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Review Article

Indicators of Environmental Sustainability in Water Resources Management

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Abstract

The paper is aimed at the analysis of the environmental sustainability concept as well as features of the performance and progress indicators as an important tool of sustainable water resource management (WRM) in context of sustainability. The research methodology is based on the comparative analysis of the content of the relevant international policy and research information as well as national reports and statistical data (Ukraine case study), published by 2022.

The concept of environmental sustainability (ES) is considered with special attention to the ES indicators in water sector. Analysis of the WRM practices demonstrates that there is no internationally accepted standard indicators' framework applicable for any WRM system, and therefore appropriate sets of indicators are designed and introduced in WRM of different water systems in many countries. For these purposes different models and assumptions were successfully used (e.g., performance model, mission - goals - objectives hierarchy model, DPSIR model, natural, economic and social relationships model, and others). Social and economic indicators in most cases reflect context implicitly while environmental sustainability indicators are mainly indirect by nature.

Detailed consideration of the WRM in Ukraine as a case study resulted in the conclusion that the country concentrates efforts on achieving the reasonable objectives (meeting demand for water of population, industries and other water users; protection of water sources, and water emergencies prevention / mitigation). At the same time, the national WRM policies and programs are still lacking explicit objectives to achieve sustainability and, consequently, relevant indicators. It is expected that raising stakeholders' awareness, strengthening the capacity of managers, and application of the best available practices of elaboration of effective WRM indicators will increase a sustainability of the WRM system in Ukraine and other countries.

INTRODUCTION

Water is a unique natural resource stipulating life in all its forms. In spite of restricted quantity on the Earth, fresh water is permanently cycling in the nature and therefore can be considered as renewable resource. Due to physical water scarcity in many regions of the planet, increasing pollution of water bodies and growing demand on clean water, effective management of water resources (WRM) is becoming an urgent requirement at national, regional and global levels, in particularly in the context of sustainable development [1].

To measure management performance, set of criteria or indicators for assessment of the performance effectiveness and efficiency should be established prior to the implementation of any near-term or strategic initiative in water sector. Such indicators are the key tool for monitoring and evaluation of the performance and results. The practice of setting up and applying systems of indicators in water resources management with a focus on sustainability is essential for sustainable development of societies however still cannot be considered as a typical approach in many countries and, in particular, in Ukraine.

Since Orange Revolution (2005), Ukraine has entered in the period of considerable transformation in economic, politic, social, and environmental sectors with focus on European values and standards. However, in spite of some progress achieved, situation in these sectors demonstrates apparent needs in more deep reforming efforts. Natural resources use, in particularly water resources management, belongs to the sectors requiring broad-scale improvements in order to meet the national and EU regulatory requirements and satisfy the needs of the society.

Preliminary review of national reports on the state of environment and water sector performance (e.g., [2, 3]) shows that most of indicators used are describing dynamic of the process rather than social impact and sustainability of actions undertaken. In general, these indicators can be integrated into some groups such as:

i) water quality indicators (quality of water sources, water supplied to customers, discharged water, etc.);

ii) performance indicators of public water supply and discharge sector;

iii) performance indicators of water use in economic sectors;

iv) progress indicators of implementation of national and local programs in the field of protection and rational use of water resources.

Part of these indicators are included in the state statistic system, others have been developed within the special programs. All sets of indicators are considered primarily in the context of effectiveness and efficiency but much less in the context of environmental sustainability of WRM and are compared with existing indicators used at regional (Europe) and global levels.

As far as water is a key issue of sustainable development of any nation, the paper is aimed at the analysis of the environmental sustainability concept as well as the features of the performance and progress indicators as an important tool of water resource management (WRM) in the context of sustainability. For this reason, the paper discusses as well the context and definition of the notion of *sustainability* in water management. An analysis of available best practices and approaches to the elaboration of effective sustainability indicators will provide an opportunity to use this experience for more sustainable water resources management in the countries and communities, which are still lacking such practices.

The research methodology of this study is based on the comparative analysis of the content of the national statistical data, national reports devoted to the progress achieved in the field of environmental protection and water resources management (Ukraine case study), reporting materials and publications of international organizations and other relevant policy and research publications. Author applies as well to the observations, personal experience and lessons learnt during participation in the implementation and monitoring of numerous environmental projects of national and regional scale in 1999 - 2021.

Taking into account the significant number of publications devoted to the consideration of indicators in the field of water management, the scope of the study is limited to the analysis of only selected cases that are indicative in the context of sustainability. Another limitation of the research concerns the time frame - the article examines research results and data published until 2022, since the Russia's invasion of Ukraine, which began on February 24, 2022, radically changed the priorities and form of natural resource management at least in Ukraine.

Environmental Sustainability

Shaping the Concept of Environmental Sustainability: Environmental sustainability is the most fragile component of sustainable development triangle and is especially important due to the fact that any social and economic improvements have environmental price. This section is to clarify the notion of *environmental sustainability* in order to determine adequate indicators for environmental improvements in WRM.

The concept of Environmental Sustainability (ES) has originated from the basic concept of sustainable development [4] and became mandatory component of the programs, action plans and projects of international technical assistance delivered mainly to developing countries (see, for example, [5]). Requirements of the international financial institutions as well include *inter alia* environmental sustainability integration into project objectives, activities and expected results so that the proposals expecting financial support in the form of grants or loans should be properly designed.

In general, Environmental Sustainability is a property of the developing system that ensures sustaining the ability of the natural environment to endless self-renewal and reproduction. Prerequisite of ES is a responsible interaction of human communities and societies with the environment aimed at avoiding the depletion and/or degradation of natural resources and allowing for long term environmental quality. In the case of non-renewable resources, their depletion is inevitable, therefore sustainability of socio-ecosystem will be ensured by solution to replace the process or these resources by other ones generating similar effect. Natural environment is considered as a living space and a primary source of resources for economic activities aimed at meeting social demands of human communities and societies. Therefore, environmental component is considered as an integral part of long-term development and, therefore, is a critical factor for achieving integral sustainability. In addition, current national or international environmental policies, legislation and regulation restrict the scope and scale of some kinds of economic activities on the one hand, and, on another hand, promote environmental initiatives, which create opportunities for economic growth and social development.

In fact, there are two basic environmental objectives in all sectors of human activities namely i) preventing harmful impact (pollution and/or deterioration) on the natural environment and ii) improving environmental quality as a precondition of healthy life. Planning activities use to envisage formulation of these objectives either in explicit or implicit form. In the opposite case depleting natural capital will pose constraints on human development, increase costs encountered due to environmental degradation and multiply potential environmental and health risks.

Striving to sustainability of water environment, we have to describe the model of water ecosystem with stable level of quality and quantity of water, capable to reproduce water taken off for human needs and resistant to the pollution and other harmful impact of human activity. Clear definition of sustainability is helping to create strategic vision in the planning process in water sector. There are a lot of such definitions.

Schnoor J defines Water sustainability as "supplying or being supplied with water for life or, perhaps more precisely, as the continual supply of clean water for human uses and for other living things" [6].

Elaborators of the California Water Plan [7, 8] have adopted the following definition: *"Water sustainability is the dynamic state of water use and supply that meets today's needs without compromising the long-term capacity of the natural and human aspects of the water system to meet the needs of future generations"*. Appropriateness of this definition was confirmed by the practice of California Water Plan development and implementation [9]. However, it does not restrict other vision and approaches to understanding the water sustainability concept.

Environmental Sustainability Principles: The core principles, which guide the application of ES issues in practical

activities, are based on the provisions of an international agreements, national environmental policy and legislation, as well as on the environmental policies of institutions, which are planning and implementing operation and development programs. These principles include but are not restricted to the following [10]:

- Planning activities and procedures are developed in a way to assess potential environmental and health risks, prevent negative environmental impact and comply with national and international environmental regulations and policies;
- Environmental considerations are integrated into the operational and strategic objectives and implementation plan;
- Environmental sustainability matters of development initiatives are subject of public information, participation in decision making and contributing to the process at all levels of initiative development, approval and implementation;
- Environmental considerations are integrated in the development initiatives through their harmonization with environmental capacity, social needs and economic priorities.

In the process of the initiative design and implementation, ES principles have been addressed through a number of different approaches and instruments.

Key Approaches for the Integration of Environmental Sustainability into Practice: Following approval of any strategic document, projects design and management (PDM) become indispensable and important instrument of the strategy implementation. The crucial issue at the stage of strategic planning and PDM is that environmental sustainability considerations should be properly integrated into strategies' / projects' objectives, activities and expected results [10]. Key approaches to integration of ES into the initiative design depend on the sector of activity and a variety of factors streaming from the social, cultural, economic and environmental spheres. An environmental component is vitally important for the initiatives that envisage physical works however it may be negligible or completely excluded from the operations having no direct relations to the natural environment. Therefore, integration instruments may have universal applications and may be specific with very narrow area of applicability. In particular in Ukraine, ES is considered as a cross-cutting theme of development initiatives at local, regional and national level, and developers apply most often the following instruments and approaches of ES integration [11]:

- *Capacity building and raising public environmental awareness* is universal approach in the practice of initiatives implementation and can be applicable within the framework of any project. Transferring appropriate knowledge and skills to target groups helps them to understand how environmentally sustainable practices may improve their short-term and long-term social and economic sustainability, reduce or mitigate production risks, improve their access to environmentally friendly goods and services and thus improve their wellbeing.
- *Ensuring compliance with national legal and regulatory framework* is a mandatory approach to most activities and first of all for those generating possible impact on the environment. In such cases Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA) tools are becoming mandatory instrument and its applicability criteria are being envisaged by legal framework.
- *Promoting application of the best environmentally sound techniques and practices* in a profitable manner is a popular approach in the sectors utilizing natural resources and/or generating impact on the natural environment and human health. This particularly relates to agriculture, water resources management, energy, construction, communal housing, transport and some others sectors.
- *Formulation of specific environmental objectives and setting up environmental targets*. These instruments belong to visible and understandable tools to include environmental considerations into territorial and sectoral planning initiatives. Water sources protection measures as an example of environmental objectives and decrease of water consumption per unit of GDP (or GRP) as an example of environmental targets are typical components of many local, regional and national strategies and programs in Ukraine (see, for example, [12]).
- *Creating demand for environmental products and services*. The market has created extensive demand for pure water and water purification technologies and devices for commercial and home use. In early 1990s, bottled drinking water as a product and drinking water supply as a service were introduced in Ukrainian market. Since that time, drinking water supply transformed into huge business sector creating jobs, providing healthy products for population and increasing income to budget.

Practice of sustainable development recognizes high interdependence of the physical, biological and social surroundings at the global and local scales and creates new opportunities for elaboration and application of other kinds of instruments aiming to sustain environment as prerequisite of sustaining the quality of human life. These management instruments are becoming very important because of, regretfully, the costs, encountered due to environmental deterioration, are increasing and natural capital is steadily depleting. Increased environmental risks are posing constraints on human development. Reactive or proactive actions in respond to these tendencies require development and application of the measuring tools.

Measuring Performance and Progress in WRM

As for now, many systems and complexes of meaningful indicators tracking progress of implementation of development initiatives have been elaborated and applied. The history of this practice is going back to the UN Conference on Environment and Development (Rio, 1992). In the field of water resources, key principles of WR planning and management were established

at the UN Conference on Water and Environment, Dublin, 1992 [13]. These principles were reflected in the decisions of the UNCED and following sustainable development (SD) forums of global and regional scale (in particular, Rio + 20 forum). The UNCED has elaborated sustainable development goals [14] and, as a consequence, necessary systems of corresponding indicators of performance and effectiveness to track progress in the implementation of global, regional and national initiatives. WRM is one of the target sectors for these initiatives. Currently, the water sector managers use general approaches to the development of progress indicators, as well as apply special indicators that are used exclusively in the water resources management. For these purposes there are a significant number of applied researches, methodological recommendations and guidelines (see, for examples [9, 15 - 21]).

WRM Performance Indicators: Indicators are recognized as a mandatory tool to measure changes in order to make any process or phenomenon manageable [15, 19, 22]. Indicators are selected quantitative or qualitative parameters of the process or system (ecological, social, economic, technical, etc.) in order to make possible monitoring of changes in the process or system over time. In reality, indicators are used mainly by managers and decision-makers. Some of them are simple parameters of the system or process, other ones are designed in the form of composite indices to assess state of country in terms of approved development goals. As an example of such indices, Water Poverty Index (WPI) represents "an integrated assessment of water stress and scarcity, linking physical estimates of water availability with socioeconomic variables that reflect poverty" [23]. Application of the indicators depends on the scale of area and objectives of monitoring and can be very specific. In particular, Water Productivity Indicator applies to the benefits generating sectors and is not applicable for the monitoring of the state of water environment. Water Productivity Index is regularly published by Eurostat

Principles and requirements, which indicators have to fulfill, are developed and applied in the projects and operational activities for quite a long time [16]. However, requirements to the ideal indicator (e.g., be representative, scientifically valid, simple and easy to interpret, show trends over time, sensitive to changes, capable of being updated, etc. [16]) are not applicable to all indicators. There is no simple set of WRM indicators accepted for monitoring and evaluation of water sector in different countries / regions and at different levels. The reasons of this state of art is complication of the system to be managed [17]. WRM applies in many sectors with different objectives, legislation and regulation - communal water supply, agriculture, energy including hydroelectric, manufacturing and extraction industries, ecosystems, flood control, etc. There are also many factors at national and global levels causing changes in WRM, which are not always considered. In particular, changes in WRM sector may represent indirect consequences of the reforms introduced in other sectors. Therefore, monitoring in WRM requires reasonable representation of different indicators.

In general, authors [17] proposed an assessment of the management performance of the targeted sector in three dimensions and considered "context" of the resource management in respect to the "function" of management measures in the framework of the prevailing "governance" approach. In this model, Context Indicators relate to the nature (e.g., water sources availability, rainfall), to infrastructure (e.g., water supply and discharge system, water treatment capacity) and to human and economic capital. Functional Indicators relates to inputs, outputs and outcomes (e.g., water abstraction, water depletion, wastewater treated, etc.) and demonstrate real water situation in the country. The Water Poverty Index, interconnecting poverty, water availability and access, social deprivation, human health and environmental integrity, is an example of Functional Indicators. Both Context and Functional Indicators relate to resource management issues, in other words, they are referring to activities aimed to achieve determined objectives. Governance Indicators show difference and reasons of such difference in the performance as a result of intervention of new policies and programs as well as regulation enforcement. Governance refers to external factors and forces influencing management process. A governance is considered as "…the web of policies, institutional arrangement and management instruments mobilized by the actors making decisions impacting the functioning of the production system on a territory" [17].

One more group of indicators have been proposed as a response on WRM practice. Integrated Performance Indicators (PI) synthesize Context, Functional and Governance Indicators and serve as a tool of evaluation of the function. Performance Indicators characterize general effectiveness or cost effectiveness of undertaken efforts – activities, policies, regulation, investments, innovations, etc. PI provide approach to measure volume of water and other resources utilized for generating goods and services. Water Productivity (WP) as an example of PI is performance metric, which is defined as a ratio of economic output (net benefits) from water use and volume of water utilized for generating this output. WP was calculated for major river basins [24].

Water Sustainability Indicators: Elaboration of the sets of performance and progress indicators applicable for WRM in different river basins is specific and exercised different water resource models and approaches. In most cases, indicator packages were developed as a part of pilot projects aimed at improvement of water resource management in different countries.

Remarkable experience in establishing the WRM indicators refers to the Sustainable Water Resources Roundtable (SWRR). This multi-stakeholder's initiative was launched to support the White House Council on Environmental Quality (USA) in developing comprehensive set of national environmental indicators [25, 26]. Based on the virtual model of the relationships among three major systems (natural, social and economic) encompassed by the concept of sustainability, SWRR has established five criteria for identifying and selecting appropriate indicators. An application of the proposed criteria helped to identify four major categories, which encompass indicators and sub-indicators, namely:

A. System capacities, quality and allocation (6 core indicators);

B. Consequences of water capacity allocation (4 core indicators);

C. Effect on people of the conditions and water resources uses (1 core indicator);

D. Underlying processes and driving forces (4 core indicators).

SWRR has proposed one more category E integrating some of indicators from described four categories - Composite Sustainability Assessment. This set comprises 2 indicators: Water use sustainability (ratio of water withdrawn to renewable supply in watershed) and Water quality sustainability (suitability of water quality for the uses desired, including ecosystem uses, in watershed). Gross Water Availability (amount of renewable water supply in the natural system) is recognized as Indicator #1 because "it is the foundation for understanding the quantities of water that are available for human and ecosystem uses" [25].

One more output of the SWRR, which is important for researchers, practitioners and decision makers, is the Matrix of Candidate SWRR Criteria and Indicators comprising 386 (!) social, economic and environmental indicators. SWRR reports are useful guidelines for elaboration of effective sets of WRM indicators applicable for regions, countries, river basins, and other territories as needed.

Developers of the California Water Plan Elaborated Indicators Framework based on the concept of Water Sustainability (see section 1.1) [7, 8]. The Framework is based on the structure of a vision-goals-objectives-indicators hierarchy and comprise 80 indicators of 5 categories (Water Supply Reliability, Water Quality, Ecosystem Health, Adaptive and Sustainable Management, and Social Benefit and Equity) [8]. Introduced Water Sustainability Indicators comprise parameters reflecting the state of water system and relationship to ecological, social, and economic systems. The indicators were applied in pilot studies to monitor progress towards sustainable water management in California.

Other examples relate to comprehensive experience in developing systems of indicators effective in WRM, which were undertaken in Europe and other regions. Mainly indicator systems were developed within the framework of pilot projects at the national and regional levels. For these purposes, the experience of previous initiatives and methodological recommendations of development agencies can be used. It looks reasonable designing the WRM indicators system on the base of the referential analytical framework adopted by the European Environmental Agency and used for monitoring and evaluation of the human – environment interactions in the form of Drivers – Pressure – State – Impact - Response (DPSIR) model [18].

Mediterranean Dialogue on Framing Sustainability in Water Policy Evaluation Project (SWAP), funded by EC, produced an indicator matrix for application in the Mediterranean countries [16]. The matrix is comprising different topics, key objectives within this topics and related indicators. The matrix structure includes 10 topics (Environmental, Economic, Social, Governance, Social-Environmental, Environmental Governance, Social-Economic, Social-Governance, Governance-Economic, Environmental-Economic) and reflects the state of environment, economy, health, quality of life, social cohesion in context of sustainable development. SWAP indicators set has been applied in the field of WRM in the Mediterranean Region.

Brief overview of the outputs of selected targeted efforts to establish frameworks of WRM indicators for different regions of the world demonstrates sufficient progress achieved. However, not all countries are equally advanced in this area. The following section describes the situation with WRM in Ukraine and focuses attention on the indicators of the performance and progress in WRM.

Water Resources Management in Ukraine

Resource factor is vitally important for the countries lacking, in particular, water resources. Water is one of the basic components of human survival and, therefore, effective water management is one of the key factors sustaining human well-being. One of the WRM objectives is ensuring environmental sustainability that is important for all countries independently on availability of natural resources. These circumstances are crucial for the quality of life and stipulate features of current situation in Ukraine.

Water Resources in Ukraine: Brief Outline: Water resources in Ukraine are limited in many regions of the country and very fragile and sensitive to natural and anthropogenic hazards. Despite quite large number of water bodies, distribution of surface and underground waters is very uneven over seasons and territory. Internal renewable water resources are approximately 1 m^3 per capita in Ukraine, almost nine time less than average amount in Europe [18, 27]. Water stock is sufficient in western and northern part of the country, at the same time, southern-east regions feel shortage of fresh water resources. For example, availability of fresh water in Kherson region does not prevail 10 thousand m^3/km^2, more than the third part of the territory of Ukraine has up to 50 thousand m^3/km^2. Moreover, water demand in these regions is sufficiently higher due to the localization of large number of industrial complexes [22]. In the long-term perspective, the situation is likely to be exacerbated even further due to climate change.

In spite of water scarcity, average water consumption by population in Ukraine is still relatively high (over 300 liters per capita per day) as compared to the average consumption volume in Western Europe (100 – 200 liters per capita per day) [2, 3, 27]. Apart from this, energy, manufacturing, extraction industry, transport, agriculture and communal sectors consume large amount of fresh water for technological processes and other purposes discharging after that polluted waters in to environment [2]. Water supply and water discharge entities are structured into the national scale water-economy complex [2].

Agricultural sector remains one of the biggest water users and, in spite of fast modernization and technological improvements, still causes sufficient harmful impact on the natural environment. Irrigation systems are mainly outdated leading to the inefficient use of water resources and, in some cases, to the degradation or salinization of soils [3]. Contamination of ground and surface waters with nitrates and other organic compounds, in particular, due to the improper application of fertilizers and other agro-chemicals leads to eutrophication of rivers and the Black and Azov Seas and also pose threats to human health.

Economic and social priorities are still dominating over environmental considerations in national and local strategies, action plans and programs. Keeping in mind current challengeable economic, social and political processes in the country, proclaimed environmental priorities will remain, in most cases, as a policy declaration. In general, we are observing steady tendencies in country population decrease, land contamination and degradation, deforestation and biodiversity loses, nature resources use increase, growing waste generation and deposition as well as water resources pollution and depletion, which can be considered as alarm indicators of unsustainability [3]. Therefore, even achieving some social and economic targets, we should recognize still unsustainable character of the current nature resource practices, which require deep and significant reforms.

National Water Policy

Provisions of the national policy in the field of water resources are reflected in strategic documents, national programs and legal acts. In this regard, special attention deserves the Law of Ukraine "On Fundamental Principles (Strategy) of Ukraine's State Environmental Policy for the Period until 20300" approved by the Parliament of Ukraine in 2019 [28]. It is the main legal document supporting and promoting sustainable development at national level. Integration of environmental policy across all sectors of the economy is among the key objectives of the Strategy. The Law declares that the goal of national environmental policy is an improvement of the state of environment through integration of environmental sustainability into social-economic development of Ukraine to ensure safe and healthy environment for population, sustainable resource use and protection of ecosystem. The Strategy determines key environmental problems in Ukraine, as well as the goals, principles, strategic objectives, tasks, expected results and the progress indicators of the national environmental policy. The basic principles of the national environmental policy are similar to those of the EU countries. The Strategy was supplemented by the National Environmental Action Plan until 2025 approved by the Cabinet of Ministers of Ukraine in 2021.

At least two objectives of the Strategy are being directly focused on the water sector: Objective 2 (Improvement of the environmental situation and the level of environmental security) and Objective 3 (Ensuring environmental and human health) however formulation of the tasks within these objectives is oriented on the protection of water environment and safe drinking water supply to population rather than on water sustainability.

The concept of sustainable development is reflected in some other laws and sub-legal acts regulation relations in the water sector of Ukraine.

National Legal Framework of WRM: At the national level, Ukraine has extensive body of environmental legislation. During the last two decades, Parliament of Ukraine reconsidered most of legal acts inherited from the former Soviet Union, and approved a large number of new laws and regulations so that national environmental legislative system is quite comprehensive and in general is completed. Further development of environmental legislation is aimed at the improvement of current laws and regulations (first of all by approximation to the EU legislative system) and strengthening the enforcement mechanisms. Ukraine's variety of legal acts in general and in the field of water resources management in particular has the following hierarchy:

- Constitution (1996);
- Codes, laws, and international treaties and conventions, to which Ukraine is a Party (e.g., Water Code, 1995; the Law on Drinking Water and Drinking Water Supply, 2003, etc.);
- Resolutions approved by the Parliament;
- Decrees of the President;
- Resolutions / Decrees of the Cabinet of Ministers;
- Regulations of the Ministries;
- Regulations of local authorities and local self-government.

Water legislation, in spite of some controversy and gaps, in general regulates practically all issues of water production, allocation, supply, rational use and protection. Enforcement of water regulations is affected through the actions of the authorities responsible for environmental protection. The State Ecological Inspection and its regional and local branches are key players in the field of enforcement and control of environmental legislation. They have the power to apply administrative sanctions in the case of violation of laws and regulation (e.g., by issuing prescriptions). Violation of prescription may cause application of criminal sanctions through the Office of Public Prosecutor, which has special environmental department dealing with violation of environmental rights and regulations, and Court of Justice. However, legislation enforcement is still a crucial issue in the country.

It is expected that the legal basis has to be strengthened due to approximation to the legislation of European Union, which is considered as a national priority and important component of the legislative reform in Ukraine. The policy in this sector is focused on the application of the EU approaches and principles during regulations development, obligatory giving the proper weight to the UE legislation provisions during the designing of new laws and regulations, training and retraining professionals in the field, and ensuring the institutional, scientific, educational, technical and financial support of the process of Ukrainian legislation adaptation. Since 2014, the country undertakes sufficient efforts to integrate the key directives in the field of water quality and water resources management into national legislation provisions (first of all, Water Framework Directive, 2000; **Floods Directive,** 2007; Marine Strategy Framework Directive, 2008; **Urban Wastewater Directive,** 1991; **Drinking Water Directive,** 1998; **and Nitrates Directive,** 1991).

Legislative reform in Ukraine is on-going, however partly the regulations, mainly concerning standards and methodologies, still date from the Soviet period. The former Soviet legislation remains in force until it is explicitly revoked by the modern legal framework harmonized with policies, legislation and regulation of the European Union.

Water Resources Management Objectives in Ukraine

According to the Constitution and other basic laws, natural

resources are of state property however divided between the national and the regional / local levels. The division into regions is administrative-territorial by nature. There are 27 administrative units in Ukraine comprising the Autonomous Republic of Crimea (currently annexed by and under control of Russian Federation), 24 regions (oblast) and the cities of Kiev and Sebastopol. As regards to the water resources, the only waters which do not extend to the territory of another region and groundwater which cannot be used as a source for centralized drinking water supply belong to the regional / local level. In practice, more than 90% of water resources are of national importance. The list of such water sources includes internal sea water and territorial sea, underground water used for centralized water supply, surface waters (rivers, lakes, reservoirs, channels and tributaries) extending the area of one region, water bodies located within boundaries of natural protected areas of the national importance, and waters of recreational status.

Effective Water Resources Management is of great importance for the country, regional and sectoral development. According to the Water Code [29], the WRM is based on the basin principle. For these reason, 9 river basins and, accordingly, 9 units for basins management have been established. They include management units for the basins of Dnipro River, Dnister River, Danube River, Southern Bug River, Don River, Visla River, Rivers of Crimea, rivers of the Azov Sea region, and rivers of the Black Sea region. Basin Management units are responsible for monitoring and implementing governance programs. As far as Dnipro River basin covers over two thirds of the country, Dnipro Basin Management Unit comprises six regional branches.

In general, WRM is focused on operational (meeting actual needs and demand in fresh water of population, agriculture, communal sector and industries) and strategic (ensuring water supply in needed quantity and quality and sustaining sources of fresh water) goals [30] and it is in compliance with determination of sustainable WRM proposed in simple form by Lutter and Schnepf: "sustainable WRM consists of local and regional practices as well as political frameworks and directives steering these practices, which ensure that the actual requirements of drinking water, irrigation water, water for industrial use, as well as for continuity of biotopes are fulfilled without constraining reaching the very same objectives in the short-term, medium-term or long-term future" [16].

Objectives of the WRM in Ukraine include but are not restricted to

- monitoring the quality of surface and underground water sources, as well as supplied drinking water and all types of water discharged;

- supplying water to population for drinking and communal purposes as well as for production purposes to industries, transport and agriculture;

- ensuring water discharge into natural water bodies;

- protecting natural waters against pollution and depletion;

- emergency prevention and response in natural and technological water systems;

- improving the governance of water resources.

These objectives are included in the operational and strategic management plans and programs.

Programming as a Mechanism of Policy Implementation

Programs in water sector elaborated either at local, regional or national level are considered as an important mechanism to implement sectoral policies. In the program hierarchy the state programs approved by laws or by resolutions of the Cabinet of Ministers represent top level of importance.

Several national programs in the field of water protection and water resources management are currently in force. **The most important are two of them – the** State Targeted Program "Drinking Water of Ukraine" for 2022-2026 (approved in 2022) [31] and State Targeted Program of the Development of Water Economy and Environmental Rehabilitation of the Dnipro River Basin till 2021 (approved in 2012, entered into force in 2013) [32]. The last program has expired in 2021, however some activities are still being implemented.

The Water Economy / Dnipro River Program was aimed at i) meeting needs of the population and national economy in water resources, ii) water conservation and rehabilitation, iii) implementation of the integrated water resources management based on the basin principle, iv) renewal of the irrigated lands, v) optimization of water consumption, and vi) prevention and mitigation of harmful water impact. The overall goal of the Drinking Water Program is ensuring secured by the Constitution rights of the citizens on the life quality and environmental safety by means of drinking water supply in required volumes and according to the approved standards.

Both programs comprise general formulation of the objectives, tasks and activities, which are specified in the corresponding action plans. Documents also provide the description of the approaches, mechanisms and instruments of the programs implementations, expected results, estimation of the necessary financial resources and funding sources. The number of such sources is restricted and includes, first of all, the state and local budgets as well as the means of the enterprises involved in water consumption and management. The programs do not have any information regarding availability of the funds required either from the local or state budget and envisage that the opportunity to fund program activities will be considered in the process of the annual planning and budgeting.

At the same time, the Action Plans are specific and provide detailed information on tasks, subordinated activities, estimated costs and the time frame, sources of funding, managing agencies, performance indicators and targets (value of indicators) distributed year by year. Review of the indicators prove that they mainly describe expected results and give information regarding the progress achieved.

However, both documents are lacking description of the monitoring, evaluation and public information regarding the programs implementation and the progress achieved. Some relevant information is available in the National Reports on the Drinking Water Quality and Drinking Water Supply in Ukraine (see, for example, last issue [2]) and the National Reports on the

State of Environment in Ukraine, which are available on the web-portal of the Ministry of Environment and Natural Resources [3]. All reports are published annually and comprise informative chapters on the state of water resources and water management in the country.

Since 2004, Ukraine has entered into challengeable phase of political, economic, and social transformations aimed at the integration into European community. Started reforms were hindered in 2011-2012 after election of the pro-Russian president, aggravated by social-political explosion in 2013, undermined by following aggression of Russian Federation and occupation of Eastern Ukraine in 2014, and suspended after Russian Federation invasion since February 24, 2022. Internal (budgetary constraints, imperfect management, etc.) and external (war with Russia) impact factors are hindering implementation of activities envisaged in the water management programs, and therefore regional / local governments are consolidating the efforts mainly on the operational activity to ensure water supply to population, industrial and other water use sectors in order to meet at least basic needs.

At the same time, progress, achieved during the program implementation in the water sector and presented in annual national reports, which is discussed in the following sub-section, create a sufficient background to make assessment of social, economic and environmental sustainability of programing activities and effectiveness of water resources management.

WRM Indicators of WRM in Ukraine

The questions whether the nation is on a sustainable course with respect to use and manage water and other natural resources [15] have been discussed by researchers and experts since the last decade of twentieth century however discussions were focused mainly on economic and social component of sustainability. This feature has been emphasized by Tarasova: for some economy sectors contradictions between priorities and objectives of different stakeholders are typical [22]. For example, understanding of outcomes and indicators of effectiveness of WRM are different from the point of view of managers of water supply (economic indicators: profitability and payback), nature protection agencies (environmental indicators: conservation of water fund) and water users (social indicators: accessibility to water and continuity). The author [22] has identified and justified the set of *environmentally oriented indicators*, which are defined as indicators *adequately reflecting degree of impact of water economy on water resources and helping to determine objectives for ecological improvements of water economy*. This set comprises the following indicators: Y_1 – water productivity (ratio of amount of consumed water to GDP, m^3/UAH); Y_2 – rationality of water use (ratio of water lost volume to water abstracted volume, %); Y_3 – degree of technogenic pressure on water bodies (ratio of volume of polluted water discharged to total volume of discharged water, %); Y_4 – technical capacity (ratio of total water treatment capacity to total volume of discharged water, %); Y_5 – investment activity in water sector (ratio of capital investments in water protection to total capital investments into sector, %); Y_6 – degree of taxation of water users (ration of environmental taxes to total taxes in the sector, %).

Proposed set of indicators is satisfactory describing and assessing an effectiveness of WRM in economic (Y_1, Y_5, Y_6), technological (Y_2, Y_3, Y_4), and environmental (Y_3, Y_4) context. Improvement of the WRM will lead to increasing (Y_4, Y_5, Y_6 --> 1) or decreasing (Y_1, Y_2, Y_3 --> 0) the value of indicators. Positive trends in indicators Y_1 - Y_4 are an evidence that WRM is on the direction to sustainability. However, the author does not consider defined indicators in the context of environmental sustainability. The set of described "environmental" indicators has been proposed for application in strategic planning as a tool for monitoring WRM at national or local levels however still there is no information on the practical steps.

As regards to the official planning procedures, there are no guidelines or conceptual paper describing determination and justification of the sustainability indicators used in WRM at national scale. Therefore, consideration of this issue is focused on the official documents including legally approved Ukraine's State Environmental Policy for the Period until 2030 [28], Water Economy / Dnipro River Program [32], Drinking Water Program [31], last national [2, 3] and international [27] reports. Summary of the review of the national WRM indicators is outlined below and reflects a situation at the beginning of 2022.

List of indicators included in the Ukraine's State Environmental Policy document [28] describes simple direct indicators related to water consumption by different users (m^3 per day), water quality in natural and technological systems (concentration of pollutants in water and bottom sediments), impact on natural water bodies (volume of discharged waters, irreversible water use for irrigation), protection measures (total length of allocated water protected zones), rivers basins management (number of management plans developed). Some indirect indicators may also refer to the water sector (e.g., number of the developed sectoral programs, a portion of energy generated by alternative sources). One of the indicators implicitly reflects sustainability – decrease of natural resources per unit of production (it is analogue of the Water Productivity indicator). Described indicators are proposed for application at national level.

State WRM programs [31, 32] encompassed huge number of indicators chosen practically for each activity. In general, they have been divided into two categories (Social and Ecological) and described in the sections "Expected results". All indicators of the Drinking Water Program [31] are specific. It means that the Program management will not use data of the State Statistic Service for monitoring performance and progress evaluation. For example, the Ecological Indicators include such indicators like the number of laboratories equipped with modern analytical devises for water quality control, the number of water abstraction utilities with arranged sanitary protection zones, etc. Examples of Social Indicators are similar: the number of constructed and reconstructed water abstraction utilities, the number of constructed and reconstructed water treatment utilities, the number of legal and regulatory acts in the field of drinking water harmonized with EU regulation, etc. In fact, we are dealing mainly with technological (like number of constructed and reconstructed water abstraction utilities) and governance (like number of legal and regulatory acts) indicators.

Activities, described in the Action Plan of the Water Economy

/ Dnipro River Program [32], are accompanied with indicators of outputs and outcomes. All indicators, like indicators of the Drinking Water Program, are specific. No division into groups however thematic of the indicators are broader and includes parameters, which relate, among others, to the flood prevention (e.g., the number of rural settlements protected against flooding), agriculture production (e.g., an area of lands with reconstructed irrigation infrastructure), education (e.g., the number of published manuals, guidelines, bulletins).

National Reports on the Drinking Water Quality and Drinking Water Supply are well structured and provide consolidated data on i) the sources of drinking water supply, ii) state of the drinking water supply and discharge system, iii) the national sanitary-epidemiological surveillance over the sources and systems of drinking water supply, iv) sectoral drinking water supply and discharge systems, v) regional systems of water supply and discharge, vi) emergency in the sector of water supply and discharge. Only official data, first of all, data of the National Statistic Service are used for each annual issue. Reports present comprehensive amount of factual data with minimum of generalization and representation of comparison / tendencies over time.

Picture of the water resource sector in Ukraine has outlined by means of the common and specific, mainly quantitative, indicators referred to social, economic, ecologic, governance and technologic nature.

Water quality control includes monitoring of drinking water sources (surface waters are main source of drinking water in Ukraine), and water supply and water discharge systems. 101 monitoring units spread over the country, make regular sampling and measure value of up to 49 hydro chemical and 2 radiological parameters. Coloration, common iron, chemical oxygen demand (COD), and biological oxygen demand (BOD) are most used parameters. Sanitary control includes some microbiological indicators. Amount of discharged water (polluted, purified or semi-purified) testifies on the pressure on natural water sources. These indicators belong to the category of environmental indicators.

Social indicators include, among others, coverage degree of settlements (urban and rural) by centralized water supply and water discharged systems (permanent and temporary). Parameters of water supply are varying by region from 100% coverage (like cities and towns of Kyiv Region) to 90,9% coverage (urban area of Chernivtsi Region). Situation in rural areas is looking different: best water supply can be seen in Kherson Region (88% of villages) while in Rivne Region, 2,7% of villages only have access to water pipelines. Social indicators as well include parameters related to the human health (e.g., number and type of outbreaks of waterborne deceases).

Technological indicators are describing the level of technical provision of water supply / discharge system (e.g., % of outdated pumping equipment, the length and conditions of water pipe line, % of reconstructed treatment facilities, % of discharge network to be replaced, etc.).

Finance and economic indicators show economic effectiveness of the WRM (e.g., prime cost of water supply service, specific energy consumption and loses, tariffs for water services for population and industries, etc.). This category also includes quite specific for the country finance indicator like debt of water supply enterprises for the used energy or debt of population for consumed water.

Reports also describe efforts undertaken in the field of regulation improvement – type and number of legal acts approved and entered into force, data on the performance of the projects and programs (including projects of technical assistance), etc. This part of the reports is based on the governance indicators, which are specific and do not arise from the State Statistic Service data base.

The last chapters of the reports represent data related to the water security, such as emergency of the water supply and water discharge facilities, technical conditions of water pipelines, threats of transboundary waters pollution, the state of underground water in Chornobyl exclusive zone, etc. Specific indicators are dominating in this part.

In general, reports present quite comprehensive picture of the water resource management in Ukraine through the year and to some extent, visible changes in comparison to previous year(s). Reports provide consolidated information regarding available water resources; the amount of consumed water by regions, economy sectors, population; the state of water supply and discharge infrastructure, and many other data which can be used for calculation of the performance indicators for national economy and social progress.

Data presented in the national reports result in the conclusion that national WRM system is not socially, economically and environmentally sustainable. Moreover, the content of policy / programming documents and used WRM indicators explicitly were not focused on achieving sustainability. Reports do not consider water sustainability issues and do not present methodology or practical approaches for examining this phenomenon in the country. The only comparison of the value of the same indicators over certain period of time may answer the question whether we are on the way to sustainable water consumption. The number of such indicators is restricted, some of them have complex nature (like Y1, Y2, Y_3, Y_4 indicators from [22]) and are still under consideration by experts and researchers.

Another distinctive feature of the WRM indicators is lack of presentation of the social effect. Most of the defined social indicators do not present properly human factor putting in shadow real parameters and their value. In fact, the ultimate goal of all our efforts in water resources area (e.g., operational improvements, implementation of policies, strategies, programs and projects, etc.) is meeting human needs in sustainable water resources and increasing wellbeing of population. However, reports do not provide information on the number of people who benefited from undertaken measures. Such indicator as % of rural settlements attached to centralized water supply network (and many others indicators of similar type) refers to social effect implicitly. The value of real indicator (number of people inhabited in these settlements) is unknown. In this case we faced violation of key characteristics that constitute a good indicator – representation and simplicity to interpretation [16]. In this

regard many technically important indicators (such as length of water supply pipelines, number of purification facilities, etc.) are becoming irrelevant in the social context if they are lacking data on how many people benefit from this. This remark relates to many other systems of indicators elaborated for monitoring performance and evaluation progress achieved in WRM of territorial and economic systems.

Another remark relates to the sources of data and information for monitoring performance and tracking progress. Operational water management at the level of water service enterprises generates and utilizes own data. However, at the level of the sector, river basin, country, region, etc. these sources of information are becoming irrelevant due to multiplication of efforts to gather and collate information from many actors. Information problem solution is working out an information from local, regional and national statistic services. For these reasons, type, format and collection methodology of statistic data should be optimized and properly standardized.

CONCLUSIONS

Summarizing discussion of the publications on the WRM sustainability and respective indicators, the following conclusion can be outlined.

1. Restricted availability of fresh water on the planet and steadfast growth of population, stipulating increased water demand on the one hand and increased anthropogenic pressure on water environment on another hand, require introduction of effective water resource management systems to ensure sustainable water supply and consumption by population in uneven environmental conditions and prevention of water sources from depletion. In this regards, performance and progress indicators, including indicators of sustainability, are becoming an important tool of the WRM. Data and information analysis demonstrates that many countries have gained positive experience in this area. At the same time, key feature of the modern interventions into WRM is focusing efforts to achieve mainly social and economic targets and much less an environmental target related to the sustainability. Consequently, appropriate representative indicators frameworks have been designed and introduced in WRM of different water systems. Social indicators in many cases reflect social context implicitly - this feature was demonstrated on the WRM-Ukraine case study. At the same time, environmental sustainability indicators are used mainly indirectly.

2. In spite of the fact that a wide variety of environmental and other indicators is presently in use in the water sector, there is no internationally accepted standard indicators' framework applicable for any WRM system. Resource managers, policy makers and other stakeholders undertake initiative in designing practical sets of indicators applicable for specific targeted WRM system (river basin, region, country, economic system, etc.). Different models and assumptions were successfully used as a background of these exercises (e.g., performance model [17], mission - goals - objectives hierarchy model [7], DPSIR model [18], natural, economic and social relationships model [25, 26], and others). Review of open information sources shows sufficient progress in this direction, demonstrates variety of the approaches, and would be helpful for managers creating sustainable WRM.

3. Consideration of the WRM-Ukraine shows that the country undertakes efforts to improve water management and governance with a focus on i) satisfying demand of population, industries and other water users, ii) protection of water sources, and iii) water emergencies prevention / mitigation. Used indicators correspond to determined activities and expected results, reflect current state of the water sector and to some extend show tendencies. However, national WRM policies and programs are lacking explicit objectives to achieve sustainability and, consequently, relevant indicators. In general, environmental sustainability as a notion and target has not been reflected in the context of national policies and programs. Ukrainian case study demonstrated that the most of defined WRM indicators (first of all social ones) do not present properly human factor and put in shadow real parameters and their value. Corresponding reports are lacking information on the social aspects of WRM (e.g., number of people increased water access or benefited from WRM measures) or present such information implicitly. Therefore, many technically important indicators (such as length of water supply pipelines, number of purification facilities, etc.) are becoming irrelevant in the social context of WRM assessment. This remark relates to many other systems of indicators elaborated for monitoring WRM performance and evaluation for different territorial and economic systems.

4. Discussed examples of the best practices of elaboration and application of effective WRM indicators create background for dissemination of successful experience by means of direct application or adaptation of available WRM indicators framework in countries striving to the development and sustainability. As far as the social value and environmental sustainability are key target of human oriented WRM, in many cases proposed indicators require revision and adaptation to be representative in social and ES context. No doubts, the best practices of water management will be demanded by stakeholders in other countries and, in particular, for the restoration of the water resources management system in Ukraine after the war. Integrating an environmental sustainability into WRM system requires raising stakeholders' awareness and strengthening the capacity of managers.

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ETHICAL STATEMENT

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