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WATER RESOURCES DEVELOPMENT: ECONOMIC ASPECTS

Water Resources and the Sustainable Development of Humankind: International Cooperation in the Rational Use of Freshwater-Lake Resources: Conclusions from Materials of Foreign Studies

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Abstract—The current and future state of the Earth's water resources under present-day trends in water use is discussed. The activity of international institutions in the organization of management of lake ecosystems and drainage basins was analyzed from the viewpoint of sustainable development. The work of International Committee on Lake Environment, International Joint Commission (USA and Canada), International Commission on Lake Constance Protection, Autonomous Bilateral Management of Lake Titicaca, Commission on Chad Lake Basin, and Fishery Organization of Lake Victoria. Recommendations are proposed for the organization of international management of water bodies and their drainage basins.

Keywords: transboundary lakes, international organizations, lake ecosystem management, sustainable development

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INTRODUCTION

The search for the optimal relation between the environmental protection requirements and the need to meet the demands of socioeconomic development is still a problem to be solved in the management of water resources and aquatic ecosystems [32]. Climate changes and the uneven distribution of water resources along with economic growth and demographic processes make the sustainable water use very difficult and do the same in the future [3]. The four major tendencies, which hamper the overcoming of water deficiency in the nearest decades are as follows [5]: the population increase, the progressing urbanization (where the population concentrating in limited areas will require even greater amounts of water), and increase per capita water consumption. While those factors will increase water consumption, climate perturbation will make water resources less available.

Estimates show that a dollar invested in water quality improvement and sanitary–hygienic measures can be expected to yield \$3-34 income, while the current investments in water sector do not exceed \$10–34 billion (\$111-180 billion per year is required [33]). It is clear now that the problems of water deficiency and poverty are closely related. One fifth of the population in developing countries cannot consume even the minimal necessary water volume (20 l day^{-1}), while the per capita water consumption in Europe and the USA is 200–600 l day^{-1}. The people living in slums pay for water 5–10 more than those who have access to public water supply [5].

WHY LAKES?

As mentioned above, lakes are, first, natural machines for maintaining water purity and, second, the major natural storages of fresh surface water that are available for humans. Moreover, in addition to their important ecological role and the considerable economic load they are subject to, the lakes contribute much to the support of social aspects of sustainable development. Based on his thirty-year studies of more than 1000 near-lake communities, L. Klessig [17] has come to the conclusion that the role of lakes in the social sphere is not limited to nature protection and recreation. He also mentioned their economic, aesthetic, cultural, and educational significance and their role in the securing of ecological and common safety, emotional release, spiritual self-perfecting, and individual freedom.

The important role in sustainable social, economic, and ecological development is obvious. Large transboundary lakes with a total area of almost 0.4 million km^2 account for nearly half volume of surface freshwater resources (Table 2). That is why, the author of this review has limited the problem of international cooperation in water use in the context of sustainable development to international cooperation in the use of freshwater lake resources.

Table 1. Per capita water use (according to [34]])

Use type	Volume, m^3 day^{-1}
Domestic	
rural	0.045
urban	0.460
Industrial	0.900
In power generation	1.600
Agricultural	2.200
Total	5.200
Including consumptive use	1.500

The number of the lake and river drainage areas distributed between several states is now 263. More than 300 international agreements on the use of water resources were concluded in the recent 60 years and 37 interstate water use conflicts took place [2]. International agreements were concluded around some transboundary lakes, resulting in the formation of international organizations (Table 3). In this paper, the author considers an international program of studies and organization of sustainable management of lakes all over the world and five regional international programs, being implemented now, each aimed at the basin of an individual water body or a group of those.

INTERNATIONAL PROGRAMS (PROJECTS) AIMED AT THE ORGANIZATION OF INTERNATIONAL COOPERATION IN THE JOINT SUSTAINABLE LAKE USE

International Committee on Lake Environment

A large number of international projects for studying and rational use of freshwater are being implemented now. An example is the REBECCA Project) Relations Between Ecological and Chemical Status of surface waters) is an example. The objective of the project is to collect new information about the relationships between European surface water chemistry and their environmental status for the implementation of the project Water Framework Directive (WFD). Much data on the eutrophication and acidification of water bodies and indicator species have been collected under this project [29, 31]. The projects already imple-

Table 2. Physiographic characteristics of large international lakes in the World (according to [35])

Lake	Surface area, km^2	Volume, km^3	Depth, m		Shoreline length, km	Water exchange time, year	Drainage area, km^2
			mean	maximal			
Albert	5300	280	25	58			
Superior	82367	12221	148	406	4768	191	124838
Victoria	68800	2750	40	84	3440	23	184000
Volvi	67	0.9	13.5	23			1247
Huron	59570	3535	53	228	5088	22.6	128464
LakeofGeneva	584	88.9	152.7	309.7	167	11.8	7975
Kariba	5400	160	31	78	2164	3	663000
Constance	539	48.53	90	252	255	4.5	10900
Maggoiore	212.5	37.5	176.5	370	170	4	6387
Memphremagog	102	1.7	17	107	121	1.7	1764
Michigan	58016	4871	84	281	2656	99.1	117845
Neusiedler	320	0.25	0.8	1.8		3.5	1300
Nyasa	6400	8400	292	706	245		6593
Ontario	19009	1638	86	224	1161	7.9	75272
SaltoGrande	783	5	6.4	33	1190	0.03	224000
Skadar	372	1.93	5	8.3	207		5490
Tanganyika	32000	17800	572	1471	1900		263000
Titicaca	8372	893	107	281	1125	1343	58000
Turkana	6750	203.6	30.2	109		12.5	130860
Chad	10000–25000	72	4	10–11	500–800	2	2426370
Champlain	1130	25.8	22.8	123	945	2.6	19881
Chilwa	1750	1.8	1	2.7	200		7500
Edward	2325	39.5	17	112			12096
Erie	25821	458	17.7	64	1369	2.6	78769
Total	410989.5	53533.41					4555551

Table 3. Organization of international cooperation at large international lakes of the World (according to [22] with modifications and supplements)

Lakes	Countries	International organization	Legal basis of activity	Function
Albert	Zaire, Uganda	–	–	–
Great Lakes	USA, Canada	International Joint Commission	International convention	Resources use management
Victoria	Tanzania, Uganda, Kenya	Fishery Organization of Lake Victoria	International agreement	Regulation
Volvi	Macedonia, Greece	–	–	–
Constance/Bodensee	Austria, Germany, Liechtenstein, Switzerland	International Commission on the Protection of Lake Constance	International convention	Recommendation
Leman/Geneva	France, Switzerland	–	–	–
Maggiore	Italy, Switzerland	–	–	–
Memphremagog	USA, Canada	International Joint Commission	International convention	Resources use management
Neusiedler See	Austria, Hungary	–	–	–
Nyasa/Malawi	Malawi, Tanzania	Malawi/Nyasa Lake Commission (project)	International convention	Coordination
Salto-Grande	Argentine, Uruguay	–	–	–
Skadar/Shkodar	Albania, Montenegro	–	–	–
Tanganyika	Tanzania, Zaire, Zambia, Burundi	Tanganyika Lake Management (project)	International agreement	Coordination
Titicaca	Peru, Bolivia	Autonomous Bilateral Management of Lake Titicaca	International agreement	Coordination
Turkana	Ethiopia, Kenya	–	–	–
Chad	Cameron, Chad, Niger, Nigeria, Central African Republic, Sudan	Commission on Lake Chad Basin	International convention	Resources use management, coordination
Champlain	USA, Canada	International Joint Commission	International convention	Resources use management
Chilwa	Malawi, Mozambique	–	–	–
Edward	Zaire, Uganda	–	–	–

mented include CASSARINA (Change, Stress, Sustainability and Aquatic ecosystem Resilience In North African wetland lakes during the 20th century) and EURO-LIMPACS (Evaluating the Impacts of Global Change on European Freshwater Ecosystems). The CASSARINA, aimed at the monitoring and paleolimnic studies of North African lakes was financed by EC in 1997–2000 [6, 8, 9, 28]. The EURO-LIMPACS, devoted to predicting the dynamics of components of European lakes under global climate changes, was implemented from 2004 to 2009, costing EC 20 million EUR, and included the creation of a database of limnological data on European lakes [7].

Let us consider a comprehensive international program, which has been carried out for over twenty years and is aimed at studying lakes and improving the mechanisms of their management for ensuring the preservation of lakes and the improvement of life of people in their basins all over the world [4].

The Objectives and Tasks of the International Lake Environment Committee. The International Lake Environment Committee (ILEC) was formed in 1986 as a nongovernmental international organization and it received legal status from the Environmental Protection Agency of Japan and the Ministry of Foreign Affairs of Japan.

The objective of ILEC is to support the management of lakes, reservoirs, and their basins for sustainable development by helping in the organization of international researches and the support of wide exchange by the acquired knowledge in the world scientific community. ILEC proceeds from the ideas that all lakes and reservoirs in the world should by managed and protected on a sustainable basis for the welfare of the future generations, that each lake in the world is

unique and has its own problems, so none organization in the world can develop a universal receipt for solving lake problems; moreover, whatever its location, size, or natural/artificial origin of a lake, conflicts inevitably exist in the interests and plans of its use.

The task of ILEC is to develop the international cooperation in the environmental protection of lakes, maintain the optimal management of lake ecosystems, develop methodologies for harmonizing the relationships at the international level between nature use, sustainable development, and researches.

To solve its problems, ILEC collects and disseminates information about the lake and the problems of their protection all over the world; develops studies in the field of lake management; helps developing countries to create systems for water resources management and planning of optimal scenarios of lake resources use; contributes to teaching the technical and economic aspects of lake ecosystem management; maintains lake management schemes proposed to the developing countries by UNEP; encourages international interaction between the national and regional bodies and research institutes; encourage any other activities contributing to the attainment of ILEC objectives.

ILEC Activity. The Committee carries out research, education, and publishing activities. A database on lakes and reservoirs has been collected and made publicly available [35], reports on "The Assessment of World Lakes"; reference books, containing data on world lakes, anthropogenic impact on them, recommendations for their management from the viewpoint of sustainable development [22, 36]. The Committee organizes and carries out World Lake Conference on a biannual basis. The Committee ensures the widest dissemination of materials of the conferences, including through their publishing in free access in the Internet [27]. The Thirteenth Conference was held in Wuhan City (China) in November 2009 [1], and the Fourteenth Conference, in Austin (USA) in November 2011. The Committee issues an information bulletin (ILEC Newsletter) in two languages and the scientific journal "Lakes and Reservoirs: Research and Management" (Blackwell Science, Melbourne and Oxford). In cooperation with UNEP and UN Center for Regional Development, the Committee will carry out training courses and seminars for researchers, post-graduates, students, practicians, businessmen, and politicians, public members for water quality assessment, water basin management, modern analysis methods, modeling in water resources management, etc. A series of books were published to become very popular among limnologists and experts in water resources management [10]. Those books were translated into Spanish, Thai, Portugal, Chinese, and French languages and available for free in the Internet. The Committee launched a pilot project on environmental education and water resources in secondary schools and refresher courses for teachers in Argentine, Brasilia, Ghana, Denmark, Thailand, and Japan. Moreover, the Committee is implementing several projects in cooperation with UNEP/IETC.

According to the World Lake Vision Action, the Committee recommends seven principles of lake use to be followed [36]: harmonic relationships between people and nature are the basis of sustainable lake use; lake drainage basin is the logical basis for planning and any management activity in sustainable water use; long-term measures must be taken to prevent lake degradation; the policies in nature use and decision making should be based on the best scientific base and the widest available information; lake management with the aim of sustainable lake use requires conflicts between competing users to be resolved with the demands of both the present-day and the future generations being taken into account; the involvement of individual inhabitants of lake areas and other concerned parties in the establishment and solution of critical problems of the lake should be encouraged; the sustainable lake use requires good management based on objectiveness, transparency, and the involvement of all concerned parties.

International Joint Commission (USA and Canada)

The Great Lakes. The Great Lakes are perhaps the most significant water bodies at the border between the United States and Canada. Their total volume is close to that of Lake Baikal, but the Great Lakes are much younger (by about 1000–2000 times), so their organic life is less developed. They have a strong effect on the economics and all aspects of life in eight US states (Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania, and New York) and two Canadian provinces (Ontario and Quebec), which, in their turn, affect the lake ecosystems. Twenty percent of US population and 60% of Canadian population live on their common drainage area. In year 2000, the industrial output in the basin of the Great Lakes amounted to $2 trillion, which is greater than the US gross domestic product. The agricultural production of the region accounts for one quarter of that in the USA (including half of soybean and corn crop) and Canada. Tens of millions of tourists visit the Great Lakes every year, and licenses to fish or shoot produce $18.5 billion for the US side and more than 20 billion CAD to the Canadian side. The priority pollutants for the Great Lakes ecosystems are PCBs (including dioxins), benz(a)pyrene, DDT, mercury, and other heavy metals.

International Joint Commission

Now, the international body with the longest history among those regulating freshwater development is the International Joint Commission (IJC) [12, 13, 21,

35], which celebrated its 100th anniversary on January 11, 2009.

By the early XX century, the US and Canadian governments recognized that any activity of either country in transboundary rivers or lakes affects the other country. The commission was established by the Convention on Transboundary Waters for solving problems of transboundary water bodies and streams, including the Great Lakes. The first Commission included 6 members: three from the USA (they were appointed by the President upon the recommendation and with the approval of the US Senate) and three from Canada (appointed by the Governor General of Canada as advised by the Prime Minister). The Commission members had to solve problems, rather than pursue the interests of their governments. Nowadays, the Commission officially regulates the interaction between the two countries in the management of near-boundary and transboundary waters and their protection for the welfare of their citizens and the future generations. In its activity, the Commission created more than 20 various expert and other departments.

When water resources are being developed by more than one user, conflicts of interests are inevitable. Indeed, transboundary waters are withdrawn for use in industry and irrigation and return as wastewaters; they are used for power production, transport, and recreation. Clearly, the representatives of different sectors of water use are in conflict. In some cases, the Commission acts as a judge, protecting the interests of the water user whose position is in better agreement with the Convention.

The Commission also carries out, by special order of both Governments, monitoring observations of transboundary water pollution and prepares recommendations for improvement of water bodies. Additionally, the Commission monitored air pollution and the atmospheric transfer of pollutants by orders of the US and Canadian governments.

Since 1991, when Air Quality Committee was established, the Commission has taken part in its activity.

The Commission involves the public in discussions about the cleaning of the Great Lakes, sponsors conferences, round tables, seminars, and meetings with the participation of representatives of the local population. The Commission also organizes public-opinion polls regarding all important issues, closely cooperates with local authorities, research and nature protection institutions, unions, associations, business; it publishes and widely disseminates the results of its work and issues a free of charge information bulletin.

The promotion of governmental programs for cleaning of the Great Lakes and seems to be the key aspect of Commission activities. The first agreement on Great Lakes water quality, in which Canada and the USA agreed to jointly control pollutant input into lake water and ensure the processing of industrial and municipal wastewaters was signed in 1972. In the next agreement (1978), both countries undertook to jointly clean the Great Lakes from nonreactive toxic agents. Finally, a Protocol was signed in 1987, ordering the Commission to observe the implementation of the "Remediation Plans." Those plans, which serve as the basis of the strategy for ensuring the sustainable development of Great Lakes region, where prepared in cooperation by the governments and the public. According to the same Protocol, the Commission looks after the implementation of "Lake Management Plans," aimed to improve water quality in the Great Lakes. The c-Commission monitors water level variations in the entire system of the Great Lakes–the St. Lawrence R. and in the Niagara R.; reviews the construction plans of dams and other hydroengineering structures throughout the near-boundary area and determines their operation regime.

In June 2007, parallel to the scheduled (biannual) meeting of the Commission, a conference on the problem of the Great Lakes was held, involving more than 300 researchers, politicians, and public representatives. The items discussed at the conference included water protection strategies in urban construction; treatment of domestic, municipal, and industrial wastewaters; construction technologies safe for the environment and human health; development of methods for assessing the state of ecosystems; invasion of alien species; cardinal revision of Water Quality Agreement for the Great Lakes; improvement of Plans for Remediation and Managements of the Lakes; and groundwater management.

In addition to the system the Great Lakes–the St. Lawrence R., the Commission exercises the management of the basins of the rivers of Kootenay, Columbia, St. Mary, Milk, Souris, and St. Cross, Rainy Lake, and many others.

Commission achievements and new problems. The main and most vivid success in the activity for protection of transboundary water bodies in the USA and Canada was the considerable decrease in pollution from point sources due to the stricter control and better treatment systems.

This success has lead to the recognition that the major hazard now is associated with diffuse pollution sources. Once the territories around lakes, which previously formed a region with clear-cut boundaries between cities, towns, and rural areas, turned into a continuous megalopolis formation with the predominance of marginal and dormitory development, crossed by numerous highways, roads, and boulevards, the washout from streets changed radically. They turned into a mixture of soil erosion products and plant remains from persisting land areas, fuels and lubricants from transport, synthetic surfactants, pesticides and herbicides from areas at cottages, household chemistry, and waste products of domestic animals.

Nearly one-fourth of the drainage area is in use as agricultural fields. After the conversion of agriculture

into agricultural production in the mid-XX century, the ecosystems of the Great Lakes suffered a shock from pesticides and chemical fertilizers. Such hazards have been practically eliminated, though a new hazard has appeared because of the increasing concentration of cattle in individual cattle-breeding farms, the inability of many farmers to get rid of manure masses and the possible spread of infectious diseases. However, while the urbanization leads to the irreversible degradation of lands, the agriculture can harmonically exist in the general nature use system in the basin based on the principles of sustainable development and ecosystem integrity. Agricultural procedures have been developed, which can be expected not only reduce the negative environmental impact of the agriculture, but also recover the disturbed lands and hydrological cycles.

A great success was the creation of interdisciplinary International Association for Great Lakes Research (IAGLR), which, on the one hand, relates the studies of the American Great Lakes with limnological studies in other great lakes of the world and, on the other hand, transforms the results of researches into the form that will be clear for politicians, businesspersons, and journalists. Moreover, during the period of Commission activity, it has become possible to bring the researchers of academic institutions closer to the personnel of federal and local governmental and private laboratories and to teach them to join the results of their studies. An important result of this convergence is the establishment of long-term monitoring of the state of ecosystem components of the Great Lakes.

New Agreement for the XXI Century. The International Joint Commission proposed to replace the current Agreement on the Great Lakes Water Quality by a shorter but more specific document, in particular, obliging both sides to most rapidly develop and accept an action plan with achievable objectives and real completion terms.

The Commission insists on the inclusion in the new agreement and action plan of a concept of ecosystem protection and planning of activities on drainage basins; the human health was declared as the objective of the work; and the theoretical basis of activities was chosen to be the ecosystem approach. Moreover, the Commission believes that more attention should be paid to the biological integrity of the region and its protection against the invasion of alien species. The public should be more widely involved in the work under the project of the new Agreement.

International Commission on the Protection of Lake Constance

Lake Constance (Bodensee) ranks second among the Alpine lakes. Its drainage basin is divided between Austria, Germany, Liechtenstein, and Switzerland. The division of the water surface is a very interesting case in the international practice. The Lower Lake (Lake Constance is divided into Lower and Upper lakes based on clear morph metric reasons) is divided between Switzerland and Germany, while in the Upper Lake, only a shallow zone 25 m in width belongs to some country, while the major portion of the lake is in joint use. The lake is used as a water source, waterway, and tourist feature.

The state of lake ecosystem has considerably changed since the 1950s because of the input of pollutants, mostly biogenic elements from more than 3500000 population on the territory of the drainage basin. Alga blooms were recorded in the lake, which were never observed before. Additionally, changes in zooplankton species composition and other signs of eutrophication were recorded. In the 1960s, it was established that the main agent of those changes is phosphate ion. The major portion of wastewater was discharged into the lake without any treatment. Phosphate concentration in the lake increased by 15% in the 1970s.

International Commission for Lake Constance Protection. To eliminate the consequences of the existing pollution and to prevent the future pollution of the lake, Austria, Germany, and Switzerland established The International Commission for the Protection of Lake Constance (also Internationale Gewässerschutzkommission für den Bodensee, IGKB) [11, 23, 35]. The Commission monitors the state of the lake, spreads information about pollution cases, prepares recommendations for preventive measures, and discusses possible scenarios of lake use.

Commission meetings are held at least once a year. The commission includes representatives of the governments of member countries and a limited number of high officials of those countries. The commission is a deliberative body, and it cannot introduce any rules or take any measures for nature protection, but, in accordance with an intergovernmental agreement, the governments of the member countries have to adopt national laws as recommended by the Commission. Technical and scientific experts work as official advisers of the Commission, develop research programs, and prepare reports on the research works approved by the Commission.

It is largely due to the activity of the Commission that, e.g., phosphorus concentration dropped from 87 μg L^{-1} in 1979 to 12 μg L^{-1} in 2001; it is planned to reduce this concentration below 10 μg L^{-1}. Nowadays, more than 90% of municipal wastewater and 90% of domestic wastewater in rural areas are subject to the primary, secondary, and tertiary treatment at more than 200 treatment facilities in the lake's basin. The construction of those facilities and their connection with the sewage systems of individual users cost 4 billion EUR. The sustainable use of the lake is possible only while its ecosystems remains intact, which requires the preservation of the results in lake protection, further drop in the load (as far as possible), and

compensation for the consequences of inevitable impacts.

Along with the Commission, the organization of sustainable nature use in Lake Constance basin at the intergovernmental level is a function of International Bodensee Conference (IBC), established in 1972. The Conference consists of 10 members: cantons of St. Gallen, Thyrgau, Schaffhausen, Appenzell Innerroden, Appenzell Auszerroden, Zurich, (Switzerland); Baden-Wuerttemberg and Bayern lands (Germany); Vorarlberg Land (Austria); and the Principality of Liechtenstein. The Conference consists of the Permanent Committee and seven Commissions. A meeting of the Conference is held every year with the participation of prime-ministers of all its members. The Conference cooperates with IGKB, and a representative of the latter is a member of the Permanent Committee of IBK.

Autonomous Bilateral Management of Titicaca Lake

Lake Titicaca. The largest lake in the South America lies between the ridges of the Eastern and Western Cordilleras in the Central Andes, at the border between Peru and Bolivia. This is the highest mountain lake among the great lakes of the world. The population in the drainage basin is about 2.8 million, of which only 22% are literate. The population of the region is the poorest in both Bolivia and Peru. In the Peruvian part of the basin, 40% of the population are poor and 34% are very poor; in the Bolivian part, 67% live below the poverty line, of which 29% are very poor. The economy of the region is based on agriculture (48% of basin area), including the cultivation of potato and other root crops (5%), pastures (22%), and forest cutting (15%). Again, tin, silver, copper, lead, zinc, and gold are being mined in the region, and textile is produced here. Despite the attractiveness of the area for tourists, there are almost none of them here. Notwithstanding the presence of a water source as large as Lake Titicaca, water is not available in the region because of the lack of water supply system.

The environmental problems include soil erosion and salinization of some rivers. The main pollution sources of lakes and streams are mining operations and municipal wastewaters. The major pollutants are organic substances, heavy metals, and pathogens. The availability of treatment facilities is 13 and 20%, and that of electric power supply is 30 and 21% for the Bolivian and Peruvian parts of the basin, respectively. Valuable fish species, such as trout and mackerel, were introduced in the lake in the 1930s, resulting in an inevitable decrease in the populations of native species, in particular, karach and bog.

The Authority of Lake Titicaca. As long ago as 1955, the Presidents of Bolivia and Peru introduced joint use of resources of Lake Titicaca and decided that a bilateral commission should be created for solving the accompanying problems. After long negotiations and reconciliations, the establishment of the Binational Autonomous Authority of Lake Titicaca (ALT) [19, 30, 35] was confirmed by exchange by diplomatic notes between 1992 and 1996.

The Authority started its work in accordance with the Binational Plan for Flood Control and Prevention and Use of Natural Resources in the Drainage Basin. In accordance with this Plan, sluice gates were constructed at Lake Titicaca (costing $7.2 million); the Desaguadero River was dredged in 2000–2005 (almost 4 million m^3 of material was extracted, the project cost was $6.7 million); an agreement with UNEP was concluded regarding the preparation of 12 thematic maps at scale of 1:250 000 for nature protection zoning of the territory with the subsequent development of GIS; an agreement with IAEA was concluded for studying Lake Titicaca pollution, purchase of a ship for sampling in the lake, organization of biological, chemical, and spectrometric laboratories; the construction and commissioning of wastewater treatment facilities, first of all, on the Desaguadero River.

Additionally, in the context of preservation of biodiversity, works will be launched for vegetation protection, reproduction of some local animal species (in particular, giant frogs and endemic fishes) under the conditions of partial captivity, education of the local population, studying the pelagic part of the lake, restoration of the population of local species.

It is worth mentioning that neither the development of the plan, nor the organization of works for its implementation will be possible without the preliminary accumulation of materials on geomorphology, climatology, hydrology, geohydrology, hydrochemistry, soil cover, erosion, natural resources, and topography of the region. Used for this purpose were the results of previous research and survey operations, as well as a meteorological and hydrometric database.

It is necessary to organize the monitoring of the environmental conditions on the lake; the activity favorable for the implementation of ALT objectives; human factor development; natural events and their consequences. Moreover, a system of indicators should be developed, based on the assessment of the state of local organism species, the level of pollution from different sources, and used in the practice.

The Authority involves the local population and representatives of all interested parties in the discussion of plans their implementation. It operates at different levels, interacting with legislators in the congresses of both countries, their governments at the level of the Secretaries of State, local authorities (prefectures, municipalities), and Indian communities and tribes. Again, the Authority encourages the participation of experts from all over the world in the studies in progress and the coverage of such activities in media.

The three interrelated tasks allotted to the Authority included the development of a system of measures

for sustainable development of natural resources; the restoration of the environmental integrity of the system through the protection of endangered species, the restoration of fish populations, the reduction of human impact on the system; the support of population development in the basin.

Some progress along the first two lines can be already observed, while the progress along the third line is too slow because of the difficulties in overcoming the total poverty in the region.

Lake Chad Basin Commission

Lake Chad in the southern Sahara is an interesting water body. A drainless and relatively shallow lake with huge evaporating surface area has remained fresh over a long time (at least, for 10 000 years), and, according to some data, it provides groundwater supply to several nearby oases. Water level in the lake is extremely variable, leading, because of Lake Chad morphometry, to a high variability of lake water area (from 25000 to 1350 km^2 from 1963 to the present time). Lake Chad dried out completely four times between years 1400 and 1910. The lake is located at the junction points of borders of four states (Chad, Cameroon, Niger, and Nigeria).

The population in lake drainage basin has grown very rapidly (from 22 million in 1991 to 37 million in 2004), though its spatial distribution is extremely uneven with population density varying from 1.5 to 37 persons/km^2. The people that live on the shores of Lake Chad are among the poorest on the Earth. In 1995, their per capita income varied from \$190 in Niger to \$660 in Cameroon; while in 2003, it varied from ~200 in Niger to \$630 in Cameroon. The child mortality is high (up to 9% die not reaching one year of age), up to 28% of the population starve; malaria, respiratory infections, yellow fever, and diphtheria are widespread. The literacy rate does not reach 30%.

The population of coastal areas lives on fishery. The catches were found to drop from 130–140 thousand t year^{-1} in the early 1970s to 60–80 thousand t year^{-1} in the late 1970s. The main component of region economy is agriculture, involving 60% of the population. The main crops in the basin are cotton and earthnut; textile, brewery, leather, flour-milling, food, and machine-building industrial branches are present. Moreover, the lake is a deposit of natural soda, whose extraction by the local population contributes largely to the preservation of the freshwater status of the lake.

The Lake Chad Basin Commission (LCBC) [18, 26, 35] was established by a quadripartite agreement on May 22, 1964. The Central African Republic joined the Commission in 1994, and Sudan joined it in 2000, though the entry of the latter has not been ratified. Both countries also possess some areas in Lake Chad drainage basin (as well as Algeria and Libya, which have not shown any intention to enter the Commission). Now the Commission is following the plan of work presented in the 20-year strategic plan developed by 1992 and ratified in 1994. The annual budget of the Commission is now around \$1 million. This budget is formed from the contributions of Nigeria (52%), Cameroon (20%), Chad (11%), Niger (7%), and CAR (4%). Each member country of the Commission has its own national plan.

The Commission will often resolve arising conflicts. Thus, during droughts, when the lake area decreases considerably and water retreats from the shore, the part of population that is dependent on the lake (e.g., fishermen), resettle following the water edge and ignoring the national borders. Two subcommissions had to be formed for the solution of this problem alone. Interethnic conflicts around water use are also common. The focus of such conflicts is often watering-places or water for irrigation. Until now, the Commission has not coped with the regulations of surface water use of Lake Chad and the division of lake watershed between member countries of the Commission.

AN EXAMPLE OF SUCCESSFUL SOLUTION OF WATER RESOURCES PROBLEMS AT INTERNATIONAL LEVEL

Lake Victoria (LVFO Project)

Lake Victoria and the problems of its sustainable use. Lake Victoria, from which the Nile originates, lies in the zone of the Great African Lakes. The lake is inhabited by species that has lived in East African rivers from 2 million years ago to the time of lake formation 10000 years ago. Explosive species formation took place in the young lake, leading, for example, to that in the 1950s, 300 cichlid species existed in different biotopes of the lake.

The lake is divided between Tanzania, Uganda, and Kenya—the countries that own 49, 45, and 6% of lake water area. Up to 600000 t of fish are caught in the lake every year, giving the near-lake countries the annual income from \$590 thousands due to export alone. Two millions out of the 30-million population in the drainage basin live only on fishery, meeting the fish demand of 22 million people. Farming (the cultivation of corn, cotton, tobacco, beans, sugar cane, and coffee, as well as flower production), cattle breeding, forest management, tourism, hydropower engineering, and transport are also developed in the drainage basin and have their effect on the lake ecosystem.

Before the 1960s, Lake Victoria ecosystem was an example of species-rich and well-balanced biocenosis. However, overfishing, the pollution by industrial and agricultural wastewaters, and especially, the intrusion of new species (Nile perch, tilapia, and water hyacinth) have lead to dramatic consequences.

Overall, 200 endemic cichlid species disappeared within 30 years. Nile perch was artificially introduced into the lake in the early 1960s with the aim to increase

the decreasing commercial fish catches and to develop sport fishery. As the result, the endemic cichlids persisted only in closed bights, near rocky shores, and in some bays, i.e., practically, only in reserves. Abundant some time ago, tilapia became a rare species, giving its place to Nile tilapia, which was introduced simultaneously with perch and showed higher competitive ability. Nowadays, the major portion of commercial catches is due to but three species: Nile perch and tilapia and the persisting local sardine.

Nevertheless, the total catches have increased. Before the introduction of Nile fish, they were 250000 t, while now they reach 600000 t. However, the catches now show wide variations, both from one part of the lake to another and from year to year. This change is quite natural and inevitable, since the number of commercial species has dropped significantly. Accordingly, the production of fish processing plants (12 plants in both Kenya and Tanzania and 10 in Uganda) is also unstable.

The water hyacinth (Eichhornia crassipes) entered the lake accidentally in 1988 and rapidly (it can double the area it occupies every five days) spread all over the lake. The thickets they form hamper fishery, navigation, and even electric power generation. Moreover, the water whose surface is covered by this plant becomes practically impotable because of high concentration of organics and hydrogen sulfide. The hyacinth is supposed to shelter insects—carriers of malaria and schistosomiasis. Changes in the trophic structure inevitably affected the rest of the organic world of the lake, i.e., aquatic insects, crustaceans, and plants.

Fishery was practically not regulated in Lake Victoria. Accordingly, fish catches were not held at the level that would ensure stable fishery. To increase their catches, fishermen actively used forbidden fishing methods, such as cast nets, traps, and even fish poisoning. The latter has caused several human deaths due to poisoning and compelled the governments of the three countries to take measures. Sport and commercial fishing in the lake were banned in March 1999; however, this ban was lifted later.

The urban population in the drainage basin increases by 6% every year, while the annual increase in the rural population is 3%. This cannot but affect the environment. Forests in the basin are being steadily cut to get free areas for agriculture, fuel, or construction materials. Forest cutting and poor farm practice cause silting of the tributaries and the lake itself. Again, the growing population increases the demand for fish and stimulates its production.

Industry grows in coastal towns, such as Kampala, Entebbe (Uganda), Mwanza, Bukoba (Tanzania), Kisumu (Kenya). Most industrial plants do not treat their effluents, and municipal wastewaters are practically not treated. Wastewaters from the production of beverages, sugar, beer, butter, other food products, soap, and leather are often directly discharged into the lake.

The agriculture contributes to the problem through intense application of fertilizers and manure, leading to eutrophication. The result is the eutrophication of bottom waters, which are anoxic all year round. Pesticides are washed out from the areas used for cultivation of corn, coffee, cotton, paddy, tea, and tobacco. Moreover, the system of wetlands adjacent to the lake is also disturbed.

Climate changes also have their effect on Lake Victoria. Thus, the upper boundary of the anoxic zone was found to more often rise to the elevation of 10 m and more. This is due to the growing temperature of air and water mass and causes fish kills.

Creation of a structure of lake preservation. Since the lake and its resources are used by three countries, any measures aimed to protect it will have an effect only when supported by all three countries. Since lake protection has become vital, the three countries developing the lake and its drainage area established in 1994 the permanent Lake Victoria Fisheries Organization (LVFO) [15, 16, 20, 24, 25, 34] for long-time protection and restoration of lake biocenoses. The main task of LVFO is the development of cooperation between Uganda, Tanzania, and Kenya in lake development, primarily, the coordination and harmonization of national programs for sustainable use of the biological resources of Lake Victoria, the development and taking of measures for the protection of lake ecosystem and its management. The negotiations between Uganda, Tanzania, and Kenya, which have resulted in the establishment of LVFO, as well as the agreement itself, offered a real opportunity for all three countries to start effective protection of Lake Victoria. Under this agreement, each government undertook to take all necessary measures, including legislative, for the implementation of decisions of the Steering LVFO Committee. Each country agreed to revise the national laws and regulations in fishery and water use in Lake Victoria basin. All three countries decided to take stringent legislative acts to prevent new species from invasion in the lake.

LVFO Secretariat is situated in Jinja (Uganda). It is headed by an executive secretary and includes the principal researcher, principal socioeconomist, and two administrative assistants, one dealing with finances and the other with information and databases. The chief bodies of LVFO are Executive Committee, whose members are directors of research institutions, fishery, and fish-production departments of member countries; Steering Committee, whose members are permanent secretaries of the ministries responsible for commercial fishery; and the Council of Ministers, which are responsible for commercial fishery. The meetings of the supreme body of LVFO—the Council of Ministers—are held once in two years. Additionally, there exist national advisory committees, which embrace the ministries responsible for water

resources environment, agriculture, forestry, and forest industry, natural resources, internal affairs, science and technology, and land use. The private sector, community and nongovernmental organizations also participate in the work of those committees.

Approaches to the Management of Drainage Basin. The primary task of VLFO was to identify all experts, interested parties, organizations dealing with Lake Victoria, and to unite them on the regional level with the aim to get the general picture and develop an action plan. Next, the general strategic plan was developed. LVFO organizes meetings of various interested parties for coordination of their activity. This contributes to the regional consensus in lake-related issues.

Attempts are made to control water hyacinth at the local, national, and regional levels. The expansion of water hyacinth at the regional level is controlled by the Secretariat of East–African Community in Arusha (Tanzania). All three countries support the integral approach to the control of this plant, the approach comprising three stages. At the first stage, the water hyacinth is to be removed manually with the aim to involve local communities in physical removal of the plant; at the second stage, the remaining hyacinth is to be removed mechanically by special mechanisms; at the third stage, snout-beetles (Neochetina bruchi and Neochetina eichhorniae) are introduced, known to reduce the productive capacity of the plant. Such approach has been tested and proved to be efficient in the part of the lake belonging to Uganda.

The introduction of species that are new for the lake was found possible only after a thorough study of the interaction between new species and all components of lake biota. The members of LVFO are very careful as to the use chemical methods of water hyacinth control. The possible consequences of their application in Eastern Africa are still studied in experiments. Whatever decision is made, the member countries realize that the efficiency of measures will be largely dependent on the decrease in the input of nutrients, enhancing the growth of water hyacinth, into the lake.

Fishery committees are established in fishery ports to solve the overfishing problem. Their responsibility includes the inspection of catches in fishing ships and boats before they reach the shore or a pier. All fishermen, as well as fish traders and transporters have been licensed for supplying only safe products to consumers. Homogeneous information is being collected in the three countries simultaneously and following the same scheme. LVFO Executive Committee will hold its meeting at least once a year, and the meetings of its technical personnel are held not rarer than once in three months. Nowadays, the catches are not limited.

LVFO also directs the implementation of projects with external financing. These include The Implementation of Fisheries Management Plan (FMP), financed by EC from 2003 to 2008 with the total fund of 30 million EUR; Socioeconomic Aspects of the Nile Perch Habitation in Lake Victoria, supported by the International Union for Nature Conservation (IUNC) and financed by the North American Aerospace Defense Command (NORAD) from 1996 to 2005; Production and Marketing of Fish Products in Eastern and Southern Africa, financed by the Common Fund for Commodities (CFC) in 2002–2007 and supported by the Common Market for Eastern and Southern Africa (COMESA); Aquaculture, financed by East-African Community (EAC), including Tanzania, Uganda, Kenya, Rwanda, Burundi, USA, and EC since 2002.

LVFO supports and coordinates the training of personnel for the extension of activity in all fields of fishery, fish breeding, and fish-processing industry; it encourages the existing research structures and creates new ones as needed; it supervises the studies of water quality, flora, fauna, and pollution of the lake.

Advances in the protection and restoration of lake ecosystem components. The main achievement of LVFP is the organization of fishery control in such a manner as to reach agreement between the documents regulating it in the partner countries. Nowadays, endemic fish species, such as Labeo victorianus, Bagrus docmak, Protopterus aethiopicus, Schilbe mystus, and Synodontis spp. are being rehabilitated, mostly due to LVFO. The organization is doing its best to strengthen the international scientific cooperation of all experts dealing with the lake.

The rate of fish production is increasing. It amounted to 250 thousand t/year in the 1960s, 400–500 thousand t/year in the 1990s, 620 thousand t in 2000, and now it reaches 800–1000 thousand t/year, of which 75% (mostly the Nile perch) is exported, and tilapia and dagaa (local sardine) are traded in the domestic market. The total reserves of commercial fish in the lake was estimated at 2.1–2.2 Mt of fish.

However, some problems are still to be solved. They are associated with water level change due to the construction of a hydropower plant and the continuing eutrophication. Those problems are gradually solved due to the efforts of the organization.

The development of an integral plan of management of Lake Victoria and its drainage basin is in progress now. For this purpose, a map of natural resources of the lake is being compiled; a bathymetric map of the lake has been compiled (the map used up to now was created in 1901); detailed studies of lake hydrological cycle are in progress; lake water balance is being studied; the distribution of water hyacinth is monitored with the help of remote sensing; laboratories for the analysis of fish quality were created; comprehensive social–ecological–economic models have been developed for the analysis of the consequence of implementation of various management scenarios in lake basin.

ASSESSMENT OF THE EFFICIENCY OF PROJECTS

Only five bodies of international management of freshwater lakes are really functioning now. Even large transboundary lakes are not subject to international regulation, including five in Europe, six in Africa, and one in South America.

One of such bodies—the Fishery Organization of Lake Victoria—works successfully, having reached good results in a short time.

Two other bodies of international management of lake basins in developing countries—Lake Titicaca Autonomous Bilateral Management and Lake Chad Basin Commission (the former is relatively young, while the latter was established more than 40 years ago)—are less successful in their functioning, maybe because of the poverty of the population in their regions.

Unfortunately, both bodies in developed countries have also shown no great success. The International Joint Commission, which was created by rich countries 100 years ago, failed to reveal and prevent either eutrophication or toxication of the Great Lakes and had to take measures (not fully successful by now) to eliminate their consequences. The International Commission for Lake Constance (also established by rich and developed countries) was created when the lake's eutrophication was already developing, but the Commission also allowed this process to go far enough and it has not return the lake to its original condition. It appears that in the two latter cases, the obstacles hampering the successful operation of international bodies where the economic welfare of the coastal countries and the excess of "democracy" for water users who did not agree with limitations on their freedom.

Some lessons can be drawn from the experience of management of transboundary lakes and their basins considered here. Those lessons are the result of analysis of the activity of International Committees on Transboundary Lakes and, partly, the conclusions that have been obtained and published before and generalize the experience in international cooperation accumulated by many organizations. Nevertheless, it is worth mentioning in order to remind them to both people and organizations that make decisions on the management of rational water use.

The management of lakes and their drainage basins should be based on the results of studies (interdisciplinary and international) obtained in cooperation by academic and sectoral, federal and local laboratories. Their results should be published.

Long-term monitoring observations are required, involving, where possible, the institutions of academies of sciences, which exist in different forms in different countries, university research centers, special laboratories, private and public institutions with different subordination (international, governmental, regional, or local).

The sustainable and rational lake use cannot be organized without cooperation of all participants of nature use in the area, either organized in some institutions or individual.

Local specifics should be taken into account, and the chief local authorities, heads of clans, voodoos, etc. should be involved in nature protection activity.

Any management activity should be based on the assumption that the lake and its drainage basin form an integral ecosystem.

Preventive long-time safety measures are always more efficient and reliable and less expensive than the elimination of the consequences of pollution, eutrophication, infection, or new species invasion.

It is also better to prevent conflicts between individual water users and types of water use than resolve them. In the resolution of conflicts, preference should be given to the side that closer adheres to the ideology and practice of sustainable development.

The results of studies of lakes and the management of lakes and their basins should be popularized, and environmental education should be introduced for the local population, starting from childhood.

CONCLUSIONS

Out of the five international organizations working in the management of transboundary lakes, only the Fishery Organization of Lake Victoria successfully solves the problems it faces. Analysis of the operation of those organizations suggests that the successful management of lakes should be based on the results of studying the lake and its basin as a single ecosystem, monitoring observations, the interaction between all participants of nature use in lake basin, local features, the development of preventive measures for lake protection and prevention of conflicts between water users, the popularization of the results of studies and management.

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SPELL: 1. Ecol, 2. morph, 3. karach, 4. dagaa