan River. An average thickness of 400 m may be reasonable for the purpose of hydrological considerations (The Hashemite Kingdom of Jordan, 2004). On the western side of the Jordan Valley, the term Shallow Aquifer Hydraulic Complex is used. It comprises Pleistocene sedimentary and alluvial deposits of the Quaternary age which receive localized annual recharge from wadi flows. The extent to which this aquifer is recharged from lower aquifers has not been determined and may be a function of faulting and fracturing.

2. Upper Cretaceous Limestone Aquifer System: On the western side of the Jordan, the aquifer system is known as the Judea Group (or also as Cretaceous Hydraulic Complex) and also here it is subdivided in at least an upper and a lower aquifer system. In terms of extracted volumes, this is the most important aquifer system in the region. It receives the major part of the groundwater recharge in the area, occurring mainly in the high mountain regions on both sides.

3. Ram-Zarqa-Kurnub Aquifer System: The Kurnub Group is of Lower Cretaceous age. It consists mainly of sandstone. For the movement of groundwater the intergranular porosity of the sandstones is of minor importance, because most of the intergranular space is filled with siliceous cement.

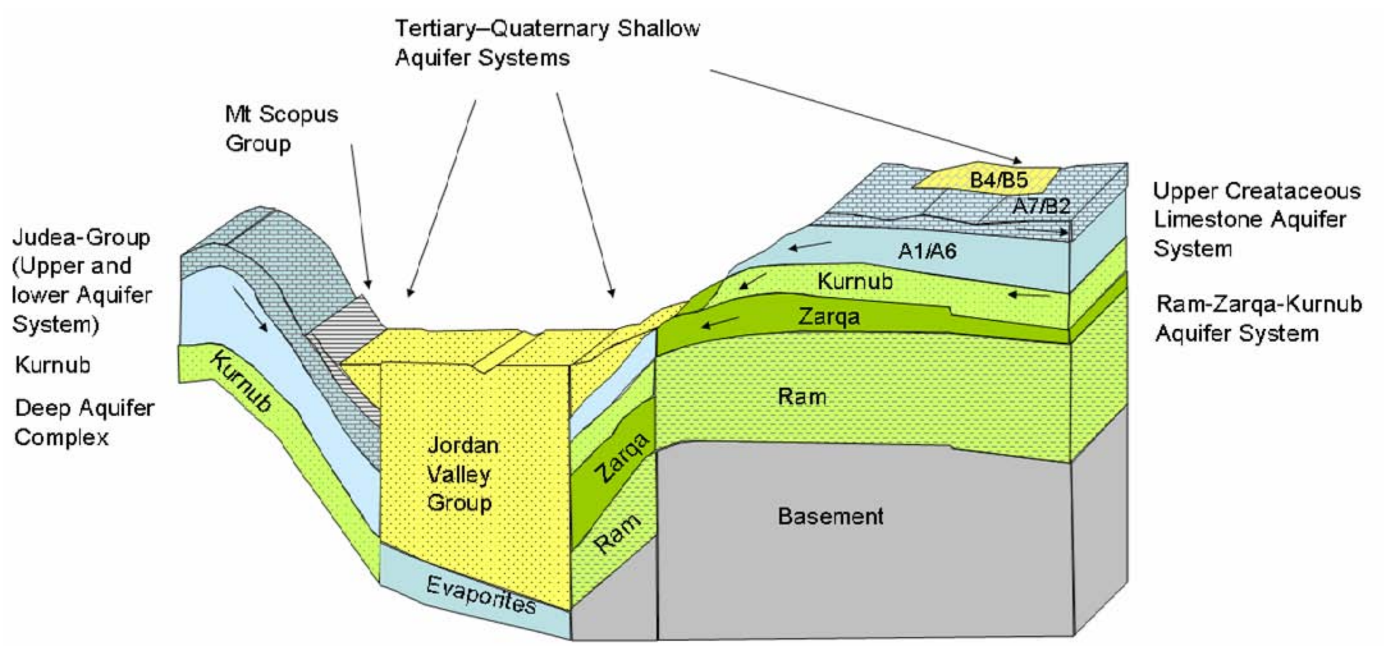


Fig 2. Schematic Hydrogelogical Profile of the Lower Jordan Valley. Assembled from various sources (Salameh and Udluft, 1985; USGS, 1998; The Hashemite Kingdom of Jordan, 2004; Sauter, 2006)

3. Introduction to MAR

Managed aquifer recharge (MAR) encompasses a whole suite of internationally used terms such as rainwater harvesting or artificial recharge. MAR describes intentional storage and treatment of water in aquifers. The term ‘artificial recharge’ has also been used to describe this, but adverse connotations of ‘artificial’, in a society where community participation in water resources management is becoming more prevalent, suggested that it was time for a new name. Managed recharge is intentional as opposed to the effects of land clearing, irrigation, and installing water mains where recharge increases are incidental (Gale, 2005). Figure 3 shows the basic types for MAR but the actual implementation of schemes is varying widely with different concepts in many cultures. Typical goals of managed aquifer recharge perceived in the region are (i) maintain and increase the natural groundwater as an economic resource. (ii) avoid further salinization and salt water intrusion (iii) decrease losses due to evaporation (iv) create a seasonal water storage (v) provide treatment and storage for reclaimed wastewater for subsequent reuse). Table illustrates the methodologies for Managed Aquifer Recharge and their applications in the Jower Jordan River Basin.

While there is more than a millennium of experiences of using rainwater and surface runoff in rural areas by various forms of rainwater harvesting, the use of treated wastewater is young in comparison. Nowadays intentional replenishment of aquifers by highly treated reclaimed waters is increasingly being practised in developed countries with the full support of communities, and health and environment regulators, for aquifers that are under stress through imbalances between rates of extraction and natural recharge (Dillon, Toze et al., 2004; Dillon and Jimenez in press). With strong population growth in many urban centres and reduction of agricultural water demand by use of innovative irrigation technologies, the need to set up more sustainable urban water systems becomes obvious.

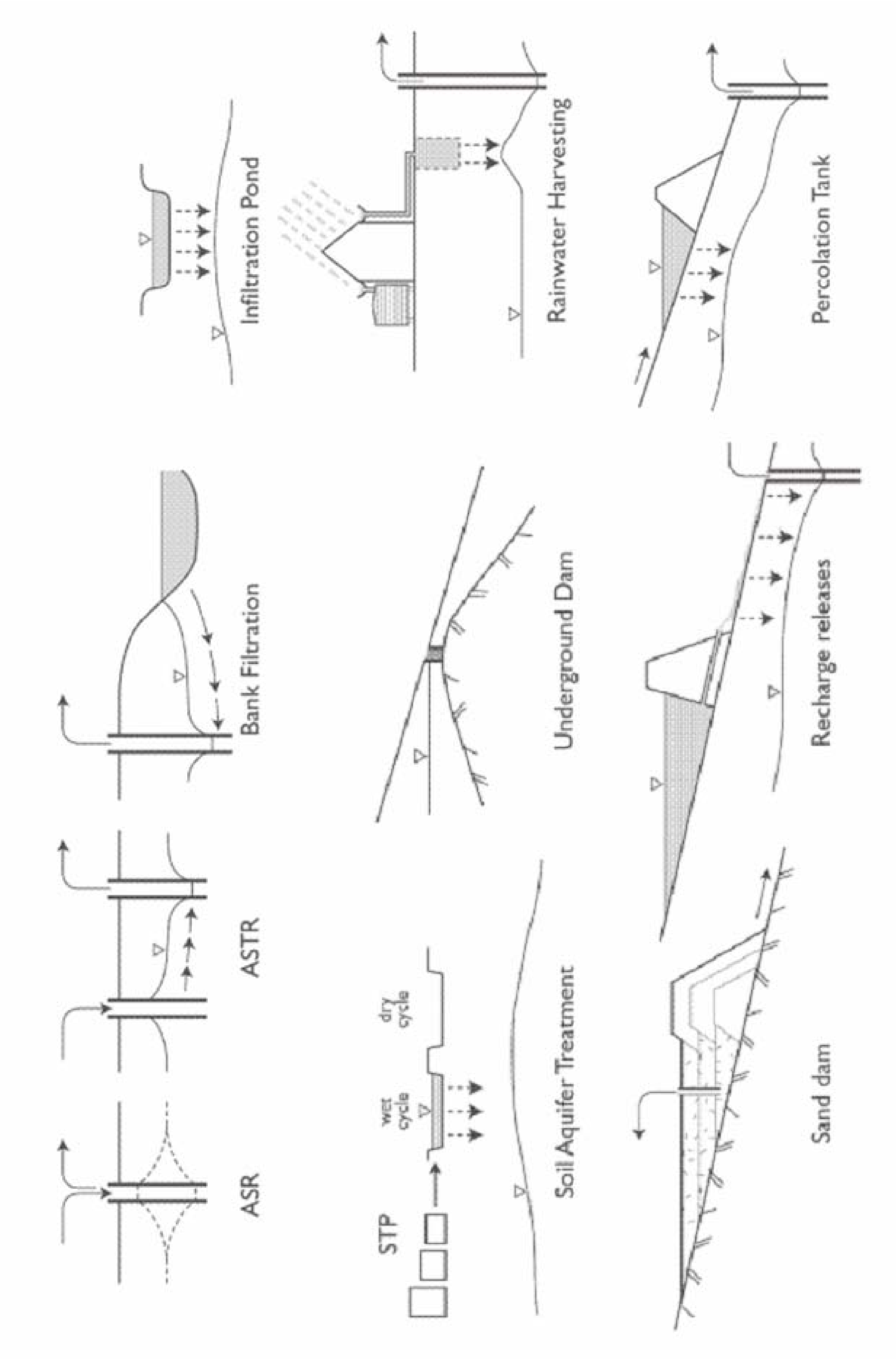


Fig. 3. Schematic of types of management of aquifer recharge (Dillon, 2005). Abbreviations: ASR=Aquifer Storage & Recovery, ASTR=Aquifer, Storage, Transfer & Recovery, STP = Sewage Treatment Plant

Table
Methodologies for Managed Aquifer Recharge (Gale, 2005)
and their applications in the Jower Jordan River Basin

General methodologies for MAR		Application in the LJRB
Spreading methods	Infiltration ponds and basins	
	Soil Aquifer Treatment	Israel (Dan region)
	Controlled flooding	
	Incidential recharge from irrigation	Jordan, Palestine, Israel
In-channel modifications	Percolation ponds behind check-dams, gabions, etc.	Jordan, Israel
	Sand storage dams	
	Subsurface dams	
	Leaky dams and recharge releases	Jordan, Israel
Well, shaft and borehole recharge	Open wells and shafts	
	Aquifer storage and recovery (ASR)	
	Aquifer storage, treatment and recovery (ASTR)	Israel
Induced bank filtration	Bank filtration	
	Inter/-dune filtration	
Rainwater harvesting	Field bunds, agricultural ponds	Jordan, Palestine, Israel
	Roof-top rainwater harvesting	Jordan, Palestine, Israel

4. MAR examples in Palestine

Rainwater collection and storage schemes are traditionally carried out in Jordan and continued especially in rural villages. One of the techniques involves the filling of excavations close to wadi beds with a clay liner at the bottom, coarse rocks in the middle and a cover at the top.

Due to the ongoing, unfavourable political situation in Palestine, there has been little scope for the construction of artificial recharge sites in the last decades. Current systems centre on rainwater harvesting, looking back upon long tradition and experience. Within the local context, managed aquifer recharge examples are grouped under the section “non conventional technologies”. Popular methods are (i) covered, underground reservoirs (locally called wells or cisterns) or (ii) pools made from earth or steel, covered with black plastic sheets to prevent algae growth (Carlo and Ghanem, 2007). The cisterns supply an estimated 6.6 mcm per year within the WestBank. Cisterns serve an essential purpose, meeting water needs left unfulfilled by the devastated infrastructure. In most cases, cisterns collect water from rooftops during the rainy season, which is then stored in subsurface containers, usually ranging in size from 60-100 cubic meters. A large percentage of water collected in cisterns is used for domestic purposes. Tankers are also used to fill cisterns, especially in the summer months when the cisterns dry up due to the lack of rainfall (Shehabadeen and Ghanem, 2007).

While these systems are effective in storing rainwater and securing the water supply during dry times, they are not recharging the groundwater directly. A direct recharge, however, is achieved through the numerous retaining walls on the agricultural fields. The retaining walls hinder surface runoff and enforce downward infiltration of water.

Incidential recharge occurs from a significant number of cesspits, but is associated with high nutrient and contaminant loads.

5. Summary and conclusion

In general, the overexploitation of all aquifers in the region calls for recharge enhancement. Even without a recovery of the injected water close to the recharge site, a major environmental benefit will be achieved. Aquifers with high transmissivities are available close to the surface and successful examples are already implemented in the region. Mixing of injected water with saline groundwater bodies has proved to be low in international case studies. Beyond the hydrogeological constraints also the source of recharge water, the proximity to this source, the quality of the source and the availability of the source water has to be evaluated. Within the LJRB, both surface runoff and wastewater are available as sources. While significant amount of wastewater is produced in the urban areas, it is as far as possible used for irrigation following treatment. However, only a between 50% and 80% of the population are already served by sewerage systems.

The alluvial fan aquifers at the inlets of the wadis to the Jordan valley offer a good potential for MAR due to their hydraulic conductivity, the gentle gradients and the long retention time. A major concern for the alluvial aquifers in the Jordan Valley is the mixing of the recharged water with saline groundwater. However, international studies have demonstrated that the mixing can be very low due to the slow groundwater movement and that efficient recovery is possible (Pavelic, Dillon et al., 2006). The Upper Cretaceous limestone aquifer system offers ample storage space but its use must be planned carefully due to the many fast discharge options via springs.

Planning for MAR must take the local circumstances into account, such as the strong seasonality of rainfall, and high intensity peak rain events which require large reservoirs to provide temporal storage for runoff during flash floods. High technology options like ASR require significant experience in set-up and maintenance, especially with regard to the prevention of clogging and may not be suitable at this point. Furthermore, surface runoff from urban areas may be strongly polluted as no effective source control measures are currently in place.

This review showed that a considerable potential in the lower Jordan River basin for managed aquifer recharge exists. However, MAR is not yet identified as a major goal in the national water master planning. Currently the main focus is on water demand management, water supply management and institutional reforms (Taha and Magiera, 2006). Considering the currently limited depth of this review of MAR activities in the Lower Jordan River basin, it is essential to increase the coverage by incorporating more of the locally available grey literature. In order to unlock the potential for MAR in the region, a series of background and feasibility studies on the following topics are recommended:

- Increase of groundwater recharge from reservoir structures by removal/disturbance of low permeability reservoir sediments.
- Artificial recharge from open reservoirs into alluvial fan aquifers.
- Use of urban surface runoff for groundwater recharge.
- Holistic urban water balances and construction of sustainable water systems in the fast growing urban areas.
- Quantification of the impact of MAR in terms of evaporation prevention.
- Cost-benefit analysis of MAR within the IWRM framework under the consideration that all the recharged water volumes (irrespective of the recovery possibilities on spot) are effectively adding up to the total water availability in the Jordan River basin.

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Water supply problems in the City of Perm

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Providing the population of Russia with drinking water is one of the priority problems to solve for health protection, better working conditions, and higher living standard. It has been a spike of ecological catastrophes lately in this country, obstructing reliable and quality uninterrupted water supply (Vladivostok, Saratov, etc.). This unfavourable situation can be explained by used water supply systems, which have been in operation since the time of the Soviet Union without sufficient investment into support and development; it is also due to the fact that operators and municipalities have been paid little attention to the issues of providing quality life support.

The City of Perm is a regional center with a population of 1 000 000 people consuming 420 000 m^3 of drinking water daily. What is significant for water supply in Perm is that water is abstracted from several artificial surface sources or water reservoirs. The water for the city supply is treated at three water treatment plants (Fig. 1).

The Chusovaya Water Treatment Plant (CWTP) is the major facility providing drinking water for over 75 % of the city population. Its melting period throughput is 305 000 m^3/day, and normal throughput is up to 375 000 m^3/day. CWTP is located upstream of Perm, and water is abstracted from the Chusovaya reach of the Kama Reservoir.

The Bolshekamsky Water Treatment Plant (BWTP) is the oldest works commissioned in 1938. The source of water is the Votkinskoye Reservoir (the Kama River). The melting period throughput is 110 000 m^3/day, and normal throughput is up to 90 000 m^3/day. BWTP is located downstream of the Kama hydropower plant dam. Its water mass originates mainly from the Kama Reservoir.

The Kirovsky District Filtering Station (KDFS) is the only city treatment plant located on the right bank of the Kama River. KDFS supplies water to a relatively small number of water consumers and its throughput is 15 000-20 000 m^3/day.

Currently, there are also 7 water wells within the city boundaries, which are located in different town districts. The total throughput of these artesian wells is not greater than 1 300 m^3/day.

A criterion of any harmful chemical substance level is its maximum allowable concentration or MAC; in case of its violation water is not suitable for one or more applications in terms of water use. Water quality has been determined according to the fish industry standards.

For the raw water quality analysis we have used the data of FGU Kamvodexpluatatsiya, a federal agency providing water quality control in the water abstraction areas. The chemical composition of water has been evaluated on the basis of extreme values of the chemical elements for the years 2003-2006. Water sampling was performed against the water abstractions along the navigation pass of the water reservoirs.

The stream conditions in the water reservoirs depend on flow regulation. The Kama Reservoir provides for seasonal regulation, so the water level is controlled by the hydropower plant operation with preset phases: (1) spring filling (V-VI), (2) summer-autumn water level stabilization (VII-XI), and (3) winter drawdown (XII-IV). From each hydrological period, we have chosen typical levels of maximum and minimum portions of elements with regard to the MAC values. The characteristics allow performing a space-time analysis of quality water supply limitation in the City of Perm.

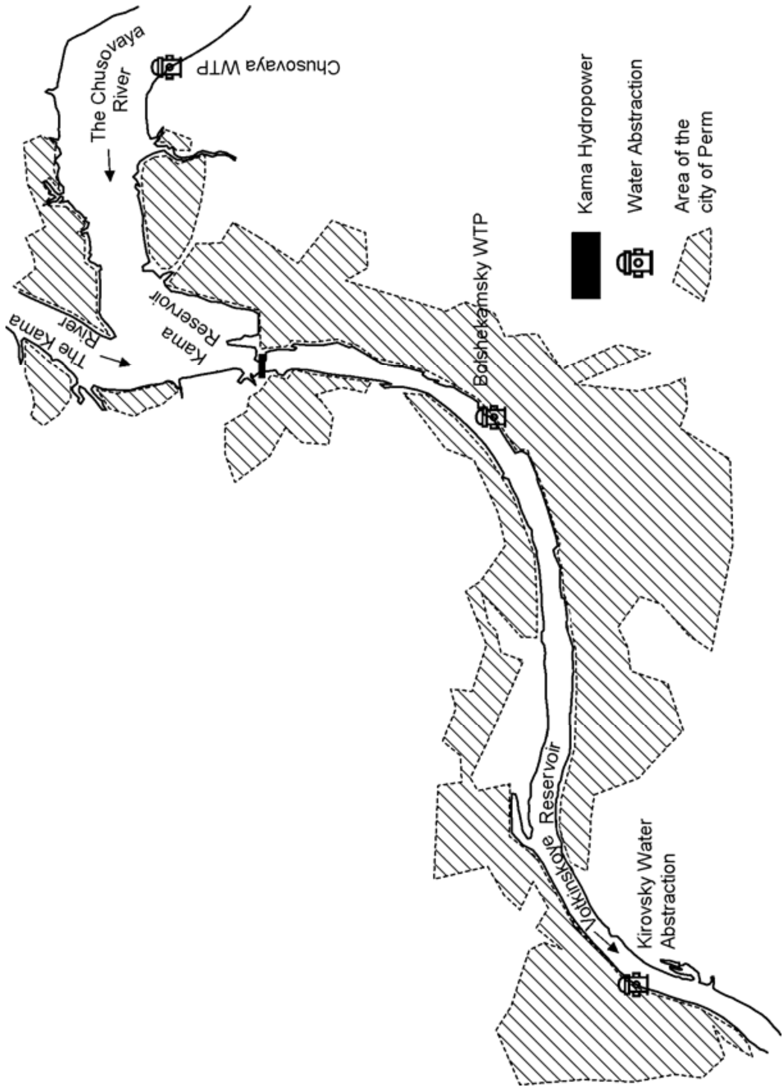


Fig. 1. Water Abstraction Layout in the City of Perm

Mineralization. The major water inflow to the Kama Reservoir is due to regulated flow of the Kama and Chusovaya Rivers. The water chemical composition of the Votkinskoeye Reservoir is influenced by natural factors (water from the upstream reservoir), operation of businesses, and activities of the local population.

The water of the Chusovaya, Bolshekamsky, and Kirovsky Water Abstractions (WA) differs in terms of mineralization and basic ion content as follows:

1. Water specific conductance (σ) of the Chusovaya WA is within 200-500 μS/cm in the filling period, 300-650 μS/cm during summer-autumn level stabilization, and 250-700 μS/cm (maximum level) during winter drawdown. At the Bolshekamsky and Kirovsky WAs the values are 90-120, 250-500, and 450-700 μS/cm, respectively.
2. The solid residual is higher at the Chusovaya WA during spring and summer (up to 0.5 MAC) with 0.3 MAC at the Votkinskoye Reservoir WAs. In winter the water amount is low resulting in larger solid residual up to 0.6 MAC at the Chusovaya and Bolshekamsky WAs and 0.9 MAC at the Kirovsky WA.
3. The level of hydrocarbonates (HCO3-) is different depending on the water content periods and defined by natural factors. The ion level at the Chusovaya WA is 50-140 mg/l with a maximum value of 170 mg/l during winter drawdown. Downstream of the Kama power plant dam this value lowers to 10-40 mg/l during the filling period, goes up to 20-100 mg/l during water level stabilization, and reaches its maximum in winter low water (60-140 mg/l).
4. The WA sulphate level is similar to the one of hydrocarbonates: minimum in spring – 50-170 mg/l at the Chusovaya WA, 20-30 mg/l at the Bolshekamsky WA, and 20-50 mg/l at the Kirovsky WA; SO42- is higher during the summer-autumn period – up to 70-400 mg/l, 10-100 mg/l, and 40-130 mg/l, respectively; maximum SO42- level in winter – 50-180 mg/l upstream of the town and 60-120 mg/l in the town. The sulphates are above the MAC values at all WAs during the summer-autumn and winter periods. The Chusovaya River natural background with high level of the SO42- ions causes high concentration of the element during the spring filling at the Chusovaya WA.
5. Most chlorides come from the waters of the Kama Reservoir and industrial wastewater of Perm City. The chloride is the main component of the water reservoir chemistry in winter. In spring the level of chlorides is low (5-10 mg/l); during the summer-autumn period it goes up to 10-50 mg/l at the Chusovaya WA and up to 5-20 and 20-70 mg/l at the Bolshekamsky and Kirovsky WAs, respectively. The maximum level of chlorine ions has been noted in winter – up to 80 mg/l at the Chusovaya WA and up to 200 mg/l within the boundaries of Perm City.
6. The Kama Reservoir water has a low content of calcium, which does not exceed the MAC value. In spring Ca2+ has a minimum level of up to 30 mg/l at the Chusovaya WA and up to 70 mg/l at the Bolshekamsky and Kirovsky WAs. During the summer-autumn period it rises up to 90 and 60 mg/l, respectively.

It reaches its maximum during winter drawdown – 40-120 mg/l at the Chusovaya WA and 50-90 mg/l at the Bolshekamsky and Kirovsky WAs.

The *biogenic matter* level varies significantly as follows:

1. In different seasons at the Perm WAs the concentration of ammonium nitrogen ranges from 0.1 to 3.5 MAC. At the Chusovaya WA it reaches its maximum of

1.5 MAC during winter drawdown when the water volume is the least. During other seasons the content can vary within 0.1-1.0 MAC. The water mass in the Votkinskoye Reservoir is greatly influenced by industrial contaminants. During the filling period the NH_4^+ MAC value is 1.3-2.4 at the Bolshekamsky WA and 1.6-3.6 at the Kirovsky WA, which is also connected with the Kama water drawdown and a low water level in the Votkinskoye Reservoir. During stabilization of the water level the nitrogen content does not exceed the MAC value. The winter drawdown period is unfavourable, since the NH_4^+ level is within 1.4-2.9 MAC.

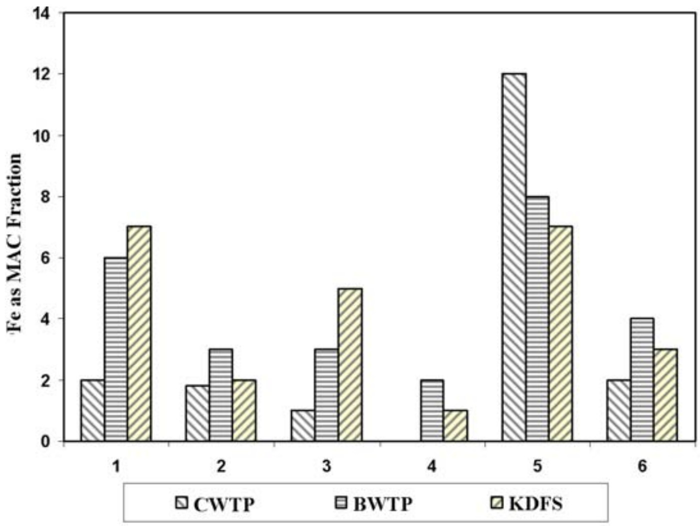
2. The level of other biogenic substances – NO_2^-, NO_3^-, and P – is within 0.0-0.3 MAC. Any specific reduction/grow trends along the WAs or in different seasons have been not traced.

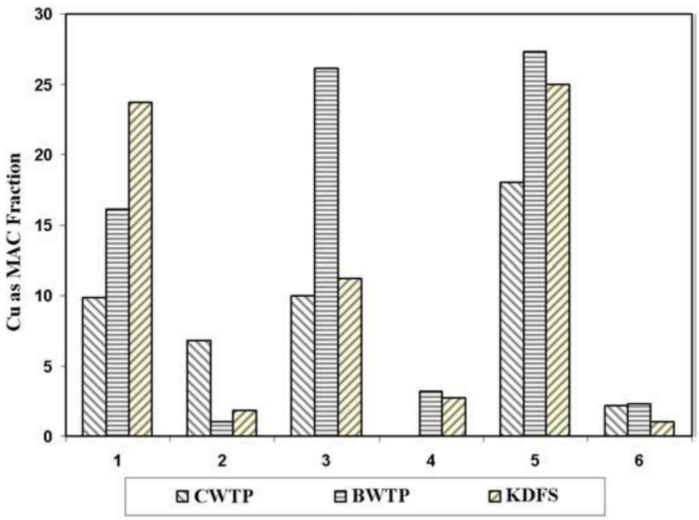
The levels of most microelements described constitute a hydrological risk for the water users by reason of high concentrations and violation of the MAC values.

1. Fe varies within 0-12 MAC (Fig. 2). During the filling period it grows from 2.0 at the Chusovaya WA up to 7.0 at the Kirovsky WA. A similar picture can be observed during the stabilization period: growth from 1.0 to 5.0 MAC. The highest level is typical for the winter period with 12 MAC at the Chusovaya WA down to 3-7 MAC at the Kirovsky WA.
2. Cu is also much higher than the MAC value (Fig. 2): from 10 MAC at the Chusovaya WA to 24 MAC at the Kirovsky WA in spring; 26 MAC at the Bolshekamsky WA and 10-11 MAC at the other WAs in summer and autumn. In winter its concentration grows up to 18 MAC at the Chusovaya WA and 27-25 MAC at the Bolshekamsky and Kirovsky WAs.
3. During the spring filling period the level of manganese grows along the WA sites from 0-5 MAC at the Chusovaya WA up to 5-13 at the Kirovsky WA. (Fig. 2). In summer it is 1-6 and 3-18 MAC, respectively. During the low water stand the Mn concentration varies significantly from 7-18 MAC at the first WA, to 12-33 MAC at the second WA, and up to 5-37 MAC at the third WA. It highly depends on operation of local factories. During winter drawdown the Mn level in the basin water reaches its maximum, for the water dilution process slows down significantly.
4. Pb belongs to heavy microelements and has a negative impact on living organisms. Observations have shown its low level, not exceeding the MAC value (up to 0.1 MAC), with one exception of a higher concentration at the Bolshekamsky WA during the navigation period due to water vessels (up to 0.5 MAC in spring and 1.0 MAC in summer).

The gas conditions generally define the evaluation of biota in reservoirs. The oxygen conditions are formed under the influence of a series of positive (wind-and-water-induced mixing, flowage, etc.) and negative (industrial contamination, water bloom, etc.) factors. Their interaction determines favourable water saturation with oxygen during the open channel period (8-10 mg/l in spring, 9-11 mg/l in summer and autumn) and its significant shortage during freeze-up (4-7 mg/l). The worse conditions are in the areas of industrial pollution. At the Chusovaya WA the oxygen level is within 0.5-0.9 MAC with minimum values in winter. The city impact is noted at the Bolshekamsky and Kirovsky WAs: 0.6-0.7 MAC during the reservoir filling period, 0.5-1.2 MAC in summer and autumn (especially when bacteria and algae are most active), and 0.5-1.3 MAC in winter.

Among other indicators of the gas conditions are the biochemical oxygen demand (BOD) and chemical oxygen demand (COD). Both characteristics indicate the conversion process of elements coming into reservoirs, especially of the biogenic ones. The BOD and COD levels differ markedly along the WA areas and in different seasons. In spring the BOD maximum is typical for the Bolshekamsky WA – 2 MAC with 0.5 MAC at other WAs. The BOD fraction of MAC grows from 1 to 2.5 and goes down to 1.5 along the city WAs. During the water level stabilization period BOD decreases from 1.2 MAC at the Chusovaya WA to 0.6 MAC at the Kirovsky WA. COD' behaviour is different: it rises from 2 to 2.5 MAC and goes down again to 2 MAC at the third WA. BOD behaviour in winter is similar: reduction from 1.1 to 0.5 MAC with increasing COD from 2.3 to 2.5 and then up to 2.6 MAC.





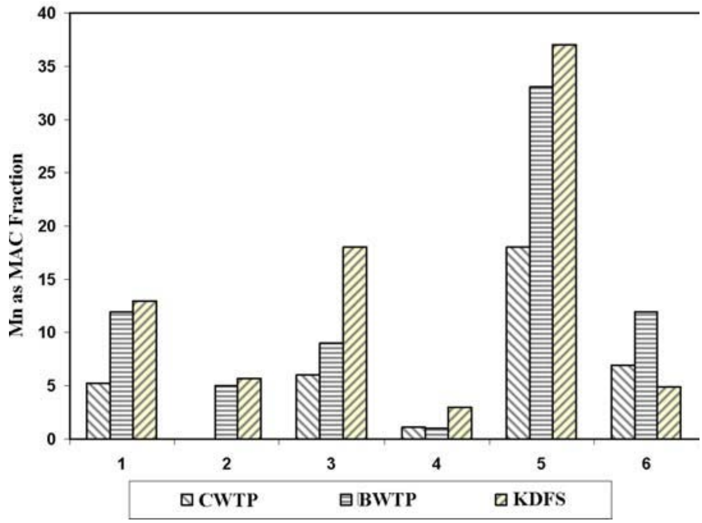


Fig. 2. Concentration of the elements at the WA points in terms of the water regime phases in MAC fractions (1 and 2 – maximum and minimum concentrations during filling; 3 and 4 – maximum and minimum concentrations during water level stabilization; 5 and 6 – maximum and minimum concentrations during drawdown)

The following is typical for the Perm WAs:

1. High element content when the water level is close to the lowest operating one. Such conditions are typical for late winter right before ice movement, as well as for the beginning of filling the reservoir in spring.
2. Among the biogenic elements, exceeding MAC is typical for NH4+ in all water regime phases, especially in spring (up to 3.6 MAC) and winter (2.9 MAC). This situation is determined by a low water mass volume of the reservoir resulting in poor self-cleaning ability.
3. The level of all elements significantly exceeds MAC, especially during the winter drawdown period.
4. The level of dissolved oxygen in the reservoir is low both in winter (while freezing up) and in summer (during algae bloom), i.e. 4.6 and 5.0 mg/dm3 or 1.3 and 1.2 MAC, respectively. At the same time the BOD and COD are up to 1.9 and 2.6 MAC, respectively.
5. The percentage of non-standard samples taken from the drinking water sources in Perm is 40% in terms of the sanitary and chemical performance and 15% as for microbiological parameters.

Alongside with current condition of the water sources described above, the city water supply system has multiple problems itself. They are primarily connected with peculiarities of the megapolis' geographical situation, including its 60-kilometre spread along the Kama River and location on both banks, as well as with the lack of an explicit development plan since the 1970s. This resulted in localized infrastructure development and uneven load on the water supply system. Consequently, today's water supply problems are as follows: low water quality for users, high leakage, low head of water in remote areas, unstable water supply during peak consumption and the melting period, absence of water reserves, low regulating capacity of the water tanks, extensive water supply zones, impossibility of reducing pressures in the network, technical and economic evaluation of current measures pertaining to rehabilitation and new construction.

However the main risk is connected with the water supply organisational plan. The major city WAs, the Bolshekamsky and Chusovaya, are located on the left bank of the Kama Reservoir, while the right-side water supply is provided through the inverted siphon laid on the bottom of the reservoir. Currently, water is supplied to the right bank through a single line with the other one under rehabilitation. So the water supply is not reliable enough. Moreover, life of the Bolshekamsky water works supplying water to the down town has almost run out for highly deteriorated and obsolete equipment.

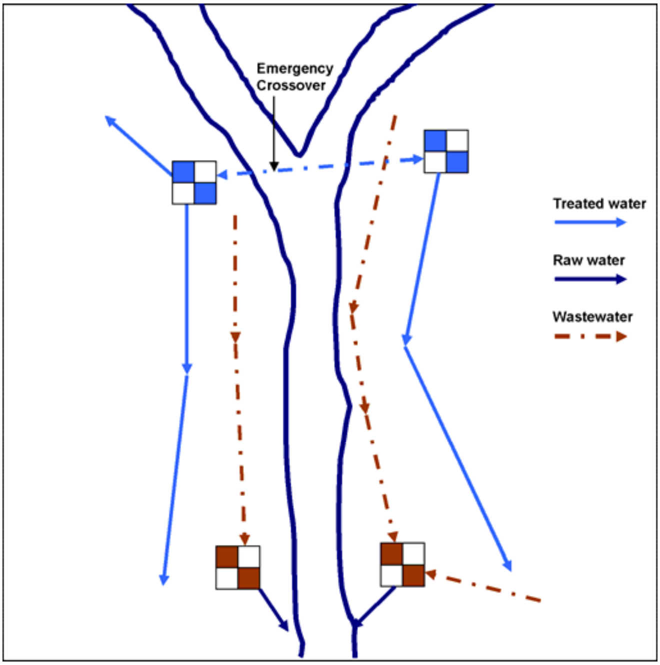


Fig. 3. Assumptive Plan of the Perm City Wastewater System

Any local measures would not help. The best solution is total system rearrangement providing two independent water supply systems on the right and left banks of the river.

Drinking water supply through the river is to be eliminated due to construction of a new right-bank water treatment plant in the Kama Reservoir water pool. The inverted siphon will be used as an emergency crossover between two separate water supplies located on different river banks. The obsolete Kirovsky and Bolshekamsky WAs are supposed to be abandoned.

On the one hand, such measures will allow avoiding the above situations and, on the other hand, they will improve the quality of water supplied to the system, for construction of a new treatment plant will enable to use up-to-date and effective methods of water treatment.

For Notes

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