AASSA REGIONAL WORKSHOP PROCEEDINGS

SUSTAINABLE MANAGEMENT OF WATER RESOURCES AND CONSERVATION OF MOUNTAIN LAKE ECOSYSTEMS OF ASIAN COUNTRIES

Edited by
Prof. Hang-Sik Shin
Dr. Marine Nalbandyan

June 25-29, 2014

Yerevan 2014

Editors: Prof. Hang-Sik Shin and Dr. Marine Nalbandyan
Compilation by Marine Nalbandyan and Armine Avetisyan

Sustainable management of water resources and conservation of mountain lake ecosystems of Asian countries. Proceedings of AASSA Regional Workshop/ Compilation by M. Nalbandyan and Armine Avetisyan; Institute of Geological Sciences of the National Academy of Sciences of the Republic of Armenia, Yerevan, 2014, 140 p.

The proceedings present papers from countries of the Asian region. The main focus is on the strategies and approaches of water resources management, sustainable management of transboundary waters and ecosystem protection of rivers and mountain lakes. The problems of water quality management and rational use of water resources in the context of climate change are also discussed.

All papers are edited.

Color version of the proceedings is available on the web site of
IGS NAS of RA:

www.geology.am

Table of Contents

MANAGEMENT STRATEGIES FOR WATER RESOURCES IN KOREA
Prof. Dr. Hang-Sik Shin ………………………………...………………5

THE EFFECT OF AGRICULTURAL WATER RESOURCES DEVELOPMENT ON ECOLOGICAL SUSTAINABILITY AND DESICCATION OF LAKE UROMIYEH IN IRAN
Dr. Amin Alizadeh ……………………………………….…………12

SOURCE ASSESSMENT FOR CATCHMENT-BASED WATER MANAGEMENT UNDER THE EUROPEAN UNION WATER FRAMEWORK DIRECTIVE
Dr. Ho-Sik Chon ……………………………………………………… 18

INTRODUCING THE EUROPEAN UNION WATER FRAMEWORK DIRECTIVE IN ARMENIA: DEBED RIVER BASIN CASE STUDY
Lusine Taslakyan ……………………………..……………………. 27

MODELING OF *Ca, Mg, Na* CONTENT IN WATER AS A TOOL FOR WATER AND SOIL CONTAMINATION MANAGEMENT AND SUSTAINABLE DEVELOPMENT IN AGRICULTURAL AREA
M.A. Nalbandyan, N.A. Ajabyan ……………………………………. 38

WATER RESOURCES OF EASTERN GEORGIA
Dr. Vakhtang Geladze, Dr. Nana Bolashvili, Dr. Tamaz Karalashvili, Dr. Nana Machavariani, Dr. Res. Nino Chikhradze, Dr. David Kartvelishvili ……………………………………………..……..…47

THE ASSESSMENT OF IMPACT OF LARGE DEEP RESERVOIRS CONSTRUCTION ON WATER QUALITY OF SIBERIAN RIVERS (EVENK RESERVOIR AS A CASE STUDY)
Prof. Dr. Yuri I. Vinokurov, Dr. Alexander T. Zinoviev, Yana E. Kuznyak……………………………………………………..………. 55

GIS FOR STATE WATER CADASTRE OF ARMENIA: CONTENTS, STRUCTURE, FUNCTIONS
Arshavir Avagyan, Hayk Yeritsian, Arayik Mkrtumyan, Aleksandr Arakelyan, Hasmik Manandyan, Anna Elbakyan, David Vardanyan, Artak Piloyan ………………………………………………………… 65

INTEGRATED STUDIES OF LAKETELETSKOYE FOR ITS CONSERVATION AND SUSTAINABLE USE (ALTAI, RUSSIA)
Prof. Dr. Yuri I. Vinokurov, Dr. Alexander T. Zinoviev, Dr. Elena Yu. Mitrofanova ………………………..…………………………76

THE PRINCIPLES OF GUIDELINE FOR THE RIVER BASIN MANAGEMENT PLANNING IN ARMENIA
Arshavir Avagyan, Alexander Arakelyan, Hayk Yeritsian, Arayik Mkrtumyan, Hasmik Manandyan, Anna Elbakyan, Artak Piloyan 87

INFLUENCE OF LAKE SEVAN CATCHMENT BASIN PHYTOPLANKTON COMMUNITY STRUCTURE ON THE SAME OF THE LAKE
PhD Hovsepyan A.A., PhD Khachikyan T.G., PhD Hambaryan L.R………………………………………………………………….102

ICE CONDITIONS OF THE SYRDARYA RIVER
Darya Fedorova ……………………………………………………113

THE CHANGE OF WATER RESOURCES IN LAKE SEVAN IN THE CONTEXT OF CLIMATE CHANGE RENEWED SCENARIOS
Dr. Levon Vardanyan, Dr. Levon Azizyan, Ph.D student Yelizaveta Yeroyan, Master Armine Danielyan 123

THE ASSESSMENT OF ECOLOGICAL STATE OF THE RIVERS OF GEORGIA, FLOWING IN THE BLACK SEA
M. Kvinikadze, V. Kirakocian, G. Todradze, N. Loria, N. Janashvili, S. Jalagania, L. Akhalbedashvili ……………………………….…129

MANAGEMENT STRATEGIES FOR WATER RESOURCES IN KOREA

Prof. Dr. Hang-Sik Shin[1]

[1]KAIST, **KOREA**

ABSTRACT

Water is one of the most important factors for economic and social development of human environment while it also has a basic function in maintaining the integrity of the natural environment. However, vast differences of water availability and supply variability from region to region due to seasonal, topographical and geological reasons have urged to develop the tailored Integrated Water Resources Management (IWRM) program to the individual circumstances of country and local region.

In Korea, the annual average precipitation is around 1,300 mm, about 1.3 times larger than the global average of 973 mm. However, per capita precipitation is 2,705m^3/year, which is 12 percent less than world's average (22,096m^3/year) due to high density of population of Korea. As consequences, Korea has been classified as a water stress country, ranked No.146 among180 countries in available water per capita as reported by the United Nations. In addition, even worse, concentrated precipitation in summer (70% of annual precipitation) and topographical limitations (rainfall loss to ocean) have affected the development of water resource management programs in Korea. In this study, therefore, Korea's integrated water resources program including mid- and long-term water supply plan, technology developments for water resources and water resources management policies and actions will be addressed.

Keywords: Water resources, Management strategy, Policy

INTRODUCTION

The Korean peninsula, about 1,300 km long and 300 km wide, is located in the northeastern region of the Asian Continent. The eastern coastline of the peninsula runs directly along the skirt of thesteep mountain slope range, while the southern and western coastlines are met by wide alluvial plains [1]. Usually, rivers running to the eastern coast are short in length and steep in channel slope. While long stretching rivers with mild gradient such as the Han River, the Nakdong River, and the Geum River discharge to the southern or western coasts.

South Korea is in the temperate zone of medium latitude, having four distinct seasons (spring, summer, fall, and winter). Under the influence of the cold continental anticyclone, winter is bitter cold and dry. In summer, however, it is hot and humid due to the North Pacific anticyclone. The average temperature throughout the year is 10~16°C except in the central mountainous area. The hottest month of year is August with 23~27°C; the coldest month is January with -6~ -7°C. Annual precipitation is 1,100~1,400 mm in the central part, and 1,000~1,800 mm in the southern, with two-thirds of the annual precipitation occurring only in the rainy summer season. On the other hand, the amount of precipitation is very low in winter and spring.
The annual average runoff is 73.1 billion m^3, which constitutes 57% of the annual average precipitation of 127.6 billion m^3. The runoff ratio of 57% is somewhat large value. Relatively topographic characteristics of Korea such as smaller basin area and steep slopes when compared to the Unites States or the countries in Europe, and short length of rivers and heavy rainfalls in Korea cause large discharge in a short period. The monthly average runoff of June to September, as with precipitation shown in Fig.1, constitutes 2/3 of the annual volume. Unlike overseas rivers, the flow of rivers in Korea is unstable due to large seasonal variations inprecipitation and discharge. The coefficient of river regime of the Han River, before major dams were constructed, was 1:300, which is relatively larger than the Thames in Britain (1:8), the Rhine in Germany (1:18), and the Seine in France (1:34) [2].

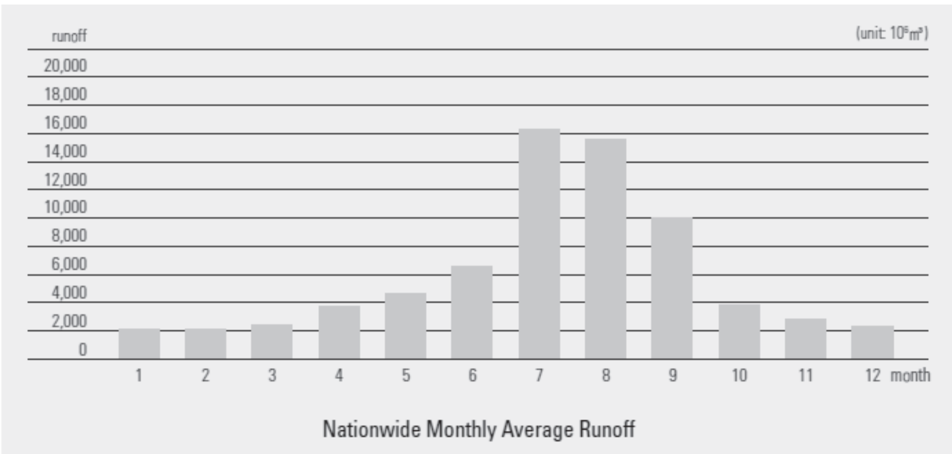


Fig. 1. National monthly average runoff

The amount of water demand has been predicted to be gradually increased around 0.2% every year until 2020. In 2020, 6.5 times larger amount of total water will be needed than that of last 40 years and 32 times larger amount for domestic water use as shown in Fig.2. Thus, to cope with future water crisis, water resource management programs have been developed by government.

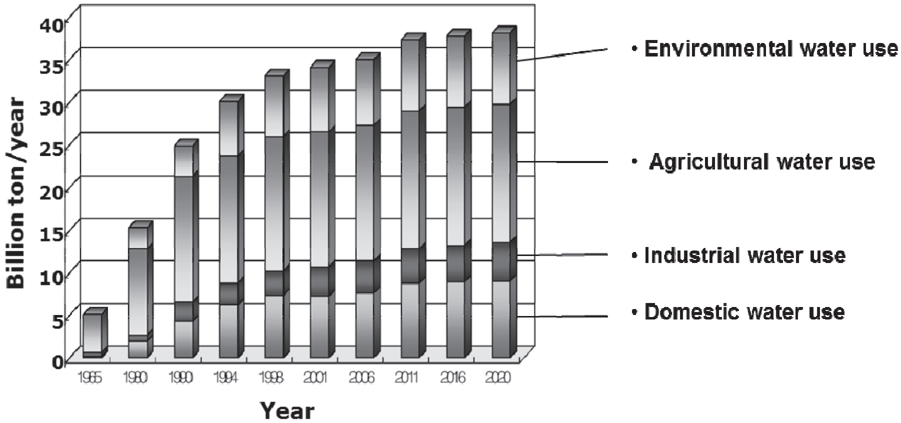


Fig. 2. Total water use in Korea

COMPREHENSIVE PLANS FOR WATER RESOURCES

To cope with future water shortage as shown in Fig.3, long term management plans including water saving and demand-control plans, construction of dams and desalination plant have been developed.

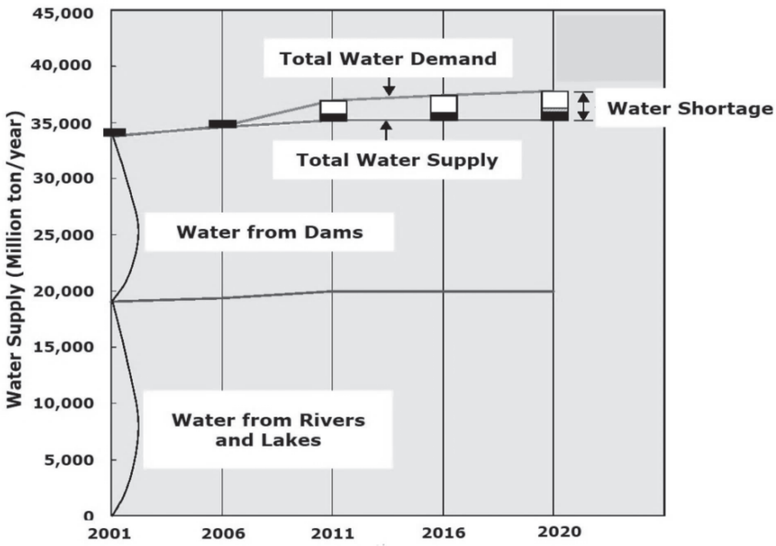


Fig. 3. Prediction of water shortage in 2020

For the domestic and industrial water use management, water reuse had been replaced up to 0.8% of the domestic water at 2006 and exfiltration ratio of pipe line was decreased from 17% at 2005 to 12 % at 2011. Through those managements, 1.33 billion ton/year of water assumes to be saved by 2020 as shown in Fig. 4. In addition, in order to enhance the water storage capability, constructions of multi-purpose dam and dams for hydraulic power have been considered coupled with construction of desalination plants for water supply in rural area and island.

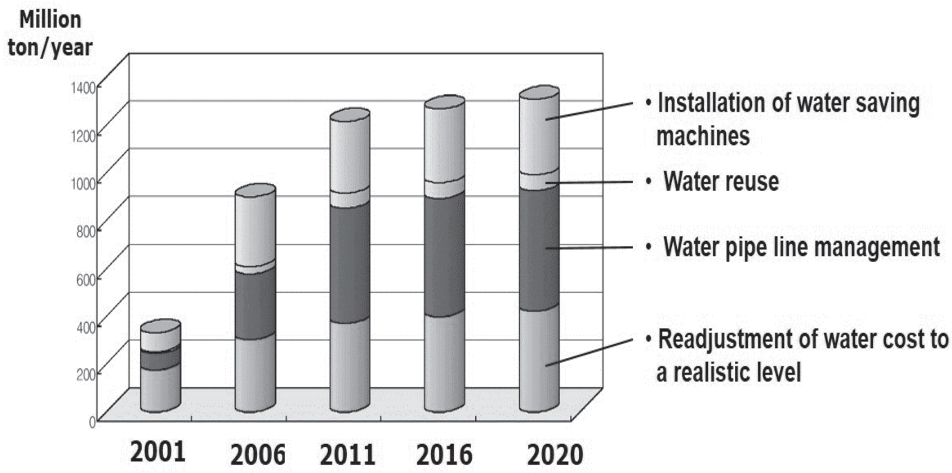


Fig. 4. Water saving plan by 2020

POLICIES AND EFFORTS FOR WATER RESOURCES

The national policies towards better water resource management are based on three principles: Improving the soundness and reliability in water use, building up social infrastructures to cope with floods, and forming river environments to be harmonized with the nature (MOCT, 2000) [3]. The agenda for the sound and reliable water use include: 1) Water demand management, 2) efficient water use and water quality improvement, 3) new water resources development to ensure reliability of water supply,and 4) capacity building for drought mitigation. The agenda for the flood control programs are: 1) Adopting basin-scaled integrated flood management plans replacing traditional river maintenance plans; 2) reducing the flood hazards and flood damage potentials; 3) promoting sustainable flood control projects; 4) reforming institutional structures and building up the capacities for better flood controls. As shown in Fig. 5, aforementioned national policies have been reflected in the water actions in Korea into several laws and long-term water resource management plans to achieve the sound water use and restoring the safe and friendly water environments.

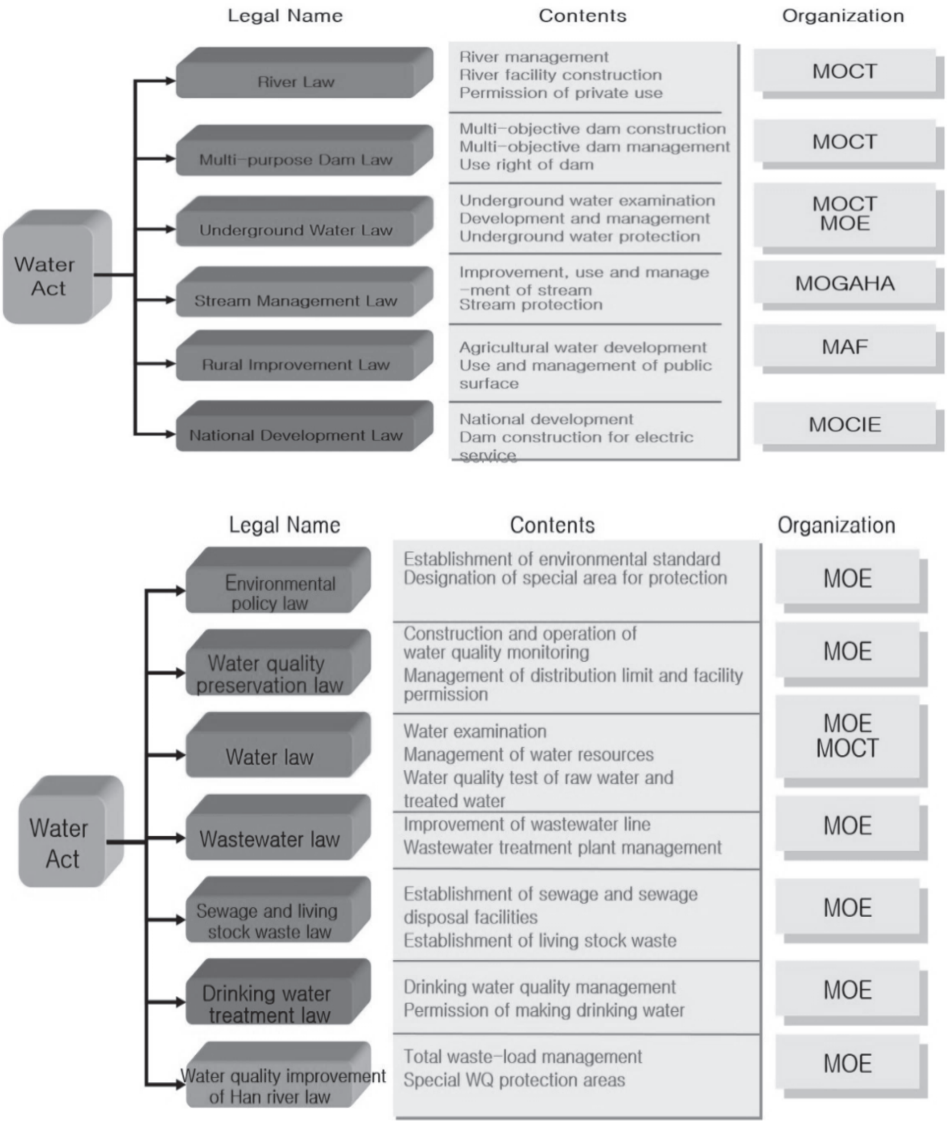


Fig. 5. Water actions in Korea

* MOCT: Ministry of Construction and Transportation, MOGAHA: Ministry of Governmental Administration and Home Affair, MOE: Ministry of Environment, MOMAF: Ministry of Maritime Affairs and Fisheries, KOWACO: Korea Water Resource Corporation

REFERENCES

[1] Water resources in Korea 2006. Ministry of Construction and Transportation, Republic of Korea

[2] Seung Woo Park. The sustainable utilization of water resources for a bio-productive environment and the role of agro-environmental education in Korea.vol.1, pp. 6-16. 2006

[3] Ministry of Construction and Transportation (MOCT), 2000. Water vision 2020. pp. 697.

THE EFFECT OF AGRICULTURAL WATER RESOURCES DEVELOPMENT ON ECOLOGICAL SUSTAINABILITY AND DESICCATION OF LAKE UROMIYEH IN IRAN

Dr. Amin Alizadeh
Associate Member of Iran Academy of Sciences
Professor of Water Science and engineering
Ferdowsi University of Mashhad, **Iran**

ABSTRACT

Lake Uromiyeh is a large shallow, hypersaline Lake at the north-western end of Iran. In 1995 the average depth of the water at this lake was 19 meter with a water surface area of 6500 sq. km. However, during the last 10 years, the Lake has desiccated significantly in such a way that at the year of 2012 the average depth of the lake became less than 3.0 meter and its water surface area shrank to less than 2300 sq. km. Due to over pumping water from the surrounding aquifers, salt intrusion into the aquifers of agricultural plains and the accumulation of slats due to blowing dusts on the surface of agricultural lands have profoundly affected the social and economical life of the people who are living in the region. Many factors are blamed to be responsible for this detrimental happening. However, it seems that agricultural and water resources developments that have been implemented around the Lake Uromiyeh may be most important factor for this phenomenon. Because of these developments the area of cultivation around the Lake has increased from 280,000 Ha in 1990 to 450,000 Ha in 2013. Consequently, water use for agriculture has also increased from 1.8 BCM/yr to 5.6 BCM/yr respectively. Since all the water which are used for agriculture is either supplied from the aquifers around the Lake or diverting from the rivers ending the Lake, hydrological parameters, as well as the ecology of the lake, is no more balanced. In this paper a perspective of the recent developments in the field of agriculture and water resourced which have been implemented in the Lake Uromiyeh basin is presented. The effect of these developments on ecological sustainability of this lake is also discussed. Finally to overcoming the social and ecological problems, some suggestions and recommendations are presented.

Keywords: Agricultural development, Desiccation, Lake Uromiyeh, Salt intrusion, Sustainability.

INTRODUCTION

Lake Uromiyeh with its several islands is located at the northwestern corner of Iran **(Figure 1)**. This lake, with hypersaline water is one of the largest lakes in the world. As a matter of fact it is the largest in the whole Middle East [1] Lake Uromiyeh is the twentieth large lake of the word and the third largest saline water lake on the earth. North-South length of this lake during the time of high water level is more than 140 km and its East-West width is 85 km [2]. Lake Uromiyeh and its surrounded wetlands have deep cultural, social, and economical bonds with the people of the region. It is estimated that 75 million people live within 500 km around the lake [3].

Fig. 1. Lake Uromiyeh location

This Lake also possesses environmental functions at national and international levels. Because of its great scenic beauty, Lake Uromiyeh has a high ecological value. It is believed among the people of Iran that the Lakeside mud has medicinal properties for bone and skin diseases. Lake Uromiyeh is considered to be a valuable piece of Gem for the country of Iran which attracts millions of visitors each year from all over the country. The Lake is protected as a national park and was declared a Wetland of International Importance by the Ramsar Convention in 1971. It has also been designated by UNESCO as a Biosphere Reserve in 1976 [4]. Lake Uromiyeh is the home to some 212 species of migratory birds including ducks, flamingos, pelicans and etc [5]. It is the home to 41 species of reptiles, 7 amphibians and 27 species of mammals too. The Lake itself is also the home to a unique salt water shrimp species, *Artemia uramiana.* This macro-zooplankton is the link in the food chain of the Lake, consuming algae and in turn consumed by migratory birds [5, 6].

ORO-HYDROGRAPHY OF LAKE UROMIYEH

Lake Oromiyeh is the dead end of a 5000 sq.km mountainous drainage system. Therefore the governing factor of the hydrographic of this lake is its lack of an outlet. This means that water should leaves the lake only by evaporation. Unexpectedly another way for leaving water has also occurred during the last years and it is the intrusion of saline water into the aquifers around the Lake. Based upon the weather condition, evaporation from the surface of the lake varies between 1000 to 2100 mm per year. Through the history of the Lake, high evaporation and incoming salt from the surrounding aquifers have caused the Lake to be very salty. The Lake is one-fourth as salty as Dead Sea, with salt content of 30 percent or 300 g/L which is 8 times as salty as sea water [7]. Because of the high salinity, Lake Uromiyeh does not support any fish or plants except some macro zooplankton like *Artemia uramiana*. However, in 2012, salt concentration of the Lake reached up to 550 g/L which threatens the life of this tolerant species too. Average annual precipitation on the lake is estimated to be 350 mm which is not enough to compensate its surface evaporation. Therefore, most of the water needed for supporting ecological sustainability of the lake should be supplied from the rivers ending to it. Although there are 14 rivers ending the lake, but the most important of them are Siminehrood and Zarrinehrood. Other rivers are either small or seasonal. On the average these rivers discharge 5300 MCM/yr into the Lake which makes the hydrology of the Lake to become balanced. Surface area of the Lake depends on the level of water. Its maximum level was recorded in 1995 which was 1287 meter above sea level. At that time average depth of the water was 19 meter, and its area was 6500 sq. km. The level of water was also recorded in 2009 which was 1271 MASL which was 14 meters less than that of 1995. At this time, the average depth of water was only 3.3 meter, and the Lake had a surface area of 2700 sq.km. At the year of 2012, average depth of the lake was estimated to be

3.0 meter with a water surface area of 2300 sq. km. Long term average level of water surface, during the last 45 years, has been recorded to be 1275 MASL and the average depth of water has been 7.5 meter.

DESICCATION OF LAKE UROMIYEH

Both measurement and surveying by satellite altimeter data show that during the last decade the surface area of Lake Uromiyeh is rapidly declining [5]. Many reasons, including climate change and drought, have been raised to be responsible for the rapid desiccation of the Lake. Since the average precipitation on the basin has not been changed significantly, therefore, drought should not be accounted for more than 10 percent of the Lake desiccation. Also any climate change in the region has not been proved yet. Comparison the status of Lake Uromiyeh with neighboring lakes, like Lake Van in Turkey or Lake Sevan, show that climate change, even if it has taken place, may not be the cause.

AGRICULTURAL AND WATER RESOURCES DEVELOPMENT

It seems that the recent agricultural and water resources development around the Lake may be more elucidate. Population within the Lake Uromiyeh basin is one the main driving force for increasing use of water resources. Because the predominant people's activity in the Lake Uromiyeh basin is agriculture, the area of cultivation has increased from 280,000 Ha in 1990 to up to 450,000 Ha in 2013. This shows an increase of 280 percent. Therefore, annual water use for agriculture has increased from 1.8 BCM/yr to 5.6 BCM/yr. All the water needed for agriculture is either supplied from the aquifers around the Lake or diverting from the rivers ending the Lake. Almost some 80,000 deep wells are dug around the Lake during the last 10 to 15 years. All these wells are in operation at now. Over pumping water from the aquifers by the wells has caused lowering the ground water level in such a way that at present situation Lake itself is discharging water to them. Almost 90% of all extracted water from groundwater resources is by wells and are used for agriculture. During the last three decades, 40 dams have been built on the rivers ending the Lake, 12 dams are also under construction and 28 other dam projects are under study. Supplied water from new dams may bring another 225,000 Ha of lands under cultivation. Besides the increase of cropping density, pattern of the cultivation has also changed dramatically. Almost 80% of agricultural areas of the basin are under the cultivation of alfalfa, tomato, vegetables, or orchards which are high water consuming crops compared with wheat or barley. While the water potential of the Basin is not more than 8.0 BCM/yr, but, at present, about 5.6 BCM/yr is used for agriculture and 0.5 BCM/yr for domestic purposes. Therefore, only 2.0 BCM/yr is left to be discharged into the Lake for its sustainability. Considering the amount of 5.0 BCM/yr of evaporation from the Lake surface and 1.2 BCM/yr of annual rainfall over the Lake, it seems there is a need of 3.8 BCM/yr of more water to maintain the ecological sustainability of Lake Uromiyeh.

POSSIBLE SOLUTIONS

Considering the above mentioned facts, it is concluded that each year 2.0 BCM of more water is needed to be discharged into the Lake. Some alternatives such as transferring water from Caspian Sea or diverting water from Zab or Aras rivers have also been proposed to save the Lake. But, even if these proposals be economic, they may have great ecological consequences plus international challenges. Therefore, the possible solution which is left may be the management of water resources. Among the proposed managing steps are:

(1) Decreasing agricultural water use by 2.5 BCM/yr.

(2) Stopping the implemention of the dams undergoing construction or studying.

(3) Decreasing water demand for agriculture.

(4) Increasing water productivity in agricultural sector.

(5) Establishing a powerful Integrated Water Management Institute at basin level.

REFERENCES

[1] Karbassi, A., Bidhendi, G., Pejman, A., & Bidhendi, M. Environmental impacts of desalination on the ecology of Lake Urmia. Journal of great lakes research, 36(3), pp. 419-424, 2010.

[2] Jalili, S., Kirchner, I., Livingstone, D. & Morid., S. The influence of large-scale atmospheric circulation weather types on variations in water level of Lake Urmia, Iran. International journal of climatology, 10.1002/joc.2422. 2011.

[3] SEDAC. Gridded population of the world. Future estimate. Socio-economic data and application center. 2011.

http://sedac.ciesin.columbia.edu/gpw.

[4] UNESCO, UNESCO-MAB Biosphere Reserves Directory. 2012. http://www.unesco.org.

[5] Scott, D. The birds of Lake Orumieh and adjacent wetlands. Islamic republic of Iran-results of surveys carried out by the Omithology Unit of the Department of the Environment. 1970. http://www.wetlands.org/reports/ris/21R003_annex.pdf.

[6] Abbaspour, M. & Nazaridoust, A., Determination of environmental water requirements of Lake Urmia, An ecological approach. International journal of environmental studies.64 (2), pp. 161-169, 2007.

[7] Eimanifar, A., & Mohebbi, F., Urmia Lake: A brief review. Saline system 3,5. 2007.

SOURCE ASSESSMENT FOR CATCHMENT-BASED WATER MANAGEMENT UNDER THE EUROPEAN UNION WATER FRAMEWORK DIRECTIVE

Dr. Ho-Sik Chon[1]

[1]Green Technology Center-Korea, **Republic of Korea**

ABSTRACT

The European Union Water Framework Directive (WFD) was enacted to monitor and recover the ecological, chemical and quantitative quality of water bodies. The WFD has caused water management to shift from a local to a river basin scale, and therefore requires a better understanding of emission sources of priority substances and their contribution to receiving waters. In order to prevent the deterioration of water quality caused by the discharge of pollutants, emission sources are needed to be assessed and controlled effectively at the catchment level. This paper aimed to understand the need for source assessment in the process of river basin management under the WFD. Outcomes from source assessment at the catchment level can provide information that helps recognize the problems in catchments and determine the required scale and location of monitoring in water bodies. Moreover, they can be used as important elements in source management that could be an effective option of Programmes of Measures to reduce the environmental impacts of human activities on river catchments. Source assessment can therefore facilitate the performance of water management stages and the improvement of the quality of surface water bodies under the implementation of the WFD.

Keywords: source assessment; catchment management; European Union Water Framework Directive; River Basin Management Plan

INTRODUCTION

The European Union (EU) Water Framework Directive (Directive 2000/60/EC) (hereafter WFD) is introduced to reduce water pollution, prevent further deterioration of the aquatic environment and as a result enhance the quality of natural water all over Europe [1]. The implementation of the WFD has been, and still is,a challenging issue [2]. A wide range of biological, chemical & physico-chemical and hydromorphological elements need to be monitored, and systemic understanding of the inter-connection between these elements in a water body is required to achieve the ecological and chemical “good” status of surface water. Multidisciplinary investigations have been undertaken to provide data for integrated water management, ecological risk assessment and catchment modelling [2].

For compliance with the objectives of the WFD, it is necessary to developa cradle to grave understanding of water pollution [3]. Based on this, the inputs of pollutants should be controlled in a cost-effective way to prevent further deterioration of water quality. For this goal, there is a great need to understandthe potential role of emission sources in the quality of aquatic systems [4]. Almost all EU member states have spent considerable time and resources in order to obtain suitable information on impacts of sources and pollutants emitted from them into river catchments [2]. In the UK for example, the Environment Agency of England and Wales (EA) established theIntegrated Catchment Science (ICS) Programme in order to develop scientific understanding of environmental processes for river basin management [5]. In this Programme, “catchment pressures” is an ongoing research theme with the following specific objectives: 1) Determining the effects of individual pressures on surface water, groundwater, air and soil ecosystems, 2) Determining how these pressures are transported through the environment and what determines impacts on chemical quality, exposure to ecological receptors, or direct impacts on ecological and human health in different ecosystems and/or environmental media and 3) Identifying the major sources of these pressures from activities and processes that potentially cause adverse ecological effects [6].

Environmental problems in a catchment can be effectively resolved if their sources are managed appropriately [7]. In order to prevent the impairment of water quality caused by the discharge of pollutants, all emission sources need to be targeted for investigations and controlled [8]. From an exposure-and-effect perspective, the most effective way of minimising environmental pollution is to reduce the probability of environmental exposure to pollutants.

A number of pollutant sources exist at the catchment level, and their effects on the quality of water bodies vary from one catchment to another. Source assessment has been used in catchment management to develop and/or select control measures which reduce concentrations of pollutants and enhance water quality, as reflected in previous studies [9, 10]. Through this assessment, sources, emission patterns and pathways of pollutants are identified. All potential factors including natural and anthropogenic influences are targeted in source assessment, and their relative contribution is estimated based on the apportionment to each source of levels of pollutants in receiving waters at the catchment level **(Fig. 1).**This paper aimed to showneed for source assessment in light of conducting river basin management under the WFD.

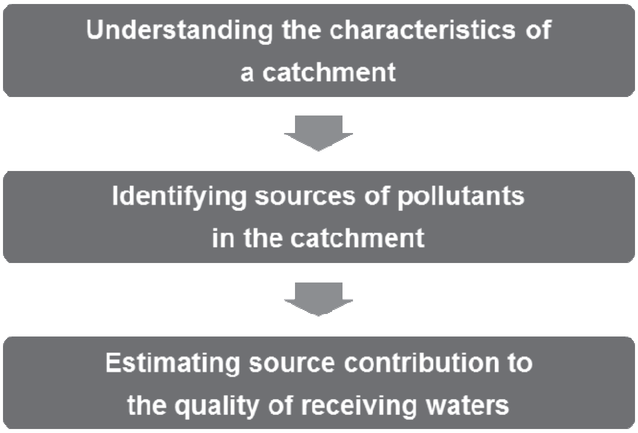


Fig.1. Procedure of source assessment at the catchment level

SOURCE ASSESSMENT FOR RIVER BASIN MANAGEMENT UNDER THE WFD

The WFD introduces a framework based on a cyclical process of river basin management. In every management cycle, four distinct stages, described in **Fig. 2**, need to be carried out in order to improve ecological, chemical and quantitative status of water bodies [11].

Under the WFD, thorough understanding of the environmental characteristics of a catchment and/or a group of catchments in a River Basin District (RBD) is essential [1]. A wide range of natural and anthropogenic impacts on water quality within catchments are required to be identified, and the economic, social and political aspects of water pollution need to be taken into account in order to evaluate pressures on the RBD [12]. Outcomes from source assessment at the catchment level can provide information that helps understand the problems in catchments and establish integrated water management plans to comply with the WFD.

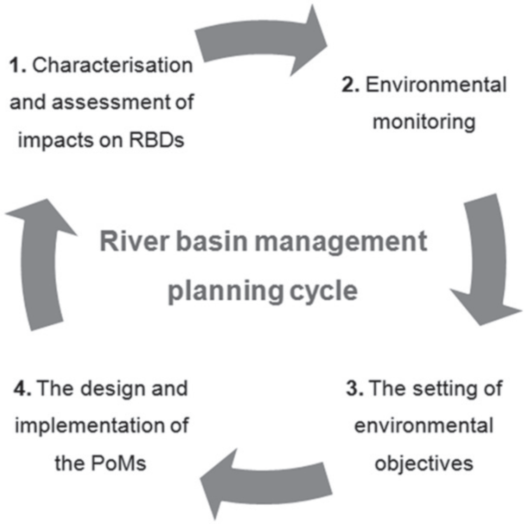


Fig. 2. Four main stages in river basin management planning cycle, presented based on a report fromthe EA [11]

Monitoring plays an important role in providing the scientific evidence that can be used to classify overall status of a water body, identify the trend of water pollution and support the selection of Programmes of Measures (PoMs) [1,13]. In addition, monitoring data are required to judge the effectiveness of PoMs selected in previous management cycles on the improvement of water quality [2]. Results of monitoring should provide information regarding the significance of human activities on ecological, chemical and quantitative status of water bodies. To achieve the objectives of monitoring under the WFD, monitoring networks should be established based on source assessment. Outcomes from source assessment can help determine the required scale and location of monitoring in water bodies. In addition, after appropriate PoMs are implemented, source assessment can be used to assess their effectiveness as well as refine the monitoring networks for subsequent cycles of river basin management [14].

The selection of the PoMs to prevent and/or control pressures from pollution sources is a basic requirement in River Basin Management Plans (RBMPs) [1]. Under such requirement, source management could be an effective option among possible PoMs to reduce environmental impacts and the inputs of priority substances into surface water bodies. Remediation of the polluted aquatic systems is a long-term process. During the process of the remediation, water quality is not protected sufficiently against ongoing pressures from various human activities discharging wastewater with priority substances into surface waters. Using an adequate method/approach for source assessment, the quantity of pollutant inputs into waters is calculated, and possible changes in pollutant release from sources according to various environmental and urban development scenarios are anticipated. Such outcomes from source assessment can be used as important elements in source management at the catchment level.

Under the implementation of the WFD, economic evaluation through cost-effectiveness analysis needs to be included into the decision making process for water management at the RBD level [15]. It is difficult to determine whether control measures associated with source management are cost-effective PoMs for river basin management. However, as the EA [3] reported, preventing water pollution at source normally requires less expenditure than remediating polluted water bodies. Based on the evidence of pollutant derivations and their influences on the quality of the aquatic environment, economic evaluation can be performed in order to assess a list of possible management options, and suggest the best options for minimising pollution in receiving waters.

DISCUSSION

Under the implementation of the WFD, a lot of guidance at national and European levels has been produced for integrated water management [16-20]. The unified management strategies result in considerable improvement in the quality of surface water and groundwater. Moreover, a number of methods for risk assessments and catchment modelling have been developed, and large amounts of data have been generated using monitoring programmes. In particular, there has been a great increase in knowledge on ecology in the aquatic environment due to the requirement of the WFD [2].

However, application of catchment-based assessment still has difficulties due to data availability. The information required is dependent on the purpose and scale of the assessment. It is a principal requirement to obtain suitable and site-specific data for source assessment at the catchment level. The limitation of data availability was a critical issue when carrying out source assessment in previous studies [21-23]. A number of parameter values used in calculations were referred to from published literature. Although data in the literature were proven to be accurate and reliable, most of them were produced in different years based on various research purposes. Urban data of given catchments such as land-use, population growth, urbanisation and industrialisation were provided not based on a hydrological catchment but based on an administrative border. Therefore, accurate catchment site-specific information could not be used in source assessment. In addition, some important parameters accounting for the characteristics of given catchments such as runoff coefficients of urban and agricultural areas were not presented at regional levels, and therefore European standards and/or national standards in other countries were cited in calculations. Such limitations resulted in uncertainties in outcomes from source assessment. There is the need to develop and/or reorganise information on catchment characteristics with consideration of integrated water management. Moreover, proper guidelines for data collection and management for catchment-based water management are required to improve the quality of source assessment at the catchment level.

Data supplied for source assessment at the catchment level are important as the benefits of a catchment-based approach, not only for water quality improvement but also water resource management, are recognised by administrators, stakeholders and other decision makers. The use of accurate, relevant information in source assessment helps prevent water pollution from various adverse effects caused by emission sources. Competent authorities should take into account inter-connections between research projects when preparing them. In fact, a number of individual projects were carried out in the same geographical area which were unconnected and resulted in increasing costs and the potential for inconsistent outcomes [24].

CONCLUSIONS

To comply with the environmental objectives of the WFD, understanding the role of emission sources in the deterioration of the aquatic environment is essential. For effective RBMPs, there is a great need to identify potential pressures of the inputs of priority substances and assess their relative importance to concentrations in river catchments. To this end, source assessment should be incorporated into the process of river basin management under the WFD. Source assessment at the catchment level can facilitate the performance of water management stages and as a result the achievement of ecological and chemical “good” status of surface water bodies.

It is a principal requirement to obtain suitable and site-specific data for reliable source assessment at the catchment level. It is necessary to develop and/or reorganise information on catchment characteristics with consideration of integrated water management. In addition, proper guidelines applied to data collection and management are required for source assessment at the catchment level. The use of accurate, relevant information in source assessment would protect the quality of water bodies against emission sources under the WFD.

REFERENCES

[1] European Commission, Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Official Journal of the European Communities, L327, pp. 1-72, 2000.

[2] Hering, D., Borja, A., Carstensen, J., Carvalho, L., Elliott, M., Feld, C.K., Heiskanen, A.S., Johnson, R.K., Moe, J., Pont, D., Solheim, A.L., & van de Bund, W., The European Water Framework Directive at the age of 10: a critical review of the achievements with recommendations for the future. Science of the Total Environment, vol. 408/issue 19, pp. 4007-4019, 2010.

[3] EA, Diffuse water pollution in England and Wales report - May 2007. 2007, Environment Agency of England and Wales.

[4] Candela, A., Freni, G., Mannina, G., & Viviani, G., Quantification of diffuse and concentrated pollutant loads at the watershed-scale: an Italian case study. Water Science and Technology, vol. 59/no.11, pp. 2125-2135, 2009.

[5] Collins, K., Learning about integrated science (ICS) for managing land and water. In Agriculture, Water Management and Climate Change. 2008. Bath, the UK: Integrating Water and Agricultural Management (IWAM).

[6] EA, EA Integrated Catchment Science Programmes priorities. 2009, Environment Agency - Imperial College Co-ordination Meeting.

[7] CIWEM, Integrated water management (IWM). 2009 [Accessed 4th November 2011]; Available from: http://www.ciwem.org/policy-and-international/current-topics/water-management/integrated-water-management.aspx.

[8] Novotny, V. & Olem, H., Water quality: prevention, identification and management of diffuse pollution. 1994, New York: Van Nostrand Reinhold.

[9] Crabtree, B., Kelly, S., Green, H., Squibbs, G., & Mitchell, G., Water Framework Directive catchment planning: a case study apportioning loads

and assessing environmental benefits of programme of measures. Water Science and Technology, vol. 59/no.3, pp. 407-416, 2009.

[10] Davis, B.S. & Birch, G.F., Catchment-wide assessment of the cost-effectiveness of stormwater remediation measures in urban areas. Environmental Science & Policy, vol. 12/issue 1, pp. 84-91, 2009.

[11] EA, The Water Framework Directive: guiding principles on the technical requirements - June 2002. 2002, Environment Agency of England and Wales.

[12] Ferrier, R.C. & Jenkins, A., The catchment management concept, In Handbook of catchment management, Ferrier, R.C. & Jenkins, A., Editors. 2010, Wiley-Blackwell: Chichester. p. 1-17.

[13] Quevauviller, P., Water status monitoring under the WFD, In The Water Framework Directive - ecological and chemical status monitoring, Quevauviller, P., Borchers, U., Thompson, C., & Simonart, T., Editors. 2008, John Wiley & Sons, Ltd.: Chichester. pp. 3-9.

[14] Collins, A., Chon, H.S., & Voulvoulis, N. WFD: surface water monitoring for the classifications of water bodies and to facilitate source assessment. In M^3 Workshop on Monitoring and Data Evaluation under the Water Framework Directive-Achievements, Deficits and New Horizons. 2010. Luxembourg-Kirchberg.

[15] van Engelen, D., Seidelin, C., van der Veeren, R., Barton, D.N., & Queb, K., Cost-effectiveness analysis for the implementation of the EU Water Framework Directive. Water Policy, vol. 10/issue 3, pp. 207-220, 2008.

[16] DEFRA, River basin planning guidance. 2006, Department for Environment, Food and Rural Affairs: London.

[17] DEFRA, River basin planning guidance, Volume 2 - August 2008. 2008, Department for Environment, Food and Rural Affairs: London.

[18] European Commission, Decision No 2455/2001/EC of the European Parliament and the Council of 20 November 2001 establishing the list of priority substances in the field of water policy and amending Directive 2000/60/EC. Official Journal of the European Communities, L331, pp. 1-5, 2001.

[19] European Commission, Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the

European Parliament and of the Council. Official Journal of the European Union, L348, pp. 84-97, 2008.

[20] UKTAG. Recommendations on surface water classification schemes for the purposes of the Water Framework Directive - December 2007. 2007 [Accessed 28th October 2011]; Available from: http://www.wfduk.org/UKCLASSPUB/LibraryPublicDocs/sw_status_ classification.

[21] Chon, H.S., Ohandja, D.G., &Voulvoulis, N., Assessing the relative contribution of wastewater treatment plants to levels of metals in receiving waters for catchment management. Water, Air, & Soil Pollution, vol. 223/issue 7, pp. 3987-4006, 2012.

[22] Chon, H.S., Ohandja, D.G., &Voulvoulis, N., The role of sediments as a source of metals in river catchments. Chemosphere, vol. 88/issue 10, pp. 1250-1256, 2012.

[23] Chon, H.S., Ohandja, D.G., &Voulvoulis, N., A risk-based approach to prioritise catchments for diffuse metal pollution management. Science of the Total Environment, vol. 437, pp. 42-52, 2012.

[24] CIWEM, Integrated water management: a CIWEM briefing report. 2011, Chartered Institution of Water and Environmental Management.

INTRODUCING THE EUROPEAN UNION WATER FRAMEWORK DIRECTIVE IN ARMENIA: DEBED RIVER BASIN CASE STUDY

LusineTaslakyan

UNDP/GEF Project "Reducing Trans-boundary Degradation in the Kura Araks River Basin", **Armenia**

ABSTRACT

During the past decade Armenia has made significant progress in establishing institutional and legislative framework for improved water management system. The second generation of water reforms in Armenia is targeted at harmonization with the European Union (EU) water legislation and application of the EU Water Framework Directive (WFD) approaches in particular.

This study uses the EU Water Framework Directive as a contextual framework for analyzing water quality data and river basin management planning in the Debed River Basin in Northern Armenia. Major water quality concerns in the basin are the concentrations of Nitrogen and Phosphorus as a result of untreated municipal wastewater discharges and agricultural activities, as well as Sulphates, Copper, Cadmium, Zink and other heavy metals as a result of mining activities in the downstream section of the basin (Alaverdi and Akhtala). More than 38% of sites within the Debed River system are classified as water bodies at risk with the status of lower than "good" (Armenian water quality class II).

The EU WFD ecological objectives will require policy changes focusing on more serious control over mining industry and tailing dams in particular, as well as budget allocations and installation of urban wastewater treatment plants for the major cities within the basin.

Keywords: EU Water Framework Directive, water quality, Debed River Basin.

INTRODUCTION

Multifaceted nature of water resources requires integrated approach for effective management of this vital resource.

The EU Water Framework Directive (WFD) adopted in 2000 by the European Parliament and the Council of Europe became an important piece of water legislation aiming at improved water quality throughout the Europe. The Directive and its Guidance Documents provide the basis and methodology for specific actions targeted at protection, enhancement and prevention of any further degradation of aquatic ecosystems. The Commission sees the Directive as a framework that would establish a common ground for the countries to ensure sustainable use of water resources and improve the status of aquatic ecosystems. To achieve this ambitious objective River Basin Management Plans (RBMP) will be developed and implemented for each river basin and updated every six years [1].

One of the most significant elements of the EU WFD is the adoption of a river basin as the management unit which reflects the natural situation of the ecosystem. River basin plan is the key tool for implementation of the new management approach. It requires complete information on the real situation in the river basin, including water quality status and any existing pressures that might affect it.

Significant efforts on piloting and testing the EU WFD approaches in Armenia have been made by the EU funded project "Trans-boundary River Management for the Kura River Basin - Armenia, Georgia and Azerbaijan Phase II" (2008-2011) followed by Phase III (2012). New EU WFD compliant monitoring program for Armenia has been proposed, and tested during the 2012 by the Environmental Impact Monitoring Centre (EIMC), the state authorized body in charge of surface water quality monitoring in Armenia [5].

This paper discusses the draft River Basin Management Plan developed for the Debed River in Northern Armenia, analyses water quality data collected in 23 sampling sites according to the new EU compliant monitoring program and is attempting to identify how will the classification of water bodies in the Debed River Basin be modified based on the new monitoring results.

The role of biological monitoring data for implementation of the WFD is explicit, since it provides essential information for assessing ecological status of a water body and defining its quality class (high, good, moderate, poor and bad) by using an ecosystem approach and assessing the ecosystem health and functions. The importance of biological data is explained by the ability of aquatic organisms (especially, the macro-invertebrates, due to their ecology and life span) to respond to impacts and changes occurring in the system over time. For example, abrupt pollution discharge would be difficult to reveal by chemical monitoring, while local biodiversity may be affected for a longer period of time.

However, there is no biological monitoring in place in Armenia. Some fragmented studies in the rivers are conducted by scientific institutes depending on the research interests and funds available for a particular study.

An important step towards the introduction of the EU WFD in Armenia has been made by adoption of Resolution No. 75-N of January 27, 2011 "On Definition of Water Quality Norms for each Water Basin Management Area, Taking into Consideration Local Specifics", which contains the WFD Priority Substances and other pollutants. Five water quality classes (I-V, corresponding to "high", "good", "moderate", "poor" and "bad") for a number of physico-chemical parameters have been specified for each of the six basin management districts in Armenia.

DEBED RIVER BASIN

Armenia is fully located in the drainage basin of the Araks and Kura Rivers. Debed River Basin is located in the north of Armenia, bordering with Georgia. Debed and Aghstev River Basins comprise the Northern Water Basin Management Area (district). Debed is shared by Armenia and Georgia and serves as a natural boundary between the two countries. The basin area is 3,790km^2, has diverse topography and covers the area between the northern latitude $40^0$41' - $41^0$18' and eastern longitude $43^0$55' - $44^0$57'. The highest point in the basin is located at 3,196 m above sea level, the Achqasar Mountain peak of the Javakhq Mountain range. The lowest point in the basin is also the lowest in Armenia and is located at 375m above the sea level in the valley of Debedavan Village (Figure 1). Although the area of the basin is relatively small, its complex topography includes folded mountain ranges with significant inclines of 150-200m, volcanic ranges with smaller incline, high mountains, wide inter-mountain depressions and river valleys [2].

Climatic conditions in the basin are also very diverse, varying from dry sub-tropical to high-mountainous zones. Precipitation across the basin is unequally distributed, with the minimums observed in the second half of summer and winter. January quantity of precipitation does not exceed 24-26mm, but snow cover in the mountainous areas can reach 1.5m.

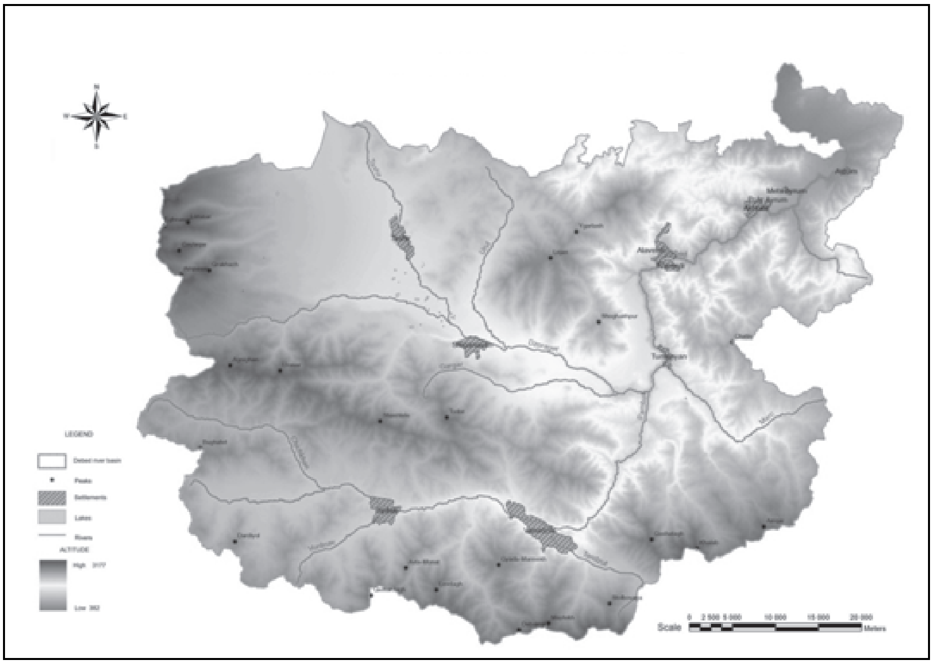


Fig. 1. Digital Elevation Map of Debed River Basin (Source: EU Kura River Project)

Diversity of landscapes in the basin is presented by sub-alpine (2,000m up to 2,600m) and alpine (above 2,600m) meadows and grasslands, forests and dry steppes. About 24% of the basin area is forested, with the most of it situated on the altitude of 2,000-2, 200m ASL. Beech, oaks, maple, ash, hornbeam are the dominating tree species.

Over 1,300 small rivers and streams form the Debed River system, through the confluence of Pambak (84 km length) and Dzoraget (67 km length) rivers. The length of Debed River (from Pambak confluence until the border with Georgia) is 176 km. Largest tributaries of Pambak are: Lernapat, Tandzut, Aralex. Tributaries of Dzoraget are: Tashir, Chqnagh, Urut, and Gargar. Martz and Shnogh are the main tributaries of the Debed River.

In a normal year maximum flows in Debed River are observed in April-August due to snowmelt and precipitation increase in spring months. The lowest flows (close to the base flow) are observed in November-February, when most precipitation is stored in the snow.

Fig. 2. River Debed, April 2004

Fig. 3. Copper smelter in Alaverdi City (Photos by L. Taslakyan)

ANTHROPOGENIC PRESSURES AND IMPACTS

Main sources of anthropogenic pressures identified in the Debed River Basin are: water abstraction, domestic and mining wastewater (tailing dams), agriculture (crop sector and livestock production), food and non-food industry, hydropower plants, solid waste and transport.

As of January 1, 2010, population in the basin was 289,500 of which 58.4% is urban, 41.6% is rural population [3]. However, difficult socio-economic situation, political and other factors led to large scale emigration, which also continues today. There is some internal migration from previously active industrial urban settlements to rural where the main occupation is agriculture.

The pressures on river water quality from agricultural activities are due to Nitrogen and Phosphorus penetrating groundwater and rivers due to washing of manure through snowmelt or rainwater. Application of fertilizers in the basin is insignificant due to high prices which are not affordable for farmers.

Transport is considered as one of the significant pollution sources in the Debed Basin, because the interstate roads, as well as the railroad from Armenia to Georgia (Yerevan-Vanadzor-Alaverdi-Georgia) which is intensively used for transportation of goods, pass through the basin. Significant section of these roads goes immediately near and along the river and affects water quality through road runoff, oil spills, atmospheric pollution, which are the sources of Nickel, Copper, Zink, Cadmium, Lead and fuel combustion by-products.

Mining industry presents significant risks for several water bodies within the Debed system due to wastewater discharge into the surface waters. Mining wastewater contains heavy metals (Copper, Zink, Cadmium), sulphates and ammonium which pollute the rivers Alaverdi, Akhtala and Debed.

The largest mining industries in the basin are Alaverdi Copper smelter and Akhtala Ore Mining Enterprise. Armanis and Akhtala poly-metallic mines produce gold and copper. Sulphur dioxide emissions by Alaverdi Copper Mining Factory (Fig. 3) are the source of sulphuric acid which eventually ends up in the river through precipitation [2].

Existing tailing dams do not fulfil their environmental functions. Chochkan tailing dam previously serving for Akhtala Ore Mine is full and in-operational, and pollutants are washed off the surface with precipitation into the Debed River. Armanis tailing dam is currently under construction. In addition, mining industry is one of the largest water users in the basin.

There are solid waste open landfills for each of the main cities in the basin: Vanadzor, Spitak, Tashir, Stepanavan, Tumanyan and Alaverdi. However, they do not comply with the sanitary requirements, and were constructed without environmental impact assessment. In terms of source of pressure on local water bodies the most significant is Vanadzor landfill, since it contains also industrial solid waste and is located downstream of the city near the road. Thus, the most affected by solid waste is the section of Pambak River from Vanadzor to confluence with Dzoraget.

According to the GEO Alaverdi Report [4], the landfill in Alaverdi is not constructed properly, and residual domestic waste is often decaying along the banks of Debed River. The same situation is observed in many other parts of the basin, especially in the sections of the river passing through rural settlements.

Wastewater is one of the serious issues not only in the Debed Basin, but throughout the whole country, since there are no treatment facilities and sewage flows directly into the rivers. Many sections of wastewater collectors are old and deteriorated or blocked. For example, only 45% of Alaverdi residents are connected to the sewage system, whereas private households in the city (about 30%), as well as houses in adjacent villages use septic pits and discharge wastewaters directly into the Debed River [4].

DATA AND METHODOLOGY

Based on the basin characterization information and pressure-impact analysis, new EU WFD compliant monitoring program for the Debed Basin has been proposed and tested during the 2012 with support from the EU Kura Project. One station was proposed for each water body and included the existing stations, where possible, to ensure long data series. Location of sampling sites considered their representativeness in terms of anthropogenic pressures, hydromorphology and accessibility of the given water body.

In order to minimize the costs of the monitoring program only one sampling station for each water body was included and the number of parameters and frequency was kept to the minimum. To the possible extent, the same sampling stations were included in the new monitoring program. In order to get proper information regarding the role of tributaries, and have good understanding of human pressures in the basin affecting water quality in tributaries, surveillance sampling stations were located as close as possible to their confluence with the main rivers, such as Pambak, Dzoraget and Debed. Two stations were proposed for reference monitoring.

Based on the results of the three rounds of sampling and analysis, water bodies within the Debed River Basin have been classified according to the five EU WFD classes: high, good, moderate, poor, bad.

Sampling was conducted in 23 sampling sites (Fig. 4) according to the proposed monitoring plan according to the following schedule: 1) May - early June 2012 (higher river flow, beginning of vegetation season); 2) August - early September 2012 (lower river flow, peak of vegetation season); 3) October 2012 (low river flow, end of vegetation season). Laboratory analysis was conducted using standardized methods for the physico-chemical quality elements and parameters.

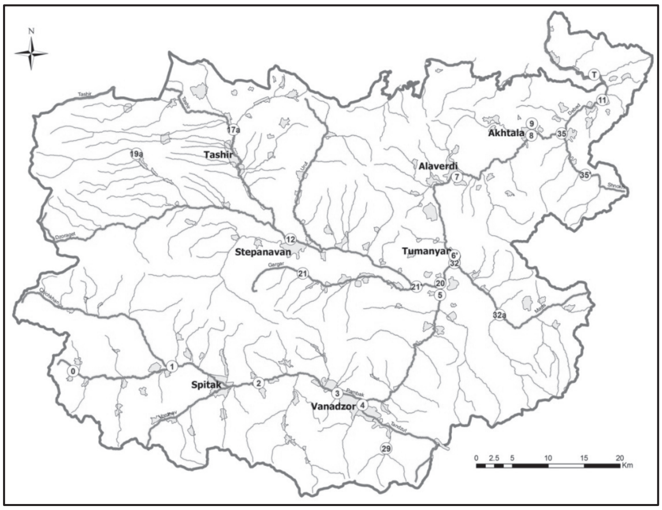


Fig. 4. Map of monitoring sampling points for 2012 in Debed River Basin.

RESULTS AND DISCUSSION

Water quality risks associated with anthropogenic pressures in the Debed Basin can be divided into two main groups: caused by biogenic elements (Nitrogen and Phosphorus) and by heavy metals (such as Copper, Cadmium, Lead, and Zink). In the 15 out of the 23 sampling sites water quality fell below the Armenian quality class II, corresponding to the EU WFD “good” status, and were defined as Water Bodies at Risk.

The results from the samples collected in Vanadzor City demonstrate significant issues with Nitrate Nitrogen. In River Pambak the Nitrogen concentrations were reaching 8.35mg/L, which falls under Armenian class IV (“poor”), but Phosphates here only slightly exceeded the threshold defined for class II (“good”), which is 1.1mg/L and fell under class III (“moderate”). Instead, Nitrate Nitrogen found in the samples collected in River Tandzut in Vanadzor City was under class III (“moderate”), but Phosphates were found under class IV, in one of the samples almost reaching the class V (“bad”): 0.39mg/L, whereas the threshold is set to 0.4mg/L.

Apparently, high concentrations of biogenic elements are explained by untreated wastewater discharges originating both from the municipal (household) sewage, food and non-food industry, as well as by the poor solid waste management practices and occasional discharges from the Vanadzor chemical factory.

The BOD5 results were good enough, revealing “good” and “high” chemical status, regardless the pressures existing in certain locations within the basin where untreated sewage is discharged to the river bodies. This can be explained by physico-morphological characteristics and peculiarities of this mountainous river with high self-purification rate, high flow velocity etc.

Analysis of monitoring results revealed that the most heavily polluted water bodies within the Debed Basin are the River Alaverdi and River Akhtala. Both water bodies fall under Armenian water quality class V corresponding to EU WFD “bad” status.

Water quality in the section of the river flowing through the city of Alaverdi is heavily modified. Sulphates, Copper and Zink are even far beyond the standards classifying the water body into the “bad” quality status. Thus, Zink in one of the samples was 935.98μg/L, while 500μg/L is the threshold of the “bad” quality class. For Copper reaching 378.8μg/L in this sampling site this threshold is 100μg/L, whereas Sulphate ions exceeded the threshold (250mg/L) twice and reached 535mg/L in one of the samples.

Main sources of pollution in this section of the Debed River flowing through the city of Alaverdi are the domestic wastewater discharge, industrial wastes, as well as by direct release of solid waste and industrial wastes into the river, and air pollution.

The most alarming situation in Debed River Basin is Akhtala River mouth, where heavy metal concentrations exceed the “bad” status concentrations several folds. For example, average concentration of Zink was over 5,132µg/L, which is 10 times more than the minimum that falls into the “bad” class of water quality (Armenian quality class V). Cadmium and Copper are also significantly beyond the “bad” class threshold. According to Armenian norms, concentrations for Cadmium in the Debed River Basin fall under class V (“bad” status), if they exceed 4.24µg/L. The average calculated from the three samplings throughout the year was 31.9 µg, while one of the samples (from September, 2012) contained 40.39 µg/L of Cadmium, which is almost 10 times beyond the “bad” water quality class (V). According to Armenian norms, the minimum desired concentration for class II (“good”) status for Cadmium is 0.24µg/L.

Similar situation was found for Zink, which falls under class V if the concentration is above 500mg/L. Average of the three samplings conducted during the year of 2012 was 5132.23, which more than 10 times exceeds the norm set for the “bad” status and more than 50 times far beyond the “good” status, which is in the range from 4.3mg/L up to 100mg/L).

The same devastating situation was observed for Copper, found in Akhtala River during the sampling conducted in June, 2012 in the amount of 928.96µg/L, while it should fall under class V (“bad” status) when it is over 100µg/L and the good status is in the range of 3.0µg/L -23µg/L.

Monitoring data confirm the status of these water bodies as being Water Bodies at Risk and provide credible evidence that due to filled tailing dams the polluted water is washed from the surface directly into the rivers. In-operational Chochkan tailing dam and untreated wastewater from Alaverdi Copper Factory and Akhtala Ore Mining Company are serious threat not only for biodiversity, but also for humans in local villages using the river water for irrigation of their gardens/plots and consuming or selling the agricultural products. Thus, immediate mitigation measures need to be taken by relevant state authorities.

As a result of analysis of the new, EU WFD compliant monitoring data, hree new WBRs were identified in the Debed Basin in addition to the 12 WBRs defined in the draft Debed RBMP [2]. The newly defined WBRs include River Tashir in Mikhaylovka Village, River Gargar flowing through Village Pushkino and River Shnogh at Teghut Village (Figure 5).The only problem revealed by monitoring of 2012 in the Shnogh tributary at Teghut Village was the concentration of phosphates, which falls under “moderate” class (0.1-0.2mg/L).However, this water body is under potential risk due to Copper and Molybdenum open pit mining activities initiated by the Vallex Group in the area known as Teghut Forest and neighbouring villages Teghut and Shnogh. Despite the protests from environmental NGOs and local citizens the Government of Armenia has approved the project and allocated an area of 1,491ha, over 80% of which is forest covered, for the construction of the Teghut mining and processing enterprise. Currently the preparatory works are under way and it is estimated that when the operation starts the mine will produce about 500 million tonnes of tailings (containing Lead, Arsenic, Zink) and about 600 million tonnes of other wastes. For a country where less than 8% of forested areas virgin forests clear-cut is a major concern. In terms of direct impact on water resources in Debed basin, the tributary Shnogh is under risk. Thus, it is recommended to closely monitor further developments and water quality and quantity dynamic in the Shnogh sub-basin and update environmental objectives and strict control measures accordingly.

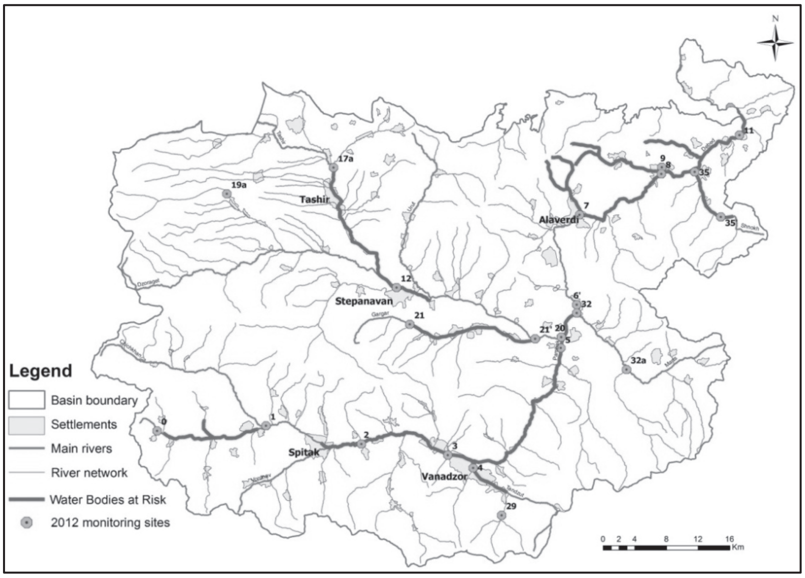


Fig. 5. Map of the Water Bodies at Risk in Debed River Basin based on 2012 monitoring results

CONCLUSIONS

In order to better understand human impacts on surface water quality in the rivers, monitoring programs need to be revised periodically based on the outcomes of the analysis of the most recent monitoring data. Updated monitoring will help to evaluate measures targeted at improved ecological status of water bodies.

In order to meet the EU WFD requirements it is absolutely necessary to establish Biological Monitoring Laboratory and include biological monitoring (which, in fact, costs less than chemical monitoring) in the state monitoring program.

State budget allocations should be made for implementation of the program of measures for improved water quality in the basin.

REFERENCES

[1] Water Framework Directive 2000/60/EC [Online] European Parliament and Council, available at http://eur-lex.europa.eu/ LexUriServ/ LexUriServ.do?uri=CELEX:32000L0060:EN:NOT

[2] Ansbaek J., Pichugin A., Tonoyan V., Gevorgyan A., Zaqaryan B., Ronchak P., Minasyan S. Debed Pilot River Basin Management Plan – Armenia. EPTISA Servicios de Ingenieria S.L. (Spain) & Carl Bro A.S. (Denmark) Consortium. EU funded project “Trans-Boundary River management Phase II for the Kura River - Armenia, Georgia and Azerbaijan.” Armenia. 2011, pp. 12-14.

[3] National Statistical Service of the Republic of Armenia. Statistical Year book of Armenia. 2009.

[4] Nazaryan, G. 2009. GEO Alaverdi: Environment and Urban Development. The Global Environmental Outlook for cities” Program by the UNEP/GRID-ARENDAL and OSCE Yerevan office.

[5] Ansbaek J., Pichugin A. Proposal for EU Water Framework Directive compliant monitoring programme for the Debed pilot river basin, Armenia. 2011. EPTISA Servicios de Ingenieria S.L. (Spain) & Carl Bro A.S. (Denmark) Consortium. EU funded project “Trans-Boundary River management Phase II for the Kura River - Armenia, Georgia and Azerbaijan.”

MODELING OF *Ca, Mg, Na* CONTENT IN WATER AS A TOOL FOR WATER AND SOIL CONTAMINATION MANAGEMENT AND SUSTAINABLE DEVELOPMENT IN AGRICULTURAL AREA

M.A. Nalbandyan[1], N.A. Ajabyan[2]

[1] Institute of Geological Sciences of the National Academy of Sciences, **Republic of Armenia**

[2]Institute for Informatics and Automation Problems ofthe National Academy of Sciences, **Republic of Armenia**

ABSTRACT

The sustainable development of agro-ecosystems is one of paramount conditions of control and planning of agriculture. Ararat valley is the main intensively cultivated area in Armenia. The main rivers in the valley are Hrazdan and Sevjur. Their waters are actively used for irrigation.

Due to the salinization of soilspecial attention is paid to managing the level of chlorine, calcium, sodium and magnesium in the system “river water-soil”.

The paper is devoted to the study of balance and distribution of the ions in the system. Using modeling approach allows assessing the risk of the soil salinization and alkalinization. Models of the process of chemical substances transfer and their phase transitions in the environment allow interpreting the available data as well as predicting spatial spread of substances in the soil. A significant impact on dynamics of the process is provided with temporal and climatic factors, including weathering, winds, intensity of precipitation, and the topsoil characteristics. Though the models are built on simple representation of element flows and assumptions on the process dynamics they provide interpretation of main quantitative characteristics of changes taking place in the soil. The identification of model parameters is based on monitoring data, detailed embedding of local territory structure, speed of element transformation and soil profile.

Keywords: agro-ecosystems, irrigation waters, salinization, modelling, sustainable development

1. INTRODUCTION

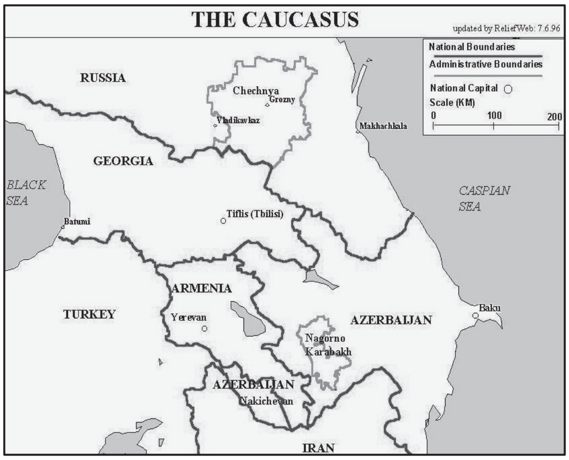
The Republic of Armenia is located in the northeast of the Armenian Highlands, at the border of Caucasus and Western Asia. Armenia borders Georgia from the north, Azerbaijan from the east, Turkey from the west and southwest, Iran from the south **(Fig.1).**

Ararat valley is the main intensively cultivated area in Armenia **(Fig.2).**

The content of calcium in the composition of exchangeable cations in ameliorated soils of the Ararat valley reached 60-93%, magnesium varied from 6 to 23% and the content of sodium is in the range 3-5% from basic hydroxides.

High percent age of calcium, magnesium and exchangeable sodium in soil presents hazard of salinization resulting from exchange processes [5]. Salinization is mainly conditioned by input of sodium to soil in exchange of calcium and magnesium ions which are washed out of colloidal phase of soil to soil solutes. Calciumandmagnesium can be adsorbed and deposit on the soil particles in the form of solid coating with increasing the potential risk of alkalinization.

The main rivers in the valley are Hrazdan and Sevjur. Their waters are activelyused for irrigation. Using of highly mineralized hydrocarbonate waters of rivers Hrazdan and Sevjour for irrigation in the Ararat valley presents serious threat of the soil alkalinization triggering the processes the soil salinization.



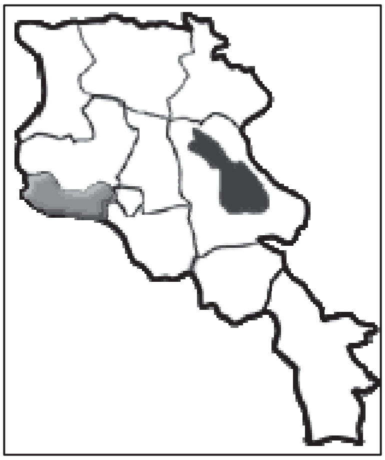


Fig.1. A Map of South Caucasus

Fig.2. Location of Ararat valley

MATHERIALS AND METHODS

One of the most arid zone of Armenia is the Ararat valley. The annual precipitation here is around 200-250 mm. Maximum precipitation is recorded in high mountainous areas at around 1000 mm per year. In Ararat valley, the average precipitation in summer months does not exceed 32-36 mm. The average annual wind velocity in Armenia is distributed unevenly in the range of 1.0-8.0 meters per second. In some regions, particularly in Ararat valley, mountain valley winds are quite common. In summer, their velocity reaches 20 m/s and over. The summer is temperate, at the end of July the temperature in Ararat valley varies between 24-26°C.

Ararat basin after the formation in result of depressions and the eruption of the Upper and Lower Quaternary basaltic lavas were exposed to intense erosion, which continues today. The geological structure of the Ararat valley involves lymno-fluvial and effusive water bearing formations which thickness reaches 500m. Beneath those formations, a folded water resistant formation is found which is represented by Paleozoic and Mezocainosoic sandstone, clayey and carbonate rocks.

Aquifers are the lava (porous and fractured basalt, slagged basalts), tuffs, lake water-bearing fluvial deposits. 80% of springs there are originated from the lavas. The water balance of the Ararat bowl involves ground waters which differ by conditions of formation, chemical composition and bedding conditions. The basic feeding source to aquifers is atmospheric precipitation and infiltration of surface waters. Water accumulation and flow mostly occurs through basaltsand loose fragmented materials of under-bed Quaternary sediments**.** Data from numerous wells and geophysical surveys prove that the basin feeding ways mostly coincide with the modern river network.

Fig.3. The Hrazdan River in Ararat valley

Fig.4. The Sevjur River in Ararat valley

The underground water in the valley lies at the depth up to 25 meters. These water-bearing layers are confined as young alluvial-diluvial deposits. Aquitard for these waters are sandy clay layers. By hydrogeological and hydrogeochemical properties ground waters of the first pressure water-bearing sub horizons comply with the requirements laid for the quality of drinking water and are exploited. Waters of the second layer are confined to cracks and pores of slagged andesite-basaltic lavas. Waters are distinguished with high piezometric pressure. The sub horizon is intensively exploited [3].

In Armenia, irrigation has been always representing 70% of the total surface and ground water use. The irrigation water demand grows in the end of April with the peak in July and the decline in October. The average annual water withdrawal per hectare is 8,000 cu m. The 40% of the irrigated areas are highly dependent upon mountain pumping stations, which pump the water to the height of above 100m. The 300,000 hectares of irrigated lands in 1985 have been reduced to current 135,000 hectares area. Major factors to contribute this decline are large-scale breakdown of infrastructure, high operation costs of pumping stations, fragmentation of former collective farms (1000-3000 hectares to numerous small farms of 1 to 2 hectares in size), as well as drainage related problems, particularly in the Ararat valley where the ground water is shallow.

River Hrazdan flows out from Lake Sevan and flows into River Araks **(Fig.3).** The river basin is a home to some 70% of Armenia's industrial enterprises and municipal-household services of cities of Sevan, Hrazdan, Charentsavan, Abovian, Yerevan, the resorts of Hankavan, Tsaghkadzor, Arzni resorts as well as a large amount of settlements and villages. The river length is 141 km. The watershed covers an area 2560 sq.km. Mean water discharge is 22.4 m^3/sec. The river plays an essential role in water economy and is intensively used in irrigation. The river is predominantly fed through rain and melted snow.

Monitoring station River Hrazdan-town of Masis is 10 km far from River Araks confluence and Turkish frontier **(Fig.5).** The sampling point is located beneath the Hovtashen-Ranchpar bridge at $40^0$01'N/$44^0$26'E. Mean water discharge on this section makes 26.0, daily max.-138, min. runoff - 2.52 m^3/sec.

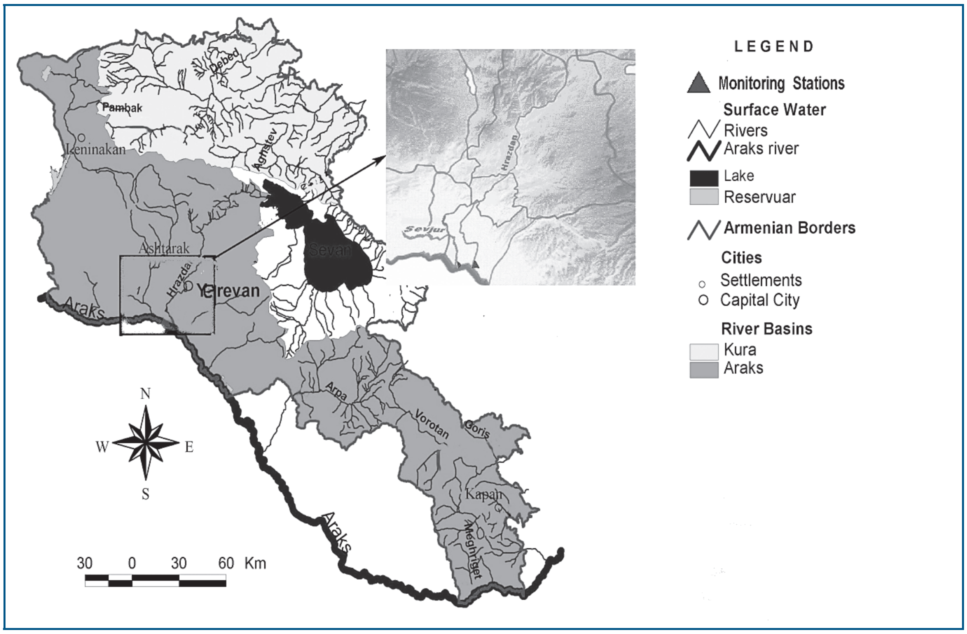


Fig.5. Location of the monitoring stations on the Hrazdan River and the Sevjur River.

The river course is straightforward and is made up of silt and pebble. The banks are gentle precipitous up to 2m high. No ice phenomena are observed in winter.

River Sevjur forms in a large spring near village of Kuli-bekli and flows between very low banks here and they are covered by thick reed-beds **(Fig.4).** The basin is situated on the slopes of Mt. Aragats and on the Ararat Valley. The river length is 38 km. The watershed covers an area 3540 sq.km. Mean water discharge makes 33.2m^3/sec. The river is fed predominantly by ground waters (80%). The river is used in irrigation and as a water supply source.

Montoring station River Sevjur-village of Ranchpar - is located 5 km far from Turkish frontier, upstream River Araks confluence beneath the Ranchpar Bridge at 40^{0}01'N/44^{0}22'E and is terminal on River Sevjur **(Fig.5).** Mean annual discharge for this section is 25.0, daily max.-149, low-water min.-5.70 m^3/sec.The river course on the post section is straitforward, made up of silt and sand, deformable. The banks are steep, precipitous, 1-2m high and here and there covered by reed-beds; during high water the right bank is inundated. No ice phenomena are observed.

For irrigational assessment of the water regarding its potential to cause salinization we used the method of Antipova - Karataeva. To assess the water quality with this method the mineralization C(g/l) is multiplied to 0.23 and the critical number is obtained. If it is less than the ratio of sum o calcium and magnesium to sodium content, then the water is not suitable for irrigation [6].

2. RESULTS AND DISCUSSION

2.1. Assessment of common ions concentrations level in river water and soil

In result of analyses on monitoring investigations the ground waters in this area are attributed to hydrocarbonate-chlorine-sulphate, calcium-sodium-magnesium class, the mineralization ranges within 406-566 mg/l. The content of calcium makes in average 43.3 mg/l, magnesium -22,5 mg/l and potassium -38.3mg/l [3,4]. Mineralization of water in the rivers Sevjur and Hrazdan makes in average 797 and 731 mg/l correspondingly. Exceeding of the MPC on potassium to 1.7 times, calcium to 1.7 time, magnesium to 1.3-1.8 times in rivers are determined, concentrations of sodium also high, and but not exceed the MPC [1,2]. Hardness of water of the rivers is 3,8-4,5 mg-eq./L.

Proceeding from the assessment of the level of general mineralization we conclude that waters of the river Hrazdan require special approach and accounting of all conditions of its using as irrigation waters. It is determined from the estimate of the water quality for irrigation by Stebler that the water can be defined as quite satisfactory, meanwhile there **is urgent need to alert the gradual accumulation of alkalis** [2].

Based on the estimate of potentials oil salinization the critical value for the river Hrazdan is less than the ratio of ions hence from this point of view the **water is not suitable for irrigation (Table 1)**.

Estimating the quality of waters of the river Hrazdan and Sevjur with respect to electrical conductivity and the level of salinity we can conclude that the water is of class 3 and is classified as the *water of high salinity*.

Therefore there is need of implementing **measures against salinity.**

Table.1. Calculated data for the evaluation of the water of the river Hrazdan on its proneness to alkalinization of soils by the method of Antipova-Karataeva

Dates	Mineralization (g/L)	C x0.23	$\frac{Ca + Mg}{Na}$
04.06	0,696	0,16	1,14
04.07	0,589	0,13	1,72
04.08	0,819	0,19	0,93
07.06	0,910	0,20	0,97
07.07	0,883	0,20	1,61
07.08	0,869	0,20	1,22
10.06	0,612	0,14	0,94
10.07	0,849	0,19	0,90
10.08	0,889	0,20	1,83

2.2. Modeling of common ions transfer in the system "river water-soil ".

Due to the salinization of soil a special attention is paid to managing the level of chlorine, calcium, sodium andmagnesium in the system "river water-soil".

Analytical methods got widespread recently. Predictions in this models are based on the process of infiltrates movement through porous media, main mechanism in the theory is the convectional diffusion. Separating distribution in horizontal and vertical dimensions allows applying numerical integration and does not require a large number of parameters. We will adopt the physically-based model developed by Wang, for detailed description to the water movement in soil column we refer to Shang [5].

The soil is divided into five 0.10 m layers, vertical movement of water is provided due to capillary rise and percolation between adjacent layers. A water balance model is used to define the change of soil moisture content of each layer. Main cations considered in the model are Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}.

We can define the vertical movement of solutes in soil with the following partial differential equation:

$$\frac{\partial}{\partial t}(Q + \theta C) \approx \frac{\partial}{\partial z}(qC)$$

Where t is time, Q is the concentration of absorbed solution, θ is the soil moisture content, C is the solution concentration, q is the water flux and z is distance.

The salt balance model will be applied to determine the salt concentration of each layer. The alkalization/de-alkalization process could be defined by two equilibrium processes: (1) due to the high concentration of sodium cations in the soil solution the calcium cations attached to soil particles are replaced by sodium cations, (2) some replaced calcium cations react with carbonate anions and generate insoluble calcium carbonate. The replacement of cations is determined by the following equation:

$$\frac{X_{Na}}{\sqrt{X_{Ca}}} = K\frac{C_{Na}}{C_{Ca}},$$

where X_{Na} and X_{Ca} are exchangeable calcium and sodium cations, measured in some equivalent units per 100 grams of solute, C_{Na} and C_{Ca} are calcium and sodium cations in solution, K is constant.

2.3 Climate change impacts

As a mountainous country with arid climatic conditions, Armenia, with its entire territory, is vulnerable to the global climate change. According to the World Bank assessment, Armenia is among the most sensitive countries in the Europe and Central Asia region in regard to climate change. Increased temperatures and reduced precipitation accelerate the desertification processes and will have a negative impact on public health and sectors, which depend on the climate. Declining water resources will have a direct impact on agriculture (reduced possibilities for irrigation, worsened conditions for dry farming, reduced crop yields), and will result in reduction of electricity production from HPPs and scarcity of technical water.

According to investigations of the climate change impact of the meteorological conditions in Ararat valley a continuous increase in temperature will be observed, and the increase will reach its maximum value in spring-summer months at 4-7°C. In Ararat valley, higher temperature rises are expected compared to other parts of the country. The forecasted climate change will result in less precipitation. More evaporation from the land surface and the saline swamplands of Ararat valley will turn into salt marshes.

CONCLUSION

Multilateral assessment of the water suitability for the irrigation purposes allows concluding that currently the water can be characterized as quite satisfactory, neverthelessa strict accounting of conditions of its use providing not only a good drainage but also monitoring of measures to prevent gradual salinization and accumulation of alkalis in soils.

To apply the model we need further development of the model and investigation the dynamics of salt concentration over years, defining average salt concentration. The leading environmental factors, including pH, soil texture and climatic variables will be used to fix site-specific peculiarities of the process. Experimental data on selected plots will be used for the model validation.

REFERENCES

[1] Saghatelyan A.K., Nalbandyan M.A.Complex assessment of ecological state of River Hrazdan. International conference "Problems of river monitoring and ecological safety in the South Caucasus", Tbilisi, Georgia, October 22-25, 2005, pp.78-87

[2] Saghatelyan A.K., Nalbandyan M.A., Grigoryan L.P. The assessment of irrigation properties of River Hrazdanwaters. Izvestiya of State Agrarian University, N 4, pp.124-128, 2009

[3] Shaginyan G.V., Khalatyan E.S., Kjuregyan T.N. Hydrochemistry of potable waters in southern districts of Yerevan. Izvestiya NAS RA, Earth Sciences, LVII, N 1, pp. 49-54, 2004

[4] Shaginyan G.V. On hydro-chemical characteristics of some potable water supplied to Yerevan, Izvestiya NAS Armenia, Earth Sciences, LVIII, N 1, pp. 41-45, 2005

[5] Z. Shang, Q. Gao, M. Dong. Impacts of grazing on the alkalinized–salinized meadow steppe ecosystem in the Songnen Plain, China – A simulation study. Plant and Soil 249: 237–251, 2003

[6] Zaydelman F.P. Soil melioration. Moscow, 1987, 360 p.

WATER RESOURCES OF EASTERN GEORGIA

Dr.Vakhtang Geladze, Dr. Nana Bolashvili, Dr. Tamaz Karalashvili, Dr. Nana Machavariani, Dr. Res. Nino Chikhradze, Dr. David Kartvelishvili

Vakhushti Bagrationi Institute of Geography, Ivane Javakhishvili Tbilisi State University, **Geogria**

Abstract. Fresh water deficit is one of the most important global problems today. About 40% of the Earth population has permanent mutual conflicts caused by shortage of water resources. Water resources of Georgia are located within the basins of two - Black and Caspian seas. According to the average height of water layer Georgia (760 mm) follows Norway (1190 mm), Switzerland (1040 mm) and Austria (800 mm) among the European countries. Despite of 810 000 m^3 of water produced annually per one km^2 of the country on the average, water supply of population at its eastern part is an acute issue. Under more or less equal conditions in the western and the eastern parts of Georgia with nearly the same population the annual fresh water volume per capita is nearly four times less. Moreover, the annual runoff distribution per month for irrigation purposes is irregular here. Kakheti region has been selected to carry out the research. Region is reach infertile and pasture lands. It is thecountry's leading viticulture region. It occupies the Iori and Alazani river basins and is notable for its deficit of water resources in the country. Hydro-meteorological observations begun since 20s of the twentieth century. In the territory of Kakheti about 40 hydrometeorological stations were functioning. Today only one station is functioning (the Alazani River - Station Shakriani). Its observation period starts since 1925. In the other stations the observation row is of 25-30 years.There are more than 2000 rivers there, but their majority (95%) is up to 10 km long. The density of rivers network is 0,45 km/km^2. During low water periods the rivers runoff is often below the ecological norm. Water resources of the region are used irrationally. The region tends to desertification which aggravate fresh water problem even more and presumably may lead to migration of local population from the area. According to the forecast [3], at the end of 21st century in the southern part of Kakheti it is expected decrease of hydrothermal coefficient from 1,1 to 0,7, which will shift the region's climate from subtropics into very dry category. The influence will be spread along the entire territory of Kakheti. On the background of current climate change for mitigation and adaptation to the mentioned process, one of the real active measures is to move to manageable water consumption for the purposes of rational use of water resources. On that basis and from the management point of view water resources of Kakheti region are the important and interesting to proceed to the controlled use of water and to estimate water deficit or excess according to its requirements. The purpose of study is to create geographical information system (GIS) of Kakheti water resources which will be used in future as a basis for introduction of contemporary water resources management technique.

Keywords: water resources, climate change, fresh water deficit

The short age of fresh water is one of the most important problems. In the light of the modern tense ecological situation and global climate warming and progressive process of desertificationis expected to face more problems. Presumably, for 50s of the 21st century more than 2 billion people of about 50 countries of the Earth will suffer water shortages.

Fresh water resource sare the most important natural resources of Georgia. There are 26000 rivers, more than 800 lakes, 40 water reservoirs, up to 700 glaciers, lots of different types of springs and wetlands. Total capacity of water resources registered in the country is about 100km^3 (Fig. 1).

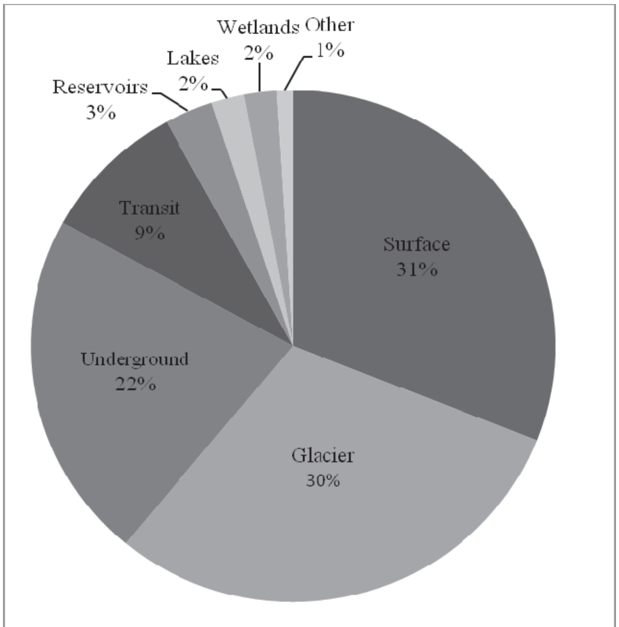


Fig. 1. Distribution of the water resources of Georgia, %

According to the mean value of water layer Georgia is behind only Norway, Switzerland and Austria among the European countries (Fig. 2). Here the water supply is 4–6 times higher than in the neighboring southern countries.

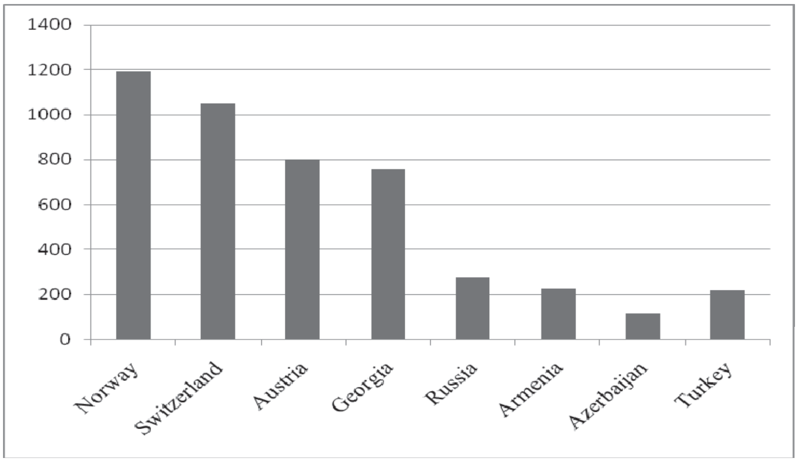


Fig. 2. Annual runoff, mm

Georgia is rich in water resources but, there a significant disbalance between the amount of water resources and water consumption because of their uneven territorial distribution in some regions. In Eastern Georgia, which is a major water consumer, water supply of the territory and population is four times less than in the western Georgia (**Table 1**). In the table the water supply of population and territory has been calculated for eastern and western Georgia's runoff with 50% and 95% (droughty year with practically ensured runoff) and for entire Georgia's runoff with 50% water supply. In addition, the intra-annual distribution of runoff is not in sinchrone with irrigation water consumption and during the low water periods the runoff in some river basins is often low than the ecological norm.

Table 1. Water resources and water supply of Georgia

Country	River runoff, km^3	Water supply of the area, $10^3 m^3$	Water supply ofthe population, 10^3m3
Western Georgia – 95 %	35.25	1087.6	15.022
Western Georgia –50%	41.52	1280.7	17.689
Eastern Georgia – 95 %	7.77	208.4	2.494
Eastern Georgia –50%	11.25	301.8	3.611
Georgia – 50%	52.77	757.1	9.660

In eastern Georgia in the last 4-5 decades modern climate change was observed by increasing of temperature (sums of positive temperature sincreased by100-150C^0) and, with the exception of the last 4-5years, by decreasing of precipitation (40-70 mm). The Mtkvati River runoff, compared to the year of 1940 was reduced by 25-30%.

All above mentioned together with an increasing of negative anthropogenic factors (destruction of irrigation systems, dramatic fall of agro-technique level, cutting down forests and wind bands, etc.) will contribute to the process of desertification of the arid areas in Georgia. This, of course, in its turn, will strain the problem of fresh water.

The shortage of water resources is of created artificially during the intensive development of population urbanization, industry and agriculture when not to taking into account the amount of water resources. It is necessary to start with the managable water consumption for sustainable development of water resources and the assessment of water shortage or surplus in relation to its demands. There are two types of water resource management approaches: 1. Territorial redistribution of water resources; and 2. Economy and settlement planning by foreseen of water factor.

Due to the political events developed in Georgia in the 90s of the last century the irrigation systems are almost completely paralyzed, agro-technique level have fallen sharply, plus the country's energy crisis and the massive emigration processes of population, which in their turn, have strained the situation. All of this, in case the trend of climate change is maintained, will create the real threat for intense desertification of arid areas in the region.

Initial reason of desertification process is droughts, and its further development is stipulated by climate change. Therefore, the drought and desertification processes should be considered in light of the entire Global Warming. In Georgia, asin the whole South Caucasus arid zones, droughts repeatability exceeds 40%. Summer drought of the year of 2000 led to the disaster in some regions. Since 1999 Georgia is a member of the United Nations Convention to Combat Desertification.

Kakhti has a leading role in Georgia according to agriculture. The major part of the population (>80%) are engaged in agriculture activities and Kakheti is a typical agrarian region.

According to the forecast, by the end of the 21st century it is expected the hydrothermal coefficient to be decreased from 1.1- to 0.7 in the southern part of Kakheti region, which will shift the region from dry subtropical to strong arid climate category. The impact will be spread more - or lessover the entire territory of Kakheti. Warming will cause the prolongation-shifting of vegetation period and the increasing of irrigation water consumption.

In light of climate change one of the real effective measures and priorities for the suspension of mentioned process and adaptation to climate change is the rehabilitation -modernization of existing irrigation systems and construction of new ones. As a result of Global Warming the natural zones future changes require the correction of the types of irrigation systems and technologies. The tendency of increasing areas of irrigation lands should be also taken into account.

Types, technologies and present problems of irrigation systems in Kakheti region are as follows:

SURFACE IRRIGATION BY GRAVITY FLOW (AREAL OF USE OF TECHNOLOGY) – the territories located mainly to the east of the main canals of Alazani upper and lower irrigation systems, to the west of Naurdali irrigation system and The Iori River basin - to the south of Samgory upper main channel.

SURFACE IRRIGATION BY MECHANICAL WATER-LIFTING (AREAL OF USE OF TECHNOLOGY) –the territories located mainly to the south of the Alazani lower irrigation system and in the Iori River basin – elevated slopes adjacent to the upper main channel of Samgory.

DRIP IRRIGATION (AREAL OF USE OF TECHNOLOGY) – poorer areas in water resources; mainly southern and south-eastern regions of Kakheti (Ole-Naomari, Taribana, Eldari, Didi Shiraki, Patara Shiraki, Jeirani Veli, etc.).

ARTIFICIAL RAINFALL (AREAL OF USE OF TECHNOLOGY) - hilly territories with flat and especially high inclination ($>10^0$); foothills of Caucasus and Gombori ranges; territory located to the south of Alazani lower irrigation system; to the right side of the Alazani River (for example, in the region of the v. Bakurtsikhe), where the orientation of the valley network complicates the application of surface gravity flow and mechanical water lifting irrigation technologies. In case of development of Global Warming process the technology will have a big work load in the lowlands of Kakheti and in especially in the hilly and mountainous regions up to1300-1500 meters above sea level.

Organized inclusion of ground waters of Alazani-Agrichai artesian basin in the irrigation network of the southern part of Alazani. The mentioned water sare standing out with large reserves and high quality. It is necessary to register and specify their reserves, exploitation resources, operating and abandoned wells.

Completion of the project on Alazani upper irrigation system (Duisi - Arashenda-Ole Lake-Taribana-Eldari. Main channel length-190km); restoration of “Zilicha” irrigation system.

MAJOR HINDERING BARRIERS FOR GRAVITY FLOW SURFACE IRRIGATION TECHNOLOGY - arrangement of drainage system in parallel with the Alazani upper and lower channels through vertical wells (about 300 wells of 5 meters depth). This work should be implemented, firstly, in Sighnahi and Dedoplistskaro municipalities; energy bearers for pumping water from the wells of the drainage system; high qualified sprinklers.

MAJOR HINDERING BARRIERS FOR MECHANICAL WATER LIFTING SURFACE IRRIGATION TECHNOLOGY - energy bearers. Most of the tributaries and dry valleys of both banks of the Alazani River are of mudflow character. One of the barrier shindering gravity flow and mechanical water lifting technologies of surface irrigationis cleaning channels from deposited solid material and protection from mudflows.

DRIP IRRIGATION TECHNOLOGY - necessary material -technical facilities for drip irrigation - head building (pumping station), complex of equipment, which distributes and regulates water in the pipes and identification of different parameters of water to ensure smooth operation of the water ways and water pipe network; energy bearers; highly qualified sprinklers; due to the high cost of the technology one of the main barriers of its use is a selection of a sphere of high rentable crops and their consumption/selling (e.g. a pomegranate for Dedoplistskaro municipality).

MAJOR HINDERING BARRIERS FOR IRRIATION TECHNOLOGY OF ARTIFICIAL RAINFALL - slope terracing and creation of natural pressure; activation of wind breaks in the areas of strong winds; highly qualified sprinklers; energy bearers.

Conditions of the irrigation systems in Georgia are not in line with modern technical requirements. The efficiency values of most of their majority do not exceed 0.4-0.6. Arrangement of the systems, installation of water registration devices, disorganized irrigation reduction, introduction of loss lesstechnology, modern irrigation methods and standards will significantly increase water use efficiency. In case of realization of the measures in eastern Georgia, even indistant perspective, the water supply of population and territory will be in normal condition. In addition, significant water amount will be saved by new irrigation norms justificated geographically, hydrologically and agroclimatically. In addition, it is possible to increase the water supply of the territory and population of eastern Georgia by means of new reservoirs, as the runoff of each river is significantly higher than the water consumption.

REFERENCES

[1] Climate change impact in Dedoplistskaro district. The 2nd National Communication, Tbilisi, Georgia,130 p., 2008.

[2] Results achieved in climate change projects in 2006. Book, Tbilisi, Georgia, 112 p., 2007.

[3] The 2nd National Communication Framework Convention for Climate Change. Book, Tbilisi, Georgia, 149 p., 2001.

THE ASSESSMENT OF IMPACT OF LARGE DEEP RESERVOIRS CONSTRUCTION ON WATER QUALITY OF SIBERIAN RIVERS (EVENK RESERVOIR AS A CASE STUDY)

Prof. Dr. Yuri I. Vinokurov, Dr. Alexander T. Zinoviev, Yana E. Kuznyak

Institute for Water and Environmental Problems SB RAS, Barnaul, **Russia**

ABSTRACT

Large scale hydro technical construction always impacts on the environment and transforms it. To define such a transformation caused by large deep reservoirs building is very complicated. The paper presents some results of the investigations used for the assessment of impact of Evenk reservoir construction on water quality of R. Nizhnyay Tunguska. The prognosis was performed for two options of the Evenk reservoir construction.

Keywords: Evenk reservoir, R. Nizhnyay Tunguska, large scale hydro technical constructions, hydro power plants, tailrace, ice-thermal regime, mathematical modeling, water quality.

INTRODUCTION

Economic development of any country including Russia depends on its energy sector development. It consists of three main energy producers: thermal power plants (TPP), nuclear power plants (NPP) and hydro power plants (HPP).

By hydro energetic potential, Russia ranks the second after China. However, by energy use the situation leaves much to be desired. Russia has a huge territory that differs greatly as by its economic development, as by the use of available hydroelectric potential in its different regions.

The recent decisions of the Russian Federation government are evidence of the establishment of large system-forming hydro-energetic complexes (i.e. Nizhne - Angarsky, Yuzhno - Yakutsky, Vitimsky and Nizhne - Yeniseisky), and the construction - the one of the largest in the world and in Russia - the Evenk HPP with output of 12 GW.

One of the main issues of HPP construction in Siberia is water quality assessment on the regulated river branches: a deep reservoir and tail water. It is known that the unfrozen patch of the water appears in winter period as a result of hydrothermal and ice regime changes in tail water of deep reservoir. Such changes in river water temperature and dissolved gases bring to the environment transformation that must be evaluated on the previous stages of the HPP project realization.

Numerous typical and specific water and environmental problems arise due the Evenk large reservoir construction on R. Nizhnyay Tunguska in Siberia. For instance, some typical problems are caused by poor preparation of the reservoir bed before the filling.

Major specific problems are the following:

- the ice and thermal regimes of projected Evenk reservoir;
- the values of total mineralization of water;
- the dissolved oxygen regime of the Evenk reservoir.

Institute for Water and Environmental Problems of Siberian Branch of Russian Academy of Science (IWEP SB RAS) realizes complex investigations in this area using field data, mathematical modeling and laboratory experiments. Some results of these investigations used for the assessment of impact of the Evenk reservoir construction on water quality of R. Nizhnyay Tunguska are presented and discussed in the paper.

EVENK RESERVOIR AS A CASE STUDY

Large-scale hydraulic engineering constructions invariably give rise to the environment changes heavily aggravated by natural conditions. The forecast of aquatic environment state in the regulated parts of a river, i.e. in a reservoir and its tailrace is of great importance at creating large and deep reservoirs in Siberia. For instance, change in hydro-ice-thermal regime brings to the formation of glades downstream from the HPPs in winter. Changes in river temperature and gaseous exchange conditions make an effect on the flora and fauna of the river including its self-purification capacity. The impact of any hydraulic engineering construction on the aquatic environment should be prevaluated, namely at the stage of studying the environmental consequences of hydroengineering projects [1-2].

Numerous water management problems arisen at the construction of HPPs in Siberia appear at the creation of the Evenk HPP on R. Nizhnyay Tunguska as well (**Fig. 1**). Here, poor preparation of the reservoir's bed before its filling may result in the problems of great concern.

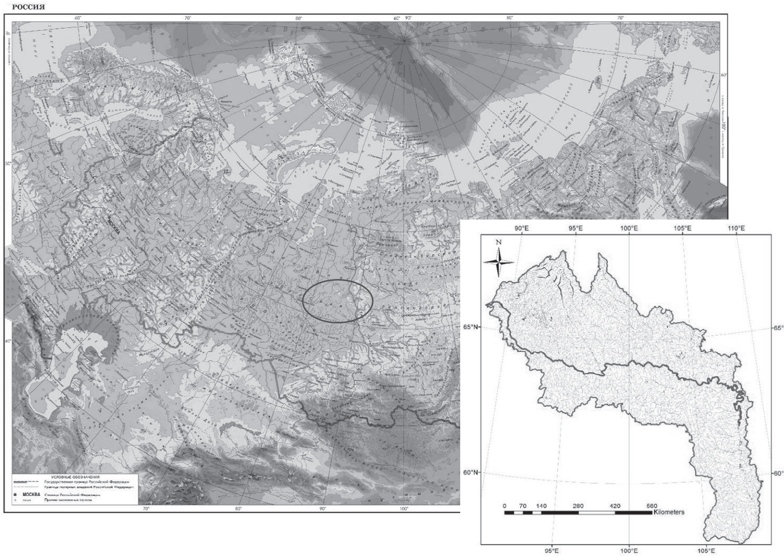


Fig. 1. Map of Russia and the Evenk HPP site.

The construction of the unique reservoir of 1200 km long (along the main channel of R. Nizhnyay Tunguska) and of volume of about 409 km^3 (one of the options) causes specific problems, solutions of which call for serious scientific studies. It is planned to build the water-engineering system in 120-km away from the mouth of R. Nizhnyay Tunguska, the right tributary of the R. Yenisei, where the climate is sharply continental. Average air temperature is +8,5 ºC, minimum winter temperature may reach -63ºC and summer maximum makes up +37 ºC. Therefore, the solution of the environmental problems related to the Evenk reservoir construction under extremely severe weather conditions greatly depends on the forecast of ice thermal regime of the reservoir and its tailrace. Most of the year the reservoir will be covered with ice; it will be ice free only in hydrological summer. Because of the large number of immersed trees and shrubs, the forecast of the water quality change in R. Nizhnyay Tunguska is one more problem to be solved. Along with the methods of comparative analysis, mathematical modeling is used for quantitative prediction of water quality change induced by the reservoir construction.

METHODS

For the Evenk reservoir, the quantitative estimate for hydrobiological regime prediction is superfluous. The analog method suggests that the biological productivity in the projected reservoir will be low. By biocenosis development, the water reservoir will be characterized as an "oligotrophic" one due to natural and economic conditions existing in the adjacent area. The formation of vertical density (temperature) stratification that substantially complicates the efficient mixing of water masses in depth and creates widespread vertical stratification of dissolved matter and gases is typical for deep reservoirs.

Oxygen regime is one of major indicators of ecological state of water bodies because practically all chemical and microbiological processes run with or in the presence of dissolved oxygen. Generally, oxygen deficiency structurally rearranges the entire cycle of substances circulation in the water body. For example, decrease in concentration of dissolved oxygen below acceptable limits adversely affects the fish fauna and fish productivity of reservoirs. During the construction of large and deep reservoirs, vertical density stratification must be considered for predicting the changes in dissolved oxygen concentration.

When making a quantitative estimate of water quality change in the river at the construction of the Evenk HPP, the dissolved oxygen concentration and the water salinity in the designed reservoir are also of great importance. A densely forested area (subject to flooding in case of the HPP construction) can effect negatively on the water quality and oxygen regime of the reservoir.

Rather high natural mineralization of surface runoff in the area of the projected HPP implies an assessment of probable water salinity of the Evenk reservoir. Without the determination of water salinity in the reservoir, it is impossible to define the quality characteristics of the water, to determine its suitability for public water supply as well as salinity of the water discharged from the reservoir into the tailrace.

To forecast the mentioned indices, we use methods developed by IWEP SB RAS for mathematical modeling of dissolved oxygen and dissolved organic matter in the deep reservoir with fairly running water [3].

The oxygen regime model for a deep reservoir is based on the principles proposed by Streeter and Phelps. Standard model equations by Streeter-Phelps assume homogeneity in chemical parameters distribution within horizontal layers of the reservoir. Typically, the model for oxygen behavior in deep stratified reservoirs includes three variables: dissolved oxygen, dissolved labile organic matter and suspended organic matter which vertical distribution is induced by convection and diffusion. To calculate the oxygen consumption due to oxidation of immersed vegetation, we apply a semi-empirical formula, where the flow value at the interface "water-bottom" is proportional to that of total mass of all matter extracted from the submerged biomaterial. Extra oxygen is spent for oxidation of organic substances extracted by water from the flooded vegetation and soil.

Numerical calculations were performed for two optional sites: the 1st is at a distance of 59,5 km from the mouth of the river, normal maximum operating level (NMOL) - 110,00, BS, and the 2nd - at a distance of 120,0 km from the mouth, NMOL 200, BS. For the 1st site, the reservoir length is 695,5 km and volume - 48,51 km^3; for the 2nd - 1229 km and 409,40 km^3 (see also **Table 1**). The flooded area is 73,6 and 868,0 ha, respectively. The simulation involves the processes of 30 years ahead, starting from the time of the reservoir filling. To do the calculations, the in-situ data on discharge and temperature of the water flowing into the reservoir, the concentration of dissolved oxygen and salinity as well as the meteorological information were used.

Table 1. Major parameters of the Evenk reservoir.

Parameters	Units	Value	
		Site 59,5 км	Site 120 км
Normal headwater level (NHL)	мBS	110	200
Surface water area for NHL	км^2	1684	9406
Volume for NHL	км^3	48,51	409,4
Max depth for NHL	м	104	185,3
Reservoir length for NHL	км	695,5	1229
Depth variation	м	27	12
Freeze-up duration	month	8	8
Water change	time/year	4	0,3

The calculations of hydrothermal regime of the Evenk reservoir show that the reservoir filling will induce quick formation of thermal stratification undergoing changes in spring and autumn due to homothermy. The calculations took into account the salinity effect on vertical distribution of water temperature throughout the year. The calculation of total mineralization of the reservoir was based on the data on salinity change in the water coming from the main river and its tributaries. Precise information on salt entering with groundwater is unavailable. We neglected the processes of salts washing-out from the flooded soils at this stage of the research because the estimates for wetlands are evidence of little contribution of salt.

Oxygen calculations for the Evenk reservoir demonstrate that the distribution of dissolved oxygen concentration in depth of the reservoir will depend on some factors, i.e. the oxygen content of the water entering the reservoir, the oxygen flow at the interfaces "air-water" and "water-bottom", including oxidation rate of organic matter and vertical turbulent exchange. It is assumed by the oxygen regime model (model DO-BOD) that oxygen flow at the interface "water-bottom" is mainly caused by washing out soluble components of wood. When the reservoir freezes, the flow of oxygen at the interface "water-ice" is absent. The most rigid calculations ignore felling in the flooded area (note: up to 92% of the flooded zone is occupied by trees and shrubs).

RESULTS AND DISCUSSION

Mathematical modeling of temperature, salinity and total dissolved oxygen for the Evenk reservoir indicates the following.

With the reservoir filling, vertical density stratification (with temperature in most water close to the one of maximum density, i.e. about 4 ºC) will be formed in no time. In summer, heat accumulation will take place in the surface layers of the reservoir, above the thermocline. After the reservoir filling, maximum temperature in the surface layers will be 2-3 ºC higher than mean annual maximum temperature of the water at site Bolshoy Porog (120,0 km from the mouth of R. Nizhnyay Tunguska).

Time of freeze-up start in the reservoir concurs with that occurred naturally. The reservoir will become ice-free in June. The maximum thickness of the reservoir's ice thickness will rise by 0,3-0,4 m as compared to the one at B. Porog.

Temperature of the water discharged into the tailrace during the first years of the reservoir operation will vary substantially (within 10 ºC). After the reservoir filling, the temperature of the outflowing water is expected to be about 4 ºC (**Fig. 2**).

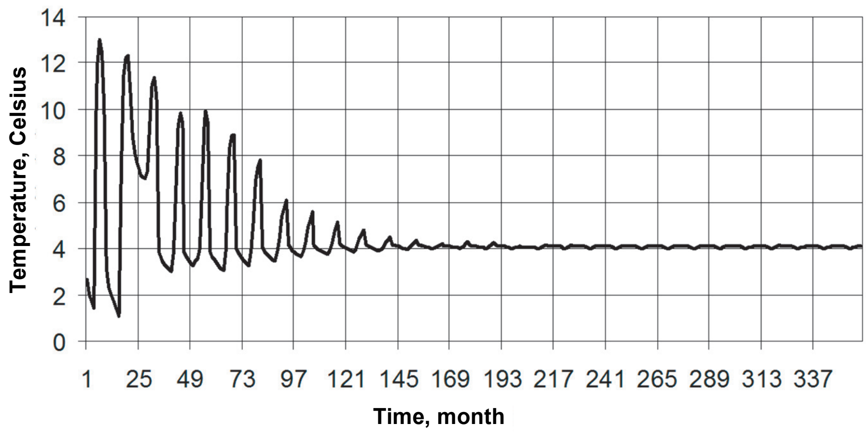


Fig. 2. Change of outflow water temperature during the Evenk reservoir filling.

With allowance made for vertical density stratification, the dissolved oxygen and salinity indices of water quality in the reservoir are generally favorable. During the first years of the reservoir operation, the oxygen deficiency in the surface layers may occur in winter. However, the reservoir filling will decrease oxygen deficit, and the dissolved oxygen concentration throughout the depth of the reservoir will be close to the saturation one (**Fig. 3**). The calculations of the dissolved oxygen concentration along the reservoir bed prove that the oxygen deficit in the reservoir is hardly probable. Water salinity of the surface layers will be less than 100 mg l^{-1}, and at the bottom - approximately 400 mg l^{-1}.

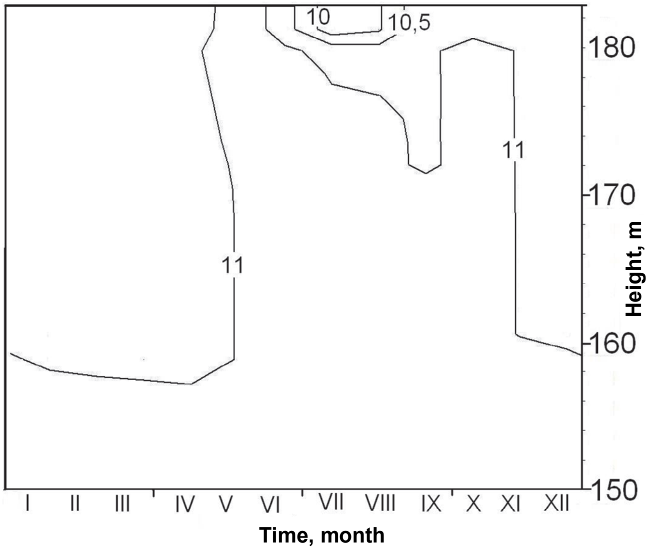


Fig. 3. Dissolved oxygen concentration (mg O_2 l^{-1}) in surface layers of the Evenk reservoir for 26th calculated year.

The calculations of ice-thermal regime in the tailrace of the operating HPP for different dam sites indicate that the site downstream from the dam up to the river mouth will be ice-free all the year round. No severe consequences at the site of confluence of rivers Nizhnyaya Tunguska and Yenisei are expected because their discharge ratio here is1/7. Thus, down city Turukhansk the Tunguska water will flow along the right bank of the Yenisei forming a jet of 1/7 the Yenisei width. All the ice-related problems are confined to this area. At a dam site of 120,0 km long, the appearance of 20-40 km glade along the right bank of R.Yenisei downstream from the R. Nizhnyaya Tunguska mouth is expected. At the dam site of 59,5 km long, some expansion of unfrozen patches of the Yenisei water will occur.

In the downstream, salinity is supposed to be equal to that in the water discharged from the reservoir. Reduction in salinity in the tailrace and its intra-annual fluctuations will be observed (**Fig. 4**).

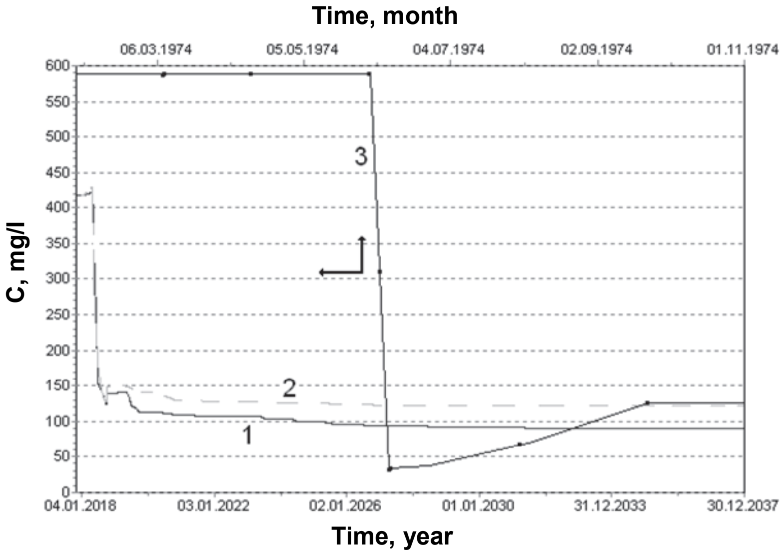


Fig. 4. Salinity in the tailrace: 1 – dam site 120 km; 2 – dam site 59,5 km; 3 - natural conditions like 1974 year.

CONCLUSION

A start on the quantitative forecasting the water quality change in R. Nizhnyaya Tunguska under the Evenk reservoir construction has been made by this research. Taking into account the intricate branchy configuration of the reservoir, a great extent of its main part stretching along the R. Nizhnyaya Tunguska bed, the adjacent dammed tributaries and its overall large depths, it seems reasonable to use a modified longitudinal vertical hydrodynamic model for hydrophysical, hydrochemical and hydrobiological processes of the Evenk reservoir with density stratification. The presence of vertical density stratification allows us to consider selective water intake as a tool for water quality management in the reservoir and its tailrace to mitigate environmental changes under the HPP construction.

REFERENCES

[1] Bocharov O.B., Vasiliev O.F. & Zinoviev A.T. Mathematical modelling of hydrothermal processes of deep-water reservoirs. Proc. XXIV IAHR Congress (9-13 September 1991, Madrid, Spain). Refined flow. Modeling, vol. C, pp. 467-476, 1991.

[2] Atavin A.A., Zinoviev A.T. & Kudishin A.V. Mathematical modelling of hydrotechnical impact construction influence on hydrothermal and ice cover behavior of rivers. Advances in Hydro-Science and Engineering, vol. 1/part A, pp. 1019-1024, 1993.

[3] Vinokurov Yu.I., Zinoviev A.T. & Epishev K.M. Ecological aspects of hydropower development in Siberia. Polzunovsky vestnik, Russia, vol. 4/2, pp. 47-51, 2011.

GIS FOR STATE WATER CADASTRE OF ARMENIA: CONTENTS, STRUCTURE, FUNCTIONS

Arshavir Avagyan, Hayk Yeritsian, Arayik Mkrtumyan, Aleksandr Arakelyan, Hasmik Manandyan, Anna Elbakyan, David Vardanyan, Artak Piloyan

Institute of Geological Sciences of National Academy of Sciences of Armenia, **Republic of Armenia**

ABSTRACT

The GIS has been developed for providing the document flow and mapping needs of State Water Cadastre of Armenia. The State Water Cadastre GIS (SWC GIS) is based on requirements and clauses of Armenian Water Code and existing practices of water resource management and conservation. According to Armenian Water Code, SWC is a "A permanent operating system, which keeps comprehensive record of quantitative and qualitative indices on water resources, water intake, watersheds, composition and quantities of materials and biological resources, which are extracted from water basin beds and coasts, as well as record of water users, water use permits and water systems use permits".

GIS automates SWC functionality and provides information (including document flow) and analytical environment for river basin management planning and implementation in Armenia.

The GIS spatial and attributive data, functionality and tasks have been regularly updated by authors during 2005-2010. The GIS is based on ESRI ArcGIS 9.2 environment with customized applications developed in Visual Basic for Applications and VB.NET.

Keywords: GIS, hydrology, cadastre, water resources management, planning, ArcGIS

1. INTRODUCTION

Increased water use and intensifying man-made pressures on the environment in Armenia have created a wide institutional system for management and protection of water resources. Such institutional setup requires an efficient information system that might provide not only management of textual data, but also manage and analyze spatial data related to water use.

The GIS has been developed for providing the document flow and mapping needs of State Water Cadastre of Armenia. The State Water Cadastre GIS (SWC GIS) is based on requirements and clauses of Armenian Water Code and existing practices of water resource management and conservation. According to Armenian Water Code, SWC is a "A permanent operating system, which keeps comprehensive record of quantitative and qualitative indices on water resources, water intake, watersheds, composition and quantities of materials and biological resources, which are extracted from water basin beds and coasts, as well as record of water users, water use permits and water systems use permits".
GIS automates SWC functionality and provides information (including document flow) and analytical environment for river basin management planning and implementation in Armenia.
The GIS spatial and attributive data, functionality and tasks have been regularly updated by authors during 2005-2010. The GIS is based on ESRI ArcGIS 9.2 environment with customized applications developed in Visual Basic for Applications and VB.NET.
SWC provides full management of textual and spatial data on water use, water resources, water formation conditions and also man-made pressures on water resources for maintaining Water Cadastre on State and River Basin Management levels.
SWC GIS consist of Geodatabase, External Database of attributive and descriptive information and two groups of Applications which are explained below.

2. MATERIALS AND METHODS

2.1. Database Structure

GIS of SWC is a scalable system and its database consists of two interrelated databases: Geospatial database and External database.
Geospatial database is an ESRI personal geodatabase and consists of 25 spatial layers, which are described below:

1. Layer of State and administrative borders of RA (Marzes) - represents marz boundaries of RA. Scale: 1:50000.

2. Layer of settlements - Settlements

   Layer represents cities and villages of Armenia. The attribute tables shows name and population according to 2001 census. Scale: 1:50000

3. Layer of Basin management area of RA – Basins

   Layer represents boundaries of Basin management areas. Scale: 1:200000

4. Layer of rivers of RA - Rivers

   Layer represents river network of RA. Scale: 1:50000.

5. Layer of reservoirs, lakes and other hydro technical structures – Reservoirs,_lakes

   Layer represents lakes, reservoirs, their names and properties. This layer was digitized from topo – maps and adjusted by ETM+ satellite imagery. Scale: 1:50000

6. Layer of water quantity monitoring stations - Water_quantity_monitoring_stations

   Layer represents locations of surface water quantity monitoring stations. Spatial data was provided by Hydrometeorological agency of Armenia. Scale: 1:100 000.

7. Layer of groundwater fresh water aquifers - Groundwater_aquifers

   Layer represents boundaries of groundwater fresh water aquifers. The source was provided by Geological fund of Armenia. Scale: 1:500 000.

8. Layer of hydrogeological wells -

   Layer represents locations of hydrogeological wells. The layer was derived from water use permits layer, as well as published and archived data. Scale: 1:50000, 2-15 meters GPS accuracy.

9. Layer of water quality monitoring stations - water_quality_monitoring_stations

   Layer represents locations of water quality monitoring stations. Database sources are data of Environmental impact monitoring center. Scale: 1:200000

10. Layer of rivers with linear referencing - Routes_rivers

    Layer represents river network with linear referencing. Scale: 1:50000.

11. Layer of river catchments - river catchments

    Layer represents boundaries of river catchments of RA. Source of data – SRTM DEM. Scale: 1:100000.

12. Layer of mudflow risk gorges - mudflow_gorges

Layer represents boundaries of mudflow risk gorge basins. The data was provided by Institute of Water Problems. Scale accuracy: 1:100000.

13. Layer of water use permits - Water_use_permits
    Layer represents locations of water use permits. The data was sourced at Water Resources Management Agency (WRMA). Scale: 1:50000 or better (2-15 m GPS accuracy).

14. Layer of Temperature observation stations - Temperature data
    Layer represents locations of temperature observation stations of RA. Data source: Hydrometeorological Agency. Scale: 1:50000

15. Layer of precipitation observation stations - Precipitation data
    Layer represents locations of precipitation observation stations of RA. Data source: Hydrometeorological Agency. Scale: 1:50000

16. Layer of landslides - Landslides
    Layer represents locations of landslides of RA. Data source: archives Scale: 1:100000

17. Layer of canals - Canals
    Layer represents canals and other drainage features. Data source: Topo maps. Scale: 1:50000.

18. Layer of average annual flow module of RA -
    Layer represents isolines of average annual flow module. Database source: Topo maps. Scale: 1:200000.

2.2. External Database

State Water Cadastre receives data from different sources, such as Hydrometeorological Service, Environmental Research and Monitoring Centre, State Water Committee, etc. These data is imported into tables in the *External Database* (in MS Access format) through a specially developed Program and stored there for query, analysis, monitoring and reporting. This is a standalone database and provides access to descriptive and temporal data for users that want to use web interface for data input and analysis. Advantage of this data organization is proved by experience of ESRI [3] and authors of this article.
The *External Database* consists of (1) tables that store data on water use permits (Register) and (2) tables that store data related to water quantity, quality and hydrometeorological observations (referred to as Tables

hereinafter). The tables in the database are managed by custom applications, which are divided into two categories- applications designed for inputting data into Register and Applications for inputting data into Tables. Visualization of water-related data may be carried out from a data view within ArcGIS or separately queried within a dialog box. Queried data may be printed or exported into a separate excel file.

The tables in MS Access Database are linked with GIS thematic layers in the geodatabase through joins, relationships and program modules that have been written with VB.NET and incorporated to ArcGIS with ArcObjects.

Access to *External Database* is organized through ArcGIS or through forms via web browser. Input of data is organized mainly through forms via web browser, so that users in Basin Management Agencies may input data from different locations.

Taking into account the source of data (Hydrometeorology Center – water discharge and water level in the river, Ministry of Nature Protection – water use permits, water quality, Ministry of Territorial Administration – hydrotechnical structures and water use), content, format and objective (Document workflow, data analysis, report generation, mapping), the of data has been classified as Static, Dynamic and Metadata.

Static Data doesn't change, or stays the same over a long period of time. This type of data usually resides in Geodatabase and the data related to it are is in the attribute table. Examples of such data are boundaries of river basins, river network, hydro-technical structures, industries, etc. An example of attribute data is a river name, river code, river basin code, river basin area, settlement name, marz name, etc.

Dynamic Data describes physical, chemical properties and technical or economic indices that permanently change. An example of such data is water level, water discharge, water quality monitoring data, etc. Such data is usually of temporal nature and is stored in an external database and linked to respective thematic layers in GIS.

Metadata includes data on the state of document workflow related to registration of water users, such as entering the documentation related to each water user, state of water user's application and termination of water user permit.

Tables in MS Access database are linked to the following thematic layers in the Geodatabase:

The layer of water quantity monitoring posts is linked to the following tables in the external database:

- Monthly and annual discharge and other main characteristics of river flow,

- Inter-annual distribution of the river flow of the 50% flow probability years,
- The main characteristics of spring tides,
- Average multiyear minimum flow values.

The layer of water quality monitoring posts is linked to the database of water pollution components.
The layer of canals is linked to the tables of the Register database.
The air temperature layer is linked to the air temperature database.
The precipitation layer is linked to the precipitation database.
The layers of meteorological stations are linked to respective databases (air temperature, precipitation).
Basin management areas (BMA) layer is linked to the following tables:

- Allocation of river basins,
- River network parameters,
- Main morphometric parameters,
- The water balance of the BMAs, (mln. m^3),
- River flow characteristics.

3. RESULTS AND DISCUSSION

3.1. Functionality

As it was mentioned above, the State Water Cadastre GIS is based on ArcGIS 9.3 software and hence takes advantage of all tools included in this software. In addition to standard functionality of ArcGIS 9.3, the GIS also includes custom functionality, which was programmed using ArcObjects and VB.NET **(Fig. 1).**

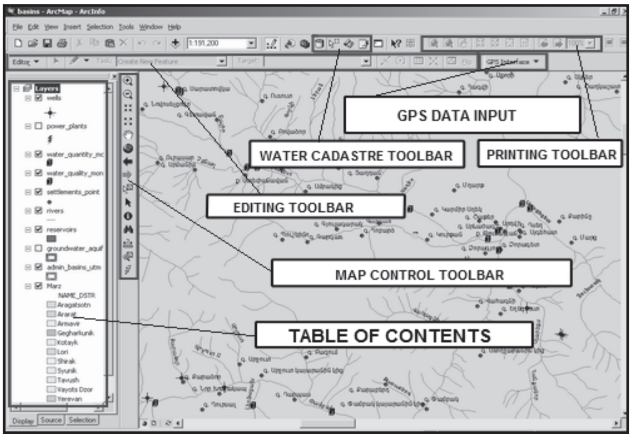


Fig. 1. Overview of State Water Cadastre GIS Toolbars

Main modules which have been customized in ArcGIS are: River Basin Management module, Temperature and Precipitation module, Water quality module, JT module, SWC profile module and Borehole section module. ArcGIS Hydro Module, which was developed by ESRI and Texas State University has also been incorporated into State Water Cadastre.

3.2. River Basin Management module

River Basin Management module aggregates water use permits, river discharge and river geomorphological features at river basin management level. The dialogue window below shows water use at river basin management level, which is stored in table 4.11. The dialogue window is activated by clicking on Basin Management Area layer on the table of contents in ArcGIS **(Fig. 2).**

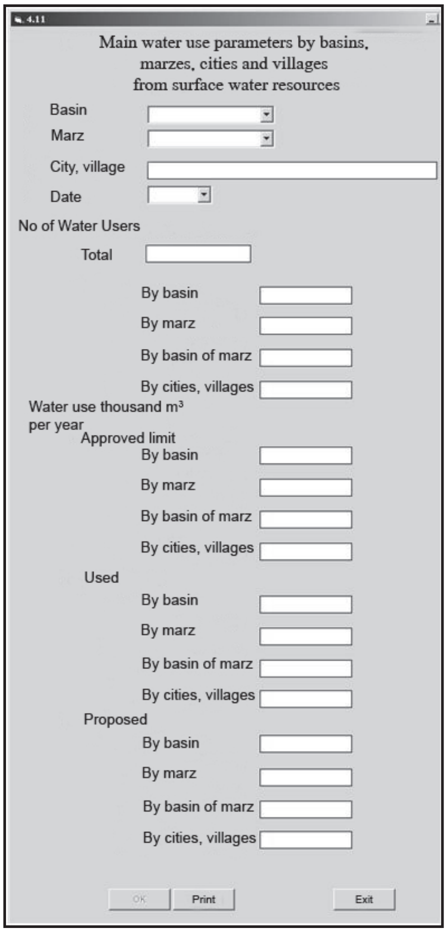


Fig. 2. Dialogue window for input and viewing of water use data

3.3. Temperature and Precipitation Modules

Temperature and Precipitation modules provide access to temperature and precipitation data (temporal) received from Hydro-meteorological Agency and stored in external database. These are linked to Meteo-stations spatial layer in table of contents. The module is activated by Meteo-stations layer in Table of contents. As a result a dialogue window pops up where user may view temperature and precipitation related data.

3.4. Water Quality Module

Water quality module provides access to water quality data received from Environmental Monitoring Center and imported in external database. These are linked to Water quality monitoring spatial layer in table of contents of ArcGIS. The module is activated by Water quality monitoring layer in Table of contents. As a result dialogue window pops up showing water quality data **(Fig. 3).**

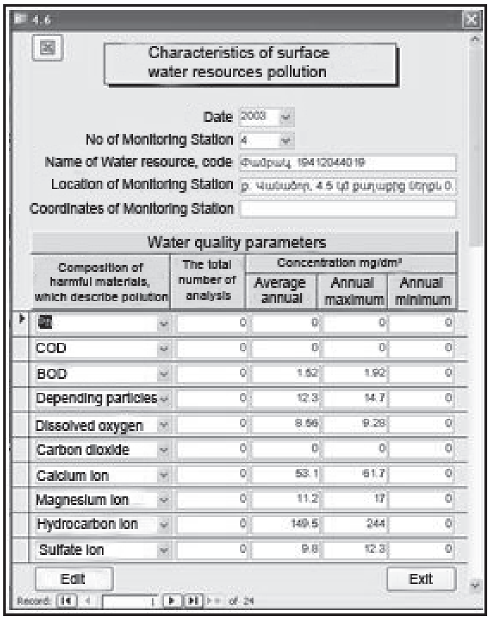


Fig. 3. Water Quality Dialogue Window

3.5. JT module

JT module allows importing and viewing of file – based information on specific water use permit. These are drawings, photos and maps for a specific water use permit **(Fig.4).**

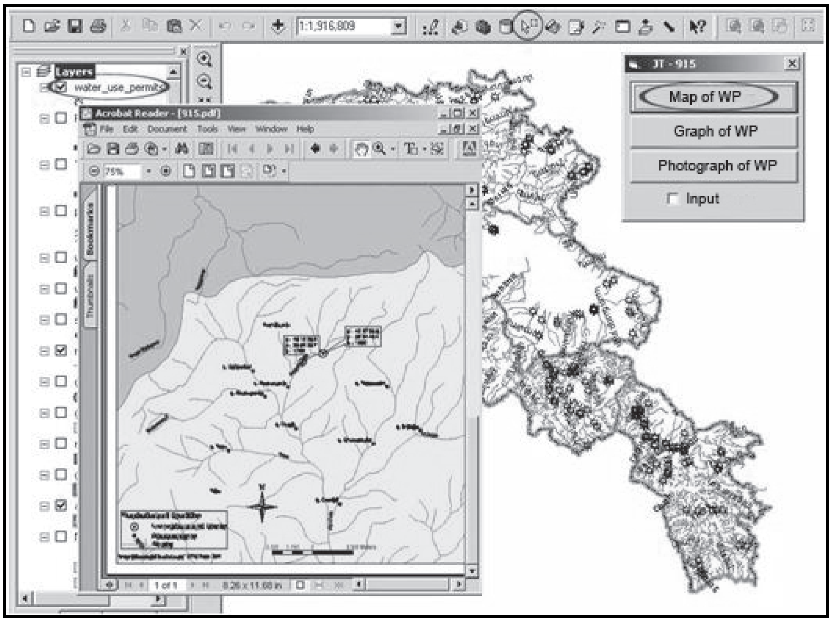


Fig. 4. JT Module showing a developed map for a particular water use permit

3.6. SWC Profile

SWC Profile module was designed for creating an elevation profile for selected river in SWC GIS. The module creates profiles from underlying Digital Elevation Model and may export data into MS Excel for further analysis **(Fig. 5).** This module is designed for river flow modeling and creating of hydro-technical structures on sections of rivers.

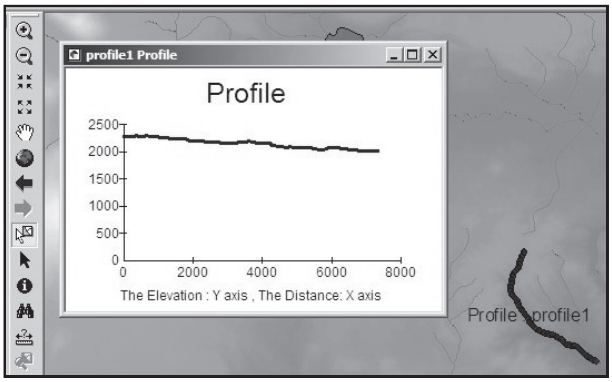


Fig. 5. Profile of a selected river

3.7. Borehole Section Module

SWC - GIS includes a layer of Groundwater wells drilled all over Armenia for water use (irrigation, drinking and fish-farming). The information related to each drill-hole is stored in an external database. Examples of data related to each drill-hole are geological layers, water quality, technical details, etc. A custom program has been developed for selecting and visualizing data for a specific drill-hole directly from ArcGIS **(Fig. 6, 7).**

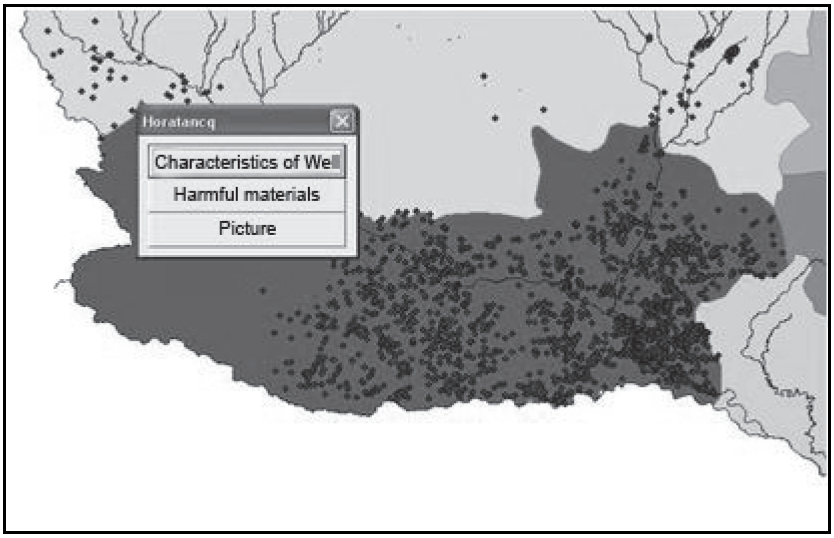


Fig. 6. Selection of a Drill-hole from a Map

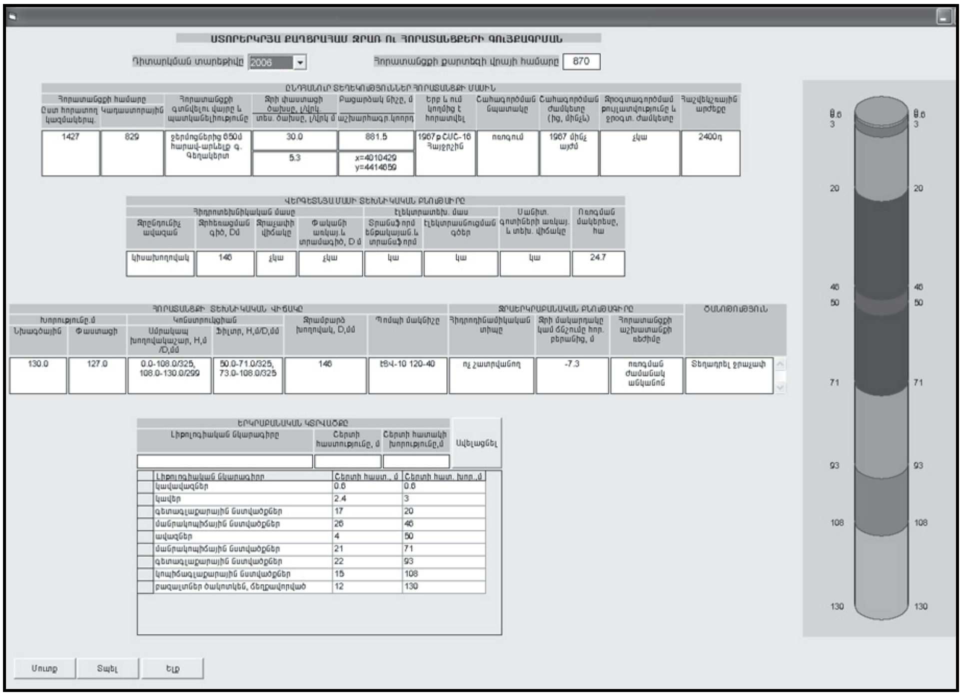


Fig. 7. Interface for visualization of data for a selected Drill-hole. Right side shows lithological layers

4. CONCLUSION

The State Water Cadastre GIS, which is based on requirements and clauses of Armenian Water Code and existing practices of water resource management and conservation, automates SWC functionality and provides information and analytical environment for river basin management planning and implementation in Armenia. The functionality of SWC are carried out GIS using Geodatabase, External Database of attributive and descriptive information and two groups of Applications.

REFERENCES

[1] Bedford M. GIS for Water Management in Europe, ESRI Press, Redlands, California, 2004, 156 p.

[2] David R. Maidment. Arc Hydro: GIS for water resources. Redlands, California, 2002, 205 p.

[3] ESRI, Building a Geodatabase, Environmental Systems and Research Institute, Redlands, California, 492 p.

INTEGRATED STUDIES OF LAKETELETSKOYE FOR ITS CONSERVATION AND SUSTAINABLE USE (ALTAI, RUSSIA)

Prof. Dr. Yuri I. Vinokurov, Dr. Alexander T. Zinoviev, Dr. Elena Yu. Mitrofanova

Institute for Water and Environmental Problems SB RAS, Barnaul, **Russia**

ABSTRACT

The paper presents the results of hydrological, hydrophysical, hydrochemical and hydrobiological studies of the Lake Teletskoye ecosystem. The data on vertical distribution of temperature, dissolved oxygen, nutrients and plankton algae in the lake for different hydrological periods were obtained. The outcomes of the integrated studies were used to assess the spatial and temporal heterogeneity of physical-chemical and biotic characteristics of the lake as well as to develop models for physical - chemical processes in deep stratified lakes and reservoirs.

Keywords: Lake Teletskoye, ecosystem, integrated studies, mathematical modeling.

INTRODUCTION

To evaluate and predict the ecosystem state of Lake Teletskoye – the unique natural object situated in the Altai Mountains in the south of West Siberia, IWEP SB RAS carried out the integrated limnological studies for the last 25 years. The study of the lake as a reservoir-analog to already operating and the projected deep Siberian reservoirs is based on the observations for hydrological, hydrophysical, hydrochemical and hydrobiological processes with the use of modern equipment. Such a research allows us to assess the spatial and temporal heterogeneity of physical-chemical and biotic characteristics of the lake, to develop models for hydrological and hydrochemical processes that are characteristic of deep stratified lakes and to perform numerical calculations and verification. The comparison of the calculated and the observed data makes it possible to estimate the accuracy of the models used for the diagnostics of the current state and the prediction of climate and anthropogenic impacts on the water environment of Lake Teletskoye.

LAKE TELETSKOYE AS A CASE STUDY

Lake Teletskoye is unique as the object of study because it is the deepest freshwater reservoir in West Siberia. Its maximum depth is 323.3 m, length – 77.8 km and width – 5.2 km. Lake Teletskoye is the second (after Baikal) by volume (41.1 km^3) of fresh and pure water among fresh-water lakes of Russia. A total of70 permanent and 150 temporary tributaries flow into the lake. In the southern part of the reservoir, the major runoff is provided by river Chulyshman (0-75 %), and in the northern part the only river Biya outflows the lake. Numerous tributaries drain the catchment area that is 91 times larger than the water area of the reservoir itself. Water renewal in the lake occurs every 5.81 years [4]. A combination of factors (e.g. seasonal formation and destruction of vertical temperature stratification, the presence of density currents, complete and incomplete freeze-up in winter) generates a complex hydrological regime of the reservoir. According to the global thermal classification of lakes, this reservoir is dimictic, with periods of maximum stratification and turbulence observed twice a year (in spring and autumn). The temperature in a water column of the lake is below 4.0°C for seven months, and below 3.0°C -for more than five months [1]. The water temperature at the surface above 10 °C lasts for two and a half months, at a depth of 20m - within a decade. Because of strong winds blowing along the lake's valley and convective mixing, heat distribution in the water extends to maximum depths. The water in the lake is rich in dissolved oxygen; it varies seasonally as 8-13mg/l; average annual saturation reaches 87%. In summer and autumn, oxygen super saturation (101-112%) is observed in the upper layers [1].

The first studies of the lake were conducted in the 20-30s of XX century during the Hydrological Institute expedition headed by S.G. Lepneva. The systematic study of the lake was started in the late 60s of the last century: in 1965, Goskomgidromet established lake station "Teletskaya" in village Yailu. Here, in the 90s, the station for the integrated background monitoring was created [5]. The basic relationships of a hydrological regime of the lake and its bottom topography were studied [1]. In the late

80s, IWEP was involved in the studies of Lake Teletskoye as an analog to the projected Katun reservoir. Being the source of the Ob'- one of the world's largest rivers, the lake is of strategic importance as a huge reservoir of clean fresh water. In the 90s of the last century, UNESCO included the lake and its catchment in the World Heritage List for its uniqueness and importance. In 2010-2013, the limnological investigations of the lake were continued by IWEP within the framework of the state and integration projects. With the use of profiler SeaCat SBE-19plus equipped with a measuring device, and along with hydrochemical and hydrobiological sampling, we made the observations to study the peculiarities of density stratification formation in the reservoir to assess the impact of dissolved ions and suspended matter impact on stratification and to evaluate spatial and temporal distribution of nutrients and aquatic organisms. The data obtained in situ were included in the GIS database "Lake Teletskoye" and used as input data for modeling hydrological processes of the lake.

RESULTS AND DISCUSSION

Temperature and dissolved oxygen were measured with the use of a probe on numerous verticals covering the entire area of Lake Teletskoye (**Fig. 1**), where as hydrochemical and hydrobiological studies were carried out on verticals located at the mouth of major tributaries in the pelagic zone.

The first measurements of temperature and oxygen were made in 2010: in the summer during heating and in the autumn during cooling (12-13.08, 29.08, 29-30.09) [6-7]. Temperature profiles (**Fig. 2**) illustrate the spatial-temporal pattern of the temperature field of the lake. Vertical distribution of temperature and dissolved oxygen at the end of summer heating (**Fig. 3**) shows an inverse relationship of dissolved oxygen on temperature in the surface layers of Lake Teletskoye.

Vertical sounding of Lake Teletskoye in 2011 (12-14.07 23-26.09 and) supports the previously identified 2-group differentiation of vertical temperature profiles. In the southern part of the lake, thermocline occurs at depths of 20-30m; when moving from south to north, thermocline thickness reaches 40-50 m and more. Perhaps, this is due to the increased wind-induced waving in the direction from south to north of the lake. The studies indicate that the Chulyshman inflow effects on a significant deep part of the lake basin and plays an essential role in the formation of its stratification density.

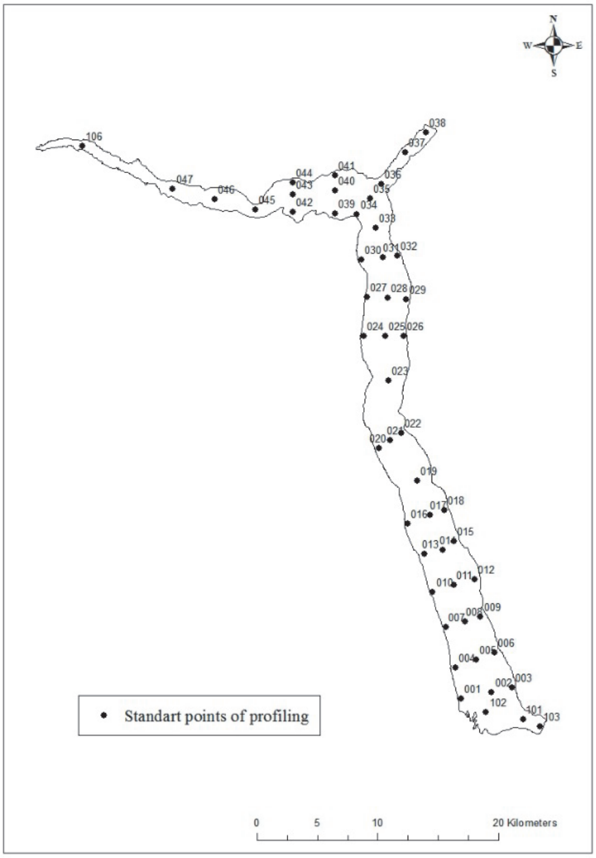


Fig. 1. Map of Lake Teletskoye with the location of measuring verticals in 2010-2012.

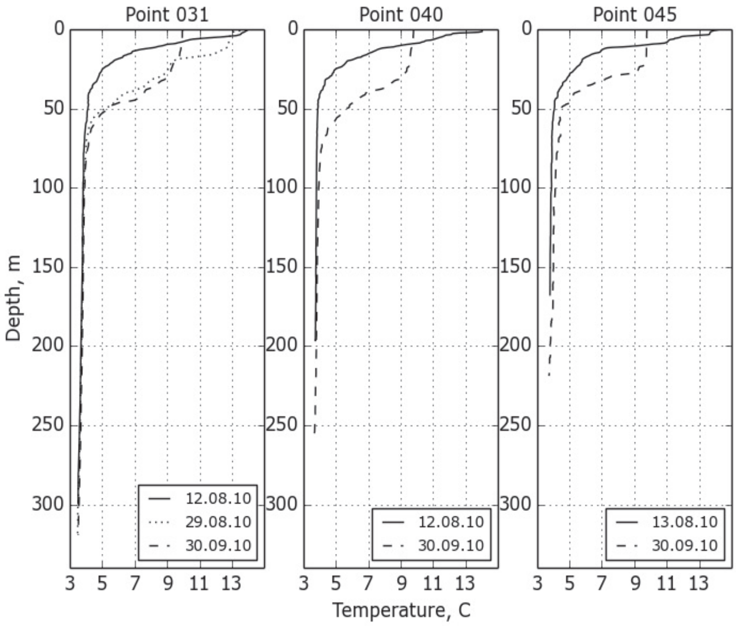


Fig. 2. Profiles of water temperature on verticals 31, 40 and 45 (for 12-13and 29 August, 30 September 2010).

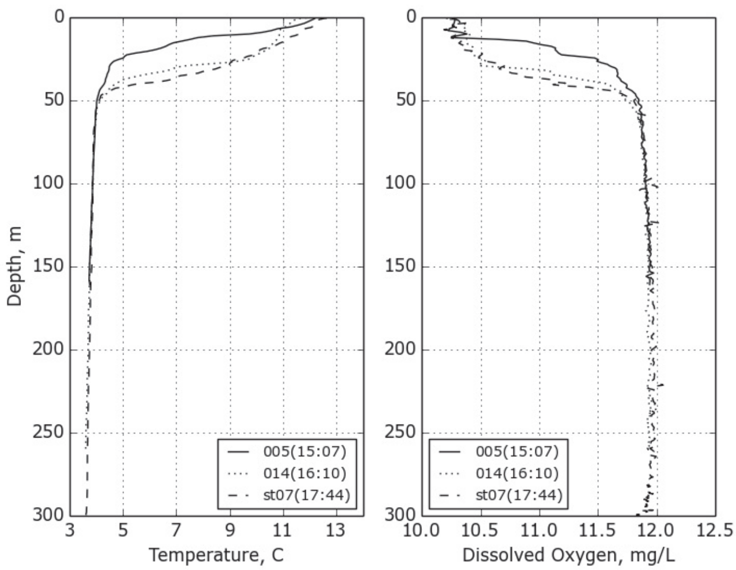
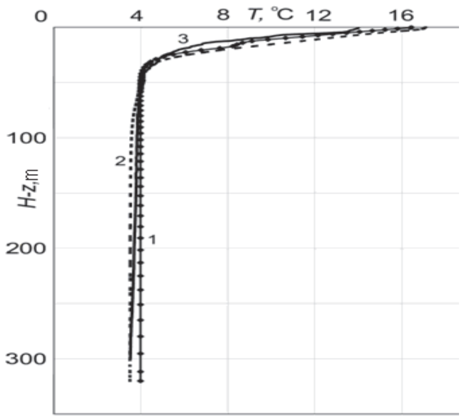


Fig. 3. Profiles of water temperature and dissolved oxygen concentration on verticals, 3, 5 and 7, according to the measurements of 29.08.2010.

Time of measurement start is given in parentheses (local summer legal time). Duration of measurements: 5-7 minutes.Cross-section temperature profiles show a substantial uniformity of the temperature field in Lake Teletskoye during the summer. In 2012, we obtained the data on the formation of stratification density and gas regime for the spring (06-08.06) and the summer heating (08-10.08) as well as for the fall cooling (16-18.10). A noticeable enlargement of thickness of the upper mixed layer confirms the earlier findings on the growing role of wind-induced mixing caused by the increased wind velocity in the direction from south to north, i.e. from the mouth of R. Chulyshman to the source of R. Biya. When calculating the temperature, we allowed for water compressibility (**Fig. 4A**). The results showed [8] that the calculated temperature profile is close to the observed one.



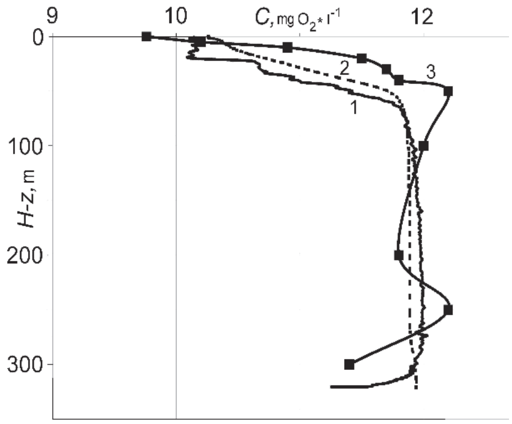


Fig. 4. Temperature profiles (A) and the dissolved oxygen concentration (C) in Lake Teletskoye of 29.08.2010: for A 1 and 2 - the calculations made with and without compressibility; 3 – in situ measurements using probe SBE- 19; for B 1 – field measurements using a probe, 2 - calculation, 3 – the Winkler method – based in-situ measurements

The model calculations of dissolved oxygen were made with the use of the input data for 2010 [8]. We neglected suspended organic matter because of its small amount in the water. The analysis of numerical results is evidence that the concentration of dissolved oxygen throughout the lake's depth of the lake is close to the saturation one. The data obtained using a measuring probe show some decrease in dissolved oxygen content in the bottom layers. Probably, this is due to the influence of brackish water of R. Chulyshman, the main tributary of Lake Teletskoye. Simulations based on models 1DV (the model for oxygen regime of Lake Teletskoye) also demonstrate a good agreement between the calculated and field data (**Fig. 4B**). Thermocline formation during the summer heating and autumn cooling hinders dissolved oxygen transport from epilimnion into hypolimnion. Hydrodynamic features of vertical mixing of the water column determine the basic spatial characteristics of the lake's ecosystem. Similarity of the calculated results and field data on dissolved oxygen in the lake allow us to consider this hydrothermal model as the basic hydrophysical one for describing hydrochemical processes in deep reservoirs designed in Siberia for making simulation and trend calculations.

According to the hydrochemical observations, the content of biogenic elements of nitrogen (NH_4^+, NO_2^-, NO_3^-) in the water of Lake Teletskoye is low. Prevalence of nitrate ions (0.66-1.86 mg/dm^3) indicates the presence of intensive nitrification processes under excess oxygen saturation. Nitrite nitrogen concentration is extremely low. Ammonium ions occupy an intermediate position between nitrate and nitrite ions; they have low concentrations (0,022-0,098mg/dm^3) that is typical for oligotrophic lakes. The study of vertical distribution of concentrations of elements from a nitrogen group shows a tendency in nitrate ions increase with depth, while ammonium ions demonstrate uneven change in the profile **(Fig. 5A, B**). Phosphate ions content in the water of Lake Teletskoye is insignificant, and their distribution along the vertical profile is uneven. The silicon concentration is 1-2 orders higher than that of other nutrients – on average it makes up 2.18-2.90 mg/dm^3. Silicon in the lake water is sufficient for normal development of diatoms. High content of dissolved oxygen and low nutrient concentration in the surface water of Lake Teletskoye and its tributaries clearly indicates the occurrence of active biochemical processes of self-purification through nitrification and photosynthesis; therefore, we can classify the studied water as clean.

In 2012, concentrations of heavy metals (As, Cd, Cr, Cu, Fe, Mn, Pb, Zn) were defined for the first time in recent years by atomic absorption spectrometry with flame atomization (acetylene - air) and electrothermal atomization based on SOLAAR M- 6 device. Most of the studied heavy metals have background levels, but sometimes their concentrations exceed MPC established for the waters of fishery reservoirs. These slightly increased concentrations of heavy metals are characteristic of the lake's chemical composition; they reflect geochemical peculiarities of geological formations of its catchment area. For instance, the increased concentration of iron detected in the estuary of R. Chulyshman in June 2012 (2 ± 0.8 mg/l) can, probably, be related to the groundwater outflow, i.e. a hydrogen sulfide source located in an active fault zone above the mouth of R. Chulyshman. Excess in copper is associated with the increased local geochemical background induced by the occurrence of sulfide and oxide ores in the form of malachite mineralization. Partially, Lake Teletskoye is attributed to the area of gold-silver-copper mineralization.

Hydrological, hydrophysical and hydrochemical factors influence on the composition and the quantity, as well as the distribution of primary producers, autotrophic organisms (plankton algae), which together with other autotrophic benthos and fouling determine the state of the lake ecosystem as a whole, since they are at the base of the food pyramid and support self-purification processes in the lake.

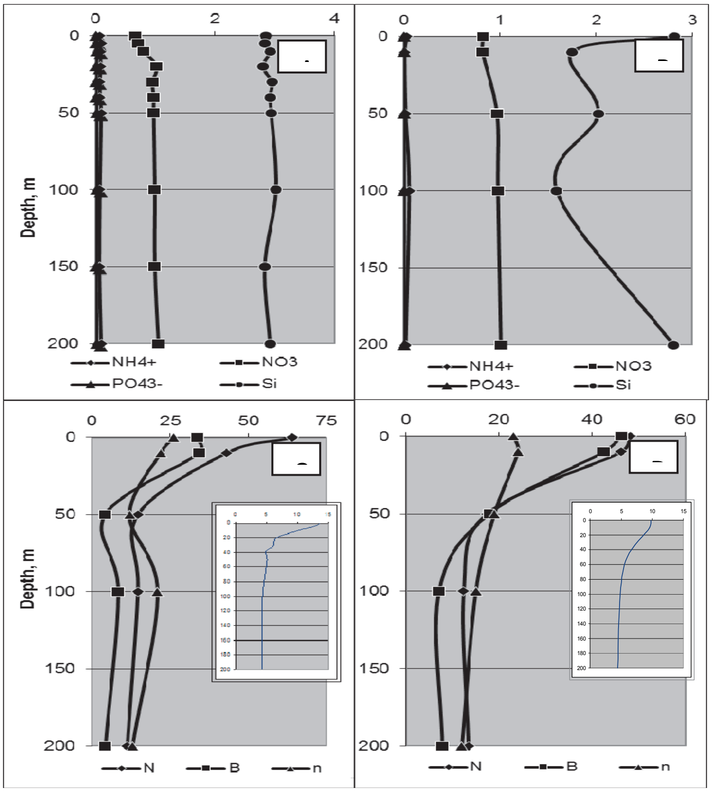


Fig. 5. Vertical change in nutrient concentration (mg/l), number (N, th.cells/l), biomass (B, mg/m^3), number of phytoplankton species (n) and water temperature (^{0}C, see inset) in Lake Teletskoye (Yailu village, the pelagic zone) in August (A, C) and September (B, D), 2010.

Phytoplankton development in the lake has its own specific features. The composition of phytoplankton is characterized by high diversity; total 337 species from 10 major taxonomic groups were found. Diatoms, a characteristic component of deep oligotrophic lakes, dominated in number of species. The studies of 2010-2012 carried out with the use of electron microscopy (SEM Hitachi S-3400N) gave more information on this group of algae, cells of which have a siliceous shell. For instance, phytoplankton dominants in abundance [9] were specified, additional data on rare [10] and common types of diatoms [11] as well as morphological changes in their valves with teratoforms formation [12] were obtained. In addition, we got the new data on other siliceous algae (chrysophycean ones) [13]. Their resting stages, or stomatocysts, are widely used in the environmental and paleolimnological studies because like diatoms they are well preserved in sediments and used as paleoindicators.

Much attention was paid to the study of vertical distribution of algae in the water column conducted in parallel with vertical profiling of temperature, dissolved oxygen and nutrients. Our studies confirmed that regardless of a hydrological season, the most of planktonic algae is concentrated in the upper part of the photic zone (0-10 m) under direct stratification and mixing of water thickness but with different quantitative values (**Fig. 5C, D**). It is found out that water temperature is more important for algae development and distribution during stratification. Analysis of concentration and vertical distribution of nutrients including phytoplankton amount in the water column suggests that an extremely low phosphorus content is the limiting factor for the phytoplankton development in the lake. Similar situation is observed in other deep-water bodies of the temperate zone. Hydrodynamic processes play a significant role in algae distribution within the water thickness of Lake Teletskoye. Due to these processes, the periods of stratification are short both in summer and in winter unlike the periods of mixing that has a negative effect on phytoplankton abundance occur. By phytoplankton biomass (up to 1 g/m^3) Lake Teletskoye was and remains the oligotrophic one still.

CONCLUSION

The studies of 2010-2012 allowed us to specify the details of spatial and temporal density stratification in the reservoir. Moreover, some insignificant hydrophysical effects (like thermobar motion and the formation of stable structures (lens) that differ from the surrounding water properties by temperature, salinity and transparency) were identified. We obtained the data on dissolved oxygen in the lake water in different hydrological periods by means of different methods. We also obtained the data on the distribution of nutrients and phytoplankton in the water column of the lake in different hydrological seasons as well as on the distribution of heavy metals in the lake basin. Factual information on the current state of Lake Teletskoye is used for the development and verification of simulation and prediction models for hydrological processes in Lake Teletskoye that allow us to assess changes occured in the aquatic environment induced by intensification of recreational activities at Lake Teletskoye and its catchment area.

REFERENCES

[1] Selegei V.V. & Selegei T.S. Lake Teletskoye. Leningrad, 142 p., 1978.

[2] Selegei V., Dehandschutter B., Klerks J. & Vysotsky A. Physical and geological environment of Lake Teletskoye. Annales Sciences Geologiquesvol. 105, pp. 1-310, 2001.

[3] Lake Teletskoye / E.Yu. Mitrofanova & V.V. Kirillov (Eds.); Institute for Water and Environmental Problems SB RAS. Novosibirsk, 28 p., 2012.

[4] Selegei V.V. Lake Teletskoye: History essays. Book I, Novosibirsk, 119 p., 2009.

[5] Selegei V.V. Lake Teletskoye: History essays. Book 3, Barnaul, 244 p., 2011.

[6] Zinoviev AT, Mitrofanova E.Yu., Tretyakova EI, Marusin KV, Dyachenko AV, Blinov VV, Granin NG & Gnatovsky R.Yu. & Complex studies of Lake Teletskoye: thermal regime, hydrophysical and hydrobiological characteristics / Water and ecological problems of Siberia and Central Asia. Vol. 1, Barnaul, 2012, pp. 42-47.

[7] Zinoviev AT, Marusin KV, Dyachenko AV, Gnatovsky R.Yu. & Blinov V.V. Complex hydrophysical studies of Lake Teletskoye. The recent problems of reservoirs and their catchments. Vol. 1, Perm, 2013, pp. 197-202.

[8] Zinoviev A.T. & Koshelev K.B. Complex of models for description of hydrophysical prosesses in deep lakes and reservoirs (Lake Teletskoye as a case study). The recent problems of reservoirs and their catchments. Vol. 1, Perm, 2013, pp. 192-197.

[9] Bazhenova OP, Mitrofanova EY & Shakhoval VE Stomatocysts of Chrysophyte Algae from Water Bodies of the Territory Near the Irtysh River in the Omsk Region and Lake Teletskoe (Mountainous Altay, Russia). Contemparary Problems of Ecology, vol. 4, pp. 571-578, 2012.

[10] Genkal S.I., Mitrophanova E.Yu. & Kulikovskiy M.S. Morphological variability, taxonomy and distribution of Cyclotella bodanica Eulenstein (Bacillariophyta) in Russia. Inland Water Biology, vol 6 (2), pp. 85-97, 2013.

[11] Mitrofanova E.Yu. Diversity of centric diatoms in the phytoplankton of a deep oligotrophic lake as a factor and indicator of the stability of its ecosystem: the example of Lake Teletskoye, Altai Mountains, Russia. Russian Journal of Ecology, vol. 42 (3), pp. 256-259, 2011.

[12] Mitrofanova E.Yu. & Genkal S.I. A noteworthy finding of rare species Nupela neogracillima (Bacillariophyta) in Lake Teletskoye (Russian Altai). Algological Studies, vol. 143, pp. 43-49, 2013.

[13] Mitrofanova E.Yu. & Tretyakova E.I. Teratological forms of diatoms in algaeflora of Lake Teletskoye. Water: chemistry and ecology, vol. 10, pp. 112-119, 2013.

THE PRINCIPLES OF GUIDELINE FOR THE RIVER BASIN MANAGEMENT PLANNING IN ARMENIA

Arshavir Avagyan, Alexander Arakelyan, Hayk Yeritsian, Arayik Mkrtumyan, Hasmik Manandyan, Anna Elbakyan, Artak Piloyan

Institute of Geological Sciences of National Academy of Sciences,
Republic of Armenia

ABSTRACT

River basin management plans are a requirement of the European Union Water Framework Directive (EU WFD) and a means for protection, improvement and sustainable use of the water environment across Europe.

In this paper the first four steps of River basin management planning are examined by the authors:

- Characterization of the river basin,
- Identification of pressures and assessment of pressure impacts,
- Delineation and classification of water resources,
- Setting of environmental objectives of water bodies.

The above mentioned steps are the scientific-methodological basis of the Integrated River Basin Management planning.

Keywords: Integrated water resources management, river basin management, water balance, water bodies, delineation, classification, maximum flow, water quality, minimum environmental flow.

1. INTRODUCTION

The sustainable development of a country requires an integrated and adaptive water resources management plan at a state level. River basin management (RBM) plans are management tools for Integrated water resources management. These plans are a requirement of the European Union Water Framework Directive (EU WFD) [12] and a means for protection, improvement and sustainable use of the water environment across Europe. This includes surface freshwaters (including lakes, streams and rivers), groundwater, ecosystems - such as wetlands that depend on groundwater, estuaries and coastal waters within one nautical mile distance from the coast.

WFD requires member states to achieve at least *good status* in each water body within their river basin districts. Each member state must produce a plan for each of the river basin districts within its territory.

Based on the concepts and approach of the EU WFD and the content of Armenia's Water Code, a River Basin Management Planning Guideline for the first time in Armenia has been developed on the example of Meghriget River Basin in 2008 [18], and Aghstev River Basin Management plan in 2009 [9] - with participation of the authors of this article.

The components of RBM plan are:

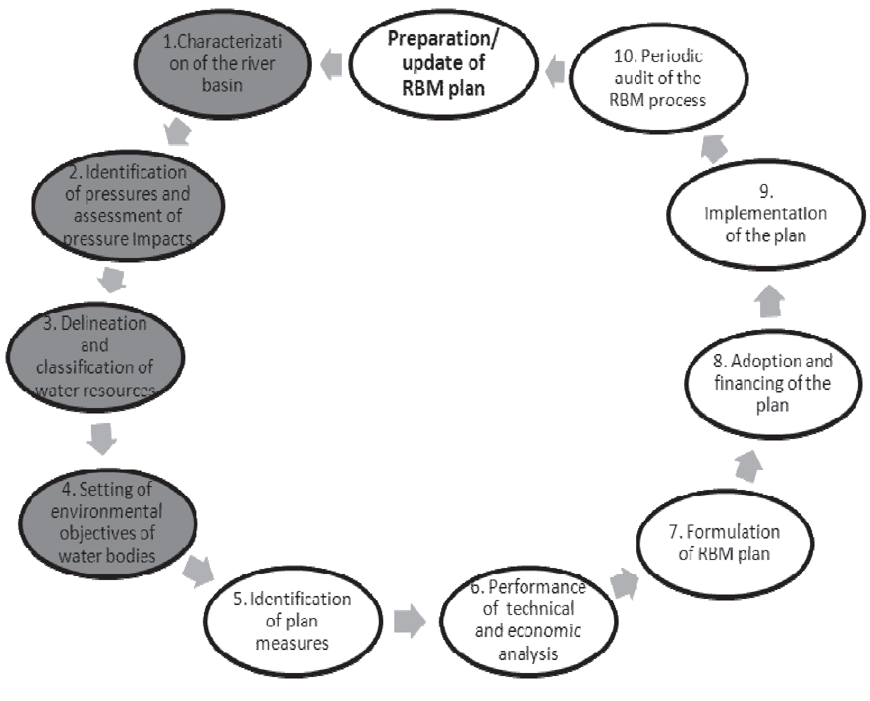


Fig. 1. River Basin Management Planning Scheme

The first four steps consist of the scientific-methodological basis of the Integrated River Basin Management planning and they are examined by the authors in this paper.

2. MATERIALS AND METHODS

2.1 Characterization of the river basin

Characterization is a review of the physical, biological, geographic, social and economic condition and water use situation in the river basin. It provides background information for next steps of planning.

2.1.1 The physical-geographic-biological characterization needs to start with identification of the river basin of interest, and a description of its location, hydrography and topography, including appropriate maps. The following items are included:

- General description of location, defined river basin by exact downstream point of discharge, and names of its major upstream tributaries,
- Location map of river basin within Armenia,
- General map of the river basin including: labeled rivers, lakes and sub-basin stream names; major towns: principal (national) highways; borders of administrative units (marzes), and national border,
- Table of hydrographic data for the river basin, including for the entire basin, and each major tributary (more than 10% of basin area): watershed area, maximum elevation, minimum elevation, length of channel, gradient, river network density ,
- Additional sample hydromorphic data on the main river channel of the basin should be included, for example depth, width, width/depth ratio, sinuosity (total length/straight line distance) and type of channel form (braided, meandering or straight), modifications that take place in-stream,
- Any natural lakes should be characterized as to area, maximum depth, average depth, and location (coordinates) in a table,
- Topographic map of the entire basin, with a minimum of 40-meter contour intervals (depending on steepness of basin).

Brief descriptions of *geology*, *hydrogeology* and *soils* of the river basin, including:

1. Geomorphologic map of basin

2. Geologic map of basin (rock types) with particular attention to limestone (calcium carbonate or “karstic”) types due to their hydrologic properties,
3. Soil maps for the basin should be provided, but soils should be aggregated into categories so that only 7-10 total types are shown (otherwise the maps become too difficult to interpret),
4. Map of major known aquifers, if it exists,
5. Hydrogeological map of the basin with major aquifers springs and wells.

The climate, water quality of the river basin, including:

- Monthly and annual precipitation, temperature statistic data for stations within the basin
- Isohyet map of estimated average annual precipitation by elevation for basin,
- A summary table and short description of long-term water quality monitoring stations in the basin, and short description of water quality status for natural surface waters are useful.
- Water quality analyses for aquifers (well data) and springs/sources should be summarized in tables, with each well site separate, if any data exists.

The biological data includes information on the ecological zones, vegetation (especially wetlands), and the principal fauna of the region, with particular emphasis on the aquatic fauna.

2.1.2 Socio-economic characterization includes a description of the pressures on water resources, including population, agricultural and industrial development, economic activity and infrastructure. These factors are the key drivers of how water is used in the river basin. Later in the river basin plan this information will be used to inform the pressures and impacts analysis.

The social data includes information about the population, its demographics, historical land use and water use, health and education status, and general infrastructure of the river basin. These data had been extracted from Census 2001 and now can be updated by Census 2011 data.

The economic data includes data on employment, income, land and water use in agriculture, Socio-economic characterization includes the following items:

- Map of social infrastructure, including: roads, railroads, water supply systems, power generation facilities and distribution networks (irrigation infrastructure will be mapped in a distinct section to be described as "water use characterization.")
- Map of all inhabited areas of the river basin (villages, towns and cities expressed in relative population size) and census Database for creating derivative table information and maps of population density, age distribution and life expectancy, immigration and emigration rates, literacy rates, and educational level of population

2.1.3 Analyses for Economic Characterization of Basin

The economic characterization should focus on the employment, income and water resource impacts of distinct sectors of the economy in the river basin. The following items are included for the river basin characterization: a) map of crops in hectares, large and medium-size dairy production facilities, poultry and pig farms, major forestry and roads crossing those, location of the major current and historical mining sites; b) tables on the employment and income statistics by sector, tables explaining area in hectares of each major crop within the basin, livestock census.

The water use characterization combined with hydrology, is the main factor affecting water quantity and water quality characteristics of the river basin. Water use data includes both water abstraction and wastewater discharges in a basin, as well as water transportation from one basin to another. The principal sectors of water use are the following: the municipal and domestic, irrigation and agricultural, large industrial, recreational, fisheries, hydropower.

Water Balance is considered as a basic quantitative characteristic of River basin and calculated as a relation of water inflow, outflow and accumulation (change of storage) in any river basin or water object in a given period (year, month, decade and other). The method is based on the difference of the volume of water inflow and the volume of water outflow in any watershed area and should be equal to the change in water quantity (increase or decrease in volume stored) within the given watershed area. The water balance quantitatively represents water circulation in nature, particularly the critical relationship between precipitation, evaporation and runoff [1], [2], [3]. One of the main advantages of proposed method is that it also allows calculation of water balance for ungauged river basin. In addition, a special computer program has been developed for calculation of water balance.

Water economic balance is the comparison of water resources and calculated water demand in the region for definition of the extent of water resources satisfying the demand, as well as the surplus or deficit of water resources due to spatial and temporal variations. Particularly, water economic balance provides a possibility to issue water use permits based on reliable information, as well as to define realistic objectives for river basin planning. Hence, based on the objectives set, it will be possible to identify corresponding measures for proper maintenance and management of water resources in the given river basin.

Water balance for aquifers is calculated based on assessment of inflow and outflow of waters to and from an aquifer. As a result, underground water resources are assessed, and possibilities of obtaining sustainable water yield from those structures are described.

The European Union Water Framework Directive provides guidance on integrated water resource planning, including the integration of surface water and ground water resources planning. The basic principle is that aquifers must be managed for good chemical status (no pollution), and for a balance between recharge and withdrawal, so that the long-term water yield is sustainable. Assessment of water balance for aquifers in a given river basin provides a possibility to obtain necessary information on potential underground water resources in the river basin, and based on it, to estimate long-term sustainable water yield to support economic development, as well as implement optimal distribution of underground waters. Once the status of an aquifer's water balance is assessed, then reasonable environmental objectives for that aquifer can be developed.

Maximum discharge is associated with flooding and mudflows. Hence the calculation of maximum discharges for different probabilities of occurrences is important for determination of frequency of the above mentioned threats [14]. Calculation of maximum discharges is an important part of planning, particularly land use, transportation and urban planning and planning of agricultural investments and hydraulic infrastructure in general [7].

3. RESULTS AND DISCUSSION

3.1 Identification of pressures and Assessment of Pressure Impacts

3.1.1 Identification of Pressures

The analysis of pressures and impacts is one of the procedures of basin planning as required by Article 5 of the Water Framework Directive (WFD) [12]. According to the WFD requirements, in order to identify pressures in the river basin, data on types and extents of significant human pressures occurring within the basin is gathered and analyzed. The identification of the pressures is implemented in accordance to the list included in Section 4.2 of WFD IMPRESS guideline [10]. Thus, the pressures are categorized by the following types:

1. Water abstraction for household purposes
2. Water abstraction for irrigation purposes
3. Water abstraction for industrial purposes
4. Urban waste waters (including use of sewage water wells)
5. Industrial waste waters from food processing industries
6. Other industrial and mining wastewaters
7. Hydro power plants
8. Fisheries
9. Crop production including use of pesticides/fertilizers
10. Livestock breeding
11. Overgrazing
12. Timber production
13. Road traffic
14. Solid wastes

The objective is from the above-mentioned pressures to select and describe those pressures which have significant impact on separate parts of the river basin.

3.1.2 Assessment of Pressure Impacts

The objective of the pressure analysis is to identify the most important, significant pressures, which by their own or together with other pressures have such impact that deteriorates water quality or quantity status. The analyses are conducted according to the EU WFD IMPRESS Guidelines [7], the results of which are used for identification of water bodies at risk.

The concentration of pollutants (C) in point source of pressure in the river is calculated by the following formula:

$$C = \frac{q_0 c_0 + q_1 c_1}{q_0 + q_1}, \text{ where}$$

q_0 is the river discharge before the pressure point, c_0 is the concentration of pollutant in the river water at the same point, q_1 is the volume of wastewater discharged into the pressure point, and c_1 is the concentration of pollutant in the wastewater.

Using the same logic the concentration of pollutants due to discharge of wastewater into the river can be calculated. These concentrations are treated as an assessment of point source pressure:

$$C = \frac{q_1 c_1}{q_0 + q_1}.$$

In order to assess the impact of pressures the final result of calculations, C, is compared to the marginal values of Danube River classification scheme [17].

In order to assess the urban wastewater discharge pressure an approach is using, which takes into consideration the number of population. This method is particularly useful for calculated the BOD_5 index. According to EU VI Framework Program during the summer low-flow period 1 mg/l of BOD_5 is considered as marginal value, above which the pressure is considered significant. Using the know norm that the quantity of BOD_5 in discharged wastewater is 60 g/day* N, where N is the number of inhabitants, the concentration of BOD_5 is calculated in the river's water at discharge point using the following formula:

$$C = ((60g / day * N * 1000) / (24 * 60 * 60)) mg / l.$$

3.2 Classification of water bodies including delineation of water bodies

The primary purpose of classification is to assign each surface water and ground water body (aquifer) to a category or type which has its own set of distinct, and ecologically appropriate environmental objectives. Water resources cannot have the same natural and anthropogenic conditions (thus the same quantity and quality indicators) throughout their entire length (rivers), volume (lakes) or area (groundwater). That is why the application of the same standards for planning and management on the entire water resources will not be efficient. It is necessary to delineate water resources into discrete sections, or “water bodies” so that each section, within its length, volume or area has similar natural and anthropogenic conditions, and as a result can be represented by a single set of water quantity and quality indicators [8], [11].

The European Water Framework directive recognizes that certain types of man-made waters, known as highly-modified water bodies (canals, some reservoirs) cannot be expected to reach the same high environmental objectives as natural waters. Armenia’s approach reflects the European approach in this and several other aspects. However, Armenia’s Water Code also requires that water bodies be “classified” or described, according to a large set of criteria. This descriptive classification is complementary and parallel to the system described here.

EU proposes the following groups of characterization indicators: physical and biological, socio-economic, actual water use in the basin, water balance, environmental factors affecting the water and water use patterns. Below the main factors are listed, the existence of which causes quantitative and qualitative changes in water resources. That is why they might serve as criteria for delineation.

1. Absolute altitude of the territory above the sea level, which defines changes in water ecology (warm and cold waters),
2. River basin relief (field, plain, mountainous, valley),
3. The main confluences (junctions) of rivers,
4. Large settlements, industrial enterprises, or intensive agricultural zones,
5. Hydro-morphological criteria, which include the extent of modification of natural river bed or lake bed.

The EU WFD criteria for classification of water bodies in physical-geographic conditions of Armenia are used as follows. Category of water resources can be defined using the systems “A” of continental ecological regions. Being a method for characterization of basins and surface water resources, these systems allow delineation of water resources into discrete bodies based on the values of characteristics, as well as the following classification of water resources and their discrete bodies [17].

Rivers: According to the system “A” it is suggested to apply the absolute altitude of rivers while being characterized as follows: high > 800m, average 200-800m, low < 200m.

In Armenia there are no rivers below 200 m. Thus according to the EU WED absolute altitude scale, the Armenian rivers will be characterized only as being average and high altitude.

The next value, according to which rivers are classified, refers to the size of the river basin. According to the WFD, the river basins are divided according to these classes: small (10-100 km^2), average (100-1000 km^2), large (1000-10000 km^2), very large (>10.000 km^2) river basins. It is suggested that this characteristic of river basins can be used to distinguish Local, National and International rivers (per definitions of the National Water Program), such that rivers with basins of less than 100 km^2 are coded as “Local,” rivers of 100-1000 km^2 are coded as “National,” and rivers of greater than 1000 km^2 (or river which form international borders) are classified as “International.”

In this case the number of classes for the territory of Armenia is reduced, since there are no river basins with an area of more than 10000 km^2. Thus, in this case the rivers or their different sections are divided into three classes.

A geology characteristic takes into consideration the type of rocks which make up the majority of the river basin. The characteristic is contingent upon the origin and composition of the rocks. The EU WFD proposes the following characteristics for geology: calcareous, siliceous and organic rocks. The geology of the Republic of Armenia is represented only by two types of rocks: calcareous and siliceous. The geology factor explains several properties of the river basin. For example, siliceous rocks are weakly dissolvable, and except cracked rocks, they have low water-bearing properties, whereas calcareous rocks are usually porous and easily dissolvable.

Lakes: According to the EU WFD Lakes are divided to the following types: high (with altitude more than 800 m), average (200 – 800 m) and low (less than 200m). Thus, all the lakes in Armenia are classified as high according to EU WFD characterization.

The average depth is a characteristic for classifying lake ecosystems. It is divided into the following interval: up to 3m, 3-15m, >15m. It is obvious that these average depths will correspond to ecosystems with different property types. Moreover, various segments of the same water resource (lake) might have significantly different depths, based on which the separate segments of the lake will be delineated (for example large and small Sevan).

According to the WFD, characterization and delineation of lakes by surface area is done using the following intervals: 0,5-1 km^2, 1-10 km^2, 10-100 km^2, 100 km^2 and more.

The geology characteristics take into consideration the origin of mountainous rocks comprising the watershed of the lake and their composition, which is the same as for the rivers.

Heavily-modified and Artificial Water Bodies such as reservoirs, drainage canals and irrigation structures, straightened, channelized, and reinforced, artificial ponds constructed for agricultural or other economic purposes urban river channels are delineated as separate water bodies.

Groundwater resources: Armenia's ground waters are delineated and mapped as 43 distinct, significant underground water bodies. They are located in different hydrogeological conditions, and thus have difference from each other in numerous properties.

As classification criteria, the main hydro-geological conditions are selected, that form the main properties of underground water bearing bodies: these are geological conditions, structure, lithology, location depth of water bodies, which has an important role in forming resources for groundwater [4], [15].

3.3 Setting of Environmental Objectives of Water Bodies

Environmental objectives are the desired conditions of water quality and water quantity which expected to be achieved during a river basin plan valid period for each distinct water body [6].

Modern river basin plans, such as recommended by the EU WFD, require water bodies to meet biological, chemical/physical and hydrologic objectives, which in combination, reflect a desired “good water status”. Armenia has sufficient monitoring data on chemical/physical and hydrologic and limited data available on biological conditions of water resources.

Evaluation and Setting of Environmental Objectives includes several vital parts of the river basin planning process. Evaluation of status is the process by which Armenian standards are compared to the actual water quality and flow characteristics of a surface water body to determine whether it meets the requirements of human health and support for aquatic life. The environmental objectives are set in order to measure the progress of improvement in water resources during a river basin planning period, usually a number of years. Environmental objectives are quantitative and can be measured by monitoring. Environmental objectives for surface waters include physical and chemical water quality (qualitative criterion), and maintenance of minimum environmental flows (quantitative criterion). For groundwater, the key objectives are to maintain a balance of recharge and discharge from the aquifers, while remaining free of toxic contaminants.

3.3.1 Setting Environmental Flow standards

Environmental flow is the minimum level of river flows, required to maintain the proper functions of river network ecosystem.

Assessment of environmental flow requires taking into consideration several factors, and is a complex issue. That is why as a first step it is necessary to consider the “environmental flow” to be the minimum quantity of water for which the river system has functioned under natural conditions. Moreover, the value of environmental flow cannot be considered constant throughout the year. Environmental flow should be defined for each month separately, to take into account that natural flows vary throughout the year, and aquatic species often require this seasonal variation in flow to implement their life cycle.

The study of many rivers of the republic showed that the natural flow reaches its minimum value in January-February, that is, until beginning of thaw next year. This can be explained by the fact that the mountainous rivers are fed mainly from spring thaw waters. The values of summer minimum natural flow of those rivers are mainly on average bigger by 10%-20% than winter minimal flows.

At the same time, based on the fact that in winter the economic impact on the river flow regime is very minimal due to irrigation termination, and the difficulty of accurate assessment of daily values of this impacts at the water intake points, it has been adopted that during January-February the flow through the river is very close to the natural flow.

Taking into consideration the hydrological regime of the rivers of the Republic of Armenia, the geographical area in which it is located, its economic use and the extent, water qualitative and quantitative structure and other factors, the RA Government in 2011 established a new approach of environmental flow determination. According to this approach, for the assessment of environmental flow the average value of the minimal flow of 10 consecutive days during the winter period is used. After that monthly values of environmental flow are calculated by the inter-annual distribution of multi-year minimum monthly flows.

3.4 Water Quality Classification

The localized version of Water Quality Canadian Index (WQCI) was used as a criteria for surface water quality for the Meghriget basin, based on 31 parameters and selected 9 parameters, which characterize the agricultural pollution.

However, given the overall objectives of identification of anthropogenic pressures on water resources in Aghstev River basin, another principle was selected for assessment of water quality and classification of water bodies according to quality. The principle is based on chemical monitoring of data and uses the background/reference concentration of heavy metals, instead of applying the principles of maximum allowable concentrations. Water quality classes are selected according to the definition of EU WFD and for that purpose use the Danube River classification scheme and the technical standards of Slovakia (for phenols and oil hydro-carbonates) [13], [16], [17] .

4. CONCLUSION

River basin management plans are important and effective tools for the management and planning of water resources within river basin.

In this paper the scientific part of the river basin management planning was examined. Presented approaches can be used for the preparation of management plans for Armenian river basins, as well as for river basins of other mountainous countries.

REFERENCES

[1] Aleksandryan G., Hakopyan A., Mnatsakanyan B., Tamazyan A. Modern Water Balance of Armenian SSR. Yerevan, 1990, 190 p. (in Russian)

[2] Atlas of Natural Conditions and Natural Resources of the Republic of Armenia, Hydrology. Yerevan, 1990, 68 p. (in Russian).

[3] Babkin V., Vuglinskiy V. Water Balance of River Basins. Leningrad, 1982, 191 p. (in Russian)

[4] Bindeman N. About operational resources of fresh groundwater of the USSR and perspectives their use. Research and Exploration of Underground Waters for Large-scale Water Supply. “Water Resources”, #3, Moscow, 1972, pp 112-124. (in Russian)

[5] Chilingaryan L., Mnatsakanyan B., Aghababyan K., Toqmajyan G. Hydrology of Armenia's Rivers and Lakes. Yerevan, , 49 p. 2002 (in Armenian)

[6] EC Directive 2008/105/EC on environmental quality standards in the field of water policy. Brussels, 2008

[7] EU Floods Directive, (2007/60/EC, Translated into Armenian). Yerevan, 2009

[8] EU Project "Trans-Boundary River Management Phase II for the Kura River basin - Armenia Georgia Azerbaijan", "Working Paper - Water Quality Classification of the Surface Water Bodies in Pilot Basin", 2009

[9] EU Project "Trans-Boundary River Management Phase II for the Kura River basin - Armenia Georgia Azerbaijan". Aghstev River Basin Management Plan. Yerevan, 2009

[10] EU Water Framework Directive (2000/60/EC) Common Implementation Strategy, Guidance Document №3, "Analysis of Presures and Impacts (IMPRESS)" (Translated into Armenian). Yerevan, 2009

[11] EU Water Framework Directive (2000/60/EC) Common Implementation Strategy, Guidance Document №2, "Identification of Water Bodies", Translated into Armenian, Yerevan, 2009

[12] EU Water Framework Directive, (2000/60/EC, Translated into Armenian). Yerevan, 2009

[13] Kimstach V. Classification of Surface Water Quality in the Countries of European Economic Union. Saint-Petersburg, 48 p. 1993, (in Russian)

[14] Luchsheva A. Practical Hydrometry. Leningrad, 423 p. 1983, (in Russian)

[15] Plotnikov V. Research and Exploration of Underground Freshwater. Moscow, 370 p..1985, (in Russian)

[16] Slovak Technical Standard STN 7221 “Water Quality - Classification of surface water”. Bratislava, 1999

[17] TNMN Yearbook and database in 2006. ICPDR, Vienna, 2008

[18] USAID Project "Model Guidelines for River Basin Management Planning in Armenia". Yerevan, 2008, (in Armenian)

INFLUENCE OF LAKE SEVAN CATCHMENT BASIN PHYTOPLANKTON COMMUNITY STRUCTURE ON THE SAME OF THE LAKE

PhD Hovsepyan A.A., PhD Khachikyan T.G., PhD Hambaryan L.R.

Scientific Centre of Zoology and Hydroecology of the National Academy of Sciences, **Republic of Armenia**

ABSTRACT

Conservation and sustainable use of freshwater resources is based on comprehensive economic assessment and effective management.

The essential freshwater stocks are located in Lake Sevan and Ararat valley in Armenia.

Destabilization of Lake Sevan ecosystem has been occurred due to artificial lowering of its water level of more than 20 m (~1916 m above sea level in its natural regime), resulting changes of hydrophysical, hydrochemical and hydrobiological parameters of the ecosystem.

Since 2002 lake water level rising is implementing aimed to reduce the negative processes and recover the ecosystem natural regime.

However, a draft of the Government of republic of Armenia (RA) is being in discussion on water releases increase from Lake Sevan till 2019. New fluctuations of lake water level and especially its reduction will certainly have an influence on the processes in the ecosystem and result its further eutrophication. Also, the catchment basin influence on the ecosystem can be increased in the result of the lake's water level lowering.

The aim of this article is to reveal the qualitative influence of phytoplankton community of Lake Sevan catchment basin on the same of the lake.

Keywords: phytoplankton, eutrophication, catchment basin, resemblance of communities

INTRODUCTION

Lake Sevan is the largest lake of Caucasus, situated at an altitude 1916 m above sea level, in the mountain-forest area with moderately cold climate. The basin of the lake is a huge tectonic hollow and consists of two parts:

Minor Sevan and Major Sevan (Figure1), having different modes of formation, origin and morphometry [4]. The lake is fed by 28 rivers, and river Hrazdan is the only watercourse flowing from it, on which a cascade of six hydropower plants is built.

The history of Lake Sevan is a unique example of negative anthropogenic influence on water bodies. Due to artificial lowering of the lake water level by 19.2 m, growth of population in its water basin and nutrients load increase eutrophication processes have been occurred in the lake as in the majority of lakes in 70s of the last century.

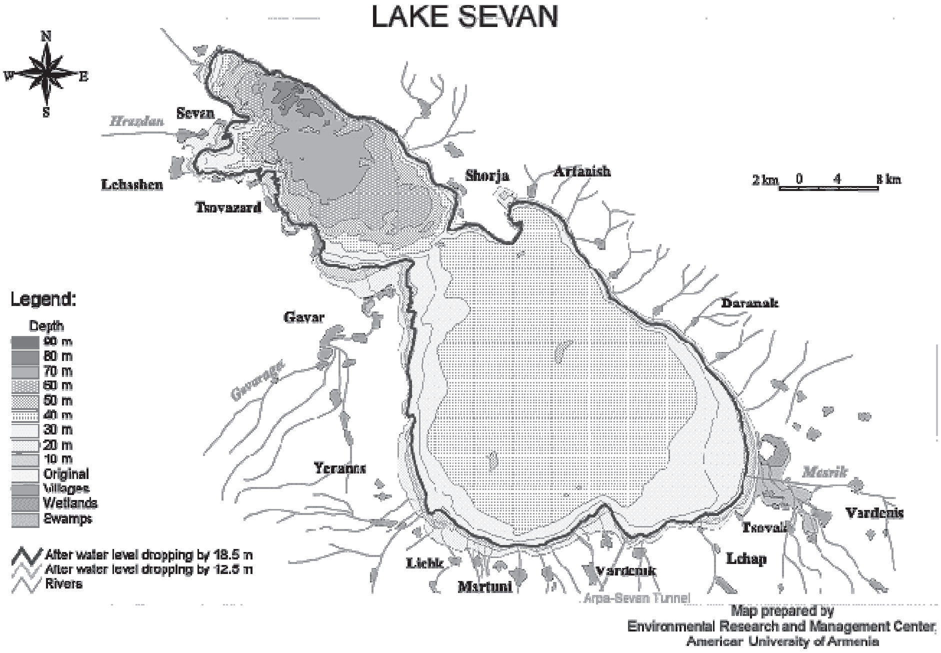


Figure 1. Map of Lake Sevan

During this period, scholars have pointed out the need to review plans for operation of the reservoir, and among the priorities was the issue of lake water level rising, study and restoration of water and biological resources [14].

In 2001 adopted a law of the RA "On approval of the annual and comprehensive measures for the conservation, restoration, reproduction and use of Lake Sevan ecosystem", in order to raise the water level (at least by 6 m) of Lake Sevan by 2030.

As a result of undertaken activities and favorable weather conditions, the lake level began to rise annually. As of December 2007, the water level of

Lake Sevan was 1898.79 meters above sea level, which is by ~ 0.5 m higher than in the same period of previous year [2]. Most of the flood banks, where in the middle of the last century trees were planted and recreational areas organized, had not been prepared and could be a source of serious effects on the limnoecosystem. Accordingly, the Commission of Lake Sevan scheduled cleaning flooded coastal areas of trees and shrubs and a gradual annual increase of the lake water level by about 21 cm to achieve the grade of 1903.5 m by 2031. In 2008 the water level of the lake compared to the previous year increased by 7 cm, 2009 - 37 cm, in 2010 - by 47 cm.

New changes of the ecosystem abiotic component will certainly occur in the result of new changes in lake water level, which in its turn will lead to new shifts in the lake interior processes as well as changes in its hydrobiological component.

Long-term monitoring of Lake Sevan main hydroecological parameters characterizing water quality revealed a link between changes in lake trophic status and phytoplankton community development. Significant changes of phytoplankton quantitative and qualitative parameters have been occurred during the different periods of lake investigation.

Formerly, one of the obvious signs of eutrophication in Lake Sevan was the succession of phytoplankton species: in pelagic plankton new species appeared, previously found only in coastal areas and bays of the lake, while some species have been found in the lake for the first time [5, 9, 10, 12, 13, 15]. During different stages of lake investigation, changes in the role of phytoplankton species were observed periodically having displaced species of planktonic algae, which were inherent in the lake natural period prior to level lowering. New species have been registered in Lake Sevan phytoplankton community during recent years as well, some of which are found for the first time in the lake, while the others were known as the representatives of the lake periphyton and its catchment basin rheoplankton [8].

The purpose of the current work is to assess the species diversity of phytoplankton of Lake Sevan and its main tributaries as well as to identify similarities in the species composition of the planktonic algae in Minor Sevan and Gavaraget, Dzknaget rivers, and phytoplankton communities in Major Sevan and Masrik, Makenis, Arpa, Vardenis, Argichi, Lichk rivers.

MATERIALS AND METHODS

The algological material was collected at two following stations: №4 - Minor Sevan, №22 - Major Sevan and 8 major tributaries. Water samples were collected, using a Ruttner bathometer with four main horizons of pelagic part (lake surface, 10 m, 20 m and bottom layer). Phytoplankton sampling at Lake Sevan was carried out during March, April, June and October, while phytoplankton samples from the tributaries were assessed from March to November.

In general, 28 phytoplankton samples were analyzed taken from Lake Sevan and 64 samples taken from Masrik, Makenis, Arpa, Vardenis, Argichi and Gavaraget rivers, which flow into Major Sevan, and rivers Gavaraget and Dzknaget flowing into Minor Sevan.

Collection, preservation and processing of algae were implemented according to standard methods [1,18]. Identification of algal species specificity was done by using various determinants [6, 7, 17, 19].

Jaccard's (1) and Sorensen's (2) indexes were used to determine algal communities' similarity given as follows:

$$k = \frac{c}{a + b} 100\% \quad (1)$$

$$k = \frac{2c}{a + b} 100\% \quad (2)$$

Where **c** - the number of species common to both sites,

a and **b**- the numbers of species found at each site [11, 20].

The saprobic value of indicator phytoplankton species was defined [3].

RESULTS AND DISCUSSION

96 taxa of algae have been registered in Lake Sevan in the investigated period of 2010, 42 % of which were from Diatomea, 33 % - from green algae and 15 % were from phylum of blue-green algae. Quantitative predominance of green algae is being observing in the phytoplankton community, which is inherent in the lake since the second half of the1980s [5, 9, 10, 12, 13, 15, 16]. Diatoms had subdominant position quantitatively, which, however, dominated by quality, in contrast to the results of previous authors' studies, when the green algae were more diverse, and diatoms quantitatively played the most important role.

Totally, 124 phytoplankton species have been registered in phytoplankton communities of main streams inflowing into Lake Sevan during 2010. As in the lake, diatoms were the most diverse phylum among the others: 69%.

The green algae percentage was 16%, and the same of the blue-green algae was only 14%.

The most diverse genera were *Navicula* (7) and *Cyclotella* (4) from diatoms, and *Oocystis*(5) and *Ankistrodesmus* (4) from green algae in the lake, while in the catchment basin the highest rate of diversity was inherent in genera *Navicula* (16), *Nitzschia* (10), *Cymbella* (9), *Pinnularia* (5), *Fragilaria* (4) and *Melosira* (5) in the group of Diatomea, *Oocystis* (5) and *Scenedesmus* (3) among the green algae and the genera *Oscillatoria* (8), *Phormidium* (3) and *Spirulina* (3) from blue-greens. Comparatively more diverse were rivers Lichk (67) and Masrik (63), and poorer were Arpa - Sevan tunnel (35) and river Vardenis (44).

Table 1. The taxonomic composition of algae of Lake Sevan and its main tributaries in 2010.

Phylum	Class	Order	Family	Genus	Species
Bacillariophyta	2	4	14	29	95
Chlorophyta	2	5	13	18	39
Cyanophyta	2	3	7	11	25
Euglenophyta	1	1	1	3	6
Xanthophyta	1	1	1	1	1
Dinoflagellata	1	2	2	2	2
Total	*9*	*16*	*38*	*64*	*168*

According to 2010 data, a total of 168 taxa of planktonic algae belonging to 64 genera have been recorded in Lake Sevan and its main tributaries (Table 1); the index of genus' coefficient of the phytoplankton community was 2.6, while the same for diatoms was 3.3, for green algae - 2.2 and 2.3 for blue-greens. This shows that there were more favourable conditions for diatoms' development: the competition among the diatoms' species was much weaker resulting the coexistance of more then one species within the same genus, rather than in the other planktonic groups.

In both parts of Lake Sevan on the basis of geographical distribution of the phytoplankton community were dominated species which characteristics are not studied enough, while in the main tributaries cosmopolitan species had the most proportion in the phytoplankton communities and less studied species were in the second place. Solitary species were also found inherent arcto-alpine latitudes (Table 2).

Table 2. Ecological and geographical characteristics of phytoplankton in Lake Sevan and its major tributaries [3].

Characteristics of species	Minor Sevan		Major Sevan		r. Gavaraget		r. Dzknaget		r. Masrik		r.Makenis		r.Arpa		r.Vardenis		r.Argichi		r.Licl
	N	n	N	n	N	n	N	n	N	n	N	n	N	n	N	n	N	n	N
Geographical location																			
Cosmopolites	26	33.3	21	39	19	35.1	20	40	21	34.4	22	38.5	14	40	17	38.6	18	35.2	21
Arcto-alpine	3	3.8	2	3.7	3	5.5	3	6	4	6.5	6	10.5	4	11.4	4	9	4	7.8	4
Boreals	9	11.5	9	16.6	16	29.6	15	30	20	32.7	13	22.8	8	22.8	13	29.5	15	29.4	20
Less studied	40	51.3	22	40.7	16	29.6	12	24	16	26.2	16	28	9	25.7	10	22.7	14	27.4	20
Saprobity																			
Xenosaprobs	-	-	-	-	1	1.8	1	2	1	1.6	2	3.5	1	2.8	2	4.5	1	2	1
Xeno-oligosaprobs	3	3.8	1	1.8	1	1.8	2	4	1	1.6	2	3.5	2	5.7	-	-	1	2	2
Xeno-β-mesosaprobes	-	-	1	1.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oligosaprobes	1	1.2	1	1.8	1	1.8	3	6	4	6.5	2	3.5	1	2.8	2	4.5	3	5.8	3
Oligo-β-mesosaprobes	9	11.5	7	13	11	20.3	7	14	10	16.4	7	12.2	9	25.7	8	18.2	9	17.6	12
β-mesosaprobes	21	27	19	35.2	22	40.7	20	40	24	39.3	21	37	15	43	16	36.3	21	41.1	27
β-o-mesosaprobes	2	2.6	1	1.8	3	5.6	2	4	3	4.9	2	3.5	-	-	3	6.8	1	2	3
β-α-mesosaprobes	1	1.2	-	-	-	-	1	2	1	1.6	1	1.8	-	-	-	-	-	-	1
α-β mesosaprobes	-	-	-	-	1	1.8	-	-	-	-	-	-	-	-	-	-	-	-	-
α-mesosaprobes	2	2.6	1	1.8	3	5.6	3	6	4	6.5	6	10.5	1	2.8	-	-	2	3.9	5
Evrisaprobes	-	-	-	-	-	-	1	2	-	-	2	3.5	-	-	2	4.5	2	3.9	2
Less studied	39	50	23	42.5	11	20.4	10	20	13	21.3	12	21	6	17	10	22.7	11	21.6	9

N – number of species, n - % from the total amount of spe

In the composition of planktonic algae of Lake Sevan and its major tributaries according to accepted saprobity scale, a large proportion fell to β-mesosaprobic species. Particularly were distinguished the following observation points: Minor Sevan - 27%, Major Sevan ~ 35%, r. Argichi and r.Lichk - ~ 41 %, r. Dzknaget - 40%, r. Gavaraget - 40.7%. The share (10% (r. Dzknaget) to (50% Minor Sevan)) of species not included in the list of saprobic organisms was also significant (Table 2). The proportion of α-mesosaprobic species in the algal list was ranged from 1.8% (Major Sevan) to 10.5% (r. Makenis). In the phytoplankton community were species which saprobic value was not found out.

Application of Jaccard’s similarity coefficient revealed insignificant similarity between phytoplankton communities of the lake and its tributaries that might serve as a sign of a weak influence of the rivers species composition on Lake Sevan to form its qualitative structure (Tables 3 -5). From the other hand according to Sorensen’s similarity index the influence of qualitative structure of lake’s catchment basin on the same of the lakewas more significant. Comparatively higher influence has shown r. Gavaraget on Minor Sevan, and rivers Arpa, Argichi andLichkand Major Sevan (Table 3).

Table 3. The generality of phytoplankton species of Lake Sevantwo parts and maintributaries inflowing in them according to Jaccard’s and Sorensen’s indexes

	Minor Sevan	r.Gavaraget	r.Dzknaget	Major Sevan	r.Masrik	r.Makenis	r.Arpa	r.Vardenis	r.Argichi	r.Lichk
N	78	54	51	54	63	57	35	44	52	67
c		20	18		12	10	12	11	13	14
kj		15.1	14		10	9	13.5	11.2	12	11.5
ks		30	28		20	18	27	22	24	23

Tables 3-5: N – total amount of species, c – number of species, which are common to both sites, k – Jaccard’s index, ks- Sorensen’s index.

Based on the summarized data for Minor Sevan with two rivers and Major Sevan with its six streams, the level of the catchment basin influence on the lake is higher then in the case of separate assessment (**Table 4**).

Table 4. The generality of phytoplankton species of Lake Sevan and its main tributaries according to Jaccard's and Sorensen's indexes

	Minor Sevan	r.Gavaragetr.Dzknaget	Major Sevan	r.Masrik, r.Makenis, r.Arpa,r.Vardenis, r.Argichi, r.Lichk
N	78	74	54	104
c		28		24
kj		18		15
ks		36		30

Comparatively high resemblance coefficient has been revealed in the result of comparison of the lake's and all the main tributaries' algocenoses.

Table 5. The generality of phytoplankton species of Lake Sevan and its catchment basin

	Lake Sevan	Rivers
N	83	124
c		38
k		18
ks		36

CONCLUSION

There is a trend of qualitative prevalence of diatoms expanding in Lake Sevan observed in the years of its level rise. This is probably contributing to changes in lake conditions as a result of its level raising.

The highest index of genus' coefficient in the phytoplankton community had phylum Diatomea which shows that there were more favourable conditions for diatoms' vegetation.

During 2010 species composition of planktonic algae revealed a significant proportion of species-indicators variations in degrees of contamination including β-mesosaprobic species.

Lake Sevan main tributaries' species richness was found in Rivers Lichk and Masrik while in Rivers Arpa and Vardenis the lowest amount of phytoplankton species was recorded.

Phytoplankton communities of Lake Sevan main tributaries were characterized by the prevalence of cosmopolitan species.

Application of Jaccard’s coefficient on separate sites of Lake Sevan and its catchment basin revealed insignificant similarity of phytoplankton communities in the lake and its tributaries, while on the basis of Sorensen’s index the resemblance of algal communities was much higher. Also, the comparison of lake total qualitative structure of phytoplankton community with the same of its catchment basin revealed a significant similarity among them. Thus, the emergence of particular new species in the pelagic zone of Lake Sevan can be linked to its catchment basin qualitative influence, and periodical observation of their significant quantitative contribution during some seasons, perhaps, is due to changing conditions in the lake.

REFERENCES

[1] Abakumov V. 1983. Manual on the methods for hydrobiological analysis of surface water and bottom sediments, Leningrad, Hydro–meteo. pp. 79–91.

[2] Akopyan S., Dzhenteredzhyan K. Macrozoobenthos of Lake Sevan // Ecology of Lake Sevan in the period of water level rising. Research results of the Russian-Armenian geological expedition for hydroecological examination of Lake Sevan (Armenia) (2005–2009). Makhachkala: „Nauka SCD”, 2010. pp. 206–214.

[3] Barinova S., Medvedeva L. 1996. Atlas of the algal indicators of saprobity (Russian Far East), Vladivostok. p. 365.

[4] Chilingaryan L., Mnatsakanyan B.Water balance and water regime of Lake Sevan // Ecology of Lake Sevan in the period of water level rising. Research results of the Russian-Armenian geological expedition for hydroecological examination of Lake Sevan (Armenia) (2005–2009). Makhachkala:„ Nauka SCD”, 2010. pp. 28–40.

[5] Hambaryan L. 2001. Phytoplankton succession during the period of level re-lowering of Lake Sevan. PhD thesis abstract, Yerevan, p. 21

[6] Han Maosen Shu Yunfang 1995 Atlas of freshwater biota in China, Beijing „China ocean press”. p. 129.

[7] Heinz Streble, Das LebenimWassertropfen, Kosmos, Stuttgard, 2001.

[8] Hovsepyan A.2013. Changes of the phytoplankton community in Lake Sevan under the circumstances of the increase of the lake water level. PhD thesis abstract, Yerevan, p. 22.

[9] Kazaryan A. 1979. Materials for investigation phytoplankton in lakeSevan. Book: Ecology of hydrobionts of Lake Sevan, Yerevan, N 17, Yerevan, pp. 75-89.

[10] Legovich N. 1979. Blooms of the lake Sevan. Book: Ecology of hydrobionts of Lake Sevan, Yerevan, N 17 pp.51–74.

[11] Makrushin A. 1974, Biological analysis of water quality. Leningrad. p. 59.

[12] Meshkova T. 1962. Current status of plankton of lake Sevan (in connection with the descent of the latter)// Proceed. Of Sevan Hydrob. Station, N17, Yerevan, pp.15-88.

[13] Mnatsakanyan A. 1984. Changes in species composition and biomass of phytoplankton in Lake Sevan. Book: Limnology of high mountain lakes. Yerevan, pp.172–173.

[14] Oganesyan R. Lake Sevan yesterday, today… Yerevan: Press of NAS of RA "Gitutyun", 1994. p. 478.

[15] Parparov A. 1979. Primary production and chlorophyll a content in phytoplankton of Lake Sevan. Book: Ecology of hydrobionts of Lake Sevan, Yerevan, N 17, Yerevan, pp. 89-99.

[16] Parparov A. 1990. Some characteristics of the community of autotrophs of Lake Sevan in connection with its eutrophication// Hydrobiologia, 191:15-21.

[17] Proshkina–Lavrenko A., Makarova I. 1968. Algae of the Caspian Sea. Nauka, Leningrad.

[18] Sudnytsina D. 2005.Algae Ecology of Pskov region. Training manual, p. 892.

[19] Tsarenko P. 1990. A guide to chlorococcus algae of the Ukrainian SSR, Kiev, Naukova Dumka. p. 206.

[20] On-line:http://abc.vvsu.ru/Books/sistemnaja_ekologija_up/page0031.asp. Dulepov V., Leskova O., Majorov I. Systematic Ecology. pp. 31-35.

ICE CONDITIONS OF THE SYRDARYA RIVER

[1]**Darya Fedorova**

[1]Kazhydromet, **Kazakhstan**

ABSTRACT

The article presents the results of researches in the field of predicting the dates of derivation of floating ice and freeze-fracture setting on the Syrdarya river on the hydrological stations Tomen-Aryk, Kerkelmes, Tasboget and Kazalinsk.

The need in these studies is caused primarily by the fact that on the Syrdarya river during the derivation of floating ice in the restricted sections of the river, occurs the formation of ice jams that cause high rises in levels of water. This high rises in water levels may be accompanied by floods, hazardous to human settlements, waterworks, roads and other objects. One of the preventive actions is forecasting the dates of the ice formation on one or another section of the river along its length. Also, these studies are of high importance for the effective planning of the mode of Shardarinsky reservoir: advance forecasting of the various phenomena of the ice conditions is very important for regulating discharges. Forecasting the dates of formation and destruction of ice cover on the river Syrdarya allow increase or reduce the amount of water releases from reservoir and helps to make the water management in the region working better.

The terms of freezing and ice destruction on Syrdarya river are variable in time. The amplitude of the dates of ice formation on the Syrdarya river on it's length is approximately 25-30 days; freeze dates - 20-25 days; ice destruction dates - 30-35 days.

The appearance of the ice on the surface due to its cooling to 0°C. Changing the temperature of the water is a result of heat exchange between the stream and the surrounding environment. Heat flow to the atmosphere plays a major role in altering the ice mode. Short-term forecast in these research is based on a simplified (empirical) dependencies. The date of forecast releasing is in conjunction with a steady transition date of average daily temperature from positive to negative values. This forecast is based on a relation between heat content stream at the time of issue of the forecast and the amount of heat needed to cool water and ice

appearance. Long-term forecast of ice conditions is based on the dependencies between the date of the formation of ice and mean monthly air temperature anomaly.

Keywords: ice conditions, Syrdarya, forecast.

INTRODUCTION

The article presents the results of researches in the field of predicting the dates of derivation of floating ice and freeze-fracture setting on the Syrdarya river on the hydrological stations Tomen-Aryk, Kerkelmes, Tasboget and Kazalinsk.

The Syrdaryariver basin is located in the five countries of Central Asia: Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan and Uzbekistan. The basin of Aral Sea and Syrdarya river is a huge, complicated ecological system, which includes the regions of mountain glaciers of the Pamir and Tien Shan and deserts of the Aral Sea region; different countries with industry, agriculture, and culture, and complicated, not always linear relations [1].

Due to the regulated flow of Syrdarya by whole cascade of water reservoirs, in Kazakhstan it's natural mode (flood peaks in May - June) is completely broken. In recent years, the maximum flow of water into the Shardarinskoe reservoir registered in February - March and sometimes in January. Water consumption during this period can exceed 1,000 m^3 per second. This leads to the fact that it's total capacity (5,200 million m^3) Shardarinskoe reservoir reaches in February - March, when Syrdarya river still freezes-up. Winter spills from reservoir are usually about 400 m^3/s, and do not change to a complete clearing of the river. Increased discharges during this period will result overflow and submersion of huge areas in the downstream of Syrdarya.

Syrdarya river basin area is about 462 000 km^2, drainage basin area lies in the mountainous regions of Central Tien - Shan, outside the borders of the Republic of Kazakhstan. Syrdarya river basin is extended from south-east to north-west; mountain part occupies the south-eastern part of the basin, north-western part is plain character, watershed line is not expressed clearly. The basin territory is a complex of natural and artificial watercourses - reservoirs, canals and rivers. Total length of sewers and canals far exceeds the length of the river system.

The length of Syrdarya from the confluence of the Naryn and Karadarya is 2212 km, from the springhead of Naryn - 3019km. Length within Kazakhstan boarders, from Shardarinskiy reservoir to the Aral Sea, is 1,627 km: on South Kazakhstan region - 346 km, Kyzylorda region - 1281 km. On the desert area of southern Kazakhstan Syrdarya river flows over 1,000 km on the Turan lowland. Left to it's water course line Kyzylkum sands, on the right side - piedmont hills (alaras) changing with flat steppe soon, that turns later into a clay-sandy desert - Aral Karakum. The river then flows into the Aral Sea.

By type of the power, Aral-Syrdarya river basin rivers are mixed - a snow-glacier- ground supply.

On the main watercourse, river basin has four reservoirs, the largest of them - Shardarinskoe, it'scapacity 5,7 km^3. Besides, there are a number of smaller reservoirs on rivers Kassansay, Akhangaran, Bugun and others. In the mountainous area of the basin lakes are mainly dammed or moraine origin, and in the plains they are mostly flood plain, there is a small group of lakes in the estuaries of rivers drying up territories, not reaching their intakes [2].

In connection with the withdrawal of water from irrigation canals Syrdarya hydrological regime is changed to artificial. In the future, due to the development of irrigation, these changes will become even more significant.

Hydrometric monitoring of the water levels of the Syrdarya river within the Republic of Kazakhstan began in 1910-1913 on four stations: Tyumen - Aryk, Kyzylorda, Karaozekand Kazalinsk. Currently, there are stations: Chinaz–Kokbulak, downstream of the Shardarinskiy reservoir, Koktyube, Bayrakum, Tyumen - Aryk, Kergelmes, Tasbuget, Karaozek, Kazalinsk and Karateren **(Fig.1**).

Fig.1. The hydrological stations location scheme.

The numbers of hydrological stations: 1 – Kokbulak; 2 –The downstream of Shardarinskoe reservoir; 3 – Bairakum; 4 – Koktyube; 5 – Tyumen-Aryk; 6 – Kergelmes; 7 – Tasbuget; 8 – Karaozek; 9 – Dzhusaly, 0,3 km lower the etuary of Karaozek branch; 10 – Kazalinsk; 11 – Karateren.

MATERIALS AND METHODS

For the prediction of ice phenomena, both long-term and short-term, the following characteristics are important: water discharge, depth of the river, flow rate, water level, water temperature in the preceding period of ice formations, air temperature, atmospheric pressure, solar radiation, e.t.c.

By applying a correlation analysis of the collected material were identified the most significant relations between dates of appearance of ice phenomena and various predictors. In this regard, the most important predictors were mean monthly air temperature at meteorological stations Kyzylorda and Kazalinsk, the value of meanmonthly air temperature anomalies and the date of transition at 0°C downwards of mean daily air temperatures.

Statistical and comparative analysis revealed the general patterns of ice phenomenas.

RESULTS AND DISCUSSION

Analysis of the collected materials shows that the ice formation on the river Syrdarya begins with the appearance of border ice, tallow and sludge. Ice regime on the river Syrdarya is generally unstable. Unstable nature of the ice regime is also evident by the time of occurrence and duration of a particular phase.

The slush formation on the river starts from the estuary up, as on all the rivers flowing from south to north. From the village of Tyumen-Aryk to the estuary ice formations are observed annually, but the timing of their appearance tend to vary widely. With strong and cold snaps extending far into the basin area, sludge appears almost simultaneously along the entire length of the river from its estuary to Tyumen-Aryk.

In years when cooling is not sharp when cooling of water temperature begins gradually, the difference in timing of the appearance of sludge in different areas may exceed one month interval.

When cold snaps do not spread far into the basin, sludge is formed only from the estuary to Kyzylorda. In strengthening of cooling sludge formation extends up the river.

Thaws in the fall season delay the formation of ice on the river or make the ice formation period interrupted. In some years the slush on the river appears in autumn 2-3, sometimes 4 times.

In the average annual contextthe first ice formations occurs at the end of November - the first ten days of December. Duration of ice formations has a very wide range from 1 to 60 days or more.

Later periods of freezing observed mainly when warm air streams from regions of Central Asia are moving, or also when there are high levels and discharges. Of recent years the latest time of the appearance of ice formations observed on the Syrdarya in 2004 (on the Tyumen-Aryk station - January 30, 2005).

The extension of ice formation on the Syrdarya river occurs from north to south, that is from the bottom up along the river, starting from the station Kazalinsk and gradually reaching Koktyube. This process is disrupted in some areas because of influence of local conditions, especially in recent years, expressed anthropogenic influence on the ice of the river. The difference in the timing of the beginning of autumn ice formation along the river varies on annual average from 1 to 20 days. The average date of the appearance of ice formation in the area of Kazalinsk town is November 30, for the part of the river from Tyumen-Aryk village to Koktyube average date is December 20. Difference in the average dates of the appearance of ice formation, from the estuary to Koktyube villageis 20 days, in some years it reaches 50 days.

Freezing rivers from the appearance of ice formations until a freeze-up occurs at a temperature of 0ºC to -10ºC.

Terms of full freeze-up vary widely. There are no strict sequence in dates of full freeze-up along the river.

Freeze-up sets annually from the river estuary to Kyzylorda city. There is no freeze-up on the upstream of river in some years. So, near the village of Tyumen-Arykon 9 years from 46 analyzed years, freezing was not observed. In some winters its duration is less than a month.

Period of hydrometeorological monitoring on the Syrdarya river can be divided into two parts - before 1967, i.e. before the commissioning of Shardarinskiy reservoir, and since 1967 - a period of intensive development of the agricultural sector and water management in the region. In the period after 1967, during the ever-increasing anthropogenic load, there is a significant change in the river flow, it’s hydrological regime and ecological situation in the whole basin.

Also not to mention about climate change, which, of course, fully affect climate depending phenomenon, as the ice regime. In the last climatic period (1970 to 2000) there is a significant warming in the winter months - an average of 1,5-2ºC in comparison with the previous period.

Average duration of ice cover near Tyumen-Aryk village for the period 1968-2014 yearsis 57 days, that is 17 days longer than in the period from 1933 to 1967 years; near Kyzylorda city - 84 days, 8 days less than in the preceding period. The longest duration in Kyzylorda is 143 days, the lowest - 6 days.

The essential difference between the periods before 1967 and after 1967 is also seen in the dates of the first appearance of ice formations, freeze-up and debacle. Thus, the average date of occurrence of ice formations in the first period from 1968 to 2014 is December 13, during the period 1933-1967 years it was December 6. Earliest date of occurrence of ice formations - 19 October (observed on station Kazalinsk in 1976), in the preceding period the earliest observed date was November 12; difference in the later dates is about two weeks in a longer way. On average, the date of the freeze-up occurs on December 22, in the period 1933-1967 years, it was observed a week earlier - on December 15. The earliest date of freeze-up is November 7, in the preceding period - November 14. The difference in dates is weeklater.

As can be seen from the above analysis, the date of the Syrdarya river freeze-up for modern anthropogenic period (after 1967) have changed. On average, for the appearance of floating ice on the river and the final freeze-up of the entire water surface noted 7 days later.

This difference in the timing of the appearance and duration of ice cover can not be explained only by anthropogenic factors. In the Syrdarya basin there is a situation thatled to such significant changes in the ice regime of the river, where the role was played both by changing of climate and intensive development of economic activities in the region.

The ice thickness at the station Tyumen-Aryk ranged from 0-100 cm, an average of 32 cm. On Kyzylorda station and the rest downstream the greatest values were 100-110 cm, the smallest - 10-15 cm. The deepestice thickness was observed on Kazalinsk station.

On the bigger part of the downstream, between cities Kyzylorda and Kazalinsk, the value of ice thickness was measured by 0.4-0.6 m, during severe winters - up to 1,1m. Shallow ducts usually freeze to the bottom.

The mean duration of the clearing of the Syrdarya river is 5-15 days, but during the lingering spring, when there are repeated return of cold, it can exceed 20-30 days. Spring debacle is usually intermittent, due to the unevenness of the clearing of the river on length.

Destruction of ice usually occurs in the second decade of February to the second decade of March. The earliest time of clearing observed on the part of river from Koktyube station to Tyumen-Aryk - the first decade of January. The latest date was recorded at the estuary of the Syrdarya river at station Kazalinsk, it was in the end of the first decade of April.

The forecast of ice conditions is based on the use of both approximate (empirical) dependencies and methods, which are based on the calculation of the heat balance of the water surface, in both cases, the forecast of ice regime needs forecast of meteorological elements [3].

In these empirical dependences the date of release of forecast is conjunct to a date of a steady transition of average daily temperature from positive to negative values and the release date of long-term weather forecast for the month, in particular, the forecast of temperature anomalies. In a general sense, the forecast of ice formations is based on a relationship between heat content stream at the time of issue of the forecast and the amount of heat needed to cool water and ice appearance. Moreover, there is some period of time between the date of transition at 0ºC and date of ice formation on the river, the longer the colder negative temperature is these days. Conditions affecting the lengthening of the period between the date of the transition temperature at 0ºC and the date of the appearance of floating ice are the initial heat content of the water masses in the river and their value (discharge). The larger the absolute value of these two factors, the longer, ceteris paribus, the specified period is. There is also a close relationship between the dates of appearance of ice formations and temperature anomaly in November and December. In cases where the anomaly is positive, the later date of the appearance of ice forms is observed. If noted the negative anomaly of air temperature the sludge and border ice formation begins earlier.

The average earlinessof forecasts based on the transition of air temperature at 0°C is: for the first appearance of floating ice and freeze-up - 7-12 days; for clearing - 4-7 days. But, as earlinessof forecasts of ice formations appearance is determined in advance of the forecast of temperature, these values should be expanded to address the timeliness of meteorological forecast values.

The main purpose of long-term forecast of ice conditions is to identify laws of development of the atmospheric processes that characterize a certain earliness features of heat exchange between the surface (water, snow, ice) and the atmosphere [3]. Since the difficulty of forecasting dates of ice formations on the Syrdarya river was also in the fact that as the date of the appearance of ice conditions, freeze-up and clearinghappen in different synoptic seasons, so it was necessary to identify significant predictors, that would allow to savesufficient earliness. There were revealed a dependencies betweenthe dates of appearance of ice conditions and air temperature anomalies of preceding periods. Were also plotted a relations, based on these dependencies, as they can be seen below (**Fig.2)**. The horizontal axis shows the average temperature in February on meteorological station Kyzylorda. On the vertical axis - the date of clearing on the Karaozek station, where for 0 was adopted January 1.

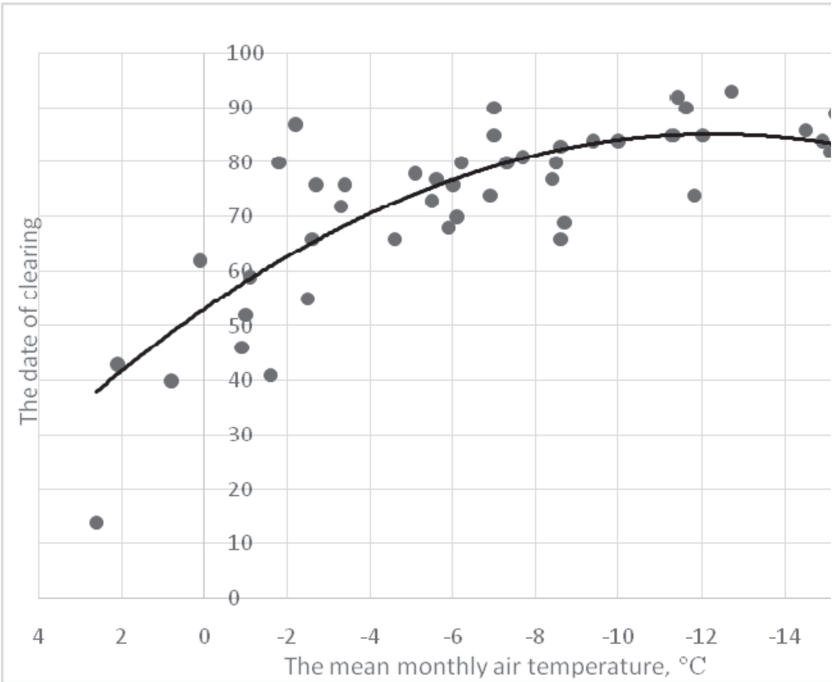


Fig. 2. Graphic chart of dependency betweenthe date of clearing of Syrdarya river on Karaozek station and the mean monthly air temperature in February onmeteorological station Kyzylorda.

Characteristics of this dependency are: the standard deviation $\bar{\sigma}$is 16,3; mean error $S$is equal to 10,0; ratio of the mean square error to the standard deviation $\bar{S}/\bar{\sigma}$is 0,61; correlation coefficient ρ is equal to 0,78; validity P is 78%. Allowable error is 10 days.

Earliness of long-term forecasts of ice formations using temperature anomalies may exceed 30 days. But the accuracy of the prediction depends on the weather forecast.

Validity of forecasts of clearing of the river higher than validity of freezing forecasts. This is due to the higher accuracy of air temperature in the spring, because of greater inertia of a homogeneous surface temperatures over snow and ice. In addition, considerable inertia effect the beginning of rising water levels at this time.

CONCLUSION

With the results of the research was compiled a methodology of forecasting the ice formations on the Syrdarya, which included all the satisfying dependencies. Average validity of this method is 70-85 %, which is a good indicator for the prediction of ice phenomena on rivers with regulated flow. This methodology is used in the department of hydrological forecasts.

REFERENCES

[1] Bishimbaev U.K. Stop the drying of sea!, Bulletin of Agricultural Science of Kazakhstan, Kazakhstan, 1996, vol. 2, p.10-14.

[2] Kipshakbaev N.K., Sokolov V.I. Water resources of Aral Sea basin, Conference “Atakent-EXPO”, Kazakhstan, 2002, p. 115.

[3] Georgievskiy Y.M., Short-term and long-term forecasts of ice phenomena on rivers, lakes and reservoirs, Russia, 1986, p. 5-10.

THE CHANGE OF WATER RESOURCES IN LAKE SEVAN IN THE CONTEXT OF CLIMATE CHANGE RENEWED SCENARIOS

Dr. Levon Vardanyan[1], Dr. Levon Azizyan[1], Ph.D student Yelizaveta Yeroyan[2], Master Armine Danielyan[1]

[1]Armenian State Hydrometeorological and Monitoring Service SNCO, **Armenia**
[2]Institute of Water Problems and Hydro-Engineering Named After I.V. Eghiazarov, **Armenia**

ABSTRACT

The free discharge from the lake is consideredas an indicator of the dynamic annual water resources of lake Sevan. The amount of water, which can be taken from the lake without level changes, is considered the free discharge. The value of free discharge depends on the region climate conditions, as well as on the height of level.

The assessment of free discharge from lake Sevan, as well as a forecast of lake levels, associated with the change of climate conditions, is important and necessary for long-term management of water resources of the lake. Multifactor regression links were created between lake`s free discharge values, air temperature values of the basin meteorological stations and observed precipitation data.

For vulnerability assessment of free discharge, in future (in 2040, 2070 and 2100) CCSM4 model results were used (air temperature and rainfall amount), which were calculated from the renewed emissions of RCP 8,5 and RCP 6,0 scenarios.

Keywords: free discharge, climate change, precipitation, vulnerability

INTRODUCTION

Lake Sevan is the high-quality natural pool for drinking water and, from this point of view, is a strategic priority importance natural resources in Armenia.

Dominant position of the lake in the Ararat valley and the surrounding mountainous areas of irrigated land masses, as well as the possibility of producing cheap electricity, is foreordained the special significance of its age-old problem of use.

Since the 20th century the lake's ecological balance has been broken, which was associated with no prudent usage of water resources, because of that the thermal regime of the lake changed, water transparency decreased, fell water quality, oxygen content in the water decreased a few times, extremely unfavorable conditions were set for the fauna of the lake [4].

For preventing or minimizing the above-mentioned and other negative effects, caused by the lake level decline, as well as for conservation and efficient use of thelake's natural resources (when the lake's water level has dropped about 18 m, compared to normal levels), In the end of the 70-ies Armenian government made a decision to halt the further decline of level, furthermore, in future even raise the lake level about 6-7 m. Due to reduction of water outflow from the lake, as well as due to the operation of the Arpa-Sevan tunnel in the 1981 (due to which yearly 200-250m^3 water flows from the Arpa river into the lake), succeeded to raise the level of the lake more than 1m to the beginning of 90s. But in the next few years, because of blockade and energy crisis, for producing energy the water release from the lake increased, as a result, in 1992-1995 the lake level fell again about 1.5 m.

On January 1 of 2014, the lake level is about 15.4 m compared with the natural level. The volume was reduced about 36%, the area was reduced about 10%.

For the lake, for protection and rational use of water resources in its basin, for increasing water level, is very important water balance adjustment in current conditions and its assessment in future.

The lake water balance data from 1927-2013 was used [2], as well as air temperature and precipitation data obtained from Martuni, Masrik, Gavar, Sevan meteorological stations **(Fig.1).**

Free discharge is a dynamic indicator of Sevan lake annual water resources. Free discharge from the lake or the active yield, is amount of water, that can be taken from the lake without changing its level. The amount of free discharge depends on region climatic conditions, as well as its height of level. Along with decrease in water level, the free discharge increases, because of the concomitant reduction in the depth, the surface of the lake decreases. As a result, the total evaporation also decreases, which leads to the increase of free discharge.

Taking into account above-mentioned, in the article intended to assess vulnerability and free discharge from lake Sevan in conditions of global climate change.

Fig. 1. The Lake Sevan basin

Despite this, the amount of precipitation, which falls on the lake surface, in such case would be getting smaller. but calculations have shown, the summary evaporation decrease is twice bigger than the summary amount of precipitation. As a result, the reduction in the level of the lake leads to increase free discharge [5].

Free discharge assessment for Sevan lake, as well as a forecast connected with the changes of climatic conditions and lake levels, is important and necessary for long-term management of water resources of the lake.

For free discharge vulnerability assessment multifactor regression link was created between free discharge long-term values and air temperature and precipitation observation data obtained from the basin meteorological stations.

In the future, in 2040, 2070 and 2100 for vulnerability assessment of free discharge was used CCSM4 model results (air temperature and rainfall amount), which were calculated from the renewed emissions of RCP 8,5 and RCP 6,0 scenarios

Multifactor regression link looks like

$$\Delta W = 4.72 + 1.42\sum X_{Martuni\,XI-II} + 0.84\sum X_{Martuni\,III-V} + 1{,}54\sum X_{Gavar\,III-V} + 1{,}76\sum X_{Martuni\,VI-VIII} + 0{,}75\sum X_{Sevan\,XI-XI} +$$
$$+ 1{,}08\sum X_{Martuni\,IX-XI} - 22{,}97\overline{T}_{Sevan\,XI-III} - 36{,}52\overline{T}_{Masrik\,III-V} - 53{,}37\overline{T}_{Sevan\,VI-VIII} + 1{,}19\overline{X}_{Martuni\,IX-XII}$$

Where

ΔW - the amount of free discharge, $\sum X$-the amount of cumulative precipitation, T-the average air temperature for the period recorded in index, written indexes are the stations names, $\overline{X}$ shows the amount of cumulative precipitation for the given duration for previous year.

The multifactor correlation coefficient value is equal to 0.88, and S/σ equation value is equal to 0.47.

According to the guidelines for forecasting, forecasting methodology is acceptable when S/σ equation has the following values.[3].

1. When $n \leq 15$, then S/$\sigma \leq 0{,}70$
2. When 15<n<25, then S/$\sigma \leq 0{,}75$;
3. When $n \geq 25$,then S/$\sigma \leq 0{,}80$:

Where n-the length of the series or number of years, S-the standard deviation of the forecasted values over the average values, σ - the standard deviation of the series members over its average.

As mentioned earlier, for the developing free discharge forecasting methodology was used the data from 1927-2013 period, that means that n=87. In this case, S /σ equation's value meets the above mentioned condition, that means that the proposed method is considered to be acceptable for annual free discharge forecast for Sevan lake.

Free discharge values, obtained from the equation,are given in the **table 1**. Lake water balance components will be changed, because of the air temperature increase and precipitation decrease, and as a result the free discharge value also will be changed.

Table 1. Seasonal average temperature (^{0}C) and seasonal precipitation deviations amount (%) compared to the average of 1961-1990[1] and estimated free dishcharge values of 2040, 2070 and 2100

Scenarios	**2040y.**			
	Temperature, ^0C			
	Winter	Spring	Summer	Fall
RCP, 6.0	1.4	1,3	1.9	0.8
RCP, 8.5	1,7	1,4	2,1	1,4
	Precipitation, %			
	Winter	Spring	Summer	Fall
RCP, 6.0	5,3	1,2	-10,1	5,0
RCP, 8.5	-5,7	4,2	-23,0	2,5
	Free discharge estimated value, mln. m^3			
RCP, 6.0	**89.6**			
RCP, 8.5	**71.5**			
Scenarios	**2070y**.			
	Temperature, ^0C			
	Winter	Spring	Summer	Fall
RCP, 6.0	2,6	2.4	3,0	2,3
RCP, 8.5	2,8	2,7	4,0	3,2
	Precipitation, %			
	Winter	Spring	Summer	Fall
RCP, 6.0	5,8	4,2	-10,8	3,2
RCP, 8.5	16,3	-8,0	-3,4	8,6
	Free discharge estimated value, mln. m^3			
RCP, 6.0	**-145.3**			
RCP, 8.5	**-213.5**			
Scenarios	**2100y.**			
	Temperature, ^0C			
	Winter	Spring	Summer	Fall
RCP, 6.0	3,6	2,7	3,8	3,0
RCP, 8.5	4,4	3,9	6,0	4,4
	Precipitation, %			
	Winter	Spring	Summer	Fall
RCP, 6.0	6,2	2,6	12,8	1,2
RCP, 8.5	2,9	2,4	-13,0	13,6
	Free discharge estimated value, mln. m^3			
RCP, 6.0	**-177.4**			
RCP, 8.5	**-384.4**			

CONCLUSION

In the article was determined the free discharge values and assessed their vulnerability connected with the expected climate change in the future. Multifactor regression links were created between lake`s free discharge values, air temperature values of the basin meteorological stations and observed precipitation data, which helped to assess free discharge vulnerability for 2040, 2070 and 2010 by using different climate change scenarios.

From the analysis of the numerical values, it appears that in 2040, if the temperature will be rised 1.7^0C and precipitation will be decreased 5.7%, the value of the free discharge will be decreased 190.0-210.0 million cubic meters compared with the standard period values 1961-1990.

In 2070 it has to have a negative value and estimation shows that it has to be -145.0 to -213 million cubic meters and gradually decreasing in 2100 it has to be -177 to -384 million m^3.

Thus, because of the climate change the expected values of temperature and precipitation will lead to decrease the free discharge of Lake Sevan. For maintenance the lake's hydro-ecological conditions will need to develop new water-economical activities.

REFERENCES

[1]. Current status and perspectives for devlopment of climate services in Armenia, Armenian state hydrometeorology and monitoring service, Yerevan, p. 40, 2013

[2]. Hydrological yearbooks m.2, No. 3-5, Publication of Hydromet, 1938-2013

[3]. Manual on Service forecast, section. 3, Part 1. Forecasts regime of surface waters. Leningrad, Hydrometeoizdat, p. 193, 1962

[4]. Mnatsakanyan B. P., Sevan basin (Nature, climate and water) Yerevan, p. 190, 2007

[5]. Nikoghosian G.T., Lasting fluctuations of free discharge of Lake Sevan, Collected works of HMC ArmMHEC vol. 2, 1986

THE ASSESSMENT OF ECOLOGICAL STATE OF THE RIVERS OF GEORGIA, FLOWING IN THE BLACK SEA

M. Kvinikadze, V. Kirakocian, G. Todradze, N. Loria, N. Janashvili, S. Jalagania, L. Akhalbedashvili

Iv. Javakhishvili Tbilisi State University, Tvalchrelidze Caucasian Institute of Mineral Resources, Tbilisi, **Georgia**

ABSTRACT

The distribution of heavy metals in river Rioni and its tributaries waters and sediments was studied and the general pattern was done. The high content of some toxic elements such as Mn, As and Cd significantly exceeds maximum permissible concentrations that is characteristic for tributaries, which are located in the riverhead of Rioni, where are many objects of mining development and ore deposits, in particular arsenic ores. The source of arsenic is not only deposits, agricultural reagents as fertilizers, pesticides, herbicides and others may be the sources of arsenic compounds too. Elevated levels of copper, lead and zinc is more typical for areas along motorways.

Keywords: pollution, waters, heavy metals, distribution

INTRODUCTION

The contamination of environment with toxic substances corresponds the biogeochemical problem, because of it connects with occurred in nature mobilization, migration, accumulation and transformation of chemical elements.

The Black Sea is the small part of world Ocean and in the same time one of the important water object for Europe. The length of the coastline is 4,000 km, of which 320 falls on Georgia. The rivers, contaminated with industrial or household wastes fall in it from many countries, threatening the ecological state of the Black Sea. In this respect, Georgia is no exception. We can distinguish two types of pollution: natural and anthropogenic. Natural pollution of the Black Sea takes place at the expense of hydrogen sulfide and methane. It is obvious that the intensity of this process depends on both natural and man- triggered causes.

The main pollutant of Black Sea on Georgian territory is river Rioni, because of along the whole river basin there are closely situated towns and villages, as well as many industrial, agricultural and domestic objects. Technological waste of major pollutants of these residential settlements are: phosphate and nitrate fertilizers, herbicides, pesticides, toxic heavy metals (HM), petroleum products, organic and inorganic complexes, sewage water, phenols, etc.

In common, general geological state of territory of Georgia is due to the followed three type of pollution with technological wastes: geochemical, hydrochemical and biogeochemical. Recent time the main objects of pollution are:

- mining districts as Chiatura, Kvaisi, Tkibuli, Cana, Madneuli and others;
- metallurgical objects as Rustavi and Zestaphoni;
- petroleum and gas pipelines as Baku – Jeihan, Vladicaucas – Tbilisi - Erevan.

In this paper we presented the research on identification and quantity of heavy metals and arsenic in waters, which was carried out in the most full-flowing river of Western Georgia - Rioni and its tributaries **(Fig. 1),** and the studied territory is one of most populous region of Georgia.

EXPERIMENTAL PART

The study-assessment carried out in two directions. First consists in visual examination and assessment of territory, second - collection and study of analytical data. Routes was planned and carried out as for r. Rioni, so for all its tributaries.

Selection, preservation, storage and preparation of samples for analysis were carried out in accordance with international standards [1, 2]. The filtration of samples was carried out through membrane filters of firm “Millipore”.

The measurements of heavy metals - Cu, Pb, Zn, Co, Ni, Cd, Mn, were carried out on atom-absorption spectrometer Perkin-Elmer AAnalyst 200 [3, 4]. The analysis of arsenic was carried out by photo colorimetric method according to [5] using organic bases.

Fig.1. Riverhead of Rioni, one of the largest river of the Caucasus, the deepest river in Georgia. In ancient times was known as Phasis.

RESULTS AND DICUSSION

According to our researches in the frame of project "Complex geo ecological study-assessment of basin of river Rioni" (government scientific grant NO 1-5/24), which were carried out in 2008-2012 years, here is described the general pattern of distribution of heavy metals in river Rioni and its tributaries waters and sediments. As indicated above the main pollutant of Black Sea in Georgian part is r. Rioni. But according to obtained data r. Rioni, one of the longest and full-flowing river of Georgia, is among the cleanest on the content of heavy metals between the rivers, flowing in Black Sea. The exceptions are the content of manganese **(Fig. 2),** arsenic and cadmium, especially in sediments.

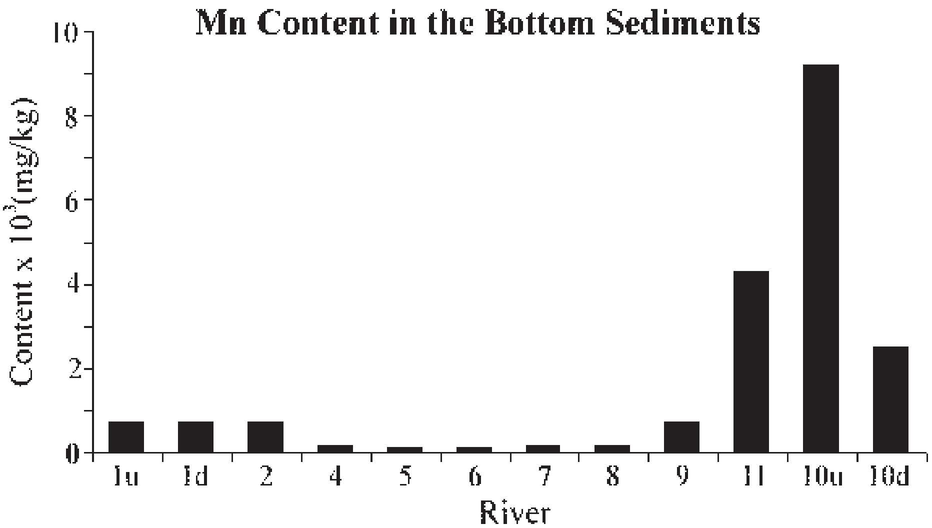


Fig.2. The content of manganese (numeration of rivers is the same that on fig. 2)

The high content of these elements is characteristic for those feeders, which are located in the riverhead of Rioni, where are many objects of mining development and ore deposits, in particular arsenic ores. But it is known that the source of arsenic is not only deposits, agricultural reagents as fertilizers, pesticides, herbicides and others may be the sources of arsenic compounds too.

The data on content of heavy metals in water and sediments resulted in tables 1 and 2 accordingly. The high zinc content is observed in the water and sediments, but the same cannot be said about the copper. Its content is a lot more in water than in the bottom sediments. The lead content is relatively higher in the left feeders of river Rioni (especially in the upper reaches) than in rivers flowing into the Rioni at Colchis lowland. Anomalously high content of cobalt and nickel were found in sediments almost in all rivers, whereas in the surface waters their content does not exceed the values that we have adopted as standards. Almost the same tendency is observed when considering the contents of arsenic and cadmium. Their content is very high in sediments, but does not exceed the norm in the aqueous part. An exception is the r. Luhunistskali, in the vicinity of which there are arsenic deposits and industrial plant. Study of manganese pollution wastes showed that the amount of manganese is high enough in sediments of r. Kvirila and Rioni, due to the presence of Chiatura manganese deposit and working Zestafoni ferroalloy plant **(Fig.3).** It should be noted the value of cadmium exceeds MPC (Maximum permissible concentration). According to the standard the MPC of cadmium is 0.8 mg/kg, but obtained by us value of cadmium reaches 7 mg/kg. This fact is explained by the circumstances that in Western Georgia soils contain high content of zinc, which is isomorphic to cadmium compounds.

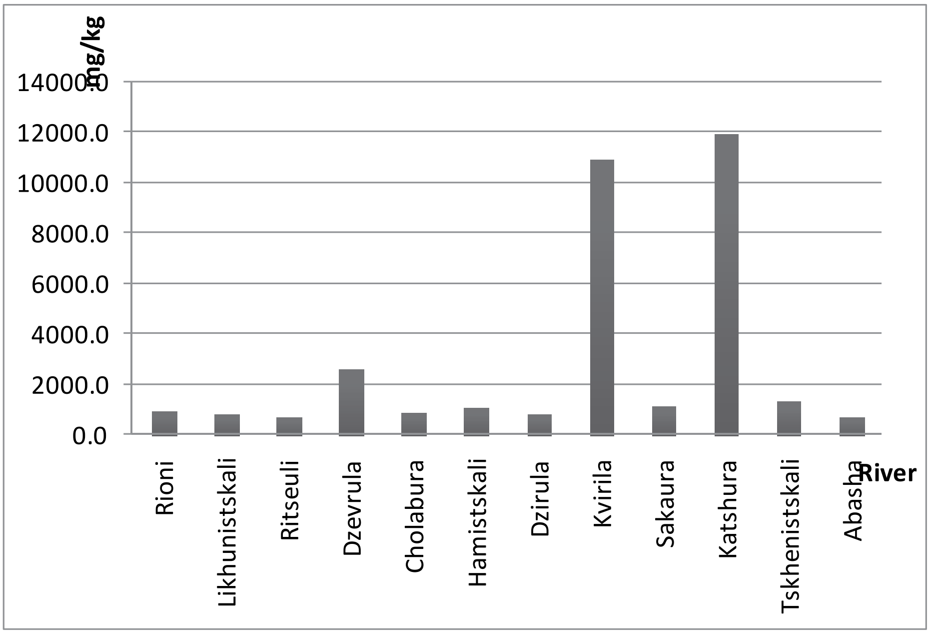


Fig.3. The average values of Mn content in sediments of some rivers in bazin of R. Rioni (MPC of Mn 1500mg/kg).

Table 1. The content of HM in waters of R. Rioni and its some tributaries (g/l)

N	River	Cu	Pb	Zn	Co	Ni	Cd	Mn	As
1	Rioni	0.0650	0.029	0.0575	0.0250	0.0310	0.0075	0.1710	0.010
2	Kvirila	0.0450	0.044	0.0250	0.0125	0.0620	0.0075	0.0263	<0.001
3	Dzirula	0.0450	0.033	0.0250	0.0250	0.0310	0.0025	0.0110	<0.001
4	Hani-stckali	0.0250	0.059	0.0500	0.0500	0.0310	0.0025	0.0131	<0.001
5	Chola-buri	0.0250	0.059	0.0500	0.0500	0.0150	0.0055	0.0263	0.006
6	Sakaura	0.0380	0.029	0.0500	0.0375	0.0310	0.0050	0.0263	0.005
7	Lukhu-nistckali	0.0750	0.015	0.0500	0.0500	0.0310	0.0025	0.0263	0.008
8	Dzevrula	0.0880	0.059	0.0500	0.0250	0.0310	0.0050	0.0283	0.010
9	Abasha	0,005	<0,01	0,020	0,011	0,020	<0,001	0,015	0
10	Tchen-stckali	0,005	<0,01	0,020	0,022	0,020	0,001	0,015	0

Table 2. The content of HM in sediments of r. Rioni and its some tributaries (mg/kg)

N	River	Cu	Pb	Zn	Co	Ni	Cd	Mn	As
1	Rioni	40.0	87.6	90.0	45.0	68.75	5.0	999.0	10.4
2	Kvirila	25.0	87.7	75.0	40.0	56.25	4.0	999.0	0,8
3	Dzirula	27.5	87.7	70.0	45.0	56.25	4.0	880.0	4,0
4	Hanistckali	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0
5	Cholaburi	40.0	105.21	45.0	35.0	50.00	4.0	932.0	5.6
6	Sakaura	30.0	99.36	105.0	45.5	59.37	3.5	954.0	8,0
7	Lukhunistckali	35.0	93.54	90.0	45.0	68.75	4.0	866.0	20.0
8	Dzevrula	15.0	70.14	50.0	40.0	56.25	5.0	2666.4	0.0
9	Abasha	21,8	33,0	53,5	13,5	17,4	0,90	680,0	0,71
10	Sakaura	25.0	93.5	80.0	45.0	68.75	3.0	1110.0	1,6
11	Tchenistckali	36,3	50,0	27,0	35,9	39,0	2,5	1040	3,9

To many people, HM pollution is a problem associated with areas of intensive industry. However, roadways and automobiles now are considered to be one of the largest sources of HM. Zinc, copper, and lead are three of the most common HM released from road travel, accounting for at least 90 of the total metals in road runoff. Lead concentrations, however, consistently have been decreasing since leaded gasoline was discontinued. Smaller amounts of many other metals, such as nickel and cadmium, are also found in road runoff and exhaust. The biological pollution is characteristic too for those rivers, on which there are located the towns and other settlements. Furthermore, the significant oil pollution is observed in the surface waters of the Black Sea in the region of Poti, where the river Rioni flows in to that is caused by the movement of maritime transport and the existence of oil terminals.

CONCLUSION

Results of conducted complex geoecological investigations in 2008-2012 yy. in the basin of the river Rioni have shown that in the waters and sediments in r. Rioni and its tributaries the content of toxic elements such as Mn, As and Cd significantly exceeds MPC of these elements.

High values of manganese and arsenic fixed in sediments of the Rioni and some of its tributaries, especially in the lower reaches and even at the confluence of the Black Sea in the vicinity of Poti are caused by the existence manganous (Chiatura) and arsenical (Urawa) deposits in basin of r. Rioni. Elevated levels of copper, lead and zinc is more typical for areas along motorways. For remote from roads locations the content of these elements is relatively lower.

REFERENCES

[1] ISO 5667-3:2012. Water quality - Sampling - Part 3: Preservation and handling of water samples, 42 p., 2012.

[2] ISO 5667-2:1991. Water quality - Sampling - Part 2: Guidance on sampling techniques, 24 p., 1991.

[3] Fomin G.S. Water. The control of chemical, bacteriological and radiation security per international standards. Encyclopedic manual. Moscow, Russia, 848 p., 2000.

[4] ISO 8288-1986. Water quality; Determination of cobalt, nickel, copper, zinc, cadmium and lead; Flame atomic absorption spectrometric methods, 11 p., 1986.

[5] ISO 6595-1982. Water quality; Determination of total arsenic; Silver diethyldithiocarbamate spectrophotometric method, 12 p., 1982.

Scientific edition

AASSA REGIONAL WORKSHOP PROCEEDINGS

SUSTAINABLE MANAGEMENT OF WATER RESOURCES AND CONSERVATION OF MOUNTAIN LAKE ECOSYSTEMS OF ASIAN COUNTRIES

Format B5
Offset Paper
Number of Printed Copies: 150
Institute of Geological Sciences of NAS of RA
Web site: www.geology.am

Printing House “Arart”
Address: M. Baghramyan Ave. 24b
E-mail: arart2009@yahoo.com