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MANAGEMENT OF THE QUALITY OF WATER RESOURCES FOR SUSTAINABLE DEVELOPMENT BASED ON INDUSTRIAL AND MANUFACTURING ENGINEERING

Abstract: *The goal of this paper is to justify the prospects and develop recommendations for consistent management of the quality of water resources for sustainable development based on industrial and manufacturing engineering, while taking into account the specific features of developed and developing countries. The originality of the research is that water resources are considered in terms of quality, and a consistent scientific view of the quality of water resources is formed for the first time in the unity of all its signs. It is suggested to use the methodology of comprehensive quality measurement which is being tested using the example of developed and developing countries in 2020. The uniqueness of the paper consists in the development of a new, non-financial approach to managing the quality of water resources, one that would involve reliance on industrial and manufacturing engineering in the digital economy. The novel nature of the research consists in examining the experience of developed and developing countries in order to identify and take into account their specific features and to develop specific highly-refined application-specific recommendations to ensure high efficiency management of the quality of water resources. In order to improve the quality of water resources in developed countries, it is recommended that e-government is developed by 95.74 per cent, and the active use of Big Data and analytics is increased by 96 per cent. In developing countries, it is recommended that the degree of robots distribution is increased by 96.02 per cent.*

Keywords: *Water; Quality Management; Water Source; Sanitation & Hygiene; Clean Water; Sustainable Development; Irrigation; Industrial and Manufacturing Engineering*.

1. Introduction

A new approach to the study, monitoring and management of water resources – from a quality perspective – emerges full blown in the context of the implementation of sustainable development goals. The basis for this is Goal 6 "Ensure availability and sustainable management of water and sanitation for all" (UN, 2020). Nevertheless, international practice preserves predominance of the former approach, in which water resources are considered from a quantitative point of view. They are not studied or managed separately, but are treated as part of general natural resources.

This is evidenced, in particular, by the fact that statistics of water resources until 2014 was kept by the World Bank in the calculation of the indicator "Annual freshwater

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withdrawals, total (% of internal resources)" reflecting the position of water resources in the totality of natural resources of economic systems. A widely accepted approach ignores high value of water resources for life and health of people through improved sanitation, and in many cases does not even take into account the importance of water resources as an independent production factor, since formally this factor is relegated to the background in many economic activities. For example, in post-industrial services economies, water resources are of little mark, while in the economies that specialize in the primary sector, other natural resources are more valuable (for example, oil and gas).

Sustainable development goals emphasized the inherent worth of water resources and require their independent consideration separately from other production factors, as well as increased focus on the quality of water resources. In respect of the aspect of sanitation, water must not only be generally available, but also clean, to be drinkable. This is a fundamentally new, understudied aspect of water resources, which needs in-depth study in the context of the implementation of sustainable development goals. Persisting reliance on former, quantitative approach and the lack of developed scientific basis for a new qualitative access constitute a critical barrier on the way towards the implementation of abovementioned sustainable development goal 6 for two reasons.

The first reason is due to the lack of a consistent vision of the quality of water resources in the economy, which has many aspects that are studied and managed separately. The fragmentary nature of scientific and practical visions of the quality of water resources prevents its comprehensive assessment and the formation of a cohesive view of its current level, challenges and strengths. The progress in the field of the quality of water resources is not measurable either in this case. Lack of information support prevents management of the quality of water resources.

The second reason is the absence of any effective measures of management of the quality of water resources. Currently implemented management measures are financial in nature and are aimed in some cases at making profit and generating income from international trade in water resources which is inconsistent with the target sustainable development goal 6. In other cases, financial management measures are intended to improve the condition of water resources. However, due to the lack of funds from the state budget, they imply reliance on public-private partnership. Attracting private investment either requires conditions to derive commercial profit from trade and use of water resources, or implies reliance on corporate responsibility and charity, which is small in scale and does not allow to fully finance the necessary activities.

This paper suggests a hypothesis that measures of non-financial management of the quality of water resources involving a wide range of stakeholders – government regulators, civil society and business entities – will help to solve the problem set. These measures must be based on industrial and manufacturing engineering in the digital economy and assume the automation of monitoring, introduction of more environmentally efficient technologies for responsible production and consumption, which allows reducing the contamination of water sources and reducing water consumption, strengthening control over water use and water treatment, which, combined, will result in an increase in the quality of water and an increase in the level of sanitation.

The goal of this paper is to justify the prospects and develop recommendations for consistent management of the quality of water resources for sustainable development based on industrial and manufacturing engineering, while taking into account the specific features of developed and developing countries. The originality of the research is that water resources are considered in terms of quality rather than in terms of quantity (which is most common), and a consistent scientific view of the quality of water resources is formed for the first time in the unity of all its signs, including: safety of drinking water and sanitation, purity of water in water bodies for bathing people, treatment of non-domestic water (for business in particular), import substitution of water of resources, protection of water resources important to the conservation of biodiversity, as well as the use of water resources for agricultural irrigation. It is suggested to use the methodology of comprehensive quality measurement which is being tested using the example of developed and developing countries in 2020.

The uniqueness of the paper consists in the development of a new, non-financial approach to managing the quality of water resources, one that would involve reliance on industrial and manufacturing engineering in the digital economy. This allows defining the system of effective management measures, generally available to various social and economic systems thanks to reduced burden on state budget and a moderate need for investment with reliance on automation, digital monitoring, and control. The novel nature of the research consists in examining the experience of developed and developing countries in order to identify and take into account their specific features and to develop specific highly-refined application-specific recommendations to ensure high efficiency management of the quality of water resources.

In order to ensure comprehensive coverage of the defined problem, achieve the target goal and ensure the stated benefits, the work is logically structured and sequentially presented as follows. A literary review is presented after the Introduction, followed by the description of materials and methodology. Further, in the Results section, first, a comprehensive assessment of the quality of water resources in developing countries is made, and the prospects for its improvement based on industrial and manufacturing engineering are identified. Second, a comprehensive assessment of the quality of water resources in developed countries is made, and quality management recommendations are developed based on industrial and manufacturing engineering. The work ends with Conclusion section.

2. Literature Review

Water resources as a production factor in the economy and entrepreneurship were studied in sufficient detail in numerous published papers. Rankoana (2020) described the impact of climate change on water resources in rural localities using the example of Limpopo province, South Africa), and noted the need for the community to adapt to the lack of water safety. Nyamwanza (2018) believes there is a need for local institutional adaptation for sustainable management of water resources in the context of the increasing variability and climate change (it using the example of the middle part of Zambezi Valley, Zimbabwe). Egan and Agyemang (2019) noted the progress in the field of sustainable management of urban water resources in Ghana.

Greenland et al. (2019) identified barriers to the introduction of sustainable innovations, which include water sustainability, food production, and drip irrigation in Australia. Adekunle and Dakare (2020) related sustainable production practices with the efficiency of the Nigerian table water industry and suggested the use of an approach to simulating the structural equation. Krishnan (2020) suggested the use of humanitarian technologies WASH (water, sanitation and hygiene) to study recovery from subsequent recurring disasters (using the example of Assam, India). Bikorimana and Shengmin (2019) identified socio-economic and demographic factors to better predict access to upgraded water supply and sanitation facilities (using the example of Rwanda).

The issues of management of water resources for sustainable development are covered in the works by authors listed below:

Manoharan et al. (2020) developed a self-sufficient system of management of water resources "smart home" for agricultural applications. Zhang and Tang (2019), in turn, came up with corporate systems for management of water resources and incentives for self-discipline. Silva Rodríguez de San Miguel et al. (2019) compiled a model for the integrated management of drinking water (with testing in Iztapalapa, Mexico City).

Egan and Agyemang (2019) substantiated the progress in the field of sustainable management of urban water resources in Ghana. Breviglieri et al. (2019) developed new tools for management of water resources in Brazil. Silva Rodríguez de San Miguel et al. (2018) described management of drinking water in Mexico. Silva Rodríguez de San Miguel (2018) related gender-based factors with management of water resources in Mexico. Stojkovic Zlatanovic et al. (2018) examined the current state and the prospects of the policy of management of water resources from the perspective of climate change (using the example of the Great Morava river).

Some aspects of measurement and management of the quality of water resources were discussed indirectly in the works of the following experts. Korzenowski et al. (2020) identified the economic sustainability of inefficient processes. Zimon et al. (2020) noted the factors of sustainable management of supply chain, as well as suggested the use of methods for their coordination with the UN sustainable development goals. Santos et al. (2019) developed the COSTATIS approach to ensuring business sustainability in tumultuous times (with testing based on data for 2008-2014). Urlica et al. (2019) noted the importance of sustainable learning, in particular, for the protection of water resources.

Klochkov et al. (2019) suggested the use of "Six Sigma" approach for sustainable business practices and standardization. Sisodia et al. (2020) conducted a strategic assessment of business risks for sustainable energy investments and interaction with stakeholders, and made proposals for energy policy in the Middle East through Khalifah funding and land grants. Goyal and Sergi (2015) related social entrepreneurship to sustainability, having offered an insight into the context and key characteristics for management of water resources. Popkova and Sergi (2019) studied social entrepreneurship in Russia and Asia, having pointed out the trends and prospects for its further development, in particular, in order to improve the quality of water resources. Popkova et al. (2020) noted the relation between innovation theory and innovative development, and provided rationalization for AI scenarios in Russia that can be used for improving the quality of water resources.

Thus, current literature review showed that the problem of management of the quality of water resources for sustainable development is understudied and is not yet solved due to a number of research gaps. One of these gaps is the lack of elaboration of the theory and methodology for measuring the quality of water resources for sustainable development and the lack of a consistent vision of the quality.

Another gap is the uncertainty of the prospects for the non-financial management of the quality of water resources for sustainable development, while most studies recognize the limitations of financial management measures and the need for the search for an alternative to them. The prospects for industrial and manufacturing engineering in the digital economy for management of the quality of water resources for sustainable development are dim. Gaps also include the understudied experience of developed and developing countries, which prevents from clearly distinguishing between them and taking into account their features in practical management of the quality of water resources for sustainable development.

This paper is aimed at filling in the entire set of abovementioned gaps and offers a comprehensive viewpoint and the scientific methodology of management of the quality of water resources for sustainable development based on industrial and manufacturing engineering while taking into account the specific features of developed and developing countries.

3. Materials and methodology

The suggested hypothesis is verified using the correlation and regression analysis method. First, the correlation analysis is carried out to find the connection between the factors and signs of the quality of water resources for sustainable development. The statistics of the World Bank (2020) about the financial factor of quality management – investment in water and sanitation with private participation (current US$) is available for developing countries. As a result, a comparative analysis of the relation (correlation) of results with the financial factor and with non-financial factors – industrial and manufacturing engineering in the digital economy is carried out. The hypothesis is deemed to be verified if the correlation with non-financial factors (industrial and manufacturing engineering in the digital economy) will be higher in absolute value that the correlation with the financial factor.

The following factors were selected as factors of industrial and manufacturing engineering: e-participation, e-government, world robots distribution, use of Big Data and analytics. The “World Digital Competitiveness Report 2020” (IMD, 2020) is the source of data on the values of these factors. All mentioned indicators are measured in positions from 1 to 63, and their values are the lower, the better.

Information on the signs of the quality of water resources for sustainable development in developing countries (unless other source is specified) was borrowed from materials of the “Sustainable Development Report 2020” (UNDP, 2020b) and assessed using such indicators as:

- population using safely managed water services, % (indicator of the quality of drinking water);
- population using safely managed sanitation services, % (indicator of the contribution of the quality of drinking water to sanitation);
- freshwater withdrawal, % of available freshwater resources (indicator of the quality of non-domestic water, for example, water for business use);
- anthropogenic wastewater that receives treatment, % (indicator of the quality of non-domestic water, for example, water for business use);
- scarce water consumption embodied in imports, m3 per capita (indicator of dependence on water importation, the lower the better);
- mean area that is protected in freshwater sites important to biodiversity, % (indicator of protection of water resources for the conservation of biodiversity);
- irrigation infrastructure, % of development (indicator of the quality of water resources for agriculture) - borrowed from materials of the “Global Food Security Index 2019” (The Economist Intelligence Unit, 2020).

Since almost all indicators are measured in percentage, and the higher are their values, the better, the reference values of these indicators are taken into account in the comprehensive assessment of the quality of water resources in developing countries. In contrast to them, the indicator of water consumption embodied in imports is measured in m3 per capita. In order to ensure its comparability with other indicators, the maximum value in the sample is determined, which, as can be seen from Table 1, is 43,1 m3 per capita (for Russia). The ratio of reference values to the maximum value is determined by country.

For example, in Indonesia, the reference value is 2.7, i.e. we obtain 2.7/43.1=15.96. Subsequently, the total amount of all values obtained is determined, which was 153.126. Then the ratio of obtained values to the total amount is determined and the product of -100% is found. For example, in Indonesia: (15.963/153.126)*(-100%)=-10.42%. The total for all countries is 100%. A comprehensive assessment of the quality of water resources in developing countries is made by finding the sum of the arithmetical mean of reference values of indicators that are measured in per cent, and the obtained value of indicator of water consumption embodied in imports in percentage terms.

The sample of developing countries was made according to the criterion of availability of data (for 2014-2019) on investment in water and sanitation with private participation in materials of the World Bank (2020), as well as on factors of industrial and manufacturing engineering (inclusion in the ranking of the 63 countries according to the IMD, 2020). Statistics for developing countries for 2020 are shown in Table 1.

Table 1. Signs of the quality of water resources for sustainable development, financial factor, as well as industrial and manufacturing engineering factors in developing countries in 2020

-	Industrial and manufacturing engineering factors, position 1-63				Financial factor of management	Signs of the quality of water resources for sustainable development						
Country	E-Participation	E-Government	World robots distribution	Use of big data and analytics	Investment in water and sanitation with private participation (current US$)	Population using at least basic drinking water services (%)	Population using at least basic sanitation services (%)	Freshwater withdrawal (% of available freshwater resources)	Anthropogenic wastewater that receives treatment (%)	Scarce water consumption embodied in imports (m3/capita)	Mean area that is protected in freshwater sites important to biodiversity (%)	Irrigation infrastructure, % of development
Indonesia	45	57	25	17	82,380	89.3	73.1	28.0	0	2.7	35.5	11.9
China	9	40	1	8	3,326,340	92.8	84.8	43.4	9.4	2.3	34.4	13.9
Philippines	45	55	40	34	32,070	93.6	76.5	26.0	0.7	1.9	36.5	15.0
Brazil	18	47	17	58	313,980	98.2	88.3	3.0	49.3	2.1	12.5	1.9
India	28	59	12	32	583,300	92.7	59.5	66.5	2.2	2.9	15.1	39.4
Mexico	35	50	10	51	237,300	99.9	91.2	32.2	31.6	4.3	15.1	6.2
Peru	44	54	54	54	121,400	91.1	74.3	2.5	46.4	1.6	48.8	11.0
Russia	26	33	32	33	1,200,000	97.1	90.5	4.4	18.5	43.1	27.3	2
Colombia	26	52	49	41	129,000	97.3	89.6	1.8	25.6	3.8	39.3	2,5
Thailand	42	49	11	35	18,800	99.9	98.8	23.0	2.2	3.9	43.6	29.2

Source: compiled by the authors based on materials of the IMD (2020), The Economist Intelligence Unit (2020), UNDP (2020b), World Bank (2020).

In developing countries, the same factors of industrial and manufacturing engineering are taken into account as in developing countries. The following indicators were selected as the signs of the quality of water resources for sustainable development:

- Mean area that is protected in freshwater sites important to biodiversity, %;
- Bathing sites of excellent quality, % (indicator of the quality of water bodies and their suitability for bathing);
- Population using safely managed water services, %;
- Population using safely managed sanitation services, %;
- Irrigation infrastructure, % of development (indicator of the quality of water resources for agriculture) - borrowed from materials of the "Global Food Security Index 2019" (The Economist Intelligence Unit, 2020).

The sample of developed countries is made on the basis of materials of "Sustainable Development Indicators 2019" (UNDP, 2020a), which presents data for developed countries with the highest-quality water resources only. The set of indicators of signs of the quality is also determined by data availability in materials (UNDP, 2020a). Since all indicators are measured in percentage, and the higher are their values, the better, a comprehensive assessment of the quality of water resources of developed countries is made by finding the arithmetical mean of reference values of indicators. Statistics for developing countries for 2020 are shown in Table 2.

Table 2. Signs of the quality of water resources for sustainable development, financial factor, as well as industrial and manufacturing engineering factors in developed countries in 2020

-	Industrial and manufacturing engineering factors, position 1-63				Signs of the quality of water resources for sustainable development				
Country	E-Participation	E-Government	World robots distribution	Use of big data and analytics	Mean area that is protected in freshwater sites important to biodiversity (%)	Bathing sites of excellent quality (%)	Population using safely managed water services (%)	Population using safely managed sanitation services (%)	Irrigation infrastructure, % of development
Denmark	9	1	30	12	100.0	87.4	96.7	93.2	8.4
Bulgaria	22	39	45	39	98.6	52.6	96.6	48.9	2.3
Ireland	28	25	43	18	97.7	71.0	98.9	70.3	0.6
Latvia	59	43	58	30	97.5	92.9	81.9	78.4	-
Lithuania	49	20	46	14	95.2	84.6	91.7	61.2	-
Estonia	1	3	47	37	93.5	66.7	81.7	92.9	-
Netherlands	9	10	21	20	93.4	72.7	100.0	97.5	29.2
Belgium	56	36	24	31	92.8	87.8	81.5	97.1	1.8
Czech Republic	50	35	16	27	92.1	81.7	97.6	81.9	1.3
Poland	9	23	19	22	91.8	28.0	93.9	77.1	1.9

"-" – the source contains no data; these cells will assume zero values during the economic analysis.
Source: compiled by the authors based on materials of the IMD (2020), The Economist Intelligence Unit (2020), UNDP (2020a).

In order to clarify correlation dependences, the regression analysis method is used to determine the accurate dependences of indicators with the highest correlation relationships.

4. Results

4.1 Comprehensive assessment of the quality of water resources in developing countries and identification of the prospects for its improvement based on industrial and manufacturing engineering

A comprehensive assessment of the quality of water resources in developing countries in 2020 based on data from Table 1 was made, and its results are presented in Figure 1.

As can be seen in Figure 1, the consistent quality of water resources in developing countries in 2020 was: (95.19+82.66+23.08+18.59+30.81+13.30)/6 +(-9.99)=33.95% (poor quality). The quality of drinking water is very high (95.19%), as well as the level of sanitation (82.66%). Nevertheless, the protection of water resources, important to biodiversity is poor (30.81%) as well as the quality of non-domestic water resources (freshwater withdrawal: 23.08% and treatment of anthropogenic wastewater: 18.59%). The quality of water resources for agricultural use (irrigation infrastructure) is very poor (13.30%). Moreover, dependence on imported water is high (-9.99%).

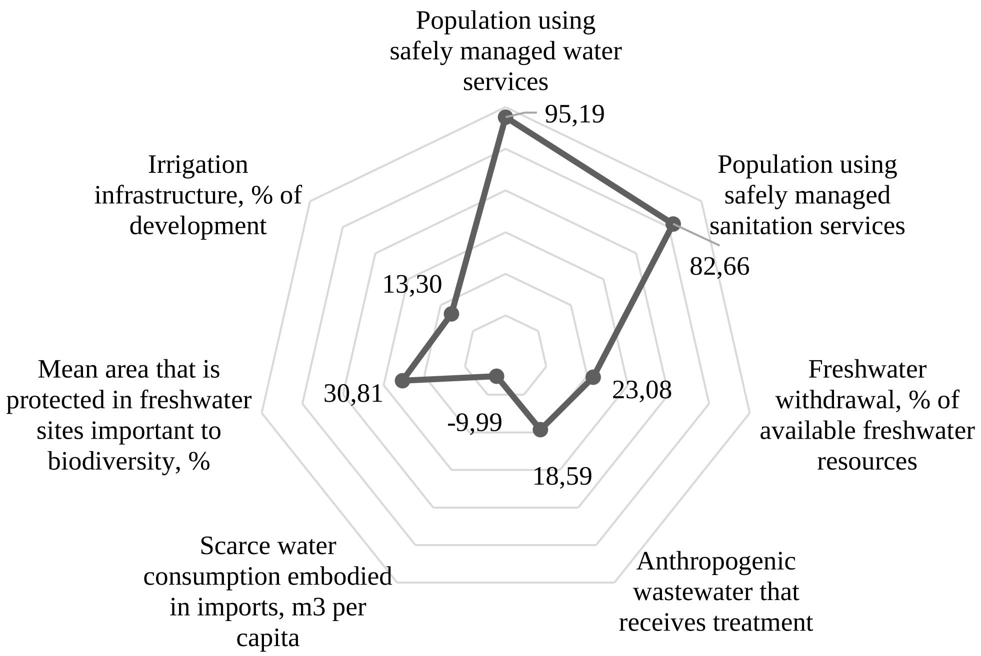

Figure 1. A comprehensive assessment of the quality of water resources in developing countries in 2020, %

Source: calculated and built by the authors.

The correlation coefficients of the financial factor and non-financial factors – industrial and manufacturing engineering in the digital economy – with the results in the field of the quality of water resources in developing countries in 2020 were calculated based on data from Table 1 and are shown in Table 3.

Table 3. Correlation coefficients of factors with the results in the field of the quality of water resources in developing countries in 2020, %

Correlation, %	Population using safely managed water services	Population using safely managed sanitation services	Freshwater withdrawal	Anthropogenic wastewater	Scarce water consumption embodied in imports	Mean area that is protected in freshwater sites	Irrigation infrastructure	In the mean for all signs of the quality of water resources for sustainable development*
E-Participation	-20.44	-18.52	-10.02	-21.63	-16.08	44.47	20.77	1.53
E-government	-39.27	-61.57	32.19	-16.50	-73.12	8.15	46.00	6.02
World robots distribution	**-24.49**	**-13.95**	**-64.65**	30.25	**11.22**	53.48	**-37.91**	**-9.78**
The use of Big Data and analytics	47.88	19.64	-52.19	79.61	-6.98	-22.80	-30.47	6.95
Investment in water and sanitation with private participation	-16.54	5.63	31.63	-14.74	19.02	-5.81	-2.68	-3.08
Mean by factors of industrial and manufacturing engineering	-9.08	-18.60	-23.67	17.93	-21.24	20.83	-0.40	-

The correlation coefficient with scarce water consumption embodied in imports was reversed in sign ((-1)) in order to ensure comparability of all correlation coefficients, since the basic indicator value (scarce water consumption embodied in imports) is the lower, the better.
Source: calculated and compiled by the authors.

As can be seen from Table 3, financial factor – investment in water and sanitation with private participation – in the mean demonstrated a negative correlation with the results for the quality of water resources (-3.08%). Hence, the growth of these investments results in the loss of quality instead of its improvement. It should be emphasized that a positive correlation was found with most non-financial factors, which has identical value. Moreover, the negative correlation was detected in the mean in results with world robots distribution (a non-financial factor): -9.78%. In other words, as the position in the ranking of world robots distribution in developing countries goes up (down), the quality of water resources increases.

Desired negative values of correlation coefficients were found in world robots distribution with such results as Population using safely managed water services, population using safely managed sanitation services, freshwater withdrawal, scarce water consumption embodied in imports, and connection of selected results with world robots distribution in developing countries, irrigation infrastructure. In order to clarify the regression curves were plotted as is shown in Figure 2.

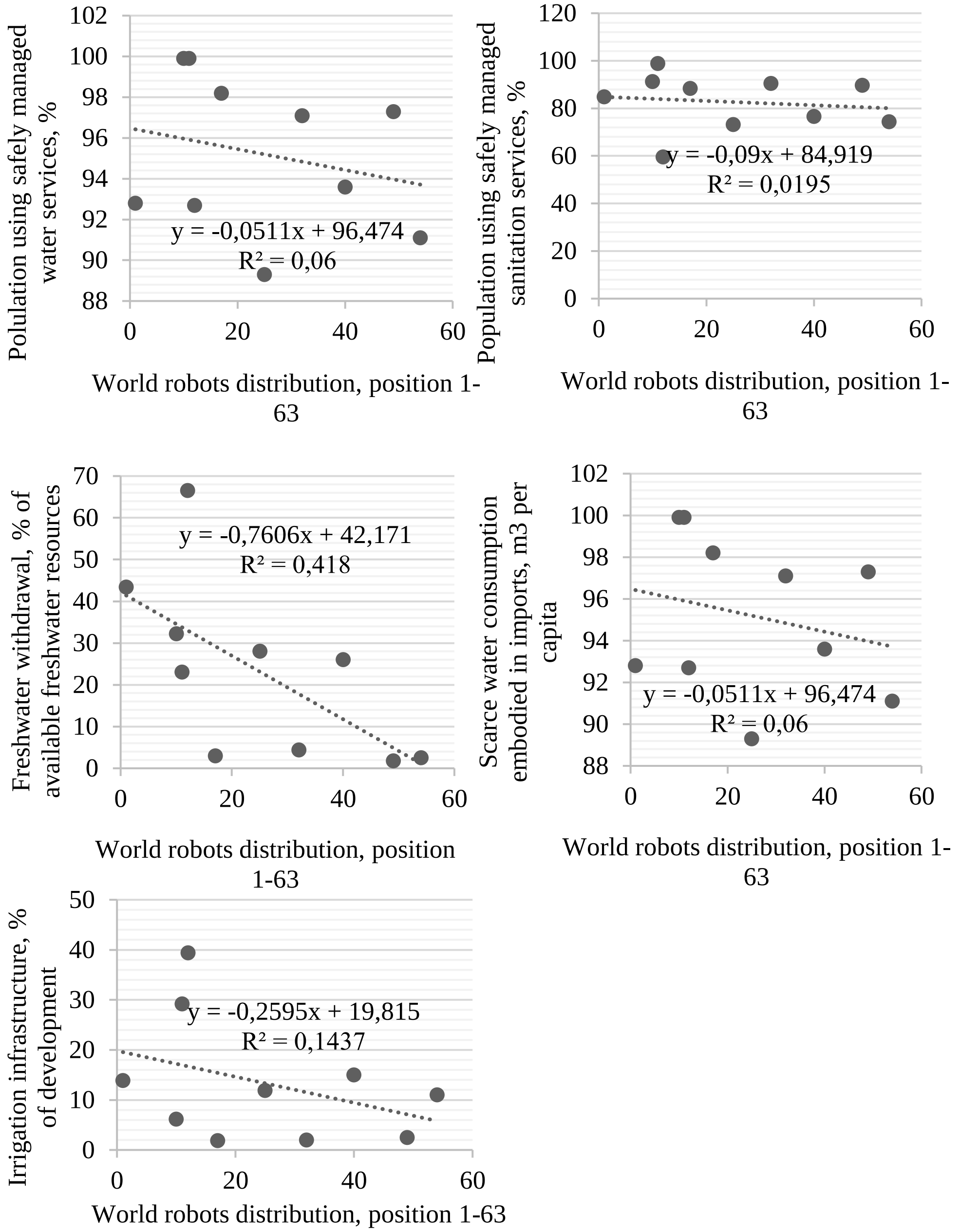

Figure 2. Regression curves reflecting the dependence of selected results on world robots distribution in developing countries

Source: calculated and built by the authors.

As can be seen in Figure 2, as world robots distribution increases (ranking position drops by 1) in developing countries in 2020, the proportion of population using safely managed water services, increases by 0.0511%, the proportion of population using safely managed sanitation services, increases by 0.09%, freshwater withdrawal increases by 0.7606%, scarce water consumption embodied in imports decreases by 0.0795 m3 per capita, and irrigation infrastructure increases by 0.2595%. Specified regression equations (Figure 2) were used as the basis for determining the maximum values of the resulting variables at maximum (top of the world's ranking) degree of robots distribution in developing countries (Figure 3).

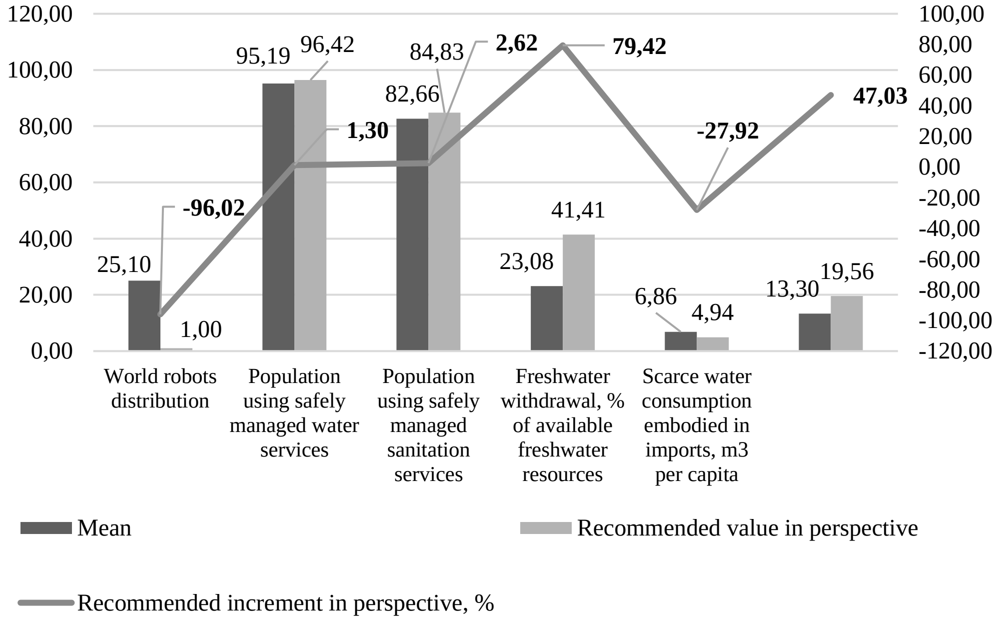

Figure 3. The prospects for improving the quality of water resources in developing countries based on industrial and manufacturing engineering
Source: calculated and built by the authors.

As can be seen in Figure 3, the prospects for improving the quality of water resources in developing countries based on industrial and manufacturing engineering at the maximum world robots distribution (+96.02% when compared to 2020) are due to:

- an increase in the proportion of population using safely managed water services from 95.19% in 2020 to 96.42% (+1.30%);
- an increase in the proportion of population using safely managed sanitation services from 82.66% in 2020 to 84.83% (+2.6%);
- an increase in the proportion of freshwater taken for treatment from 23.08% in 2020 to 41.41% (+79.42%);
- a decrease in scarce water consumption embodied in imports from 6.86 m3 per capita in 2020 to 4.94 m3 per capita (-27.92%);
- development of irrigation infrastructure from 13.30% in 2020 to 19.56% (+47.03%).

Great prospects were identified which make it possible to recommend accelerated and large-scale robotization of the economy in developing countries in order to improve the quality of water resources for sustainable development.

4.2 Comprehensive assessment of the quality of water resources in developed countries and development of quality management recommendations based on industrial and manufacturing engineering

A comprehensive assessment of the quality of water resources in developed countries in 2020 based on data from Table 2 was made, and its results are presented in Figure 4.

As can be seen, the consistent quality of water resources in developed countries in 2020 was: (95.26+72.54+92.05+79.85+4.55)/5=68.85% (high quality). The quality of drinking water is very high (92.05%) as well as the level of sanitation (79.85%) and the protection of water resources important to biodiversity (95.26%). Most (72.54%) bathing sites are of excellent quality. Nevertheless, the quality of water resources for agricultural use (irrigation infrastructure) is very poor (4.55%).

Correlation coefficients of non-financial factors – industrial and manufacturing engineering in the digital economy - with the results in the field of the quality of water resources in developed countries in 2020 were calculated based on data from Table 2 and are shown in Table 4.

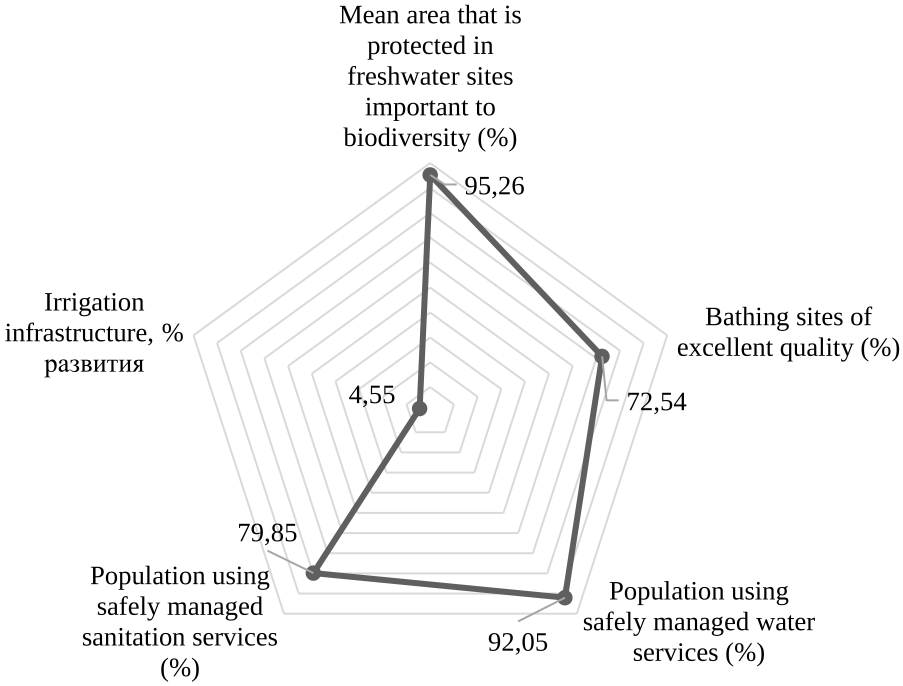

Figure 4. Comprehensive assessment of the quality of water resources in developed countries in 2020, %
Source: calculated and built by the authors.

Table 4. Correlation coefficients of factors with the results in the field of the quality of water resources in developed countries in 2020, %

Correlation, %	Mean area that is protected in freshwater sites important to biodiversity	Bathing sites of excellent quality	Population using safely managed water services	Population using safely managed sanitation services	Irrigation infrastructure	In the mean
E-Participation	-5.31	59.10	-34.22	-18.74	-40.80	-7.99
E-government	**-2.87**	5.42	**-18.17**	**-46.61**	**-41.87**	-20.82
World robots distribution	58.39	23.63	-42.02	-45.35	-41.70	-9.41
The use of Big Data and analytics	**-17.17**	-19.34	**-49.82**	**-11.63**	**-29.12**	-25.42
In the mean	8.26	17.20	-36.06	-30.58	-38.37	-15.91

Source: calculated and compiled by the authors.

As can be seen from Table 4, the mean correlation of factors of industrial and manufacturing engineering in the digital economy with the results in the field of the quality of water resources in developed countries in 2020 turned out to be negative (desired, which was 5.91%), which is indicative of the positive influence of factors under consideration on the quality. Overall, e-Participation demonstrated poor quality (-7.99%) with the results for the quality of water resources, as well as world robots distribution (-9.41%). The correlation of results with E-government (-20.82%, x1) and with the use of Big Data and analytics (-25,42%, x2) turned out to be the highest one (although moderate).

Selected key factors simultaneously demonstrated a negative correlation with these results. They are as follows: mean area that is protected in freshwater sites important to biodiversity (y1), population using safely managed water services (y2), population using safely managed sanitation services (y3), as well as irrigation infrastructure (y4). The following equations of multiple linear regression were obtained for the selected factors:

- $y_1=96.56+0.01x_1-0.06x_2$;
- $y_2=101.98+0.02x_1-0.42x_2$;
- $y_3=88.06-0.56*x_1+0.19x_2$;
- $y_4=12.82-0.22x_1-0.13x_2$.

The obtained regression equations mean that as the development of e-government progresses in developed countries, the proportion of population using safely managed sanitation services as well as the level of development of irrigation infrastructure increase, but the mean area that is protected in freshwater sites important to biodiversity as well as the proportion of population using safely managed water services decrease. As the use of Big Data and analytics becomes more active in developed countries, mean area that is protected in freshwater sites important to biodiversity, the proportion of population using safely managed water services, as well as the level of development of irrigation infrastructure, increase; however, the proportion of population using safely managed sanitation services, decreases.

Specified regression equations were used as the basis for determining the maximum values of the resulting variables at maximum (top of the world's ranking) level of development of e-government and the active use of Big Data and analytics in developed countries (Figure 5).

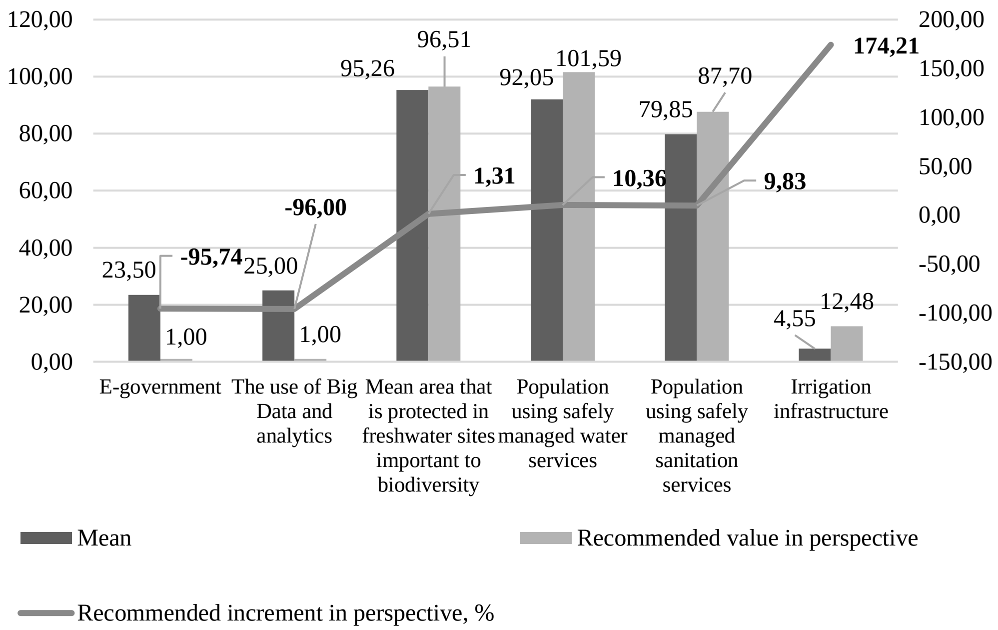

Figure 5. The prospects for improving the quality of water resources in developed countries based on industrial and manufacturing engineering
Source: calculated and built by the authors.

As can be seen in Figure 5, the prospects for improving the quality of water resources in developing countries based on industrial and manufacturing engineering at the maximum level of development of e-government (+95.74% when compared to 2020) and the active use of Big Data and analytics (+96% when compared to 2020) in developed countries are due to:

- an increase in the mean area that is protected in freshwater sites important to biodiversity from 95.26% in 2020 to 96.51% (+1.31%);
- an increase in the proportion of population using safely managed water services, from 92.05% in 2020 to 100% (+10.36%);
- an increase in the proportion of the population using safely managed sanitation services, from 79.85% in 2020 to 87.70% (+9.83%);
- an increase in the level of development of irrigation infrastructure from 4.55% in 2020 to 12.48% (+174.21%).

Great prospects were identified which make it possible to recommend accelerated and large-scale development of e-government and an increase in the active use of Big Data and analytics in developed countries in order to improve the quality of water resources for sustainable development.

5. Conclusion

Thus, adequate and strong scientific arguments were collected for the verification of the suggested hypothesis. The example of developing countries was used to demonstrate that the financial factor (an increase in investment in water and sanitation with private participation) has a negative impact on the quality of water resources, resulting in its loss (the correlation is -3.08%). Moreover, a non-financial factor was found that has a positive impact on the quality of water resources in developing countries (industrial and manufacturing engineering in the digital economy) – world robots distribution, the correlation with which was 9.78% (in absolute value).

A comprehensive assessment of the quality of water resources in developing countries in 2020 was made; it demonstrated that it is poor, being 33.95%. The biggest shortcomings (quality issues) include poor quality of non-domestic water resources (freshwater withdrawal and treatment of anthropogenic wastewater), as well as poor quality of water resources for agricultural use (irrigation infrastructure). In this regard, as a natural result, high dependence on imported water was found (9.99%, in absolute value).

High quality of water resources was found in developed countries, which in 2020 was 68.85%. Poor quality of water resources for agricultural use (irrigation infrastructure) turned out to be a shortcoming (a quality issue): 4.55%, which is below the level demonstrated in developing countries. Correlation coefficients of non-financial factors – industrial and manufacturing engineering in the digital economy - with the results in the field of the quality of water resources in developed countries in 2020 turned out to be desired (negative) and turned out to be the highest (in absolute value) with E-government (20.82%) and the use of Big Data and analytics (25.42%).

Different recommendations for developed and developing countries were made according to the identified features. In order to improve the quality of water resources in developing countries, it is recommended that the degree of robots distribution is increased by 96.02%. The prospects for improving the quality of water resources in developing countries through the proposed recommendation are involved with an increase in the proportion of population using safely managed water services, by 1.30%, an increase in the proportion of the population using safely managed sanitation services, by 2.6%, an increase in the proportion of freshwater taken for treatment by 79.42%, a decrease in scarce water consumption embodied in imports (import substitution) by 27.92% and development of irrigation infrastructure by 47.03%.

In order to improve the quality of water resources in developed countries, it is recommended that e-government is developed by 95.74 per cent, and the active use of Big Data and analytics is increased by 96 per cent. The prospects for improving the quality of water resources in developing countries through the proposed recommendation are involved with the increase in the mean area that is protected in freshwater sites important to biodiversity, by 1.31%, an increase in the proportion of population using safely managed water services, by 10.36%, an increase in the proportion of the population using safely managed sanitation services, by 9.83% and an increase in the level of development of irrigation infrastructure by 174.21%.

The contribution of this research consists in the development of a new approach to the measurement and management of development of water resources for sustainable development – through the consistent improvement of their quality based on industrial and manufacturing engineering in the digital economy. The consideration of the specific features of developed and developing countries allows achieving the highest efficiency in management of the quality of water resources for sustainable development based on industrial and manufacturing engineering in the digital economy. The prospects for further research are related to the testing of suggested recommendations and their detailed elaboration for some developed and developing countries.

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