Sustainable Water Resources Management (2024) 10:79
https://doi.org/10.1007/s40899-024-01057-8

ORIGINAL ARTICLE

An analysis of barriers and perspectives for circular economy in industrial water use in Kazakhstan

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Received: 1 September 2023 / Accepted: 31 January 2024

Abstract
Problems related to an ambiguous situation regarding water resources have been accepted as the priority direction for the implementation of the circular economy (CE) in developing countries like Kazakhstan. The process may hit obstacles, which should be identified. As the initial step, it is important to understand the state-of-the-art perception of key stakeholders to such changes. The aim of this work is to assess the water management system in a Kazakhstani industrial region and identify existing imperfections and potentials for sustainable and circular water use. For this purpose, interviews were conducted with representatives from local industries, governmental bodies, water supply utilities, and academia to understand the willingness of stakeholders to accept and implement the CE principles. The results of the interviews were examined using the SWOT approach. The associated Likert and analytic hierarchy process (AHP) analyses were used for prioritizing barriers and opportunities towards reduction of freshwater withdrawal and water contamination in the region. The following factors were recognized as the most critical: conditions of existing water infrastructure and associated cost for renovation projects, low water tariffs, and the impact of the governmental regulation. The particular focus should be placed on the willingness of stakeholders to eliminate corruption-related risks in the water sector, to control existing shortcomings in the legislation, to invest in water infrastructure despite associated costs, and to enhance environmental awareness at all business levels.

Keywords Circular economy · Industrial water use · Kazakhstan · SWOT–AHP · Water management

Introduction

The global shortage of available freshwater resources has become increasingly alarming, with escalating risks of water scarcity in the near future (Jia et al. 2020). While the total population growth is projected to reach 8.6 billion by 2030 and 9.8 billion by 2050, the global water demand is projected to increase by 55% between 2000 and 2050 (Salem et al. 2022). The water scarcity risks are also accelerated by various "nature-managed" and "human-managed" issues, such as climate change, natural disasters, overuse and wastage of water, degradation of water quality, etc. (Bashe et al. 2022). In response to these pressing issues, the concept of sustainable water use (SWU) has emerged as a potential solution (Radelyuk et al. 2023). The SWU entails balancing three factors of sustainability in managing water resources: (i) environmental factors, which means a maximal reduction of water withdrawal and water pollution; (ii) economic factors, which means ensuring access to water for a wide audience while yielding economic benefits through cost savings; and (iii) social factors, which are associated with the equal and responsible access to safe and available water. It is important to find and promote the balance between environmental resilience and socio-economic activities (Tan and Yao 2023). However, limited research has been done dedicated to a comprehensive approach applied in this area. According to Xenarios et al. (2021), environmental dimension has been prioritized by researchers, whereas water professionals have ranked the economic dimension as the most crucial factor of water security.

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Published online: 10 March 2024

The implementation of circular economy (CE) principles in the water sector can be an adequate response for achieving sustainable water use (SWU). The CE is a concept that involves shifting from a linear model of resource use to a circular model with the rooted "4Rs" of reduction, reuse, recycling, and recovery. Water, as one of the most limited resources worldwide, is also under special consideration of the CE principles (Morseletto et al. 2022). The expected outcomes of the implementation include: firstly, alleviation of the stress on freshwater supply by increasing water reuse and adaptation of water-saving technologies; secondly, reducing associated water and energy losses due to ineffective water delivery systems; thirdly, the potential for resource recovery, and decreasing pressure on the extraction of new resources (Zarei 2020); and finally, extra attention being paid to the safe utilization of potentially toxic substances without their direct release into the environment (Voulvoulis 2018). The estimation of annually generated wastewater is 380 billion m^3 worldwide, which is the potentially available resource for reuse. The volume is expected to increase by 24% by 2030 and 51% by 2050. The full nutrient recovery from such volume of wastewater would offset 13.4% of the global demand for these nutrients in agriculture, including 16.6 Tg (Tg—million metric ton) of nitrogen, 3.0 Tg of phosphorus, and 6.3 Tg of potassium. At the energy front, the energy embedded in wastewater would be enough to provide electricity to 158 million households (Qadir et al. 2020).

The successful implementation of the CE approach requires feasible innovative technologies and infrastructure that match the respective and efficient legislation and standards. The efficiency of the approach may decrease if there is a lack of planning and design of methodology for both individual and regional cases, as seen in the case of the EU Water Framework Directive and the failure of some of its initial directives (Voulvoulis et al. 2017). Thus, the implementation should be based on a systematic view and respective investigations (Biswas and Tortajada 2010). It is recommended to investigate the potential for water circularity on a regional scale (Jia et al. 2020), rather than on fragmented sectoral evaluations, which can provide the wrong picture of water resource use and their natural capacity (Nika et al. 2020).

Kazakhstan is a country in Central Asia, which experiences threatening situation in water resources. Kazakhstan exhibits moderate water stress (Wang et al. 2022) and faces known mismanagement problems in the water sector. According to Karatayev et al. (2017), Kazakhstan faces the risk of water scarcity in the future, significant water losses due to obsolete infrastructure of water facilities, and damaging pollution of natural water sources. Moreover, the impact of climate change, increasing water demand, weak institutional approaches, and uncontrolled use of water resources by upstream neighbourhoods only exacerbate the situation. Kazakhstan shows a low score for environmental water security index, indicating a dangerous level of water quality in natural bodies. In 2013, Kazakhstan accepted the national programme for transitioning towards a "Green Economy" with the adaptation of CE principles (President 2013). Water issues have been accepted as one of the priority direction in the implementation of CE in the respected national programme (Kazakhstan 2020).

Industries are significant water consumers and are under special consideration for adoption of the SWU and the CE principles (Klemeš 2012). They are responsible for implementing adaptation measures for concerns related to water availability, quality, access, increased regulation regarding water use, and rising water prices (Lambooy 2011). However, in Kazakhstan, research in this direction has been rare. A search in the Scopus database using the keywords TITLE-ABS-KEY (sustainable AND water AND use AND Kazakhstan AND industry) showed that no research has been carried out covering the entire concept of "Sustainability" and considering all three dimensions of it. Fragmented studies have been conducted in this context, such as the description of water pollution issues caused by industries (Alimbaev et al. 2021), the impact of climate change scenarios on water demand and supply with a focus on basin management (Saimova et al. 2020), the conditions of urban water infrastructure (Zhalmurziyeva et al. 2021), the readiness of the government to develop the water sector as a separate direction (Yessymkhanova et al. 2021), etc. It is particularly interesting to note that there is no study on process integration (especially water integration) in water use issues in Kazakhstan, which is an efficient tool for implementing the CE principles into industrial processes (Klemeš et al. 2018).

The implementation of the CE and establishing the goal to achieve the SWU seems to be an emerging initiative. However, this transition faces many issues, such as the readiness of the stakeholders to adapt new technologies and practices, driven by increasingly stringent regulations, informed by breakthrough science, compelled to respond to climate change impacts and urbanization, and opaque market conditions (IWA 2016). To understand how to apply and adopt roadmaps of the circular economy in the water sector, there is a need to assess the perspectives and potential obstacles in the water sector under the particular conditions of a particular region. The SWOT analysis is a commonly used tool to perform such investigations. It allows for an audit and analysis of the overall strategic position of a business and its environment by identifying its strengths, weaknesses, opportunities, and threats (Xiao et al. 2020). "Strengths" can be defined as characteristics that give advantages to achieve established targets over others, while "Weaknesses" are qualities that hinder it from achieving its full potential. "Opportunities" suggest elements in the environment that the project could exploit to its advantage, while "Threats" refer to elements in the environment that could cause trouble for the successful implementation. Initially applied to economic research, the SWOT analysis has been extended to various research fields, including holistic assessment of the CE in the water sector. For example, it has been applied to studies on the willingness of residents to participate in the circular economy (Hao et al. 2020); the readiness of water utilities for transition towards the CE (Dimova et al. 2022); the analysis of barriers and opportunities for reclaimed wastewater use in agriculture (Mesa-Pérez and Berbel 2020); the development and selection of sustainable water use and water resources sustainable utilization strategies (Gao et al. 2017); and the involvement of the scientific community in the potential application of constructed wetlands within the CE paradigm (Masi et al. 2018).

This study focuses on conducting tailor-made research on the circular economy in the water sector in developing countries like Kazakhstan. The focus is paid to a specific industrial region of Kazakhstan, with a particular emphasis on potential implementation of the sustainable water use in the industries in this area. The objective is to analyse the current state of the water management system employed by different water users in the Pavlodar region and to identify the primary factors that positively or negatively impact the system in the context of the circular economy. The research aims to identify these factors and to provide a comprehensive analysis for decision-making in adopting the CE in the studied region.

Methodology

Research flow and methods

This work was performed following five stages: (i) identifying stakeholders in a selected region for interviewing and developing questionnaires for participants; (ii) field and business visits and semi-structured interviewing "on place" with the selected stakeholders; (iii) extraction and arranging of the SWOT factors based on the carried-out interviews; (iv) distributing the questionnaire with the identified SWOT factors among the stakeholders for quantitative evaluation using a Likert scale and the pairwise comparison between factors inside each group; and (v) analysis of the obtained results by the descriptive statistics and the analytic hierarchy process (AHP) tools.

The subjects for interviewing and dissemination of the developed questionnaire were: (i) key engineers responsible for water supply and water use at the industries; (ii) representatives of the government, including municipality employee; (iii) representatives from water supply and water disposal operating companies; and (iv) representatives from academia who provide training for the employee in the water use sector in industries and researchers in the related academic field. A plan to perform the unstructured interviews in an in-depth way was to identify the weaknesses and opportunities in the sectoral water management systems, to understand the willingness of stakeholders to accept and implement the principles of the rational and sustainable water use. Examples of the questions for interviewing included, but not limited to: conditions of infrastructure such as the pipelines and treatment units, statistics of water losses due to damages, opinions about water tariffs, access to efficient water-saving techniques, evaluation of the staff competencies, the existence of water-saving potential in the selected sectors, perspectives towards implementation of nature-based solutions and the CE principles, drawbacks and advantages of the current water institutes, etc.

Both the interviews and the questionnaires conformed to the principles of privacy and integrity. The respondents were guaranteed confidentiality of their names and positions. Any obtained information was supposed to be used for analytical and research purposes only and did not aim to compromise any organizations or individuals (Lancaster 2017).

After identification of the SWOT factors, the stakeholders were suggested to assess the compliance of suggested indicators to selected criteria using a Likert scale (Zhalmurziyeva et al. 2021). This assessment aimed to evaluate the state-of-the-art of the influence of the factors on the water management systems. The evaluation process was based on a 5-point scale (1—not significant, 5—highly significant) in which the experts were able to give weight to the indicators based on their level of conformity to the targeted requests.

AHP was initially introduced by Saaty (1987) and has been widely applied for providing information about the relative importance of the identified factors including water management (e.g., Dhakal et al. 2021; Ruiz-Villaverde et al. 2013; Chitsaz and Azarnivand 2017; Pagano et al. 2021; Goyal and Kumar 2021). The pairwise comparison and building the respective matrices before applying the AHP were carried out in pairs for each criterion and alternative to assess a nine-point scale for expressing opinions as shown in Table 1 (Razak et al. 2022).

The resulting ranking can be shown in the form of a matrix of weights, where the designated relative weight is keyed into the matrix as an element a_{ij} (element of row i, column j), and its reciprocal ($1/a_{ij}$) is then designated as element a_{ji}. All values for a_{ij} where $i=j$ are 1:

$$A = \left(a_{ij}\right) = \begin{bmatrix} 1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & 1 & \cdots & w_2/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \cdots & 1 \end{bmatrix}. \quad (1)$$

Table 1 Scale for pairwise comparison

Score value	Definition
1	Two elements are equally important
3	One element is slightly more important than the other
5	One element is more important than the other
7	One element is more essential than the other
9	One element is more important than the other elements
2, 4, 6, 8	A value between adjacent considerations
1/3, 1/5, 1/7, 1/9	Reciprocal for inverse comparison

Here, rows specify weight ratios of individual factors, and all $a_{ij} > 0$. Multiplying matrix A by the transpose of the vector of weights (say matrix W) gives:

$$AW = NW = \lambda_{\max} W, \tag{2}$$

where N is the number of rows and columns, $W = (W1, W2,..., Wn)$, and λ_{max} is the largest eigenfactor. A consistency test is then conducted, whereby if the matrix is consistent, then $\lambda_{max} = N$. However, if the responses are inconsistent, then $\lambda_{max} \neq N$. Thus, matrix A must be examined for consistency using:

$$CI = \frac{\left(\lambda_{\max} - N\right)}{N - 1}, \tag{3}$$

$$CR = 100\left(\frac{\mathrm{CI}}{\mathrm{ACI}}\right). \tag{4}$$

To arrive at index values which are independent of matrix size, *CI* values need to be converted into *CR* values. This is done by making use of the average consistency index (*ACI*) of randomly generated comparisons (Karatayev et al. 2016).

Study area

This study focuses on the Pavlodar region, which is one of the largest industrial centres in Kazakhstan. Metallurgical, chemical, and petrochemical industrial activities remain a major impact on water resources in the region (Radelyuk et al. 2021a). Therefore, special attention should be paid to the water use processes by huge industrial clusters. According to national statistics (Bulletin of National Statistics 2022), over 53.5 million m^3 of water has been supplied to industry in the main city, out of a total of 78.5 million m^3. At the same time, a 15.7% water loss has been registered. The manufacturing, energy, and agricultural sectors have been listed as top water consumers. Also, around 31 million m^3 wastewater has been received by wastewater treatment stations from the whole city and almost all of it has been released into nature after treatment.

The region heavily relies on the Irtysh River as the major water source. The largest river in Kazakhstan, it plays a significant role in social, economic, industrial, energy generation, and irrigation activities. The state of the hydrological budget of the river can be classified as stable in the medium-term period, while contrary processes exist in the basin, such as a projected increase in water consumption in upstream and a higher rate of evapotranspiration, and slowly, but permanently, increased snowmelt and precipitation rate (Radelyuk et al. 2022).

Spatial boundaries of the project were defined by the main water users connected to the centralized systems of water supply and/or wastewater discharge. The following key stakeholders for providing the first-hand information and data were selected: municipalities, water utility companies, oil and gas refining companies (including one of three oil refineries in Kazakhstan), energy utility companies, metallurgy enterprises (including the only aluminium smelter in Kazakhstan and the only enterprise in Kazakhstan to produce alumina and bauxite), and relevant governmental representatives. In total, 16 relevant stakeholders were identified, of which 15 participated in the study. Figure 1 represents the schematic location of all the selected and participating stakeholders responsible for water supply, use, distribution, and disposal. The first part of the interview was conducted during September and December 2022, and the second part of the questionnaire distribution and filling was performed from January to March 2023. Table 2 lists all the stakeholders available in the region.

Results and discussion

Identification of the SWOT factors

The identification of the relevant SWOT factors was based on the detailed semi-structure long interviews with seven stakeholders: five from industry, one from a water supply company, and one from a governmental body. Also, preliminary literature review, official documentation survey, and discussion with the colleagues contributed to the identification of the SWOT factors and development of the questionnaire was carried out.

The SWOT–Likert and the SWOT–AHP analyses were based on the responses from 15 stakeholders: 3 from academia, 6 from industries, 3 from water supply companies, and 3 from the governmental bodies. The factors identified and extracted during the interviews were grouped in the respective SWOT factors, which can be found in Table 3. The average value of consistency ratio in the SWOT–AHP analysis was 0.14, which was close to the recommended

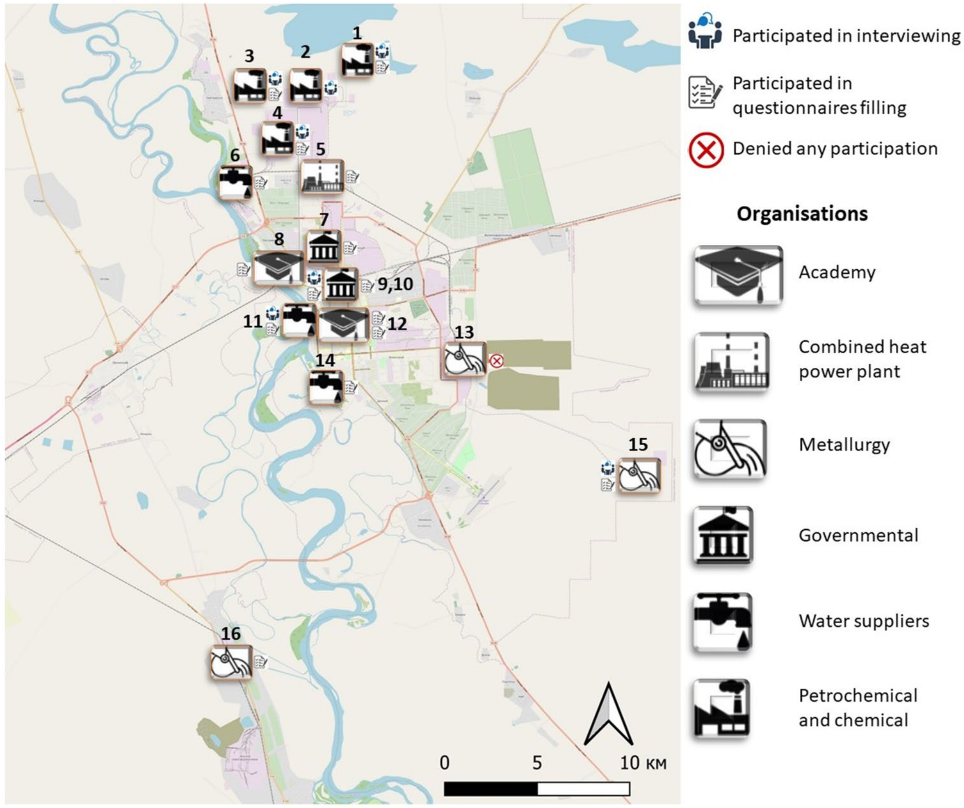


Fig. 1 Map of the study area

Table 2 The list of stakeholders

#	Name	Sector
Industries		
1	"UPNK-PV" LLP	Petrochemical
2	"Caustic" JSC	Chemical
3	"Neftekhim LTD" LLP	Petrochemical
4	"POCR" LLP	Oil refining
5	CHP-3 (on behalf of "PAVLODARENERGO" JSC)	Thermal power plant
13	"Aluminium of Kazakhstan" JSC	Metallurgy
15	"Kazakhstan Aluminium Smelter" JSC	Metallurgy
16	Aksu Ferroalloys Plant (on behalf of JSC TNC "Kazchrome")	Metallurgy
Water utilities		
6	LLP "Pavlodar-Vodokanal Severnyj"	Water treatment and supply
11	RSE "Kazvodkhoz" of the Committee on Water Resources of the Ministry of Ecology, Geology and Natural Resources of the Republic of Kazakhstan (Pavlodar branch)	Water treatment and supply
12	LLP "Pavlodar Vodokanal"	Water treatment, supply, and disposal
Governmental bodies		
7	Committee for Environmental Regulation and Control of the Ministry of Ecology, Geology and Natural Resources of the Republic of Kazakhstan (Pavlodar branch)	Ministries
9	Department of Subsoil Use, Environment and Water Resources of Pavlodar Region	Municipality
10	Department of Energy and Housing and Utilities of Pavlodar region	Municipality
Academy		
8	NGO Ecom	Non-governmental
12	Toraighyrov University	Educational

Table 3 Identified SWOT factors (alphabetically)

Strengths	
(S1)	Availability of water infrastructure
(S2)	Availability of water resources in the region
(S3)	Existence of flowmeter networks for efficient water consumption metering
(S4)	Existence of regulatory standards and legislative framework
(S5)	Influence of government policies on the transition to water-saving technologies and emissions reduction
(S6)	Presence of the circulating water supply systems
Weaknesses	
(W1)	Impact of the COVID-19 pandemic
(W2)	Lack of research-based solutions\research in the water use sectors
(W3)	Lack of competencies with employee on places\lack of employee
(W4)	Poor\obsolete conditions of the water infrastructure
(W5)	Significant water losses
(W6)	The current tariffs of water use
Opportunities	
(O1)	Enterprises' plans for transition to advanced methods waste-\reused waters
(O2)	Implementation of infrastructure projects (major repairs of existing and building of new infrastructure)
(O3)	Large volume of generated treated wastewater, which are potentially eligible for reuse
(O4)	Opportunities for regeneration of associated resources from wastewater (energy, phosphorus, etc.)
(O5)	Potential for expanding of water saving by development and implementation of water reuse schemes
Threats	
(T1)	Climate change
(T2)	Contamination of water resources
(T3)	Corruption
(T4)	Increase in water consumption
(T5)	Influence of associated costs on modernization
(T6)	Influence of external political factors and force majeure
(T7)	Lack of environmental awareness and related specific knowledge

value of 0.1 (Finan and Hurley 1997). However, the relevance of this parameter has been argued because the pairwise comparisons are based on subjective opinions of the respondents (Gómez-Limón and Atance 2004).

The association of the identified factors with the sustainability dimensions has shown following interconnections (Fig. 2). The "Strengths" have been distributed along all dimensions, which is a positive sign for meeting the criteria of sustainability. Specifically, half of the strengths (S1, S3, S6) were related to economic factors, indicating ongoing processes towards water-saving actions by the stakeholders. All three factors focused on the technological aspects and readiness of enterprises to enhance perspectives of water reuse and decreased water withdrawal. However, the even distribution of "Weaknesses" among the social and economic dimensions considered that this transition has reached its capacity. This group of economic factors (W4, W5, W6) has highlighted the disadvantages of the system, which creates obstacles to developing the steps needed to achieve the goals established by the government. Social weaknesses (W1, W2, W3) depended mainly on external factors rather than on the industries themselves, but still require attention to be addressed. The factors from the "Opportunities" group have been disseminated among the environmental and economic dimensions. The economic factors (O1, O2) reflected the existing weaknesses and proposed ways to cope with them. In case the opportunities are taken seriously and applied intensively, they will directly reflect a decrease in environmental burdens, as reflected in the environmental factors (O3, O4, O5). The existing and potential "Threats" occurred at all levels, with varying scores of importance, indicating the complexity of the situation in its current conditions. The threats were independent of each other, making it difficult to mitigate them and increasing the number of stakeholders involved in achieving the established goals.

SWOT–Likert and SWOT–AHP analyses

This section presents the outcomes of the responses to the questionnaire, which was distributed among stakeholders and consisted of two parts. The first part of the questionnaire

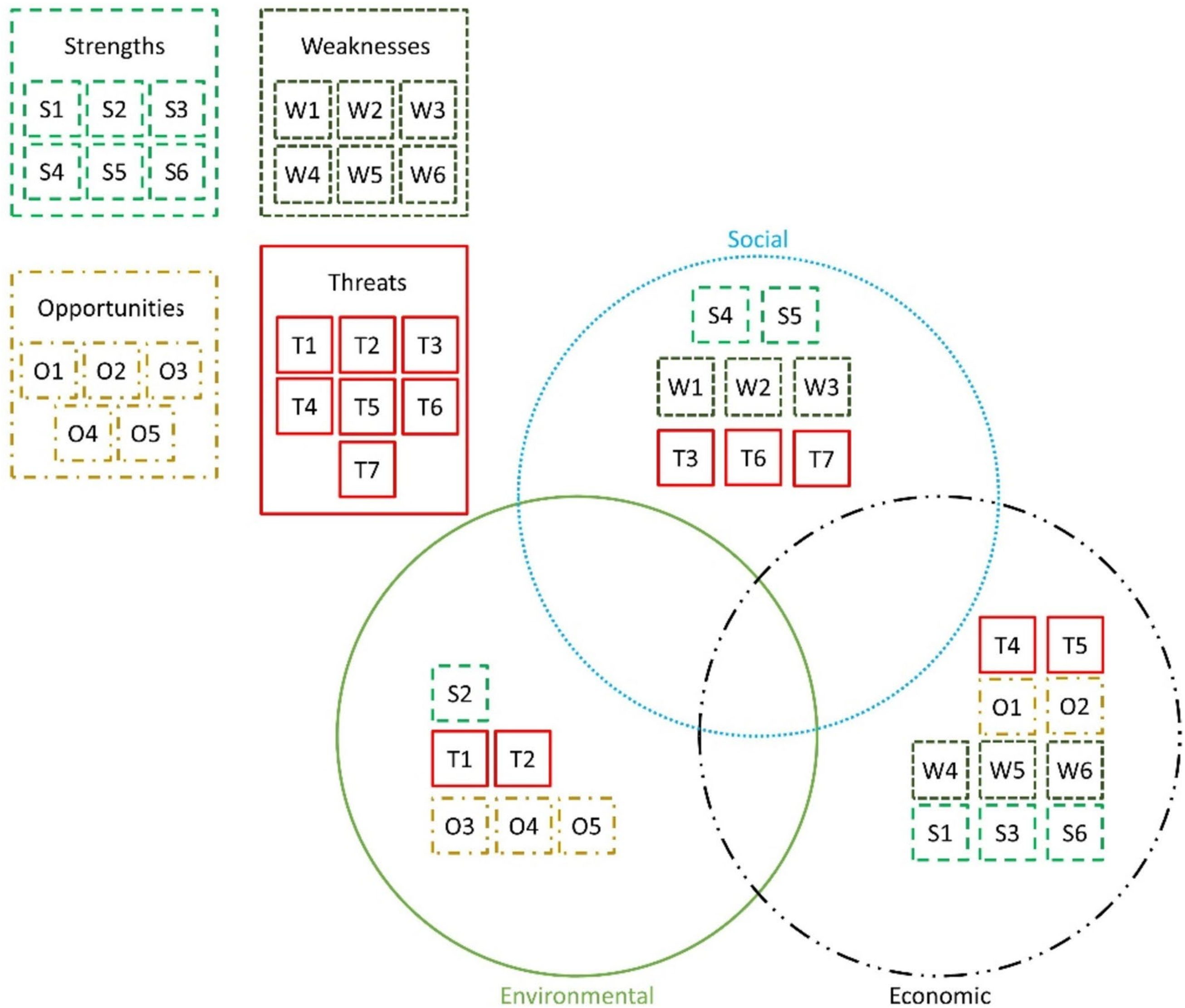


Fig. 2 The association of the identified SWOT factors with the sustainability dimensions

was designed to assess the state of the art of the identified SWOT factors using Likert scale. The second part was to understand the priorities of the factors according to the stakeholders' opinion in the context of their consideration of circular economy.

Strengths

The respondents were requested to respond to the following instruction: "In your opinion, evaluate the level of implementation of the following factors from the "Strengths" group in the water management system in your organization or in the industrial sector in the region nowadays (on a scale from 1 to 5, where 1—"absolutely not implemented" and 5—"in active use")."

The results of this evaluation are presented in Fig. 3. The overall average scores reflected relatively good status of implementation of all the factors (approximately 4.1). The distribution of the scores among stakeholders showed that the industries positively self-evaluate themselves, which is reflected in their high scores. Water suppliers responded with below average scores, with the lowest scores for all the factors compared to other stakeholders, and reported that some of the factors were not implemented in their water management systems. The factor S1 "Availability of water infrastructure" gained the highest average score (4.6), which was evaluated equally high among the representatives from the industries, water suppliers, and governmental bodies. The factor S2 "Availability of water resources in the region" (average score 4.3) received equally high scores among the representatives of the industry and academia. However,

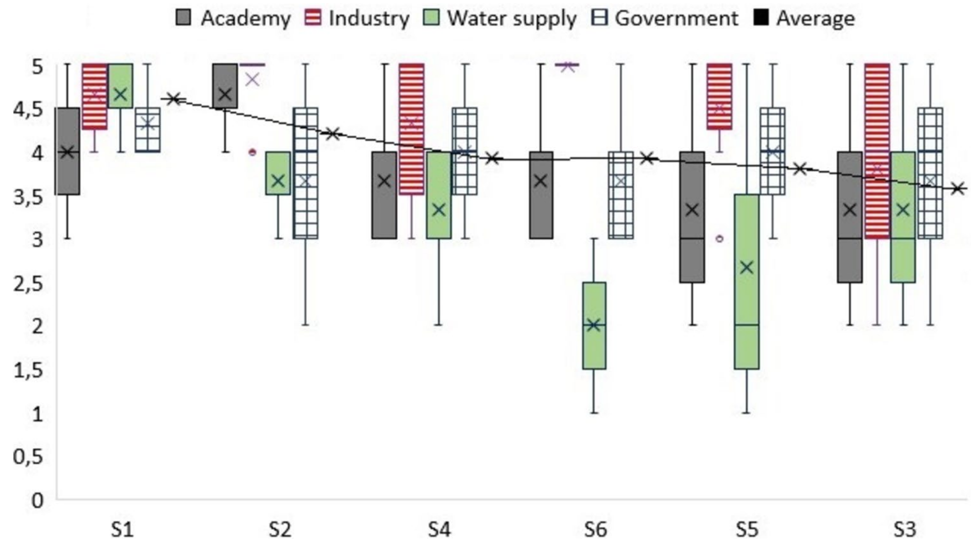


Fig. 3 The level of implementation of the “Strengths” factors according to Likert scale

water suppliers and the governmental organizations did not rank this factor with the top scores. The factors S4 “Existence of regulatory standards and legislative framework” and S6 “Presence of the circulating water supply systems” received equal average scores (4.0). S4 was equally distributed among all stakeholders, which reflects the common opinion about the efficiency of the existing water legislative regulation with its advantages and disadvantages. S6 was positively rated by the industries with the highest possible scores, as they are the target group to evaluate such factor. The factor S5 “Influence of government policies on the transition to water-saving technologies and emissions reduction” gained an average score of 3.9. The high level of implementation of this factor according to the industries can be explained by forthcoming changes in the governmental policy, which aims to encourage the transition towards the environmental resilience of the industries as the first priority. The factor S3 gained the lowest score (3.6), as it has been accepted by all the respondents that so far the industries are poorly equipped with water consumption measuring facilities, mainly at the inlet and outlet points. This creates obstacles for monitoring the water use processes and associated water losses, and seeking suitable water-saving solutions.

The respondents were requested to respond to the following instruction in the second part of the questionnaire: “Please, compare in pairs the importance of the factors from the “Strengths” group in the context of implementation of the principles of water conservation and the "Circular Economy" in your organization or in the industrial sector in the region”. The average scores of the parameters among all stakeholders were evenly distributed, but specific groups of respondents prioritized different factors (Fig. 4). Interviewees from the industries evaluated the factor S3 “Existence of flowmeter networks for efficient water consumption metering”, as the most important for implementation, despite being considered the weakest factor in the previous part of the questionnaire. Only a few enterprises have installed comprehensive water flowmeter systems to monitor and identify water losses.

The water suppliers preferred factor S6 “Presence of the circulating water supply systems”, as the most important. It can be explained by their role and possibilities to measure the amount of supplied water, which is under the opportunities of potential saving. Surprisingly, this factor has the lowest score in the responses from the industries. It can be partly explained by the fact that several enterprises have reported that up to 60% of processed water had already been reused after the preliminary treatment. However, almost all the reused water had been sent to cooling towers and released via evaporation.

Academia and non-governmental organizations rated the factor S5 “Influence of government policies on the transition to water-saving technologies and emissions reduction” as the most important. The government has made efforts to establish policies and legal frameworks for the transition to a green economy, but currently lacks mechanisms like financial incentives or promotional tools to facilitate the introduction of green technologies in all industry branches (UNECE 2019). The most recent priority document in this factor is the newly updated version of the Ecological Code, which claims and promotes the use of Best Available Techniques (BAT) as the core driver to improve the environmental conditions in the mid-term perspective and shift towards the resources use optimization in the long term (Kazakhstan 2021a). The version of the Code states that new rules will be put in place in 2025 to give the enterprises time to adopt new requirements. Most of the interviewed industries are listed in the list of TOP-50 polluters among Kazakhstan and obliged to implement BAT in the forefront (Government 2022). The idea to base the main regulatory

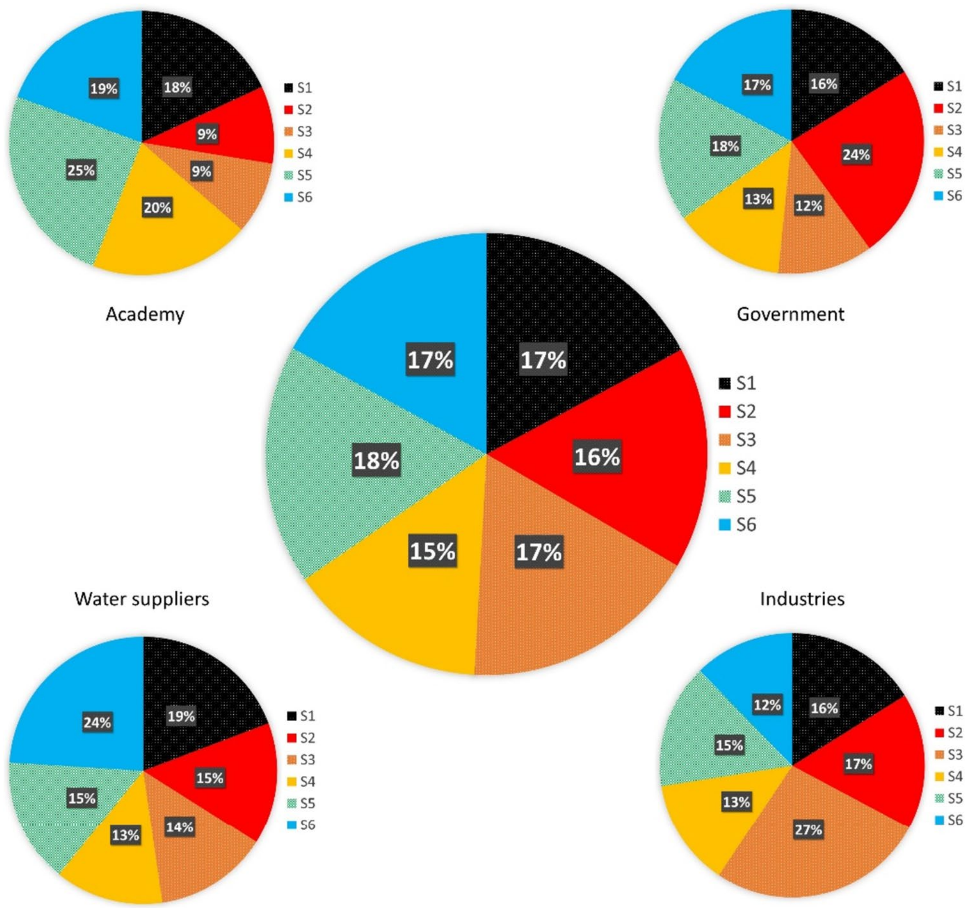


Fig. 4 The distribution of the importance of the "Strengths" factors according to AHP

decisions on the usage of the BAT raises two types of concerns in the Kazakhstani context. Firstly, there is a questionable decision that the enterprises implemented BAT will be exempt from any environmental-related payments (Kazakhstan 2021b). Secondly, new BAT Guidelines will be developed for every sector of the industry in Kazakhstan. The developers should ensure that the Guidelines contain the list of the most advanced treatment techniques, which will be efficiently implemented (Radelyuk et al. 2023).

Despite the fact that the region is located near the largest river in Kazakhstan, the factor S2 "Availability of water resources in the region" has been ranked with lower importance by all stakeholders, except governmental bodies, under the context of the transition to the circular economy in water sectors. This may indicate that stakeholders understand that water availability is not as crucial as its efficient usage under the CE principles.

The remaining factors S4 "Existence of regulatory standards and legislative framework" and S1 "Availability of water infrastructure" have been mentioned and highlighted during the interviews. S4 has been reflected by the fact that industrial enterprises already have strong management system, and special attention should be paid to the implementation of the undeveloped factors. This framework regulates water use processes for each unit including water supply and water discharge. These established standards are regularly reviewed, typically every 5 years, and revised according to the updated technical conditions of the enterprises and government requirements.

Weaknesses

The interviewees were asked to respond to the following instruction in the first part of the questionnaire: "In your opinion, evaluate the level of influence of the following factors from the "Weaknesses" group in the water management system in your organization or in the industrial sector in the region nowadays (on a scale from 1 to 5, where 1—"does not have any impact" and 5—"has a direct influence")."

The results in Fig. 5 show that water suppliers and governmental bodies consider the identified weaknesses to have a higher impact compared to the opinions from the industries. The representatives from academia tend to give higher scores to the identified "Weaknesses" compared to other stakeholders. The factor W6 "The current tariffs of water use" received the highest average score (3.5), indicating the highest impact on the water management system. The water

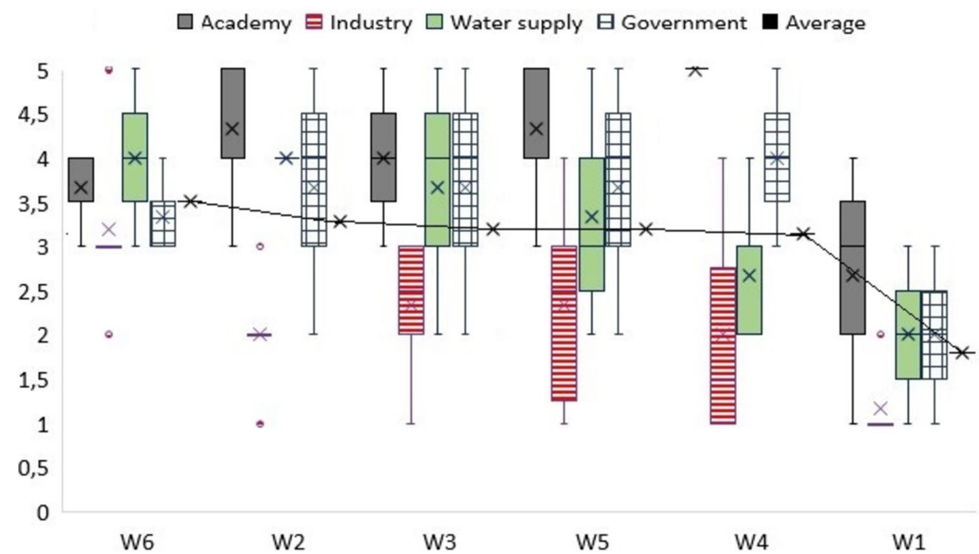


Fig. 5 The level of implementation of the "Weaknesses" factors according to Likert scale

suppliers assigned the highest score to this factor comparing with other stakeholders, reflecting the significant impact of water prices on their operation. The factors W2, W3, W5, and W4 were graded with approximately the same score (3.0), reflecting their not critical influence on the water management in the region. However, the distribution of answers differs among stakeholders. There is no unified opinion for the score for factor W2 "Lack of research-based solutions/research in the water use sectors" among stakeholders. The water suppliers are united in the opinion that this factor is lacking in their field and highly demanded implementation. The representatives from the industries scored this factor between 1 and 3, which reflects low interest in this direction. The factor W3 "Lack of competencies with employee on places/Lack of employee" showed the same tendency as W2. The governmental bodies unanimously agreed that the factor W4 "Poor/obsolete conditions of the water infrastructure" has the highest influence on the water management in the region, while the industries graded the parameter with the broad variety of scores from 1 to 4 with an average score of 2.0. The factors W2 and W5 "Significant water losses" are the most critical parameters according to the opinions of academia with an average score of 4.0. The lowest grade was given to the factor W1 "Impact of the COVID-19 pandemic" (1.9) with the lowest score from the representatives from industries (1.0).

The following was asked in the questionnaire: "Please compare in pairs the degree of influence of the factors from the "Weaknesses" group in the context of (potential) implementation of the principles of water conservation and the "Circular Economy" in your organization or in the industrial sector in the region". The results are presented in Fig. 6. The factor W4 "Poor/obsolete conditions of the water infrastructure" was evaluated as the most influential factor in the industrial water management systems of the region, with the highest rating from academia and government. This factor can be considered as the weakest factor and the primary obstacle to the CE in the water sector. Representatives from large industries expressed their concern on the conditions of the water infrastructure, particularly pipelines built during the Soviet Era (in 1960s–1970s) requiring renovation which can be a costly procedure and slowly, but permanently replaced. Additionally, tough climatic conditions and the impact of groundwater can also affect the infrastructure and increase corrosion, which leads to frequent incidents and damage to the pipelines. Representatives from the industry also reported that their capacity to reuse wastewater was limited by the feasibility of treating them to certain usable quality with the existing conditions of treatment units. The main complication arises from the presence of salts (represented as total dissolved solids) in even the treated wastewater, which can cause corrosion in the pipelines and inhibit the removal of heavily degradable pollutants from wastewater during the treatment process (Bruno et al. 2020).

Representatives from the industries highlighted W6 as the most influential parameter. Respondents admitted to very low tariffication for the water supplied for processing needs (around 0.04–0.10 USD per m^3), which is near the lowest level known worldwide (Vásquez-Lavín et al. 2020). This factor does not act as the driving force for industries towards the CE concept in water sector. The industries do not see profits from the implementation of additional water saving and enhanced water reuse while neglecting environmental awareness. The major investments for improving the water distribution network also come from the governmental subsidies. Therefore, some industries disagree with even these low tariffs and the methodology of their establishing. The UN World Water Development Report on "Valuing Water" has blamed governments worldwide for their failure to establish a clear value on water (UN 2021), as there are

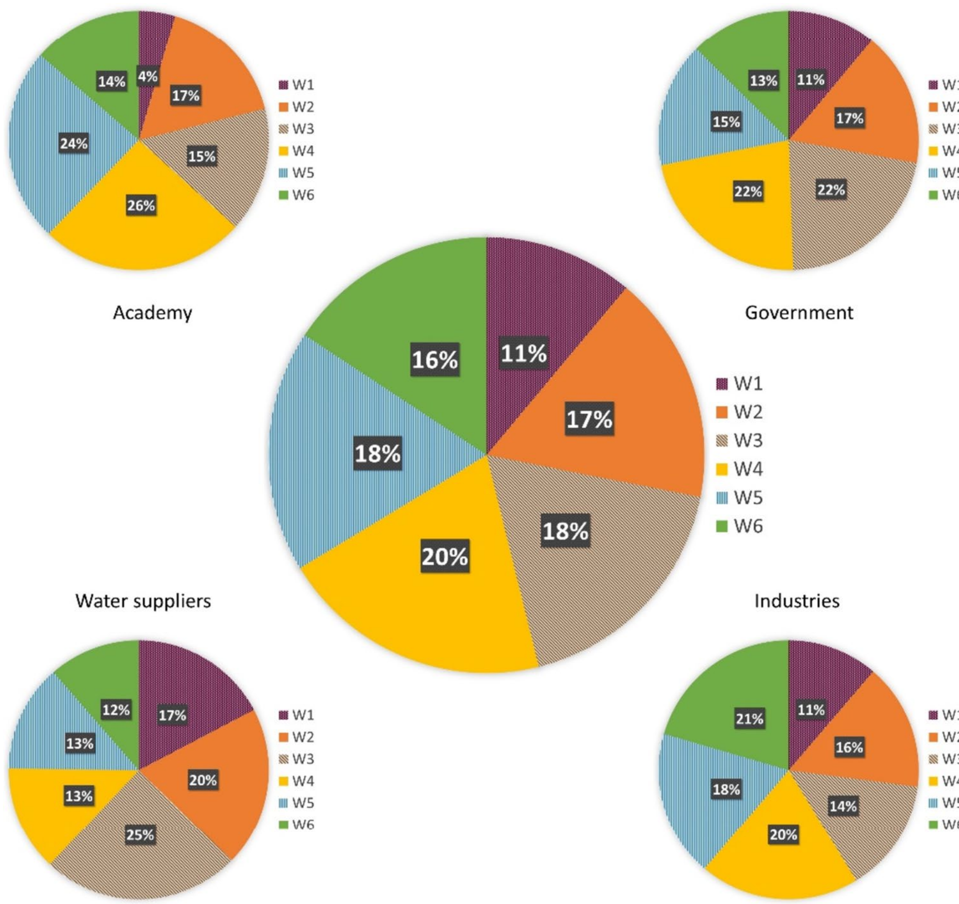


Fig. 6 The distribution of the importance of the "Weaknesses" factors according to AHP

cases of inefficient water use due to slow implementation of water-saving technologies affected by weak tariffication systems (Wan Rosely and Voulvoulis 2022). It has been generally admitted that clean fresh water that can be used without additional cost for treatment is at high risk of shortage. Recent studies have shown that volumetric variable pricing mechanisms are most effective at maximizing water use efficiency (Babamiri et al. 2020) and implementation of the CE approach (Mbavarira and Grimm 2021). Even the announcement of increasing tariffs may have a greater effect on reducing water consumption than the implementation of price increases (Agarwal et al. 2023).

The factor W3 "Lack of competencies with employee on places\Lack of employee" has been emphasized by both water supply companies and governmental bodies. To manage the water network as a complex system, the region should be considered a unified entity when it comes to water sources assessment and water distribution planning. This approach requires highly qualified staff. A lack of capacity building for university faculty, outdated curriculum, limited internship opportunities, and the salaries for water engineers and hydrologists remain low, which causes lack of competent staff (Assaubayeva 2023). This factor is closely followed by the factor W2 "Lack of research-based solutions\research in the water use sectors". Both factors can be considered crucial in terms of institutional transition to the circular economy in the water sector. The lack of an institutional approach and fragmentation in the sector due to multiple government agencies regulating water use at different levels creates obstacles in establishing limits for emissions into the environment or maintaining tariffs for water supply (Karatayev et al. 2017). Researchers have expressed their concerns about the barriers to providing necessary data for suggesting potential solutions, low interest in the research direction in general, and the major focus on daily tasks. For example, a local water supply company showed low interest and declined to participate in the interview, despite participating in filling out the questionnaire.

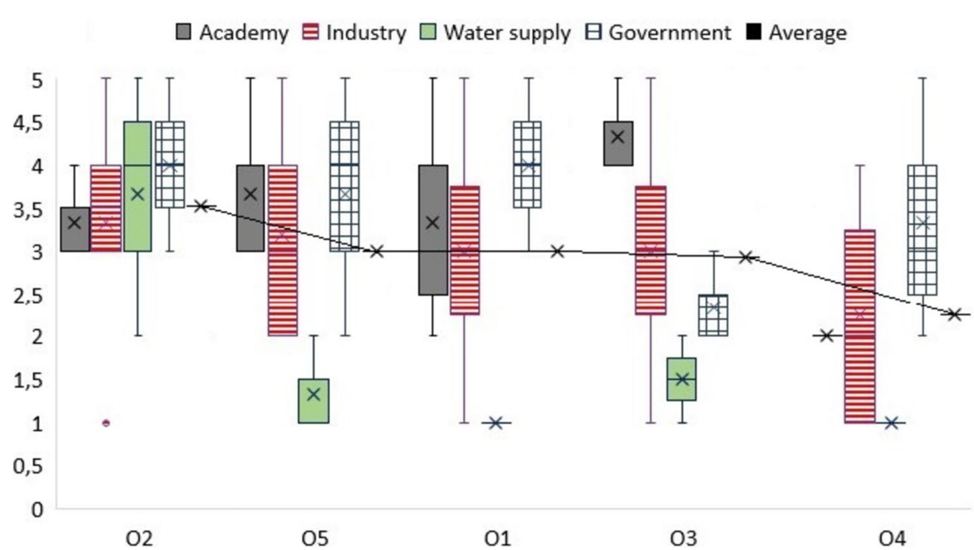
Researchers and non-governmental organizations are highly concerned about factor W5 "Significant water losses", as unbiased assessors of the system of water use. The factor W1 "Impact of the COVID-19 pandemic" has been included in the list as it caused delays in implementing some projects for building and development of water infrastructure, leading to increased costs and waste of time. Such limitations in mobility and industrial activities were not unique to Kazakhstan. The situation worldwide has led to changes in the industrial development patterns, requiring further adaptation and updates to the current water networks (Jia et al. 2021).

Opportunities

The interviewees were requested to respond to the following instruction: "In your opinion, evaluate the perspectives of implementation of the following factors from the "Opportunities" group in the water management system in your organization or in the industrial sector in the region nowadays (on a scale from 1 to 5, where 1—"does not have any perspectives" and 5—"planned to be implemented soon")". The "Opportunities" group was identified as the most underestimated group, and all the identified factors received relatively low average scores, indicating that they are not currently prioritized (Fig. 7). It can be seen from the graph that the water supplier representatives are highly negative about any opportunities except for the most ranked factor O2 "Implementation of infrastructure projects (major repairs of existing and building of new infrastructure)". This factor has been rated as the most promising for implementation in the region by all stakeholders with the average score 3.5. It addresses the urgent need to restore infrastructure and prevent unnecessary water and energy losses, especially according to the opinions from the industries and the governmental bodies. The average score for factors O5 "Potential for expanding of water saving by development and implementation of water reuse schemes", O1 "Enterprises' plans for transition to advanced methods waste-\reused- waters", and O3 "Large volume of generated treated wastewater, which are potentially eligible for reuse" is the same at 3.0, but the perception of the stakeholders differs. Governmental bodies are more positive for the factors O5 and O1, as it was reported that the enterprises have been planning to implement such tools to reduce freshwater withdrawal, and also due to the acceptance of respective national programmes. For example, the national programme "Green Kazakhstan" prescribes reducing the intake of fresh water in the republic by 24% from 5.8 to 4.4 km^3 by 2025 (Government 2021). The representatives from the academia are confident that there is potential for the implementation of the factor O3. However, the strategy for its implementation appears to be challenging and requires specific competencies and technical possibilities. The average score for the lowest-ranked factor O4 "Opportunities for regeneration of associated resources from wastewater (energy, phosphorus, etc.)" is 2.4. Surprisingly, the water supplier representatives have evaluated this factor as not promising, despite the fact that they are operators of wastewater treatment plants and targeted companies for the implementation of such incentives.

The following was asked for filling the questionnaire in the second part: "Please compare in pairs the importance of the factors from the "Opportunities" group in the context of implementation of the principles of water conservation and the "Circular Economy" in your organization or in the industrial sector in the region". The factors were evenly distributed in most responses (Fig. 8). However, the factor O2 "Implementation of infrastructure projects (major repairs of existing and building of new infrastructure)" received the highest score among the five factors. Renovation and maintenance of networks was rated as the highest impact factor in the context of water demand policies, which indicates the high importance of this parameter (Stavenhagen et al. 2018). This issue has been recognized as a challenge even in developed countries to meet the requirements for a sustainable status according to the respective benchmarks (Najar and Persson 2023). During the interviews, most of the industrial enterprises have reported plans to repair pipelines, pumps, and already existing infrastructure, emphasizing the importance of enhancing the efficiency of the

Fig. 7 The level of implementation of the "Opportunities" factors according to Likert scale



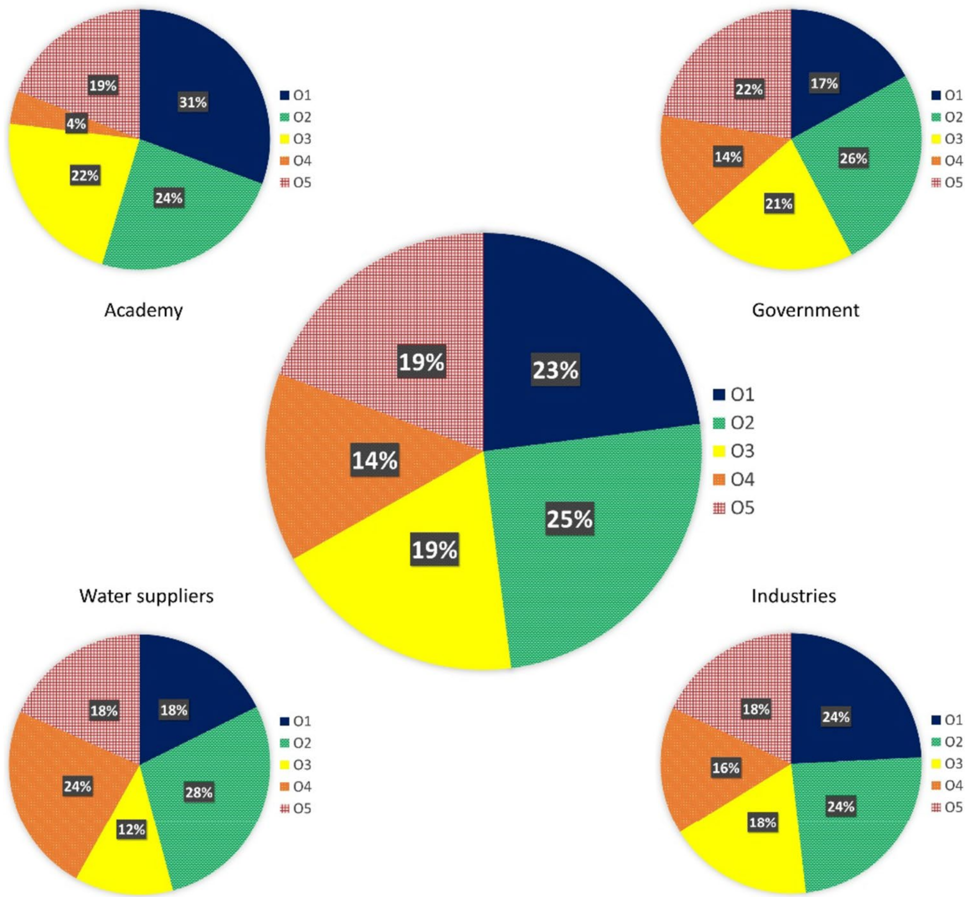


Fig. 8 The distribution of the importance of the "Opportunities" factors according to AHP

existing infrastructure for water saving. This factor is followed by O1 "Enterprises' plans for transition to advanced methods waste-\reused waters" with the particular plans to shift towards advanced wastewater treatment techniques with the specified goal to increase water reuse. An interesting situation has arisen in the context of the factors O3 and O5. Some enterprises have reported that they have reused all possible treated wastewater from technological units within the plant and still have capacity to reuse more. Conversely, other factories generate large volumes of cleaned wastewater that are ready for reuse, but do not have such high demand for water consumption. The factor O4 is barely visible to industries and governmental bodies and has only been rated as important for future potential implementation by water supply companies.

Threats

The first part of the questionnaire dedicated to the group of "Threats" contained the following instruction: "In your opinion, evaluate the potential and or existing level of influence of the following factors from the "Threats" group in the water management system in your organization or in the industrial sector in the region nowadays (on a scale from 1 to 5, where 1—"does not have any impact" and 5—"has a direct influence")". Representatives from academia and the government tended to assign higher scores compared to industries and water suppliers (Fig. 9). The most influential factor was the factor T5 "Influence of associated costs on modernization". This factor is followed by the factor T4 "Increase in water consumption", which is a forecasted threat to water resource management in the region. It is worth mentioning that there was a wide variation in the obtained scores for factors T7 "Lack of environmental awareness and related specific knowledge" (average score 3.5) and T3 "Corruption" (average score 2.8). The least impactful identified factors were T6 "Influence of external political factors and force majeure" and T1 "Climate change" (average scores 2.5). These factors have not been considered crucial in the context of sustainable water use in the region.

The respondents were suggested to respond to the instruction in the second part of the questionnaire: "Please compare in pairs the degree of influence of the factors from the "Threats" group in the context of (potential) implementation of the principles of water conservation and the "Circular Economy" in your organization or in the industrial sector in the region". The results are shown in Fig. 10. The factors T2 and T5 were ranked as the most influential

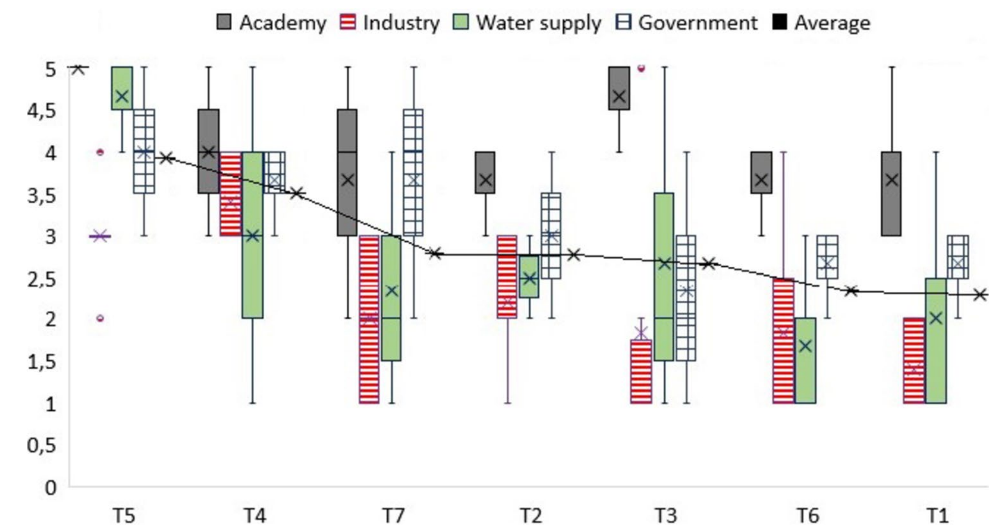


Fig. 9 The level of implementation of the "Threats" factors according to Likert scale

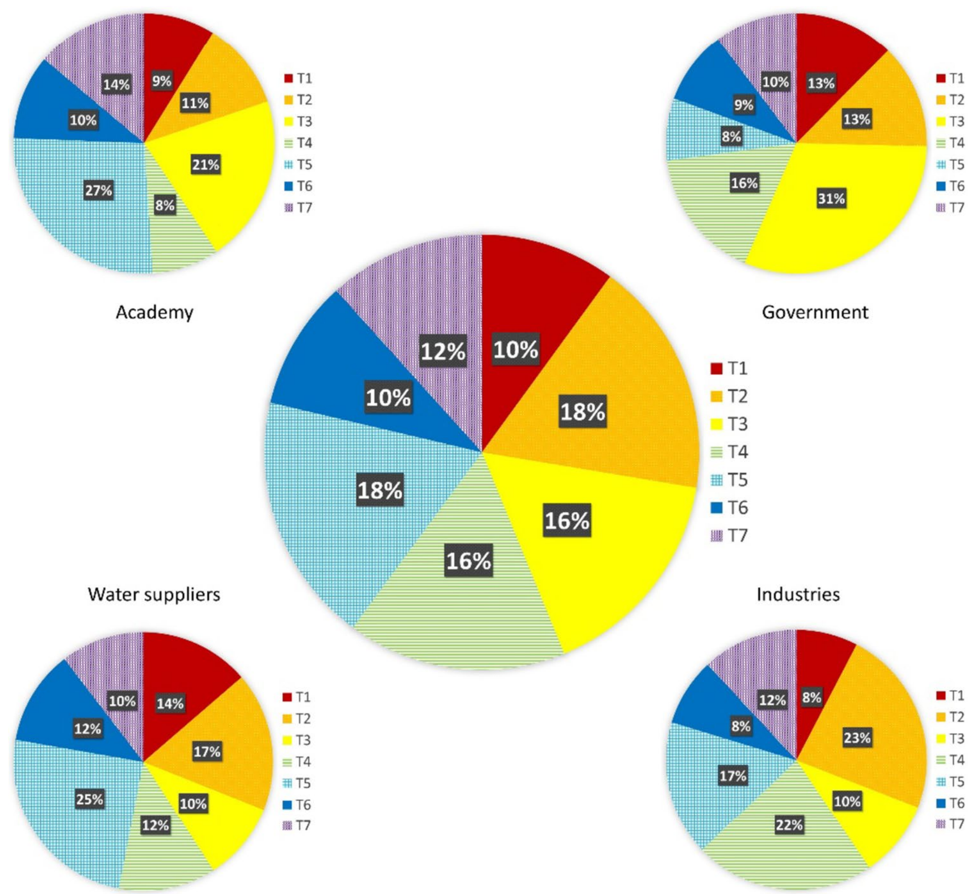


Fig. 10 The distribution of the importance of the "Threats" factors according to AHP

parameters in the group. The factor T2 "Contamination of water resources" was accepted as one of the most influential by almost all of the respondents, including the industries. Environmental threats by industries in Kazakhstan have already been presented in detail in Radelyuk et al. (2021b). The government only plans to ask industries to implement automated systems for monitoring emissions into the environment during industrial environmental control. However, even the updated version of the law has shortcomings. According to it, if an industrial enterprise discharges wastewater into evaporation ponds, they are exempt from such requirements (Minister of Ecology, Geology and Natural

Resources 2021). This situation creates possibilities for continuation of environmental pollution.

The problems caused can be fixed by installing modern equipment, while the cost for the installation is usually very high, which is reflected by the significance of the factor T5 “Influence of associated costs on modernization”. The factors T3 and T4 were also rated with high significance. The importance of T4 “Increase in water consumption” can be explained by the forecasted population increase in the Irtysh River basin and associated pressure on the water resources of the region. The threat of the factor T3 “Corruption” has been claimed by both internal and external assessors. High economic growth in Kazakhstan has come with a considerable environmental cost, as corruption has been widely prevalent with the influence of big companies on environmental policies and following environmental damage (Nugumanova et al. 2017).

Other parameters have also been pointed out by respondents and accepted for their presence, but were not considered by all the interviewees. Some respondents raised concern about the factor T7 “Lack of environmental awareness and related specific knowledge” due to consumer culture in Kazakhstani society and the insufficient environmental education on all business levels (Kumar 2022). Respondents have also admitted the impact of the COVID-19 pandemic, lockdown, and the Russian invasion in Ukraine, which affected the existing supply chains and resulted in sanctions. Interestingly, the factor of climate change is barely considered as a driving force towards transitioning to the circular economy in industrial water use in the region.

To face and mitigate such potential challenges and threats, the identified factors can be divided into three categories based on temporal distribution, namely short-term, long-term, and unpredictable threats. The responses to these factors depend on various circumstances, including willingness of stakeholders to eliminate corruption risks in the water sector, invest in water infrastructure despite associated costs, and enhance environmental awareness at all business levels (Perron et al. 2006). Mitigating long-term threats, such as climate change, risks of shortage in water availability, and expected increases in water consumption, rely heavily on stakeholders’ understanding of these risks and should be based on reliable trends assessments (Xiao et al. 2021). The third group of unpredictable risks depends on the government’s integrity and is beyond the scope of this paper.

Policy implications of the most rated SWOT factors

Table 4 summarizes all the opinions of the stakeholders in terms of the high importance of the factors. Nowadays, almost all stakeholders rely on the availability of water resources of the region, considering it as the most developed and important strength among others, which can be explained by endowment of the region with the resources. However, these resources are undervalued which is reflected by the respectively low tariffs. Governmental bodies tend to continue relying on such wealth of water in future, despite the clarified movement towards the CE.

While most actors accept the inappropriacy of the current tariffs, only the representatives from the industry put this factor to the top as the most impacting weakness towards the CE. The poor conditions of the infrastructure also raise awareness in both currently and for future implementation. Another issue is the prediction for lacking experts and staff in the water sector, which may affect the efficiency of maintenance and operation of the infrastructure.

Building capacity of the infrastructure by its repair and upgrade (with the special emphasis by the industries for implementation of advanced treatment techniques) is rated as the top opportunity for both the present and further plans.

Major identified threats are T4 “Increase in water consumption” (according to the industries) and T5 “Influence of the cost on the modernization and realization of the projects” (according to other stakeholders). These factors are already experienced and expected to grow in future. Most stakeholders showed their concern that these factors coupled to high level of corruption risks would cause increasing rate of contamination of water resources, also as a significant threat.

Table 5 aims to link the identified top factors to the respective legislative documents, and to show their positive or negative influence on achievement of their aims. All respondents noted that the respective legislative changes positively impact the transition towards the green economy, which is reflected in the presence of the circulating water supply systems and flowmeter networks or plans to implement them (which is reflected in the respective O-factors). Nevertheless, prioritization of the factors using the AHP analysis highlighted weak points in the associated shortcomings in legislation. These may lead to several hazards associated with the high level of water losses and severe water resources pollution, which were reflected in the respective W- and T- factors. This fact may indicate failure of the updated legislation and the silent sabotage by the industries towards active water-saving actions.

Table 4 Summary of the most rated SWOT factors

Stakeholders	Strengths		Weaknesses		Opportunities		Threats	
	Likert scale	AHP	Likert scale	AHP	Likert scale	AHP	Likert scale	AHP
Governmental bodies	S2 (Availability of water resources in the region)	S2 (Availability of water resources in the region)	W4 (Poor\ bsolete conditions of the water infrastructure)	W3 (Lack of competencies with employee on places\ ack of employee) W4 (Poor\obsolete conditions of the water infrastructure)	O2 (Implementation of infrastructure projects (major repairs of existing and building of new infrastructure)	O2 (Implementation of infrastructure projects (major repairs of existing and building of new infrastructure)	T5 (Influence of associated costs on modernization)	T3 (Corruption)
Industries	S1 (Availability of water infrastructure)	S3 (Existence of flowmeter networks for efficient water consumption metering)	W6 (The current tariffs of water use)	W4 (Poor\obsolete conditions of the water infrastructure) W6 (The current tariffs of water use)	O2 (Implementation of infrastructure projects (major repairs of existing and building of new infrastructure)	O2 (Implementation of infrastructure projects (major repairs of existing and building of new infrastructure) O1 (Enterprises' plans for transition to advanced methods waste-\ reused waters)	T4 (Increase in water consumption)	T2 (Contamination of water resources) T4 (Increase in water consumption)
Water suppliers	S2 (Availability of water resources in the region)	S6 (Presence of the circulating water supply systems)	W6 (The current tariffs of water use) W2 (Lack of research-based solutions\ research in the water use sectors)	W3 (Lack of competencies with employee on places\Lack of employee)	O2 (Implementation of infrastructure projects (major repairs of existing and building of new infrastructure)	O2 (Implementation of infrastructure projects (major repairs of existing and building of new infrastructure)	T5 (Influence of associated costs on modernization)	T5 (Influence of associated costs on modernization)
Academia	S2 (Availability of water resources in the region)	S5 (Influence of government policies on the transition to water-saving technologies and emissions reduction)	W4 (Poor \ obsolete conditions of the water infrastructure)	W4 (Poor \ obsolete conditions of the water infrastructure)	O3 (Large volume of generated treated wastewater, which are potentially eligible for reuse)	O1 (Enterprises' plans for transition to advanced methods waste-\ reused waters)	T5 (Influence of associated costs on modernization)	T5 (Influence of associated costs on modernization)

Table 5 The most positively (+) and negatively (–) impacting SWOT factors

Legislative document	Aim of the document	(+) Factors (S–O)	(–) Factors (W–T)
About the Concept for the transition of the Republic of Kazakhstan to a "green economy" (President 2013)	The adaptation of the principles of Circular Economy	S5 (Influence of government policies on the transition to water-saving technologies and emissions reduction)	W2 (Lack of research-based solutions\research in the water use sectors) T4 (Increase in water consumption)
On approval of the Action Plan for the implementation of the Concept for the transition of the Republic of Kazakhstan to a "green economy" for 2021–2030 (Kazakhstan 2020)	Acceptance of water issues as a priority direction in the implementation of the CE in the respected national programme	S3 (Existence of flowmeter networks for efficient water consumption metering) S5 (Influence of government policies on the transition to water-saving technologies and emissions reduction) S6 (Presence of the circulating water supply systems) O2 (Implementation of infrastructure projects (major repairs of existing and building of new infrastructure) O3 (Large volume of generated treated wastewater, which are potentially eligible for reuse)	W2 (Lack of research-based solutions\research in the water use sectors) W3 (Lack of competencies with employee on places\Lack of employee) W4 (Poor\ bsolete conditions of the water infrastructure) T4 (Increase in water consumption) T5 (Influence of associated costs on modernization)
On approval of the national project "Green Kazakhstan" (Government 2021)	Reduction of the intake of fresh water in the republic by 24% from 5.8 to 4.4 km^3 by 2025	S3 (Existence of flowmeter networks for efficient water consumption metering) S5 (Influence of government policies on the transition to water-saving technologies and emissions reduction) S6 (Presence of the circulating water supply systems) O1 (Enterprises' plans for transition to advanced methods waste-\reused- waters) O2 (Implementation of infrastructure projects (major repairs of existing and building of new infrastructure) O3 (Large volume of generated treated wastewater, which are potentially eligible for reuse)	W2 (Lack of research-based solutions\research in the water use sectors) W3 (Lack of competencies with employee on places\l ack of employee) W4 (Poor\obsolete conditions of the water infrastructure) W6 (The current tariffs of water use) T4 (Increase in water consumption) T5 (Influence of associated costs on modernization)
Ecological Code of the Republic of Kazakhstan (Kazakhstan 2021a)	Claim and promotion of Best Available Techniques (BAT) as the core driver to improve the environmental conditions	S5 (Influence of government policies on the transition to water-saving technologies and emissions reduction) S6 (Presence of the circulating water supply systems) O1 (Enterprises' plans for transition to advanced methods waste-\reused waters) O2 (Implementation of infrastructure projects (major repairs of existing and building of new infrastructure) O3 (Large volume of generated treated wastewater, which are potentially eligible for reuse	W4 (Poor\obsolete conditions of the water infrastructure) T3 (Corruption) T5 (Influence of associated costs on modernization)

Table 5 (continued)

Legislative document	Aim of the document	(+) Factors (S–O)	(–) Factors (W–T)
On approval of the Requirements for maintaining an automated system for monitoring emissions into the environment during industrial environmental control (Minister of Ecology, Geology and Natural Resources 2021)	Exemption for industrial enterprises to implement automated systems for monitoring emissions into the environment if they discharge wastewater into evaporation ponds		W4 (Poor \ obsolete conditions of the water infrastructure) T2 (Contamination of water resources) T3 (Corruption) T4 (Increase in water consumption) T5 (Influence of associated costs on modernization)
On approval of the List of TOP-50 largest emitters as of January 1, 2021 (Government 2022)	Obligation for the most emitters to implement the BAT	S3 (Existence of flowmeter networks for efficient water consumption metering) S5 (Influence of government policies on the transition to water-saving technologies and emissions reduction) S6 (Presence of the circulating water supply systems) O1 (Enterprises' plans for transition to advanced methods waste-\reused waters) O2 (Implementation of infrastructure projects (major repairs of existing and building of new infrastructure) O3 (Large volume of generated treated wastewater, which are potentially eligible for reuse)	W2 (Lack of research-based solutions\research in the water use sectors) W4 (Poor \ obsolete conditions of the water infrastructure) T2 (Contamination of water resources) T3 (Corruption) T4 (Increase in water consumption) T5 (Influence of associated costs on modernization)

Conclusions

This research reveals different opinions of the stakeholders in their perception of changes needed to reach the overall implementation of the circular economy in the industrial water sector in developing countries like Kazakhstan. Various water actors in the Pavlodar region identified primary factors that positively or negatively impact the industrial water use. Establishing the common aim: to reduce water intake and to restore the local ecosystems, there is no unified opinion on how to achieve this aim. Existing water infrastructure was recognized by all stakeholders as the major strength nowadays, and one of the most important factors for the implementation the CE in future. Industries wish to improve their monitoring system and put this factor as a priority of the "Strengths" group, while its implementation nowadays was ranked as the weakest factor among all stakeholders. In the "Weaknesses" group, the industries tended to underestimate the identified factors, which was reflected in the significantly low scores given to the factors of that group comparing with other stakeholders. The current water tariffs are significantly low and do not reflect the fair value of water. Thus, there is no incentive drive to shift to advanced water-saving techniques. Poor and obsolete conditions of the water infrastructure have been recognized as the most influential factors in the industrial water management systems of the region in the long term, which is closely related with the potential investment, considering the reasonable water prices. Opportunities to implement the CE principles were barely visible. Stakeholders are mainly focused on the solid plans to repair the existing water infrastructure, rather than adopting advanced ways to reuse water and decrease freshwater withdrawal. Mitigation of existing and potential threats demands political will and respective governmental management in the water sector. Main challenges are to eliminate corruption risks in the water sector, invest in water infrastructure despite the associated costs, and enhance environmental awareness at all business levels.

This research sheds light on the processes lying beyond the visible aspects of water management and identifies the possible ways to overcome the obstacles towards the CE and the SWU in the Pavlodar region in Kazakhstan. Based on the retrospective and cultural context, this research can be extrapolated to the whole country. It is worth mentioning that this research is based on the subjective opinions from water professionals of the region, which can be biased. Therefore, these opinions were confirmed and supported by multiple official reports and generally shared opinions by different representatives in each group of the stakeholders. Further research should be carried out to investigate the possibility of implementing advanced and efficient water-saving techniques into the regional water management system considering the local social and political condition.

Acknowledgements The whole research is dedicated to the memory of Prof Jiří Jaromír Klemeš—the Head of Sustainable Process Integration Laboratory—SPIL, who was the leading researcher in the area of process integration. He passed away in January 2023.

Author contributions I. R.: conceptualization, methodology, investigation, formal analysis, writing—original draft, writing—review and editing. X. J.: conceptualization, formal analysis, writing—review and editing. M. Y.: conceptualization, data curation, resources, writing—review and editing. D. A.: conceptualization, investigation, writing—review and editing.

Funding This research was funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. AP14972725).

Data and materials availability Data sets generated during the current study are available from the corresponding author on reasonable request due to the principles of privacy and integrity of the interviewed stakeholders.

Declarations

Conflict of interest No potential conflict of interest was reported by the authors. The authors have no relevant financial or non-financial interests to disclose.

Ethical approval and consent to participate Not applicable.

Consent to publish All authors have consented to publish this manuscript.

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