USING HYDROMETEOROLOGICAL SCIENCE BY DECISION - MAKERS OF WATER-DEPENDED SECTORS OF THE ECONOMY SHOULD BE ENHANCED: A CASE STUDY OF UKRAINE

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Abstracts. The paper is devoted to the present state, problematic issues and possible ways of their solution in using hydrometeorological sciences (meteorology, climatology, hydrology) in activities of Ukraine's water-depended sectors, including water management, agriculture, energy production, environment protection, emergencies. The author sees the solution of problems in: a) developing social trend in hydrometeorological sciences, which will integrate the Earth sciences knowledge, and social and economic sciences; b) improving the knowledge of needs of water-depended sectors among scientists and skills of using the scientific results by consumers.

Problem identification

The water-related problems belong to the most urgent economic and social challenges of Ukraine. Almost all industrial production in Ukraine, as well as more than 90% of its urban population, is supplied with fresh waters from rivers. A scarcity of fresh surface waters, declining surface waters quality are the typical phenomena for many Ukrainian regions, especially, located in the southern and south-eastern parts of the country.

On the other hand, extreme rainfalls, river floods and related inundations are very serious natural hazards for many regions, especially for those located in the Carpathians Mountains. That is why water quantity and quality have become the hindering factor of sustainable development of the Ukrainian society.

Resolving of these problems largely depends on improving the basics of efficient, environmentally sound use, reproduction and protection of water resources. In order to prevent a deterioration of the quantity and quality of water resources and to provide the integrated water resource management, it is necessary to use the results of researches in various sciences. Presently, there is a growing consensus that knowledge and capacity in the water management sector is a primary condition for sustainable development and management of water services, declared among the main targets of the Sustainable Development Goals. It is obviously that Earth sciences play a vital role in devising the solutions that are necessary to overcome the water-related problems.

The aim of this article is to present the current status and problematic issues in using hydrometeorological sciences (meteorology, climatology and hydrology) in resolving water-related problems of water-depended sectors of the Ukrainian economy.

Methodology

The study is based on:

- the long-term experience of author's work as the Deputy Director of the State Hydrometeorological Service of Ukraine and a Senior Researcher of the Ukrainian Hydrometeorological Institute;
- the results of study "The role of the hydrometeorological sciences and education in the sustainable development of the Ukrainian society". The study was carried out by the Ukrainian Hydrometeorological Institute and the Institute of Demography and Social Studies of the National Academy of Sciences. The author was nominated as the responsible person for a coordination of these researches.

In addition, the materials of Arthur M. Sackler Colloquium "The role of science in solving the earth's emerging water problems" (October 8-10, 2004, the Beckman Center, Irvine, CA, USA) and a number of IAHS publications gave author the invaluable help in shaping the conceptual frameworks, the conclusions and recommendations presented in the article.

Water Resources and Water Problems of Ukraine

General information

The potential resources of river waters of Ukraine are about 210 km^3, of which only about 25% are formed in Ukraine while the rest come from neibouring countries - Russia, Belarus and the Danube river basin countries. The average annual runoff of these main river basins is shown in the Table 1.

Table 1. Average annual runoff of main river basins of Ukraine

River basins	Average annual runoff, km^3		
	Total	Formed within the territory of Ukraine	Inflow from other countries
Western Bug	1.4	1.4	
Danube	133.8	10.8	123.0
Dnister	10.7	9.7	1.0
Southern Bug	3.2	3.2	
Dnipro	53.5	19.1	34.4
Siversky Donets	4.81	2.96	1.85
Black and Azov river basins	1.82	1.82	
Total	209.23	48.98	160.25

Water resources are not equally distributed throughout Ukraine. More than a half of potential water resources are concentrated in the Danube river basin, where water demand does not exceed 5%. Sufficient resources are also found in the north and the north-west of the country, while the south is poorly endowed. Ukraine can be

referred to the countries with insufficient water supply (1,6 km^3 of water in a year per inhabitant). According to this index, Ukraine occupies one of the last positions in Europe.

The water resource distribution in the territory of Ukraine is irregular and does not correspond to requirements of industries and agriculture which are the most important water consumers in Ukraine. The eastern and southern regions of the country, having the highest concentration of industries and agriculture, are impacted by a deficit of fresh surface water.

The total water withdrawal for population and economy for last years is about 15 km^3 per year (for industry needs - about 49%; for agriculture needs – about 26%; for domestic water supply – about 23%; for other needs - about 2%).

The ecological status of the surface water is also a serious concern. About 8.0 km^3 of sewage waters came into the surface waters of Ukraine. A large volume of pollutants (soil products, sulphates, chlorides, organic matter, pesticides, heavy metals and others) have been thrown down into the water objects together with a sewage waters. Municipal economy, ferrous and non-ferrous metallurgy, heavy engineering and agriculture are the most serious factors of pollution.

A significant damage to Ukraine's population and economy are caused by water disasters. The river floods of different origin and related inundations are common for rivers in Ukraine. The inundations are among the most frequent hazards in Ukraine. The spring floods are the most characteristic phase of the hydrological regime of plain rivers. The snow-rainfall floods occur on the Carpathians mountain rivers during the winter-spring period. The rain floods are typical hydrological events for Carpathian mountain's rivers from April to October.

About one-third of the Ukraine's population is affected by floods. The frequency and intensity of floods as well as the magnitude of damage caused have increased in many regions of Ukraine during the past decades. Tthe mean annual losses from water disasters in Ukraine are estimated at 700 - 800 mln USD. The researches have shown the global and regional climate changes are the principal reason of this. The studies also show that there is a significant chance of strengthening the risks of disastrous floods in the next 20-30 years. Due to this reason, surface waters can be regarded as a restricting factor for the economic and social development in the most regions of Ukraine.

Present state of water management

The Water Code of Ukraine provides the basic framework for Ukraine's water legislation. It specifies the ownership of surface waters and groundwaters and regulates the management, conservation and use of the water resources. Furthemore, the Water Code regulates the competencies of the central and local bodies with executive power for management, control of use and renewal of water resources.

At the same time, an ever-expanding framework of regulations and other normative acts exist, which actually perform the legislative functions. This framework includes

among others the normative requirements on water quality for water supply and industrial use, limit values for concentration of pollutants in natural water bodies and the regulation of standards for maximum permissible discharge of pollutants and a list of relevant pollutants. It includes also the regulation for the state water monitoring system..

Special authorities of the state executive power in water resources management are: the Ministry of Environment and Natural Resources, the State Agency of Water Resources, the State Service of Emergencies, the Ministry of Infrastructure, the Ministry of Energy and Coal Industry, the Ministry of Public Health.

The Hydrometeorological Service, which is subordinated by the State Service of Emergencies, operates the most extensive network of surface water-quantity and water-quality monitoring. The Hydrometeorological Service is also responsible for meteorological (including air pollution) observation, weather and hydrological regime forecasting. The Hydrometeorological Service provides stakeholders of the water sector with current meteorological and hydrological information, as well as hydrometeorological forecasts and warnings. These information, forecasts and warnings are very significant for water sector stakeholders because they help them to plan their work.

Water problems

The water management problems reflect general economic and social problems of Ukraine. They are as following: 1) the erroneous technocratic concept of the national economy development, resulting in environmental and economical crisis and social tensions; 2) scarcity of the budget funds for providing sustainable water resources management and water protection; the water management is based on extensive water use; 3) separate planning and management of social, ecological and economical aspects of water management, restraining its economical tools realization; 4) in some cases, duplication of activities of several institutions involved in water management; 5) sector-oriented networks and information systems on water quantity and quality observation are not suitable to meet the complex information requirements for integrated water resources management; 6) a large number of water-quality standards, norms, water use instructions and regulations; 7) low level of public participation in the water-related activity.

Scientific Background of Water Sector Operating in the Field of Hydrometeorology

General background

The Ukrainian Hydrometeorological Institute is the principal scientific organization in the structure of the Hydrometeorological Service in Ukraine, which carry out the complex researches in the areas of meteorology, climatology, hydrology, air and water pollution monitoring. The fields of the Institute's research activities include:

- study of: a) patterns of physical processes in the atmosphere, hydrosphere; b) hydrometeorological regime and agro-climatic conditions, including hazardous for economic activities and population;

- developing methods and technologies of hydrometeorological observations and forecasting, including, technologies of warning of dangerous hydrometeorological phenomena;
- study of climate of Ukraine and factors of its variation; developing climatic projections as well as recommendations for adaptations to climate change;
- developing instruments, equipment and software for hydrometeorological observations.

The main consumers of the research 'products' of the Ukrainian Hydrometeorological Institute are the State Hydrometeorological Service, the governmental authorities, enterprises and companies from water-depended sectors of the national economy, first of all, from the Water Management, Agriculture, Energy Production, Environment Protection, Emergencies Protection.

The main forms of presenting the research results are: the research reports on topics made to order by customers; the publications in the scientific books, journals, including, the electronic resources as well as the consultations of decision-makers by leading scientists of the Institute.

In this article we understand the definition "Using the hydrometeorological sciences…" as using any scientific information and technology (results of researches, new technologies, publications, recommendations, consultations) in the area of hydrometeorology in the activity of water-depended sectors.

In the mentioned study "The role of the hydrometeorological science and education in sustainable development of the Ukrainian society", the level of using of hydrometeorological science was estimated through analysis of:

- using results of researches and recommendations of the hydrometeorological science in the strategic documents (plans, programs) of development of water-depended sectors which have been adopted for the last 20 years. The official information and reports from the water-dependent sectors were used for this purpose.
- results of the special survey of persons from central and local branches of water-depended sectors (Water Management, Energy Production, Environment Protection, Agriculture, Emergencies Protection). The responses from 157 respondents were summarized.

Using the results of researches and recommendations of hydrometeorological science in the strategic documents of water-depended sectors

More than 70 documents (strategies, plans and programs) adopted by the authorities of water-depended sectors at the national and regional levels were considered. Depending on the period of implementation, these documents were divided in three groups: short-term (up to one year), medium-term (from one year to three years) and long - term (more than three years). The following results were revealed.

Water Management Sector. 23 strategic documents (9 short-term, 6 medium-term and 8 long-term) were adopted in this sector. These documents contained the measures of: a) protecting and restoring water resources; b) guaranteed supply of population, industry and agriculture with fresh waters; c) protection from water

hazards (floods and draughts); d) developing of the integrated water resources management.

Practically, in all short–term and in most of medium-term documents the following results of researches were taken into account: a) assessing the present status of quantity and quality of water resources of Ukrainian; b) assessing the impact of economic activities on the hydrological regime of rivers.

But, the results of these researches were not included in any long - term document. The recommendations of the Ukrainian Hydrometeorological Institute about the impact of climate change on water resources were also not taken into account in all groups of documents

Agriculture Sector. 16 documents (10 medium-term and 6 long-term ones) were considered. The documents were devoted to the issues of irrigation and protection of agricultural land from floods and droughts.

Data about the present water resources which are available for agricultural needs can be found in 4 medium-term and 3 long-term documents. However, a number of important recommendations of hydrometeorological science were not included in these documents, for example, the need to consider the issues of: a) quality of water resources before and after their use for agriculture needs; b) increased risks of floods and droughts for agriculture due to the expected climate change.

Energy Production Sector. The Energy Strategy of Ukraine till 2030 adopted by the Ukrainian Government and 4 medium – term documents adopted by the Ministry of Energy and Coal Industry were analyzed. According to these documents the power production in Ukraine should increase up to 387.5 billion kWh by 2030. It will cause a significant increase in the water intake.

In general, the issues of technological development in the Energy Sector were considered in these documents. The recommendations of hydrometeorological sciences on the Energy Sector supply with water resources, practically, were not considered.

Environment Protection Sector. 11 medium – term and 8 long-term documents in the area of policy adaptation to the climate change and protection of surface waters from the exhaustion and pollution were considered. The most of these documents contain information about climate characteristics, air and water pollution parameters, which are measured on observation networks of the Hydrometeorological Service.

Unfortunately, in order to estimate the expected climate changes in Ukraine, the authors of documents took into account mainly the results of IPCC reports, but they did not use the results of researches of the Ukrainian Hydrometeorological Institute. During last 15 years the scientists from the Institute have elaborated the projections of regional climate change till 2030 and 2050. Besides, assessing the impact of climate change on the hydrological regime and water resources of the Ukrainian rivers was also carried out.

Emergencies Protection Sector. 6 medium – term and 3 long-term documents adopted by the State Service for Emergencies were considered. These documents regulate the issues of protection of population and territories from the technogenic and natural hazards, including, from hydrometeorological disasters.

In our opinion, the authors of these documents took into account the hydrometeorological science significantly. Planning and implementing two major stages of reduction of hydrometeorological disasters (pre-disaster and past-disaster-activities) in these documents is based on recommendations of hydrometeorological sciences. But, it is desirable to reflect the latest results of researches on the expected increase in the risk of extreme weather-related events in Ukraine in the next 15-25 years in new versions of these documents.

Results of a special survey of respondents from water-depended sectors

The following questions were prepared for respondents of this survey:

1) Which is your level of decision-making? Three variants of decision-making levels were identified: high - for heads of departments/divisions and above; medium - for heads of task groups and for leading experts; low - for engineers with university education.
2) How do you evaluate the level of your knowledge in areas of meteorology, climatology and hydrology? Two variants of answers were proposed: sufficiently; insufficiently.
3) To what extent directions and level of researches of the Ukrainian Hydrometeorological Institute meet the needs of your sector?
4) How do you evaluate the types of communication used by the Ukrainian Hydrometeorological Institute to provide users with the results of researches?
5) How do you evaluate the level of using hydrometeorological sciences in your sectors?
6) How do you evaluate the level of partnership between your sector and the Ukrainian Hydrometeorological Institute?

Three possible answers to questions from #3 to #6 were proposed: “fully satisfied”, “partly satisfied”, “unsatisfied". Besides, the participants of survey were asked to give their additional comments and suggestions to every question.

Obtained survey’s results

Question 1. As it has been noted, 157 respondents from water-depended sectors were interviewed: 36 persons from Water Management, 28 - from Agriculture, 27 - from Energy Production, 31 - from Environment Protection, 35 - from Emergencies Protection. The following distribution of respondents by decision-making levels was observed (Table 2).

Table 2. Distribution of the survey respondents by decision-making levels

Sectors	Distribution of decision-making level, number of persons		
	high	medium	low
Water Management	12	15	9

Agriculture	8	13	7
Energy Production	9	12	6
Environment Protection	11	12	8
Emergencies Protection	13	14	8
Total	53	66	38

As we can see, the number of people with a high level of decision-making varies from 28% in Agriculture Sector to 37% in Emergencies Protection Sector; the number of people with a medium level - from 40% in Emergencies Protection Sector to 46% in Agriculture Sector, the number of people with a low level of decision-making does not exceed 23% -26% in all sectors.

Question 2. Data about persons from water-depended sectors, who have "sufficient" knowledge in meteorological, climatological and hydrological sciences are presented in Table 3.

Table 3. Level of knowledge in areas of meteorology, climatology and hydrology among the survey respondents

Sectors	Number of people from different levels of decision-making with “sufficient” level of knowledge		
	high	medium	low
Water Management	6	11	3
Agriculture	3	7	3
Energy Production	2	5	3
Environment Protection	5	5	4
Emergencies Protection	3	8	3
Total	19	31	16

Data show that the largest number of people with "sufficient" level of knowledge was observed in Water Management Sector (56%), the lowest level - in Energy Production Sector (37%). In other sectors, this number varies from 40% to 47%. However, only a small number of people have the diplomas of higher education in the field of hydrometeorology. Most of them gained the knowledge, while they were studying other specialties - the hydraulic engineering, the agriculture and ecological sciences.

Question 3. All participants of the survey provided “partly satisfied” response.
The representatives from the water-depended sectors gave their suggestions to expand the directions of researches. The participants from the Water Management, the Energy Production and the Emergencies Protection sectors think that hydrometeorological sciences should pay more attention to elaborating the methods of forecasting of the extreme river floods with lead time of three and more months. According to the opinion of representatives from Agriculture Sector, the hydrometeorological sciences pay insufficient attention to a study of influence of hydrometeorological factors on the properties of soils and erosion processes in the catchments. The representatives from Environment Protection Sector would like hydrometeorological sciences to pay more attention to a study of impact of the expected climate change on ecological status of surface waters.

Question 4. Only representatives from Emergencies Protection Sector responded "fully satisfied". It can be explained by the fact that the Ukrainian Hydrometeorological Institute is subordinated to the State Service for Emergencies. The answers "partly satisfied" were obtained from the representatives of other sectors. The participants from these sectors provided very similar propositions - the Institute should improve the level of presenting results of researches. They submitted the following proposals: wider use of the Internet technologies, including, 'the Internet of things'; b) create the web-page dedicated to the issue of impact of weather, climate and water resources on the social and economic development; c) organize the annual scientific conferences with international participation devoted to the specific problems of hydrometeorological sciences; d) organize the regular roundtables, seminars for representatives of weather - and water-depended sectors.

Question 5. The answer "fully satisfied" was provided by respondents from Water Management, Environment Protection and Emergencies Protection sectors. But, they made it clear that they take into consideration only the existing results of researches.

The representatives from Agriculture Sector estimated the level of using the results of researches as "unsatisfied". In their opinion, the economic and social problems in the sector of agriculture make it impossible to implement the recommendations of hydrometeorological sciences.

The answers "partly satisfied" were obtained from respondents of Energy Production Sector. But, there was no any comment or suggestion from this sector.

Question 6. The survey participants from Water Management, Emergencies Protection and Environment Protection sectors provided answers "fully satisfied". Indeed, the Institute has a long and fruitful collaboration with authorities and organizations from these sectors. However, representatives of these sectors believe that the leading scientists from the Institute should be more involved into work of advisory bodies of the Ministry of Environment Protection, the State Service of Emergencies and the State Agency of Water Resources.

The representatives from Agriculture Sector provided answers "partly satisfied". They proposed to improve the cooperation between the Agriculture Sector and the Institute, the Ministry of Agriculture and the enterprises from the Agriculture Sector.

The answer "unsatisfied" was received from representatives of Energy Production Sector. They see the reason of this in the insufficient knowledge of Institute's researches by the top managers of enterprises from this sector. This comment was unexpected for author because the Energy Production Sector is one of major users of products and services of the Hydrometeorological Service of Ukraine: the current information, forecasts and warnings.

Discussion of results

The researches have shown that there are a number of shortcomings in the issues of using the researches of hydrometeorological sciences in the water-depended sectors

These issues can be divided (somewhat arbitrarily) into two groups. The first group of issues reflects the present level of researches in Ukraine as well as the possibilities of hydrometeorological sciences in general. The second group of issues mostly concern to the knowledge and correct using “products” of hydrometeorological sciences in order to obtain a benefits from them.

The first group of issues. Practically, all water-depended sectors use the results of researches in the areas of meteorology, climatology and hydrology in their activities. This is done directly through the use of research results of the Ukrainian Hydrometeorological Institute, or indirectly, by using products and services of the Hydrometeorological Service of Ukraine. It is expected that the needs in such researches will increase in the future.

In some cases, the consumers complain that researches and recommendations of hydrometeorological scinces don't take into account the specificity of their activities in full. Sometimes, their wishes don't consider possibilities of hydrometeorological sciences. For instance, consumers from Energy Production Sector wish to get the forecasts of mean monthly temperatures for a cold period of a year (from October to March) yet in September. Consumers from the sectors of Energy Production, Water Management and Emergencies Protection would like to receive the forecasts of expected characteristics of the spring flow on all Ukrainian rivers at the beginning of winter.

At the same time, the present level of hydrometeorological sciences does not meet the new challenges in the areas of water resources management. For decades, the study of river flow and water resources mostly under the impact of hydrometeorological factors and processes has dominated in the hydrological science. No doubt, consideration of hydrological processes and meteorological factors is extremely important to plan and govern the water policy. But, the growing importance of studying a "feedback" between natural and anthropogenic components in the processes of formation of water resources is becoming increasingly clear for the scientific community. It urges the acceptance of a new concept of development of hydrometeorological sciences to understand the interaction between the natural and human-induced processes with the aim to provide the sustainable use of water resources (Young *et al,* 2015). Hydrometeorological sciences should explore the natural processes within river basins in the close correlation with economic and social activities. In order to decide these tasks, a transformation of hydrometeorological sciences from mostly "natural sciences" into the multi-disciplinary "social-natural sciences" is needed.

The methodological basis of social hydrometeorology is a wide range of methods used in the meteorological, hydrological, ecological, social and economic sciences. Such integration of scientists from the different areas of knowledge will strengthen a position of social hydrometeorology as a multidisciplinary science. Thus, development of social hydrometeorology should be regarded as a priority strategic objective for the Ukrainian hydrometeorological community in the coming years.

In addition, there are some "tactical" issues which need to be addressed in the near future. There is a need in: a) an increase in a level of knowledge of researches on the specific needs of water-depended sectors of economy; b) extend and improve of

presentation of researches by establishing the special scientific journal entitled "Social and hydrometeorological researches" as well as establishing a special unit in the framework of the "Earth Sciences" section of the National Academy of Sciences of Ukraine; c) a use of the modern Internet technologies for presenting the scientific “products”.

The second group of issues. The long-term experience of working with decision-makers from water-depended sectors shows insufficient understanding of the role of hydrometeorological sciences to ensure a sustainable development of these sectors. Thus, the water-depended sectors demonstrate the interest in issues of impact of the climate change. But, these sectors often don't include the results of study and recommendations of hydrometeorological sciences in the strategic documents which determine the development of sectors. Unfortunately, a lot of managers from these sectors are not aware about the results of studies, which have been performed by the Ukrainian Hydrometeorological Institute on this topic over the past 10 years. The increased list of publications on this issue, which are often scientifically unreasonable and sometimes of a conjecture character, makes it is difficult to understand a nature of this problem.

This not only hinders the development of sectors, but also makes it impossible to study the feedback in the "science-to-consumer” system to evaluate the effectiveness of the research results use. That is why, it is very important to strengthen knowledge in the field of hydrometeorology among managers from water-depended sectors to improve the quality of hydrometeorological researches and use their results in practice.

Conclusions and recommendations

The researches of hydrometeorological sciences are extremely valuable for a sustainable development of water-depended sectors of economy. The directions of researches provided by the Ukrainian Hydrometeorological Institute have expanded considerably during the last decade. Despite of it, there is a significant potential and the need in improving the quality of these researches and the benefits from using them in the activity of sectors. Researchers and consumers should understand that the problem of ensuring the high-level studies and efficient use of their results can be successfully solved only through the joint efforts of all stakeholders.

The author has the following recommendations which would facilitate the collaboration between providers and consumers of scientific "products" and, as result, would address the issue of using hydrometeorological sciences in resolving of water problems

The first recommendation is addressed to the scientific community. It is necessary to create and develop a social trend in hydrometeorological sciences, which would integrate the research methods from the Earth sciences as well as from the social and economic sciences.

The second recommendation is to both parties, including scientists and consumers of scientific results. It is necessary to strengthen the capacity-building of participants from both parties to improve the knowledge on the needs of water-depended sectors

in scientific community and the skills of using scientific results by their users through the relevant education and training programs.

In order to "push" these activities, the concept of development of socio-hydrometeorological sciences in Ukraine is being elaborated by the author in a cooperation with a number of experts from the Ukrainian Hydrometeorological Institute and from some the weather – and water-depended sectors. After finishing this work, the document will be submitted to all interested parties for their consideration.

References

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