sustainability

MDPI

Review

Implementation and Integration of Sustainability in the Water Industry: A Systematic Literature Review

Jorge Alejandro Silva

Escuela Superior de Comercio y Administración Unidad Santo Tomás, Instituto Politécnico Nacional, Mexico City 11350, Mexico; jasilva@ipn.mx; Tel.: +52-55-5729-6000

Abstract: The changing stature of the environment and society, in general, necessitates a shift from the business-as-usual approaches to sustainable frameworks in the water industry. The industry's reliance on conventional methods has created gaps in service delivery and the attainment of Sustainable Development Goals. Sustainable approaches have been implemented but are yet to reap any benefits for the foreseeable future. The flailing nature of the industry has created a need for the integration of sustainable initiatives such as the circular economy and Industry 4.0 technologies. A systematic review was conducted to determine the implementation and integration of sustainability in the water industry. The examination utilized the PRISMA framework to identify the best fit articles for inclusion. A total of 48 articles were identified that explored both the concepts of implementation and integration. The findings indicate that the circular economy initiatives will close the loops through the 6R model. Furthermore, the application of Industry 4.0 technologies such as artificial intelligence, IoT, and big data will increase the efficiency/performance of the industry. The paper has a favorable implication for society and the industry, as it recommends specific tools/interventions for sustainable water management.

Keywords: circular economy; green growth; Industry 4.0; sustainability; water management

Citation: Silva, J.A. Implementation and Integration of Sustainability in the Water Industry: A Systematic Literature Review. *Sustainability* **2022**, *14*, 15919. https://doi.org/10.3390/su142315919

Academic Editor: Alessandra Neri

Received: 29 October 2022
Accepted: 25 November 2022
Published: 29 November 2022

1. Introduction

1.1. Background

Over the past 50 years, global freshwater consumption has quadrupled, with at least 5000 km^3 of fresh water being used annually from the year 2000 [1]. Agriculture is the sector that uses up the most significant portion of the world's water resources, accounting for up to 70% of its use, with industries taking up 20% and households using the remaining 10% [1]. With increased industrialization that has been buoyed by unprecedented technological advancements in recent years, there is a growing need for industrial water. Highly populated countries such as China and India are currently growing their GDPs by high single-digit or double-digit factors, creating concerns that it is only a matter of time before the world experiences strain in freshwater accessibility [2]. At the crux of the cross-cutting clamor for world sustainability is the water industry, a sector that in pivotal to the future of humanity as thriving species living on a healthy planet. Until 2022, water issues were ranked among the top five global risk factors by the World Health Organization and World Economic Forum [3]. In 2018, water was determined to have the highest likelihood of causing a world crisis in the next ten years. If the water industry does not identify, implement, and integrate sustainable approaches to averting an almost probable crisis, humanity and all other organisms face an existential threat.

1.2. Problem Overview and Scope of Work

Some of the current issues that pose an existential threat to humanity include water scarcity, climate change and government regulations [4]. High costs of maintenance and innovation are also a major concern [4]. Water challenges are complicated and interrelated;

thus, they are considered wicked problems [3]. Generally, the wicked problem refers to a complex issue for which there is no simple solution or method since it affects the things society depends upon. They are hinged on social dynamics and must deal with the changing outcomes and behaviors that are normally unforeseen.

While a wide raft of sustainable approaches has been adopted in recent years, the urgency to implement conservation approaches that make use of the technological advancements of recent years has been lacking. The current model of the international water industry involves applying business-as-usual approaches, which are less likely to address the risks presented by the wicked problem. The business-as-usual approaches have created an environment whereby human ambitions exceed the Earth's limits. Presently, technological, economic, and demographic trends have accelerated the modification of the environment, thus undermining sustainability [5]. The approaches have placed human beings at the core of environmental change and modification with their actions impacting the environment including the climate [3]. Initially, the propositions were formulated with the aim of reducing the deleterious effects of human actions and behaviors on the environment. They were designed based on historical observations of the climate to determine supply and demand [6]. Furthermore, statistical analyses and interpretations helped practitioners determine the probability of specific events occurring.

The approaches have been faced with decreasing efficiency due to a myriad of trends and external and internal factors. Currently, the water industry is unable to function as it once did due to the changing nature of the planet. The Earth is confronted with a situation whereby human beings can influence the atmosphere while degrading the biosphere [7]. Climate change, due to human activities such as deforestation and industrial pollution, has in turn, contributed to a decline in the efficiency of the water industry to define supply and demand [4]. Practitioners are currently finding it hard to rely on the stationary assumption with historical data providing inadequate information when planning for climate extremes and variability. The constant changes are exacerbated by a decline in planetary stewardship, which places the water industry at risk if it does not introduce sustainable strategies in its operations.

Practitioners confer that the methods are also unable to sustain the world's water needs in the coming years, with humanity realizing that fresh water is both a fragile and finite resource. Over two thirds of water withdrawals are used in the agricultural industry for rearing livestock and irrigation. Furthermore, power generation and manufacturing come second in the industries that use the most water. The increased water withdrawals and usage will increase the global demand by 55% by the first half of the 21st century [6]. The increased demand is correlated with an influx in global temperatures, contributing to frequent and severe droughts over the next five decades [6]. Failures in the implementation and integration of sustainability in the industry will in the future negatively impact water management [5].

The World Economic Forum additionally highlights that the lack of planetary stewardship has contributed to a surge in demand, which causes a supply gap. There is a 40% supply gap that is correlated with the technological, economic, and demographic trends [3]. The technological and economic trends have exacerbated the gap through the introduction of factories and entities that rely on water for their operations. Furthermore, the economic trend involves organizations setting up shops in urban centers, which contribute to demographic trends such as urbanization. An increase in urbanization is commingled with a surge in demand for freshwater, which is scarce due to the existence of waste in water bodies [6]. The waste is largely generated from economic activities, thus signaling an endless cycle of below-par supply and high demand.

The global population is poised to hit 9.8 billion by 2050, based on the current growth trend of approximately 83 million annually [3]. The growth will be linked with the expansion of cities, which contributes to industrialization and increased water use [4]. The manufacturing, food/beverage, agriculture, and mining industries are likely to be among the thirstiest due to their overreliance on water for their operations [3]. Furthermore, the growing population will merit increased food production, which requires water. Specifically, low- and mid-income nations will witness a shift toward protein diets, thus placing stress on the coastal, agricultural, and freshwater resources.

Based on the preceding wicked problem analysis, it is understood that clean water is essential to human health, the environment, and society in general. The growing populations, climate change, and increasing food demands necessitate the introduction of new sustainable schemes/frameworks in the water industry to balance demand and supply [7]. The sustainable water structures will ensure that the nations/states can be water self-sufficient, ensuring enough water to meet multiple needs ranging from industrial to agricultural and municipal complexes. Considering this, the following review presents an expository analysis on the implementation and integration of sustainability in the water industry.

The previous results on this research topic have both cons and pros. Makropoulos and Butler state that the current frameworks in the water industry are unproven [8]. This implies that the water industry has the potential for additional improvements such as integrating new technologies that will promote sustainable water management. Nevertheless, Makropoulos and Butler fail to mention some of the technological solutions that can be adopted by the water sector [8]. Matias et al. found that productive maintenance has a positive correlation with an improvement in water provision [9]. However, this publication does not mention how this approach can address the gap in the water supply to the ever-growing global population. Abu-Ghunmi, Abu Ghunmi, Kayal and Bino support the adoption of the circular economy model that focuses on sustainability and conservation [10]. This finding is directly linked to the inefficiencies of the end-of-pipe approach that is widely applicable in the water industry. Civerchia et al. reveal that the introduction of new technologies in the water industry can positively improve water quality monitoring [11]. Conversely, it omits information on the specific water quality monitoring technologies to be adopted by the industry. Palmaccio, Dicuonzo and Belyaeva reveal that technologies such as the IoT can reduce costs incurred by the water industry [12]. On the contrary, information on how this technology fits into the circular economy model is incomplete. The need for the current research is attributed to the gaps in the previous results, especially on the integration of sustainability in the water industry. The traditional water conservation techniques are marred with inefficiencies that range from water leakages to a significant rise in costs. By continually depending on these techniques, the industry may in the future fail to meet the rising water demand. To fill this gap, there is a need for the water industry to embrace the circular economy model. A collaboration between the water sector and Industry 4.0 will not only ensure that the model is successfully implemented but will also ensure that integrated water resource management is attained. Some of the papers with a similar scope to this study are Roest et al. [13], Abu-Ghunmi, Abu Ghunmi, Kayal and Bino [10], Lange and Kleynhans [14] and Rodriguez, Florido, and Jacob [15]. These papers emphasize the need for the integration of sustainable water management in the water industry (a collaboration between Industry 4.0 and the water industry), which is in line with the circular economy model.

Following the identified gaps from previous research, a systematic review was conducted wherein divergent works of literature were identified. The themes derived from the works were divided and explored into two significant sections focusing on implementing and integrating sustainability. The content is distributed into four successive components, including the methodology, results, discussion, and conclusions. The findings from the research are substantial in improving water sustainability and management in the industry while addressing the barriers/drivers that influence operational efficiency. The principal conclusions highlight that the changing stature of the environment merits the introduction of a circular economy in place of the business-as-usual approaches. The approaches have thus far failed in their ameliorative mandate that contributes to supply gaps. Furthermore, the conclusions show that there is a need for the water industry to adopt and integrate sustainable technologies that will collect data, monitor changes, and predict trends to improve decision-making processes.

1.3. Aim of the Research

The overarching purpose of this research is to analyze the water industry's future from the sustainability perspective. The paper focuses on the need for the implementation of integrated sustainable technologies that will not only bolster water management but also address the existing challenges that the industry faces.

2. Sustainability Implementation in the Water Industry

This section provides a brief introduction to the sustainability implementation and integration in industrial firms and industrial systems.

2.1. Implementing Sustainability in Industrial Firms and Industrial Systems

Water sustainability is at the core of disputatious debates with congruent denotations defining it as the ability to meet the present's water needs without compromising future generations' ability to do the same [16]. On a global scale, sustainable water management entails ensuring that all people around the world have access to estimated 20 to 50 L of water that they require to sustain their lives [17]. As a component of integrated water resource management, the push for sustainable water supply has been on the rise at industrial and global levels [17]. Implementing water sustainability in industrial firms and systems requires adopting a multidisciplinary and holistic approach. The approach addresses technical, environmental, social, and economic issues. Interventions that address water shortages, demand and supply and withdrawals should be embraced by the industry [16].

The agricultural industry is currently the largest consumer of water around the world. It accounts for estimated 70% of water withdrawals globally, with the figures varying from one nation to the other [17]. By 2050, it has been projected that the industry will have to produce approximately 60% more food worldwide, which means that its demand for water will continue increasing [17]. Therefore, to curb water deficiencies, the sector has embarked on implementing sustainable water management approaches. The measures involve formulating water management policies that encourage the planning, design, and construction of infrastructure [16,18,19]. These policies are seminal in reducing the risk of pushing scarcity downstream through conventional upstream water management. The interventions will further help scale up agricultural water management impacts through various instruments such as knowledge management, project financing, and policy engagement [20]. Subsequently, implementing sustainability targets the decision-making processes in the water industry.

Other than the agricultural sector, all other industries are also dependent on water. Currently, industry and energy account for an estimated 20% of the global water demand [17]. This consumption, coupled with climate change, has forced the water industry to settle for approaches that can, in the long term, ensure that consumer needs are met [20]. Dependence on data to analyze consumer trends, forecast future consumption rates and assess global wastages has proven effective in promoting water sustainability [20]. The data influences investment operation and maintenance decisions while leveraging key aspects such as inclusion and improved attainment of predefined goals [18]. Various decision-making tools can be used to implement sustainability, such as the info-gap model, which seeks to optimize robustness to failure under deep uncertainty. The decision-making model focuses on satisfying the minimum performance requirements over a wide range of potential scenarios under future conditions [18]. Furthermore, it allows firms in the water industries to introduce adaptation strategies as the maximum radius of localized uncertainties in the future that can be negotiated.

The sustainability implementation further explores the barriers and drivers of water management. The key obstacles to sustainable water resources management include pollution, high demand, and willingness to pay levels among the customers/users [21–26]. Furthermore, the future of sustainability in the water industry is influenced by critical drivers such as population, technology, rainwater harvesting, land reform, and education. Understanding the barriers and drivers will significantly improve sustainability and environmental stewardship among water firms.

2.2. Integrating Sustainability in Industrial Firms and Industrial Systems

Integrating sustainability is a viable approach that can improve the water industry's future based on key barriers and drivers [27]. The continued population growth and rapid urbanization are likely to contribute to a significant rise in the demand for water resource. Failures in addressing this intense pressure on the existing resource may result in scarcity. Considering this, sustainability can be integrated into industrial firms/systems through the circular economy, which relieves the escalating pressures on crucial resources such as water, food, energy, and materials [27–29]. The circular economy integrates sustainability by offering a vital and resilient framework for current and future generations. Furthermore, it provides a mechanism for transitioning growth in the water industry into a positive environmental trend [30]. The circular economy will not only create value for the local municipalities/communities but will also help close the loops for water recovery. The water industry will also have the unique opportunity to lead the effort toward linking the desired closed loops and improving service provision/goal attainment [31].

The circular economy is complemented by the implementation of technologies via Industry 4.0 aimed at enhancing operational excellence. The centralized systems used in water management have necessitated the introduction of new digital solutions that cost-effectively manage utilities [31]. The Aquasys technologies are one of the innovations that the industry has adopted in ensuring that it safeguards water with real-time insights [32]. The technology helps the staff to monitor water from its source to the discharge locations [32]. Therefore, this ensures that any areas that require improvements due to pipe leakages are highlighted. This technology has been instrumental in reducing water wastages [20]. Moreover, individual firms in the industry have integrated robotics and remote sensing technologies in their operations to effectively identify leaks and fast track repairs and infrastructure maintenances.

In line with the integrated water resource management, artificial intelligence is an innovative technology that is also instrumental in the promotion of water sustainability. Industry 4.0 is currently working closely with wastewater treatment centers to bolster their efficacies [10,13,31,33,34]. AI is one of the digital tools that are being integrated to help ensure the safety of the water produced in the treatment centers while reducing the risk of pollution. Smol, Adam, Preisner [35] and Uche-Soria and Rodríguez-Monroy [36] explored the use of artificial intelligence in wastewater treatment plants where it improves ultrafiltration membranes. Artificial intelligence is connected to the operating system in treatment centers, which initiates cleaning protocols for the filtration systems depending on the system's overall performance [36–38]. The algorithm improves operational efficiency by choosing the perfect cleaning intensity compared to conventional cleaning mechanisms that either under- or over-clean water.

Water quality monitoring is also a critical component of sustainable water management [39]. Some of its objectives include ensuring that water is economically viable, promoting environmental integrity and enhancing good public health. The water industry has invested heavily in water quality sensors to improve its ability to monitor water resources [20]. This ensures that water that reaches to the consumers meets all the safety standards. Adoption of the big data system and the IOT-based smart water quality monitoring system has also proven instrumental toward improving water quality monitoring due to its ability to provide first-hand data on physical, biological, and chemical characteristics of water [40].

3. Methods

The researcher deemed it fit to use a systematic literature methodology to determine the water industry's future from the sustainability perspective. The systematic literature review methodology was chosen, as it helps identify, select, and critically appraise the research to answer the burgeoning or predefined question. The systematic literature review was also founded on the Preferred Reporting Item for Systematic Reviews (PRISMA), chosen as it allows for identifying and evaluating articles using specific criteria. Some of the reasons for using the framework include: it allows the researcher to select articles that are ideal for the study, and it demonstrates the quality of review and provides the researcher with a platform for replicating review methods [20]. It also makes the selection process transparent by reporting the exclusion and inclusion criteria at the various systematic review stages [20]. The PRISMA method consists of four phases, with the first focusing on identification, where the researcher identifies the specific articles related to the research topic. The second phase is screening, whereby the potentially eligible studies are identified by reviewing the titles and abstracts. The researcher then assesses the articles via full-text review while contacting study investigators where necessary. Furthermore, the screening phases consist of automation whereby records are eliminated while others are prioritized based on their ability to answer or address the research topic. The third phase is eligibility, which involves the creation of criteria to determine which articles should be included. The research questions and objectives are used to structure the reporting of eligibility criteria while focusing on the year of dissemination, language, and significance. This phase also involves the researcher clearly indicating whether the studies are ineligible based on whether they measure the outcomes or interest or are riddled with biased results. The final phase is the formulation of inclusion criteria, with the researcher specifying the key metrics and how many reviewers are involved in the screening process. The series of steps included in the data collection process following the PRISMA methodology are outlined in the succeeding phases of the paper.

3.1. Question Formulation

The first step in the systematic literature review involved formulating and identifying the research question. The researcher aimed to identify articles that answered the research question, "how can the water industry implement and foster sustainable transition that improves decision making, performance, and efficiency?" The research question was defined by the CIMO logic, which identified the context (water industry), intervention (implementation/integration), mechanisms (sustainability), and outcome (performance/efficiency).

3.2. Source Identification

The second step required the researcher to conduct electronic searches through Scopus and the Web of Science between 18 and 22 October 2022. The electronic searchers involved keying in free-text words including "sustainability", "decision-making models", "circular economy", "Industry 4.0", "operations", "barriers", "drivers" and "quality management". The keywords were based on previous works of erudition on the same topic, with the researcher ensuring that they were apt and complete for the scope of the work.

The Boolean operators' method was also used to combine search terms in specific ways that could broaden and narrow the results. The Boolean operator helped improve the search process by focusing on "sustainability" AND "water industry". Furthermore, the search process included the use of search limits that narrowed the results and allowed the researcher to retrieve articles that were most relevant to the research question. The researcher limited the types by a database with the limit conventions, including article/publication type, publication dates, language, and subject.

The keyword, Boolean operators, and search limits methods were complemented by snowballing sampling, whereby the researcher identified papers that did not directly answer the research question. The snowballing method involved using the reference list of various papers to identify additional papers [41,42]. The researcher began with a few existing articles on or around the topic. The papers were used as the starter set with the researcher identifying keywords and formulating the search strings. The start set was derived from Scopus and the Web of Science, with the articles being included in the systematic literature review. The main reason why the researcher chose two databases for the starter set was to avoid the risk of bias in favor of specific publishers. The starter set also involved determining if the papers came from different communities while reducing the risk that relevant papers could fall into independent clusters. It was substantial for the researcher that the papers referred to each other or the topic at hand. The important issue in the starter set was diversity, whereby the papers had to come from divergent publishers, authors, and years.

The second step in the snowballing sampling method involved making iterations to the starter set with both backward and forward snowballing applied. The backward snowballing involved the analysis of the reference list while excluding papers that did not fulfil the basic criteria of the limit conventions mentioned prior. The researcher then removed papers from the list that had already been examined and identified using the keyword, Boolean operators, and search limits methods. The remaining papers were determined viable to be included in the abstract/full-text review.

On the other hand, the forward snowballing method involved identifying new papers based on the ones citing the paper being evaluated. The researcher utilized citation tracking offered by Scopus and Web of Science to conduct the forward snowballing. Every candidate paper was reviewed with screening relying on citation tracking; if the researcher surmised that the information was insufficient for a decision, then the paper would be studied in more detail.

The third step involved analyzing the authors after conducting the iterations via both backward and forward sampling. The efficiency of the sampling method was gauged by checking the number of included papers and the total number of papers examined based on the exclusion criteria. The researcher ascertained that the frequency of papers identified in the starter set, backward sampling, and forward snowballing was tracked. The tracking process came in handy in reducing the number of new papers that were included in every step while determining the risk of bias. Once the researcher surmised that there were no new papers, the loop in the sampling was closed. The researcher then proceeded to the fourth step, which involved extracting the data in line with the research questions. The data extraction was conducted at the same time as defining which paper should be included or not in the final table.

An exclusion criterion was used in the source identification, limiting the articles to the English language from 2000 to 2022. The period was used due to the relevance and application of the topic. As opined prior, the topic focused on the implementation and integration of sustainability in the water industry. The concept of sustainability was introduced in society at the turn of the century due to rising concerns about the changing nature of the environment. Furthermore, the concept was created to align with the millennium development goal 7, which focuses on ensuring environmental sustainability. The goal requires individuals and organizations to engage in inclusive and environmentally sound growth, which builds shared prosperity for people today and in the future. Therefore, focusing on articles written/published between 2000 and 2022 helped determine the steps taken by the water industry to attain sustainability and the specific recommendations for future growth.

3.3. Source Selection and Evaluation

The study selection occurred in two phases, the first involving title and abstract screening. The researcher reviewed the title and abstract for every paper to determine whether it should be included based on the eligibility criteria. The reviewer documented the overall decision during the screening to improve concerted decision making.

Furthermore, the researcher included sub-questions related to the inclusion and exclusion criteria that guided the initial screening. The key questions included:

- Are the eligibility criteria expressed in a clear manner?
- Is the article relevant and published between 2000 and 2022?
- Does the article explore sustainability implementation and integration in the
- Water industry?

- Is the source a journal, website, book, or policy paper?
- Does the source have any bias apparent in terms of funding or affiliation?

The responses to the questions served as useful reminders when reviewing the conflicts among the reviewers regarding which articles to include. The researcher also conducted pilot testing of the questions and trained the reviewers to improve inter-rater reliability and Cohen's kappa. The pilot testing involved checking whether the questions were clear and provided each reviewer with guidance on how to approach the screening process. The researcher also pilot-tested the questions to determine whether they were affirmative. The questions that were not affirmative were removed to ensure that the screening was a success. The pilot testing was important, as it helped the researcher score the feasibility of the PRISMA methodology and data collection process. Furthermore, it provided insight into how to allocate resources seminal in the screening, inclusion, and exclusion steps. The training process involved providing the reviewers with a guide that influenced their analysis of the articles. The guide improved inter-rater reliability, as the reviewers were able to monitor the quality of the data collection process and articles. Furthermore, the researcher modified the assessment tool to remove qualitative wording and interrogative questions. The researcher added descriptors of expected behavior to improve reliability. Cohen's Kappa, on the other hand, is the level of agreement among the inter-raters, which helps determine whether they effectively collaborated and determined which articles should be included. The researcher trained the reviewers on how to improve the Kappa by reducing objective assessments or evaluations or the articles. The reviewers had to approach the evaluation with an objective mindset, thereby reducing the probability of bias influencing the article selection and evaluation processes.

The title screening process was conducted after the removal of all duplicate records. The researcher first screened the articles using the eligibility criteria with help from two reviewers. The reviewers checked the title to determine whether they were acceptable or not. Furthermore, the criteria were assessed in order of importance with the reviewers listing the primary reasons for not including specific articles. The researcher further formulated a protocol for screening disagreements that helped resolve any conflicts. Moreover, the title screening involved manual coding, whereby the researcher did not consider any suggestions regarding the exclusion of contributions. The title analysis helped identify 300 articles, with 50 being excluded because they were too general. The articles that were identified through manual search were 100 (total number of articles N = 400). After excluding 50 articles, the remaining 350 were considered eligible for the abstract analysis. During the abstract analysis, the researcher evaluated whether the articles effectively highlighted their originality, methodology, results, and implications for research, practice, and society. The abstract analysis narrowed the list of sources to 200, with the remaining articles being considered for the second phase of full-text analysis.

The full-text review involved retrieving and analyzing all records advanced from the first phase. The researcher used the predefined eligibility criteria when selecting the studies that could be included in the review. The eligibility criteria also helped in ranking the articles based on the order of importance. If any criterion was not met, then the reviewers and the researcher had to list the primary reason for exclusion. The reviewers worked through the list of records by checking the methods, content, findings, and discussion sections. The reviewers then cast their votes to determine whether the studies met the inclusion/exclusion criteria. The full-text review helped remove 152 articles that did not propose sustainability initiatives for the water industry (Figure 1). At least 48 contributions were deemed relevant for the analysis, which was then included in the final set, as shown in Table 1. Some of the reasons for working with the 48 articles included: they have detailed findings and reviews on sustainability gaps in the water industry and highlights on the significances for the integration of sustainability in the water industry. Some of these articles also showcased the need for the adoption of the circular economy model in the water industry, which is in line with integrated water resource management. Figure 1 provides a visual analysis of the PRISMA, as applied in this study.

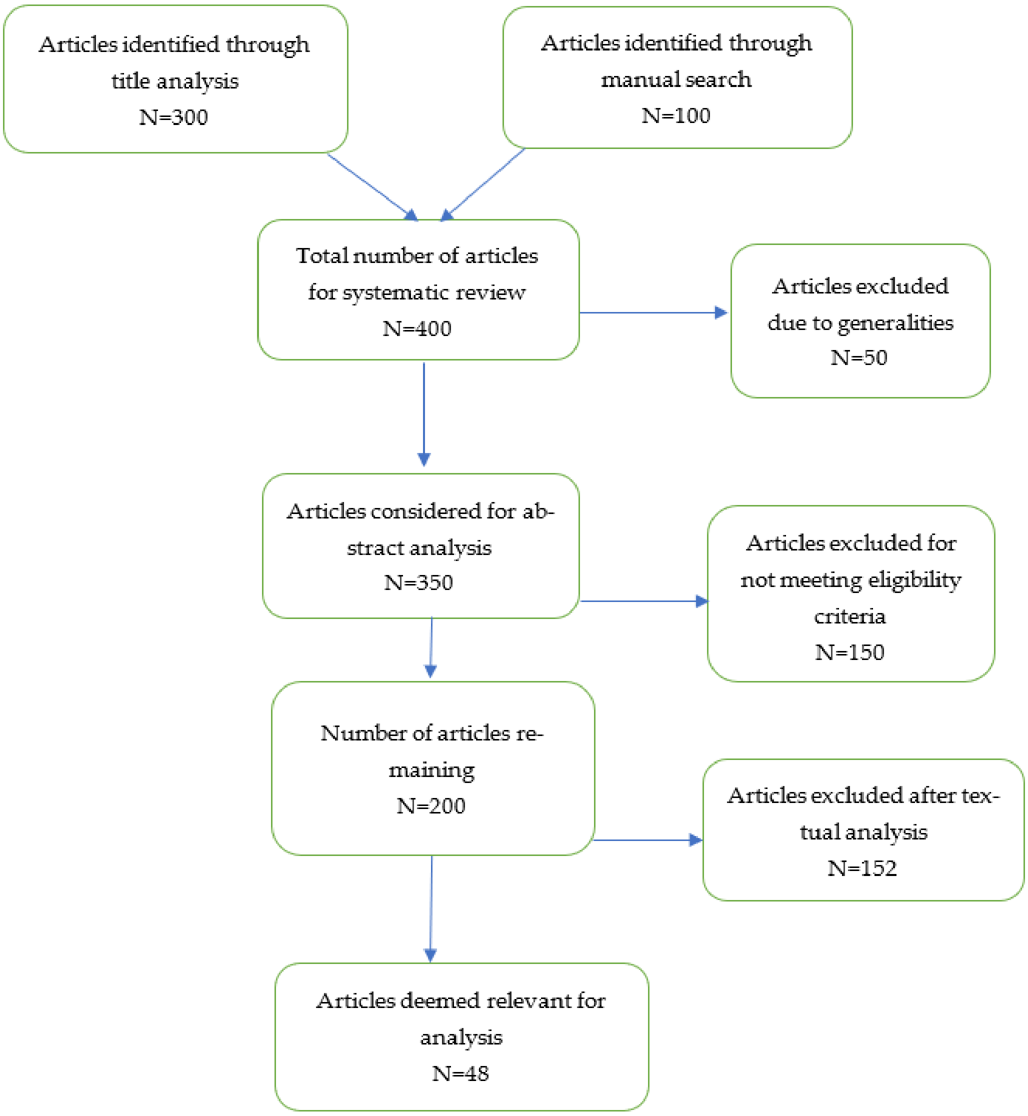

Figure 1. PRISMA flowchart.

Table 1. Inter-rater agreement.

Article Group	Rater 1	Rater 2	Rater 3	Agreement
1	6	6	6	1
2	7	4	7	1
3	4	3	7	1
4	4	2	5	1
5	6	2	2	1
				5/5

The retrieved articles were classified according to the critical dimensions, including the title, document type, authors, and main findings. The researcher then conducted a content analysis of the material with at least three reviewers, helping determine the articles' quality, ingenuity, and validity. The three reviewers were chosen to reduce bias and improve the quality of the reported outcomes. The reviewers also helped increase the number of relevant studies that could be used in the systematic review while removing any duplicate articles from the final count. At every step, the reviewers discussed the individual results, with the common result being defined and agreed upon. The screeners were encouraged by limiting time on the task. The screeners should only work for short periods to maximize concentration and engagement.

3.4. Data Analysis

The data analysis helped the researcher capture relevant information by critically investigating the articles. The researcher calculated the level of agreement among the reviewers through Cohen's kappa, which determined the inter-rater reliability. The reliability helped identify the tendency of the reviewers to deviate from the review process as it became more familiar to them. The analysis also involved reviewing the content in terms of emerging themes relating to implementing and integrating sustainability in the water industry for the future. The calculation of the inter-rater reliability occurred in a series of steps. The first step involved creating a table with the percentage agreement for every rater, as shown below. The percentage agreement focused on at least 48 of the initial articles, which were classified as 10. The second step involved counting the number of ratings in the agreement in tandem with the total number of ratings, which is five. The results showed that there was a 5/5 agreement among the inter-raters, which brought the percentage agreement to 100%.

3.5. Data Charting

The data analysis helped develop a preliminary data chart, as shown below. The researcher piloted the data while extracting data based on the title, type of document, author name, and main findings.

3.6. Study Risk of Bias Assessment

The researcher implemented the robvis visualization tool, which determined the risk of bias assessment in the systematic review. The data were loaded onto the visualization tool with example data sets and summary plots provided. The tool developed summary plots that displayed a weighted bar chart of the distribution of risk of bias judgments across the various papers. Furthermore, it consisted of two domains focusing on the relevance and reliability. The visualization tool was complemented by a Likert scale that determined the quality of the articles using a range of 0 to 10. The researcher excluded any studies with a lower quality store based on their study designs and the inclusion criteria.

3.7. Synthesis Methods

The data derived from the assessment were synthesized using qualitative methodologies. The qualitative data synthesis involved identifying the theme and content while using textual descriptions to describe them. The thematic synthesis was conducted in three stages, with the first involving textual coding line by line. The coding made way for the second stage, whereby the researcher developed descriptive themes aligned to the integration and implementation of sustainability. The descriptive analysis was based on identifying and reporting repeated patterns while interpreting the codes. The final stage of the synthesis involved the generation of analytical themes. The stage was characterized by the reviewers moving past the primary studies and using forward/backward snowballing to generate new explanations or interpretive constructs.

The qualitative synthesis was chosen because it provides a general summary of the findings and characteristics of the various works of erudition. Furthermore, it allowed the researcher to analyze the study relationships while exploring patterns [43]. The researcher was able to review the applicability of the body of evidence to the research question while critiquing the strengths and weaknesses. The critique results are highlighted in the discussion section in tandem with the gaps in evidence. Consequently, the qualitative synthesis was important in comparing the systematic review findings with existing conventional wisdom when apt.

3.8. Certainty Assessment

The final stage in the systematic review involved using the GRADE framework after deciding on the research question. The framework allowed the researcher to rate the quality of evidence based on the outcome using four levels of evidence, including "very low," "low," "moderate," and "high. "The four levels were applied across five domains, focusing first on the risk of bias. The researcher considered that bias occurs whenever the design limitations undermine the study results. The GRADE framework was used to rate the body of evidence based on the findings and implications rather than the type. The researcher determined whether the risk of bias is large to the point that the confidence of the information is lower. The determination helped narrow the articles that could be included in the final analysis.

The second domain is imprecision, which is followed by inconsistency. The two work in tandem with each other to determine whether the evidence effectively answers the research question. The imprecision domain also focused on whether the researchers provided recommendations for the future. The recommendations were evaluated based on their applicability in the water industry, cost, and associated benefits.

The fourth domain is indirectness, whereby the researcher gauged whether the research topic/abstract differs from the findings. The domain also involved rating the evidence based on inter-rater confidence. If the reviewers exhibited low confidence about the results, then the evidence could not be included in the final review. The reviewers, however, had to provide a detailed description of why they were not confident of the evidence so as to improve agreeability and reduce the risk of conflict.

The final domain is publication bias, in which the researcher evaluates if the study results were unevenly reported. The domain consisted of visual methods that helped detect publication bias. The researcher and reviewers worked to identify grey literature, language, and media attention bias. The grey literature bias focuses on whether the articles ignored literature such as government reports that offer an insight into sustainability in the water industry. The language bias, on the other hand, explored if the literature excluded foreign language studies from the analysis. The media attention bias finally reviewed whether news articles were included in the analysis and if they were subjective or objective by nature. Furthermore, the researcher analyzed whether there was reporting bias that correlates with dissemination bias in terms of the results provided.

4. Results

Implementing the PRISMA technique and the GRADE framework helped identify 48 articles, as shown in Table 2. The author reviewed the articles based on their content, validity, bias, and application in the water industry. The results from the robvis visualization tool showed that there was a low risk of bias, thus meaning that the screening and analysis process was top tier. Consequently, the summations from the GRADE framework indicated that the certainty ratings were moderate, with the author believing that the actual effect is close to the estimated impact.

Table 2. Selected literature.

Title	Type of Document	Authors and Date	Findings
Strategic decision-making for water resource management in semi-arid metropolitan and rural areas	Journal article	Lange and Kleynhans, 2006 [14]	It recommends the introduction of the integrated water resource planning in water utilities that can improve sustainability and resource allocation.
Distributed water infrastructure for sustainable communities	Journal article	Makropoulos and Butler, 2010 [8]	The findings indicate that the water industry holds a high potential for improvement that involves the deployment of technological infrastructure in its operations.
Green Growth: Managing the Transition to Sustainable Economies	Book chapter	Vazquez-Brust and Sarkis, 2012 [44]	It highlights that green growth will help in the implementation of a sustainable economy through the water industry.
Management and operations maintenance for a water treatment and supply company	Journal article	Matias et al., 2015 [9]	It highlights that the introduction of total productive maintenance in the water industry can help improve company performance with regards to the provision of water services.
Circular economy and the opportunity cost of not "closing the loop" of water industry: The case of Jordan	Journal article	Abu-Ghunmi, Abu Ghunmi, Kayal and Bino, 2016 [10]	It highlights that the end-of-pipe approach used in the water industry is inefficient in handling the changing nature of the society. The authors recommend the adoption of the circular economy model.
Added-value from linking the value chains of wastewater treatment, crop production and bioenergy production: A case study on reusing wastewater and sludge in crop production in Braunschweig	Journal article	Maaß and Grundman, 2016 [34]	It shows that there is an economic value in connecting wastewater treatment and crop production.
Drivers and barriers towards sustainable water and land management in the Olifants-Doorn water management area, South Africa	Journal article	Knuppe and Meissner, 2016 [45]	It highlights that sustainability can be implemented by increasing environmental awareness of all stakeholders in the society and the water industry.
Decision Making Methods for Water Resources Management Under Deep Uncertainty	Article	Roach, 2016 [18]	It highlights the various decision-making methods that can be used in the water industry to address issues of scarcity and availability.

Table 2. *Cont.*

Title	Type of Document	Authors and Date	Findings
Applicability of decentralized versus centralized drinking water production and wastewater treatment in an office park as example of a sustainable circular economy in Amsterdam, The Netherlands	Journal article	Roest et al., 2016 [13]	It shows that the adoption of new technologies will reduce health risks, increase sustainability via life cycle assessment as well as improve financial performance.
Water at the heart of the Circular Economy	Policy paper	Veolia, 2016 [7]	The findings show that water is at the center of the circular economy. It provides a resilient and restorative framework that can help improve water management.
Water Quality Monitoring Using Wireless Sensor Networks: Current Trends and Future Research Directions	Journal article	Adu-Manu, Tapparello, Heinzelman and Katsriku, 2017 [46]	The authors argue that the use of wireless sensor networks will ensure environmental sustainability by setting up effective monitoring systems.
Industrial Internet of Things monitoring solution for advanced predictive maintenance applications	Journal article	Civerchia et al., 2017 [11]	It explores the use of IoT for predictive maintenance in the water industry that saves on time and reduces costs associated with water management.
Easing the Transition to Commercial Finance for Sustainable Water and Sanitation	Policy Paper	Goksu, Tremolet, Kolker and Kingdom, 2017 [2]	It shows that the water industry should make more efficient upstream choices that will improve their capital expenditure and ability to balance between demand and supply levels.
Water management interventions push scarcity downstream	Article	International Institute for Applied Systems Analysis, 2017 [47]	It explores how the current challenges in the water industry are exacerbated by conventional approaches to water management such as building reservoirs or dams.
Global Barriers To Improving Water Quality: A Critical Review	Policy paper	Metcalfe, Guppy and Qadir, 2017 [48]	It indicates that the introduction of technologies in water quality monitoring will strengthen the industry and allow for the development of effective policies safeguarding human health.
The Future Of Water Management	Online article	Nye, 2017 [49]	The findings indicate that the networks can help monitor leakages, improve service levels, promote water conservation, and reduce pollution.
How far are we from closing the loop of sewage resource recovery? A real picture of municipal wastewater treatment plants in Italy	Journal article	Papa, Foladori, Guglielmi and Bertanza, 2017 [33]	It shows that the adoption of innovative options for material and energy recovery can close the loop of sewage recovery.

Table 2. *Cont.*

Title	Type of Document	Authors and Date	Findings
Leveraging Big Data Tools and Technologies: Addressing the Challenges of the Water Quality Sector	Journal article	Romero, Hallett and Jude, 2017 [50]	The findings highlight that the water industry can implement big data tools and technologies to address the issue of pollution.
5 water industry challenges, and how Industry 4.0 solves them	Online article	Coward, 2018 [51]	It shows that the introduction of Industry 4.0 is substantial improving the reliability and monitoring levels of the water industry.
The importance of urban rainwater harvesting in circular economy: The case of Guadalajara city	Journal article	Espindola, Cordova and Flores, 2018 [27]	The authors argue that the utilization of rainwater catchment systems will reduce the demand for water in tandem with the cost of production. Furthermore, they will increase the recharging of aquifers and improve wastewater treatment processes.
Digitalized Water And Smart Cities—How Can Telecommunication Networks Be Used For Environmental Resilience?	Journal article	Paska, 2018 [52]	It shows that the implementation of an IoT-based system can improve water quality monitoring especially in smart cities.
Digital Single Market for Water Services Action Plan	Policy paper	Anzaldi, 2018 [53]	The paper shows that the digitalization of the water industry will improve monitoring, reporting and the identification of leakages.
Measuring User Compliance and Cost Effectiveness of Safe Drinking Water Programs: A Cluster-Randomized Study of Household Ultraviolet Disinfection in Rural Mexico	Journal article	Reygadas, Gruber, Dreizler, Nelson and Ray, 2018 [54]	The authors explore the current gaps in the water industry and how they can be improved through measurement tools.
Harnessing the Fourth Industrial Revolution for Water	Policy paper	World Economic Forum, 2018 [3]	It indicates that Industry 4.0 will help proactively manage the associated risks while harnessing an enabling environment for the water industry in the future.
Industry 4.0: Innovative Solutions For The Water Industry	Conference proceedings	Alabi, Telukdarie and Rensburg, 2019 [31]	The authors opine that the implementation of IoT can help firms in the water industry to monitor leakages and plan as well as distribute resources effectively.
The Future of Water: A collection of essays on 'disruptive' technologies that may transform the water sector in the next 10 years	Policy paper	Daigger, Voutchkov, Sarni and Lall, 2019 [55]	It highlights that the sustainability in the water industry can be attained through the introduction of innovative schemes.

Table 2. *Cont.*

Title	Type of Document	Authors and Date	Findings
Concretizing Green Growth and Sustainable Business Models in the Water Sector of Jordan	Journal article	Englemann, Al-Saidi and Hamhaber, 2019 [56]	The authors opine that the implementation of the green growth paradigm in the water industry can help improve sustainability, performance and operational efficiency.
Barriers and drivers in a circular economy: The case of the built environment.	Journal article	Hart et al., 2019 [57]	The authors argue that technological and regulatory barriers hinder the implementation of a circular economy in the water industry.
Mining Big Data For Sustainable Water Management	Article	Pekmez, 2019 [58]	The author denotes that advanced analytics are substantial in the management of water resources. The utilization of Industry 4.0 can help water utilities collect the requisite data to improve sustainability.
Smart Water Management towards Future Water Sustainable Networks	Journal article	Ramos, McNabola, Lopez-Jimenez and Perez Sanchez, 2019 [59]	It indicates that the application of smart water management policies will improve the efficiency and sustainability of the industry.
Operational Efficiency of Mexican Water Utilities: Results of a Double-Bootstrap Data Envelopment Analysis	Journal article	Ablanedo-Rosas et al., 2020 [60]	The findings adumbrate that the introduction of decision-making tools can improve sustainability in water utilities.
Applying a deployment strategy and data analysis model for water quality continuous monitoring and management	Journal article	Chen, Yang, Peng and Lin, 2020 [61]	It highlights that the implementation of technologies for water quality monitoring can help identify sources of pollution.
Social water environment governance innovation in China driven by big data: Frontier trends, dilemma challenges and optimization paths	Conference proceedings	Liu, Hu and Miao, 2020 [62]	The authors argue that big data technology is seminal in improving the operational efficiency of water companies.
Transitioning the Water Industry with the Circular Economy	Policy paper	Mukheibir, Jazbec and Turner, 2020 [63]	The authors argue that there is a need for the water industry to move beyond sustaining toward the restoration of the material balance.
Circular Economy Contributions to the Tourism Sector: A Critical Literature Review	Journal article	Rodriguez, Florido and Jacob, 2020 [15]	It adumbrates that the circular economy is a viable alternative to the current model of production and consumption that can solve wicked problems/environmental challenges.

Table 2. *Cont.*

Title	Type of Document	Authors and Date	Findings
Water Management Is the Wave of the Future	Online article	Ahuja, 2021 [64]	It shows that the introduction of water quality management software will reduce pollution levels and the risk of violations.
A Water-Energy Nexus analysis to a sustainable transition path for Sao Paulo State, Brazil	Journal article	Bortoleto et al., 2021 [65]	It shows that the transition to sustainability in the water industry requires in-depth understanding of the nexus between water and energy.
Enhancing a Transition to a Circular Economy in the Water Sector: The EU Project WIDER UPTAKE	Journal article	Mannina et al., 2021 [66]	It highlights that the transition toward a sustainable circular economy is complicated by regulatory, technical, social and economic barriers.
A Systemic View on Circular Economy in the Water Industry: Learnings from a Belgian and Dutch Case	Journal article	Mbavarira and Grimm, 2021 [67]	It shows that the circular economy provides firms in the water industry with various strategies under the 6Rs framework including reducing, reusing, recycling, reclaiming, recovering and restoration.
Reuse of water and materials as a cleaner production practice in the textile industry contributing to blue economy	Journal article	Neto, Silva, Tucci and Amorim, 2021 [26]	The study findings indicate that the adoption of the blue economy strategy will ensure the sustainable exploitation of water resources while conserving the environment for future generations.
The Future of Digital Water Quality Monitoring	Online article	Sankaran, 2021 [68]	The author expatiates that the introduction of technologies such as artificial intelligence or machine learning will help digitize water quality monitoring.
Implementing Industry 4.0 through Cleaner Production and Social Stakeholders: Holistic and Sustainable Model	Journal article	Satyro et al., 2021 [16]	It highlights that the introduction of Industry 4.0 will help in the integration of sustainable infrastructure, processes, and technologies.
Making waves: Time for chemical surface water quality monitoring to catch up with its technical potential	Journal article	Arndt et al., 2022 [69]	The findings indicate that the current monitoring tools used in the water industry do not fully meet the environmental and social demands.
Data-based decision-making processes for WASH	Article	Erlman, 2022 [70]	It denotes that data tools and techniques are seminal in improving decision-making processes in the water industry.
Resilience and Sustainability of the Water Sector during the COVID-19 Pandemic	Journal article	Goldin et al., 2022 [71]	The authors recommend the implementation of new models in the water sector that address shortages and paradigm shifts in society.

Table 2. *Cont.*

Title	Type of Document	Authors and Date	Findings
Assessing Barriers in Adaptation of Water Management Innovations under Rotational Canal Water Distribution System	Journal article	Sajid, Tischbein, Borgemeister and Florke, 2022 [72]	It highlights that the lack of training, financial resources and low awareness are key barriers to the implementation of water management innovations.
Advances in Technological Research for Online and In Situ Water Quality Monitoring—A Review	Journal article	Silva et al., 2022 [73]	The authors opine that the monitoring process is improved upon through the use of nanotechnologies that proactively identify and reduce the ill effects of pollutants.
Drivers and barriers towards sustainable water management in Erbil Kurdistan Region of Iraq	Journal article	Sulaiman, Hamad and Andrea, 2022 [74]	It shows that the lack of coherence between stakeholders is a major issue undermining sustainable water management.

5. Discussion

The topic of the water industry's future has undoubtedly garnered the attention of various scholars from divergent fields. The systematic review showed that most of the conventional literature focused solely on implementing sustainable measures in the water industry to attain green growth. Green growth refers to fostering economic growth and development while ascertaining that natural assets continuously provide the necessary resources and services for human wellbeing [75]. Suffice it to say, the sole focus on implementation created a gap in how to integrate sustainability in the water industry. To bridge this gap, the researcher combined the findings on implementation and integration, which are highlighted in the subsequent section.

5.1. Implementing Sustainability in Industrial Firms and Industrial Systems

A diachronic analysis of various works of literature highlights that most of them focused on the implementation of interventions tailored to attain Sustainable Development Goal 6 [75]. The SDG focuses on introducing mechanisms that ensure the availability and management of water and sanitation for all. It also addresses the sustainability of water and sanitation access by focusing on the quality, availability, and management of freshwater resources [76].

Water is a crosscutting resource; thus, its security contributes to SDG 6 and the WEF nexus comprising water, energy, and food [65]. The first intervention for water security in the industry identified in the literature is adopting a green growth strategy. Therefore, there is no one size fits all scheme for fostering green growth. Instead, decision makers need to formulate policies and set up institutions that create a green growth path for an economy [44,56,77,78]. Furthermore, the green growth strategy promotes social equity while allowing for society's effective distribution of resources.

The efficiency of green growth strategies hinges on economic approaches that evaluate the complexity of human–environment relationships [44,45]. The water industry has failed in its mandate to attain sustainability due to the lack of understanding of the relationship between humans and the environment. The green growth strategy allows firms and industries to address quantity and quality issues [45]. The quantity issues focus on the levels of demand among humans/society and the supply capabilities in the environment. The insight derived from the analysis helps develop water-related innovation, which effectively balances the human–environment relationships [45].

Additionally, the green growth economy relies on clear policies and managerial techniques that promote synergies between growth and the environment. The guidelines bring together multiple stakeholders and governance structures that minimize decoupling and improve synergetic relationships [45]. The end outcome of the synergetic relationships is innovation in water infrastructure, which enhances water availability and reduces conflicts. Knupper and Meisner build upon this disposition by highlighting that the implementation process can be conducted by increasing the environmental awareness of all stakeholders in society and the water industry. The understanding will help in the establishment of new policies that act as critical drivers toward increased sustainability [45].

Now, the demand for the green economy has facilitated the introduction of various decision-making tools and models that offer insight into the human–environment relationships while improving multi-stakeholder engagement [14]. Implementing sustainable initiatives in the water industry requires strategic thinking and analysis. Strategic thinking is facilitated by exploring the levels of certainty and uncertainty since water is a wicked problem and a scarce resource. Previously, water resource managers applied the principle of marginal benefit by using bulk water resource management [14,18,70,79–81]. The competitive market was implemented as a tool to allocate water use rights that inadvertently alienated specific groups and caused failures due to high transaction costs, externalities, and information asymmetry.

Lange and Kleynhans highlight that the market failures caused by decision making in the water industry can be addressed through integrated water resource planning. The decision-making model implies the systematic consideration of the divergent dimensions of water quality and quantity [14]. The two dimensions are correlated with the green growth strategy mentioned prior and directly determine how resources will be allocated. Lange and Kleynhans show that integrated water resource planning informs entities that water is part of an ecological system comprising various components. Each component is correlated, thus meaning that a decline in one can inadvertently affect the availability of another [14]. Additionally, integrated water resource planning implies that water interacts with other systems such as land and the environment; thus, there are direct consequences caused by the relationships [79,82]. This implication nudges water entities to focus on issues such as waste disposal, floodplain management, recreational use of water, and erosion control.

Lange and Kleynhans further allude that decision support and decision analysis facilitate planning by producing insight and promoting creativity. The decision support relates to explaining decision-making behavior following the utility theory. Water firms should formulate a feasible set that is defined by actions satisfying the physical, logical, and socio-economic constraints [14]. The feasible set acts as the decision-making criteria for the companies in the water industry. Following the rational choice theory, the decision-making processes must determine the causal situation or structure determining the correlation between an action and outcome. Furthermore, the rational choice theory guides practitioners on how they can subjectively rank feasible alternatives based on expected outcomes.

Various decision-making models implement the rational choice theory, thus facilitating integrated water resource planning. Roach opined that the water industry could use data-based decision-making models, which help them systematically consider how to improve quality and quantity. Specifically, the researcher identified the decision-scaling model as applicable in line with the topic [18]. The model is a bottom-up analysis approach that evaluates the system's vulnerability. The evaluation permits the decision maker or water entities to scale the range of uncertainties, focusing on the critical conditions that might impact quantity or quality [18,83]. Using this approach, water companies will be able to categorize the seminal conditions that influence planning, with future projections helping characterize the relative probability or plausibility of the conditions occurring.

Additionally, organizations in the water industry can resort to the use of multi-criteria decision analysis tools. The tools adopt a deterministic approach that accounts for multiple objectives and uncertainties. It determines the quality and quantity of water based on each criterion's performance while producing an overall aggregated score [16,72,80]. The score is weighted into one utility function that allows the organizations to determine their performance levels.

Moving forward, it was noted that barriers and drivers directly affect the outcomes of the decision-making processes and interventions. Sajid, Tischbein, Borgemeister, and Florke highlight that the lack of training, financial resources, and low awareness are key barriers to implementing water management innovations. First, the lack of training undermines the inherent ability of practitioners in the water industry to monitor, manage or restore operations [72].

Furthermore, the practitioners are unaware of their responsibilities in engaging in practices that can improve sustainability and reduce wastage. Second, the lack of financial resources hinders the long-term implementation of sustainable plans such as the green economy. The plans are piloted and left halfway, exposing the intended beneficiaries to a broad cornucopia of risks. Moreover, low awareness levels among the stakeholders undermine the implementation of participatory approaches focused on driving sustainability [57,63,74]. Most people are unaware of water policies, making it easy for policymakers to use their power to sway the masses and reduce resistance. Most water governance programs are plagued by power relations that involve the elite capture and unfair distribution of resources.

On the other hand, the drivers are inclusive management support and coherence between the stakeholders. The management support allows for the provision of resources that enhance sustainability objectives [74]. The coherence, on the other hand, improves awareness and instills the notion or need for sustainability in every stakeholder, thus reducing conflicts or impartiality.

5.2. Implementing Sustainability in Industrial Firms and Industrial Systems in the Future

The business-as-usual approaches currently used in the water industry should be replaced with the green growth strategy in the future. The strategy is substantial, as it addresses various aspects of water management, including water allocation, investment/innovation, and storage. Specifically, the strategy will guide organizations on how to allocate water to specific sectors that add the most value. As noted, prior, the manufacturing, food/beverage, agriculture, and mining industries are likely to be among the most desperate due to their overreliance on the water for their operations [3]. This correlates with an influx in demand and the occurrence of supply gaps. By applying the green growth strategy, the water industry will be able to dole out water effectively, which handles the demographic, technological, and economic trends associated with the industries.

Furthermore, the investment and innovation aspect of green growth involves introducing technologies in specific areas that enhance water efficiency. The innovations will permit organizations in the water industry to determine demand and supply through prediction models. The historical prediction models have thus far been ineffective in highlighting which areas require resource allocation [57]. The use of innovative schemes will improve decision making and water resource planning. Furthermore, they will save on costs with the finances being used for other areas in the water management industry.

The storage aspect can be addressed in the future by securing access in the face of uncertainty. Lange and Kleyhnans [14] report that decision-support frameworks and innovations will help organizations determine/predict the levels of demand and supply in the face of uncertainty. The adoption of the decision-scaling model recommended by Roach will improve storage capabilities by reducing the deleterious effects of various human trends on the environment.

While at it, the water industry must consider the pillars of pricing and innovation that influence water management, demand, and supply. Roach opines that water scarcity and demand correlate with pricing frameworks [18]. Therefore, the water industry should introduce sustainable pricing of water, which will promote efficiency while managing demand [57]. The industry should apply social support and participatory mechanisms rather than low tariffs. The participatory mechanisms allow people to actively engage in the management of the water industry [63]. In addition, the targeted social support allows the industry to dole out investments in water supply, thus increasing affordability.

Furthermore, the water industry should adopt an integrated water resources management approach in the future. The approach offers a lens through which the various drivers and consequences of trends are identified. In addition, it guides the entities on how to coordinate their actions with the aim of achieving economic efficiency, environmental sustainability, and social equity. It is imperative to note that a fragmented approach to water management will not contribute to green growth [65,74]. Therefore, the industry should understand that there is a synergistic and mutually reinforcing relationship between water security and green growth. The relationship requires valuing/protecting ecosystems while reducing the waste of resources. In addition, it involves balancing the intrinsic value of water while harnessing its productive power, maintaining water quality, avoiding pollution, and ensuring there is enough water for both social and economic development.

5.3. Integrating Sustainability in Industrial Firms and Industrial Systems

The previous section explored how the water industry has implemented sustainability in its operations. This section details how the industry can integrate sustainability into its existing policies, frameworks, and services. Sustainability integration focuses on combining various aspects and tools to become a whole. Integrating sustainability will first involve the introduction of the circular economy identified by Rodriguez, Florido, and Jacob as a byproduct of environmental economics. The model was introduced in 1970 by Pearce and Turner with the aim of designing out waste and pollution. Furthermore, the main principle of the model is to transform today's waste into tomorrow's resources that harness environmental, social, and economic benefits [15].

The circular economy aims to integrate science into sustainability and sustainable development based on the ecological circulation of natural materials. Mbavarira and Grimm highlight that the circular economy has gained attention in the water industry due to its focus on the 6Rs strategy of reducing, reusing, recycling, reclaiming, recovering, and restoring. The circular economy is seminal in keeping water in circulation/closed loop, thus benefiting the current and future generations [67]. The closed loop involves water extraction, consumption, utilization, collection, and disposal.

The closed loop hinges on the creation of decentralized solutions to the current infrastructure used in the water industry. Makropoulos and Butler highlight that the circular economy provides decentralized solutions that are more sustainable, as they increase the potential for water conservation and reuse. Furthermore, the decentralized solutions accentuate the resilient nature of water infrastructure while reducing the replacement cost [8]. Roest et al. build upon this disposition by highlighting the introduction of technologies that improve quality monitoring in the water industry. The study shows that adopting new technologies will reduce health risks, increase sustainability via life cycle assessment, and improve financial performance in the water industry [13].

Mannina et al. adumbrate that the circular economy can provide the water industry with a path that modifies how the systems operate. The path focuses on decreasing the water withdrawal levels previously identified as a major issue that accounts for societal water scarcity [8,66]. Mbavarira and Grimm criticized the traditional "business as usual" approach as shortsighted and unable to adapt to the changing climatic conditions. The shift toward the circular economy will help the water industry decouple economic growth from negative externalities on resource use. Specifically, the circular economy is holistic, as it ensures a steady flow of resources by integrating the relevant sectors that create a mutual benefit in the value chain [66].

The 6Rs of the circular economy are applicable in the water industry, with the reduction strategy focusing on decreasing freshwater consumption rates. Scholars allude that the high levels of demand for freshwater have contributed to short- and long-term scarcities that undermine the longevity of water sources [84–88]. Subsequently, the "reuse" strategy involves the utilization of wastewater in its crude form rather than disposing of it in the waterways [26]. It is common for companies to dispose of their wastewater in the water bodies, which increases the risk of pollution. The companies in the water industry can, instead, reuse the water for their various processes, thus cutting down the need to resupply or the risk of replenishing the water source [2,58,62,89–91].

Mbavarira and Grimm laud recycling strategies as substantial in integrating sustainability. The strategies involve using treated wastewater within the same loop or in the same process. Recycling further reduces the risk of pollution and improves savings potential. The next R is "reclaim", whereby organizations can treat wastewater and use it outside the loop [67,89,92,93]. The reclamation strategy is complemented by recovery whereby the water industry can extract valuable resources in wastewater, such as energy or material. The wastewater can be used to generate energy that can light up houses or factories.

The final "R" in the circular economy focuses on restoration whereby the water industry can increase awareness about how the masses can replenish water resources. The replenishment processes will involve artificial interventions such as rainwater harvesting, aquifer recharges, and rejuvenation of water bodies [67,84,90,94]. Espindola et al. researched the use of urban rainwater harvesting as a replenishment strategy. The authors highlighted that rainwater harvesting had played a major role in the circular economy by reducing the cost of damages caused by floods. Furthermore, it helped the water industry manage the demand for water and minimize production costs [27]. Considering this, the authors recommend continuous investment in the vitality of the watershed through wetland restoration and forest management.

The investments are part of the artificial interventions that are aimed at creating circular solutions and rainfall. Furthermore, introducing green infrastructure can unlock the natural environment through natural water treatment and buffering [95]. The infrastructure supports a cost-effective, resilient approach that will manage climate change's adverse effects, such as floods and droughts.

The sustainability of the circular economy also relies on the use of ICT technology and alignment with Industry 4.0. Romero, Hallett and Jude argue that ICT technology is a key enabler to improve the management of water resources in line with SDG6. The authors highlight that the water industry's future hinges on adopting innovative and resource-efficient tools or frameworks. Industry 4.0 has facilitated the use of ICT technologies that will allow companies in the industry to improve their production processes substantially [96]. The basic approach of Industry 4.0 is not to aim for zero but rather to reduce waste accretion and provide the necessary solutions to wicked problems compounding companies.

The World Economic Forum conducted a study into the application of Industry 4.0 in the water industry based on various challenges. The first challenge identified is the aging infrastructure and the need to maintain assets. The companies in the water industry are faced with the issue of obsolescence and aging equipment that undermine their production processes [3,50]. As the systems and equipment age, the availability and uptime are reduced, increasing capital and operational expenditure.

Conversely, ICT technologies such as IoT-enabled sensors, data analysis, and machine learning have thus far proven effective in reducing maintenance challenges. The technologies follow advanced automated processes that allow for predictive maintenance. For instance, the IoT-enabled sensors can detect leakages in the pipeline with information being relayed to the experts [3,12,51,59]. Furthermore, machine learning algorithms can detect blockages a few hours before customer reports by checking the pattern and flow of water. Adopting Industry 4.0 solutions will reduce the cost, demand, and pressures linked with reactive maintenance [46]. Consequently, they will enable prompt response and improve accountability in the water industry.

The second challenge identified is population growth in rural and urban areas, which increases the demand for services. The challenge of urbanization is maintaining water quality and meeting the inherent needs of customers in both rural and urban areas. Individuals living in urban areas often face water scarcity or consume polluted water due to low supply levels [61,71,97]. World Economic Forum reports that there is a projected gap of 40% by 2030 between the supply and demand of water. The gap is exacerbated by traditional business-as-usual processes and the general lack of a circular economy. The competition for scarce water resources is bound to increase between the rural and urban areas contributing to biased and difficult allocation choices made by the policymakers [3].

Conversely, the introduction of demand management systems can help the water industry to integrate site data and external information data sets. The integration will improve the monitoring of water resources in real time while forecasting a spike in demand or supply while addressing the needs of the target market [83,98–100]. Additionally, the companies can implement drones and remote monitoring that will determine the water levels and provide real-time data on the demand rates. The World Economic Forum recommends using satellite and radar technologies to measure how water bodies change over time. The radar technologies are complemented by advanced satellite imagery and machine learning to provide a distinct continental-scale platform. The platform aims to democratize the water demand and supply processes.

Moreover, companies can utilize precision irrigation techniques with smart sensors that provide data about soil conditions. Precision irrigation techniques will reduce the amount of water wasted through irrigation and improve reclamation and reuse [101]. The issue of population growth can be addressed through artificial intelligence that enables smart water metering. The metering will provide information on the areas that record the highest demand for water and how to improve supply. Consequently, enabling peer-to-peer trading of water allocations among users via blockchains will improve water use and encourage customer stewardship [11,12,77,102].

The third challenge is environment and sustainability with the water industry facing issues such as flooding, sewer spillage risks, and climate change. Urban sprawl has increased the amount of waste passed through the sewage lines, which can contribute to blockages or spills [64,101]. The spills undermine the quality of water, sanitation, and hygiene services. According to the World Economic Forum, at least 4 billion people live in water-scarce regions, with 2 billion lacking access to essential sanitation services. Furthermore, the spills from sewage lines increase the risk of contracting waterborne diseases linked to more than half a million deaths each year.

The companies can address the spills through IoT sensors monitoring sewage lines. Furthermore, the IoT sensors can be introduced to previously unmonitored water sites in real time [103]. The visibility will allow the utilities to react quickly in the event of spillages and improve the effective management of the resources. The implementation of blockchain-based smart contracts will trigger repairs by pre-approved suppliers as well as dole out payments for their services. Smart contracts will reduce the apparent bureaucracy and time spent approving service requests.

The final challenge is operations and quality monitoring with the current practices involving the use of traditional methods for analysis purposes. The existing tools are quite expensive and take a lot of time before the provision of results hampers decision-making processes [49,73]. Industry 4.0 technologies such as remote sensing and monitoring will help improve quality analysis. The technologies allow offline laboratory analysis, which can be transferred to automated online monitoring platforms. The platforms are adapted to tolerate extended maintenance intervals based on process and quality control [73]. The adaptation process improves the continuous water quality analysis and prompt release of results that can guide the companies on problem areas.

Industry 4.0 is lauded for its efficiency in facilitating the shift toward decentralized or off-grid systems. The shift is imperative since the current centralized systems cannot meet the needs of the growing population while experiencing challenges when obtaining financing. Scholars allude that the fourth industrial revolution can guide companies in introducing micro-grid structures that buffer the supply infrastructure from vulnerabilities associated with extreme weather events [68,69]. Adopting real-time and remote monitoring of water system performance will also improve zero-mass water schemes that permit water generation off the grid. The decentralized approaches will reduce the need for costly maintenance while enhancing the ability to reach alienated or disparaged communities [4,9,47,48,52–55,60,104]. The speed of deployment will increase in tandem with customer satisfaction levels.

5.4. Integrating Sustainability in Industrial Firms and Industrial Systems in the Future

The 6Rs introduced by the circular economy concept are substantial in improving the future of the water industry when combined with Industry 4.0 technologies/innovations. Going into the future, the water industry should consider redesigning the supply chains with the aim of closing the gap. The current water industry is centralized, which contributes to issues in decision making and resource allocation. Even though Industry 4.0 technologies have allowed for inherent connectivity of smart devices, there are still issues regarding the monitoring of water networks and improving service provision levels.

The advanced technologies and the circular economy will enable the entities to disrupt the water-intensive supply chains. The industry participants will gain a better understanding of the water-related risks while formulating new strategies to address the issues. Specifically, key sectors such as agriculture require the introduction of technologies that optimize water use and accentuate productivity [31]. The technologies will help unlock new models that reduce overreliance on the water while improving efficiency. Furthermore, the supply sources will be diversified in tandem with the trajectory of global development. The introduction of nanotechnology can help uncover new water sources at scale, thus increasing the supply while effectively managing the demand levels. The nanotechnologies provided by Industry 4.0 will help in the manipulation and manufacturing of new materials, systems, and devices that can be used in the water industry. For example, the technologies can help convert non-usable water sources into sources of portable water, thus increasing availability [11,31].

In addition, the future of the water industry relies on revolutionizing data acquisition and analytics. The revolution involves setting up new technologies that reduce the apparent dearth of knowledge and improve assessment processes. The industry will increase its efficiency levels through innovative systems that monitor system reliance, predict breakdowns, and accentuate protection of the water sources [4,33]. Automated data processing and evaluation will improve quality assurance and control, which reduce redundancy in the industry and improve decision-making processes.

6. Conclusions

In due summation, the water industry's future hinges on the implementation and integration of sustainability in its operations. The preceding systematic review explored various literature on the multiple interventions, decision-making processes, barriers, and drivers of sustainability. Congruent denotations showed that the water industry should adopt green growth strategies aligned with the Sustainable Development Goal 6. The strategies will help determine the human–environment relationships, thus offering insight into water management's quality and quantity dimensions. Furthermore, the adoption of decision support and decision analysis will promote creativity when addressing demand and supply constraints. The adoption process should further reduce the ill effects of significant barriers such as lack of awareness while harnessing coherence between stakeholders. Coherence can only be attained when and if enough information can influence positive decision making.

Moving forward, it is recommended that the water industry should shift from the "business-as-usual approaches" toward the circular economy and green growth. The two provide an integrated water resource management framework that will facilitate and lead the process toward sustainability. Moreover, the industry should adopt new technologies offered via Industry 4.0 to improve their prediction capacities while focusing on economic, technological, and demographic trends. The various technologies such as internet of things and data optimization will improve decision making, revamp the supply chain and accentuate service provision.

The paper has several positive implications related to the integration of sustainability in the water industry. The first implication is that it recommends the introduction of the circular economy, which emphasizes reducing, reusing, recycling, reclaiming, recovering, and restoring water. The circular economy will push the industry from the business-as-usual approaches toward frameworks that align with the changing environmental demands. Additionally, the paper provides an in-depth analysis of various water industry challenges and proposed solutions via Industry 4.0. The summations highlight that Industry 4.0 will facilitate a move toward decentralized systems, thus improving resource allocation and reducing scarcity, bureaucracy, and conflicts.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Davé, B. Sustainable Development: Role of Industrial Water Management. In *National Research Council (US) Chemical Sciences Roundtable*; Water and Sustainable Development: Opportunities for the Chemical Sciences: A Workshop Report to the Chemical Sciences Roundtablel; Norling, P., Wood-Black, F., Masciangioli, T.M., Eds.; National Academies Press: Washington, DC, USA, 2004. Available online: https://www.ncbi.nlm.nih.gov/books/NBK83724/ (accessed on 22 October 2022).
2. Goksu, A.; Tremolet, S.; Kolker, J.; Kingdom, B. *Easing the Transition to Commercial Finance for Sustainable Water and Sanitation*; World Bank: Washington, DC, USA, 2017.
3. World Economic Forum. Harnessing the Fourth Industrial Revolution for Water. 2018. Available online: https://www3.weforum.org/docs/WEF_WR129_Harnessing_4IR_Water_Online.pdf (accessed on 22 October 2022).
4. Aqua Tech. Sustainable Water: Our Essential Guide to Sustainable Water Resource Management Solutions & Strategies. Available online: https://www.aquatechtrade.com/news/water-treatment/sustainable-water-essential-guide/ (accessed on 22 October 2022).
5. Porcher, S.; Saussier, S. (Eds.) *Facing the Challenges of Water Governance*; Palgrave Macmillan: Cham, Switzerland, 2019.
6. Tiseo. Global Water Industry—Statistics & Facts. Available online: https://www.statista.com/topics/1575/water/#topicHeader__wrapper (accessed on 22 October 2022).
7. Veolia. Water at the Heart of the Circular Economy. Available online: https://www.veolia.com/sites/g/files/dvc4206/files/document/2014/12/economy-circular-water.pdf?fbclid=IwAR18db6PZiMw1GkfrlM7s3m7HpVPzk7JjC150A5KVvlxOWAqdMXYeX2BFfA (accessed on 22 October 2022).
8. Makropoulos, C.; Butler, D. Distributed Water Infrastructure for Sustainable Communities. *Water Resour. Manag.* **2010**, *24*, 2795–2816. [CrossRef]
9. Matias, J.; Calais, G.; Azevedo, S.; Matias, J.; Catalao, J. Management and operations maintenance for a water treatment and supply company. *Int. J. Ind. Syst. Eng.* **2015**, *25*, 360–382. [CrossRef]
10. Abu-Ghunmi, D.; Abu-Ghunmi, L.; Kayal, B.; Bino, A. Circular economy and the opportunity cost of not 'closing the loop' of water industry: The case of Jordan. *J. Clean. Prod.* **2016**, *131*, 228–236. [CrossRef]
11. Civerchia, F.; Bocchino, S.; Salvadori, C.; Rossi, E.; Maggiani, L.; Petracca, M. Industrial Internet of Things monitoring solution for advanced predictive maintenance applications. *J. Ind. Inf. Integr.* **2017**, *7*, 4–12. [CrossRef]
12. Palmaccio, M.; Dicuonzo, G.; Belyaeva, Z.S. The internet of things and corporate business models: A systematic literature review. *J. Bus. Res.* **2021**, *131*, 610–618. [CrossRef]
13. Roest, K.; Smeets, P.; Brand, T.; Zwertvaegher, A.; Cortial, H.; Odijk, S.; Klaversma, E. Applicability of decentralized versus centralized drinking water production and wastewater treatment in an office park as example of a sustainble circular economy in Amsterdam, The Netherlands. *Procedia Environ. Sci. Eng. Manag.* **2016**, *3*, 139–148.
14. Lange, W.; Kleynhans, T. Strategic decision-making for water resource management in semi-arid metropolitan and rural areas. *Sustain. Irrig. Manag. Technol. Policies* **2006**, *94*, 277–286.
15. Rodriguez, C.; Florido, C.; Jacob, M. Circular Economy Contributions to the Tourism Sector: A Critical Literature Review. *Sustainability* **2020**, *12*, 4338. [CrossRef]
16. Satyro, W.; Contador, J.; Contador, J.; Fragomeni, A.; Monken, S.; Ribeiro, A.; Lima, A.; Gomes, J.; Nascimento, J.; Araujo, J.; et al. Implementing Industry 4.0 through Cleaner Production and Social Stakeholders: Holistic and Sustainable Model. *Sustainability* **2021**, *13*, 22. [CrossRef]
17. Levitt, H.M. *Essentials of Critical-Constructivist Grounded Theory Research*; American Psychological Association: Washington, DC, USA, 2021.
18. Roach, T. Decision Making Methods for Water Resources Management Under Deep Uncertainty. Ph.D. Thesis, University of Exeter, Exeter, UK, 2016.
19. Kehrein, P.; van Loosdrecht, M.; Osseweijer, P.; Posada, J.; Dewulf, J. The SPPD-WRF Framework: A Novel and Holistic Methodology for Strategically Planning and Process Design of Water Resource Factories. *Sustainability* **2020**, *12*, 4168. [CrossRef]
20. Butler, D.; Ward, S.; Sweetapple, C.; Astaraie-Imani, M.; Diao, K.; Farmani, R.; Fu, G. Reliable, resilient and sustainable water management: The Safe & SuRe approach. *Glob. Chall.* **2017**, *1*, 63–77. [PubMed]
21. Leigh, N.G.; Lee, H. Sustainable and Resilient Urban Water Systems: The Role of Decentralization and Planning. *Sustainability* **2019**, *11*, 918. [CrossRef]
22. Liu, L.; Wu, T.; Xu, Z.; Pan, X. The Water-Economy Nexus and Sustainable Transition of the Pearl River Delta, China (1999–2015). *Sustainability* **2018**, *10*, 2595. [CrossRef]
23. Lacovidou, E.; Millward-Hopkins, J.; Busch, J.; Purnell, P.; Velis, C.A.; Hahladakis, J.N.; Zwirner, O.; Brown, A. A pathway to circular economy: Developing a conceptual framework for complex value assessment of resources recovered from waste. *J. Clean. Prod.* **2017**, *168*, 1279–1288. [CrossRef]
24. Van Loosdrecht, M.C.M.; Brdjanovic, D. Anticipating the next century of wastewater treatment. *Science* **2014**, *344*, 1452–1453. [CrossRef] [PubMed]
25. Wan, J.; Gu, J.; Zhao, Q.; Liu, Y. COD capture: A feasible option towards energy self-sufficient domestic wastewater treatment. *Sci. Rep.* **2016**, *6*, 1–9. [CrossRef]
26. Neto, O.; Silva, P.; Tucci, H.; Amorim, M. Reuse of water and materials as a cleaner production practice in the textile industry contributing to blue economy. *J. Clean. Prod.* **2021**, *305*, 127075. [CrossRef]

27. Espindola, J.; Cordova, F.; Flores, C. The importance of urban rainwater harvesting in circular economy: The case of Guadalajara city. *Manag. Res. Rev.* **2018**, *5*, 535–553.
28. Larsen, T.A.; Maurer, M.; Eggen, R.I.L.; Pronk, W.; Lienert, J. Decision support in urban water management based on generic scenarios: The example of NoMix technology. *J. Environ. Manag.* **2010**, *91*, 2676–2687. [CrossRef]
29. Farrelly, M.; Brown, R. Rethinking urban water management: Experimentation as a way forward? *Glob. Environ. Chang.* **2011**, *21*, 721–732. [CrossRef]
30. Geng, Y.; Doberstein, B. Developing the circular economy in China: Challenges and opportunities for achieving 'leapfrog development'. *Int. J. Sustain. Dev. World Ecol.* **2008**, *15*, 231–239. [CrossRef] [PubMed]
31. Alabi, M.; Telukdarie, A.; Renbsurg, N. Industry 4.0: Innovative Solutions for the Water Industry. In Proceedings of the American Society for Engineering Management 2019 International Annual Conference, Philadelphia, PA, USA, 23–26 October 2019.
32. AquaTech. Sustainable Water | Essential Guide | Aquatech. Available online: https://www.aquatechtrade.com/news/essential-guides/ (accessed on 22 October 2022).
33. Papa, M.; Foladori, P.; Guglielmi, L.; Bertanza, G. How far are we from closing the loop of sewage resource recovery? A real picture of municipal wastewater treatment plants in Italy. *J. Environ. Manag.* **2017**, *198*, 9–15. [CrossRef] [PubMed]
34. Maaß, O.; Grundman, P. Added-value from linking the value chains of wastewater treatment, crop production and bioenergy production: A case study on reusing wastewater and sludge in crop production in Braunschweig (Germany). *Resour. Conserv. Recycl.* **2016**, *107*, 195–211. [CrossRef]
35. Smol, M.; Adam, C.; Preisner, M. Circular economy model framework in the European water and wastewater sector. *J. Mater. Cycles Waste Manag.* **2020**, *22*, 682–697. [CrossRef]
36. Uche-Soria, M.; Rodríguez-Monroy, C. An Efficient Waste-To-Energy Model in Isolated Environments. Case Study: La Gomera (Canary Islands). *Sustainability* **2019**, *11*, 3198. [CrossRef]
37. Shirkoohi, M.G.; Doghri, M.; Duchesne, S. Short-term water demand predictions coupling an artificial neural network model and a genetic algorithm. *Water Supply.* **2021**, *21*, 2374–2386. [CrossRef]
38. Niknam, A.; Zare, H.K.; Hosseininasab, H.; Mostafaeipour, A.; Herrera, M. A Critical Review of Short-Term Water Demand Forecasting Tools—What Method Should I Use? *Sustainability* **2022**, *14*, 5412. [CrossRef]
39. Nestle. Sustainable Water Management in Our Operations. Nestlé Global. 2022. Available online: https://www.nestle.com/sustainability/water/sustainable-water-efficiency-operations (accessed on 22 October 2022).
40. Behmel, S.; Damour, M.; Ludwig, R.; Rodriguez, M.J. Water quality monitoring strategies—A review and future perspectives. *Sci. Total Environ.* **2016**, *571*, 1312–1329. [CrossRef]
41. Kohli, A. "Snowballing" in Systematic Literature Review. Available online: https://www.linkedin.com/pulse/snowballing-systematic-literature-review-amanpreet-kohli/ (accessed on 24 October 2022).
42. Genter, F.; Willetts, J.; Foster, T. Faecal contamination of groundwater self-supply in low- and middle income countries: Systematic review and meta-analysis. *Water Res.* **2021**, *201*, 117350. Available online: https://www.sciencedirect.com/science/article/pii/S0043135421005480#sec0002 (accessed on 22 October 2022). [CrossRef]
43. Lawati MH, A.; Dennis, S.; Short, S.D.; Abdulhadi, N.N. Patient Safety and Safety Culture in Primary Health Care: A Systematic Review. BMC Family Practice. 2018. Available online: https://bmcprimcare.biomedcentral.com/articles/10.1186/s12875-018-0793-7 (accessed on 22 October 2022).
44. Vazquez-Brust, D.; Sarkis, J. *Green Growth: Managing the Transition to Sustainable Economies*; Springer: Berlin/Heidelberg, Germany, 2012.
45. Knupper, K.; Meissner, R. Drivers and barriers towards sustainable water and land management in the Olifants-Doorn water management area, South Africa. *Environ. Dev.* **2015**, *20*, 3–14. [CrossRef]
46. Adu-Manu, K.; Tapparello, C.; Heinzelman, W.; Katsriku, F. Water Quality Monitoring Using Wireless Sensor Networks: Current Trends and Future Research Directions. *ACM Trans. Sens. Netw.* **2017**, *13*, 1. [CrossRef]
47. International Institute for Applied Systems Analysis. Water management interventions push scarcity downstream. *Science Daily* **2017**. Available online: https://www.sciencedaily.com/releases/2017/06/170615085015.htm (accessed on 22 October 2022).
48. Metcalfe, C.D.; Guppy, L.; Qadir, M. *Global Barriers to Improving Water Quality: A Critical Review*; UNU-INWEH Report Series; United Nations University Institute for Water, Environment and Health (UNU-INWEH): Hamilton, ON, Canada, 2017.
49. Nye, J. The Future of Water Management. Available online: https://www.wateronline.com/doc/the-future-of-water-management-0001 (accessed on 22 October 2022).
50. Romero, P.; Hallett, S.; Jude, S. Leveraging Big Data Tools and Technologies: Addressing the Challenges of the Water Quality Sector. *Sustainability* **2017**, *12*, 2160. [CrossRef]
51. Coward, S. 5 Water Industry Challenges, and How Industry 4.0 Solves Them. Available online: https://www.sageautomation.com/blog/5-water-industry-challenges-and-how-industry-4.0-solves-them (accessed on 22 October 2022).
52. Paska, D. Digitalized water and smart cities—How can telecommunication networks be used for environmental resilience? *ITU J. ICT Discov.* **2018**, *2*, 9.
53. Anzaldi, G.A. *Digital Single Market for Water Services Action Plan*; European Union: Luxembourg, Belgium, 2018.
54. Reygadas, F.; Gruber, J.S.; Dreizler, L.; Nelson, K.L.; Ray, I. Measuring User Compliance and Cost Effectiveness of Safe Drinking Water Programs: A Cluster-Randomized Study of Household Ultraviolet Disinfection in Rural Mexico. *Am. J. Trop. Med. Hyg.* **2018**, *98*, 824–834. [CrossRef]

55. Daigger, G.; Voutchkov, N.; Lall, U.; Sarni, W. The Future of Water: A collection of essays on 'disruptive' technologies that may transform the water sector in the next 10 years. *Nature* **2019**, *504*, 657.
56. Engelmann, J.; Al-Saidi, M.; Hamhaber, J. Concretizing Green Growth and Sustainable Business Models in the Water Sector of Jordan. *Resources* **2019**, *8*, 92. [CrossRef]
57. Hart, J.; Adams, K.; Jannik, G.; Tingley, D.; Pomponi, F. Barriers and drivers in a circular economy: The case of the built environment. *Procedia CIRP* **2019**, *80*, 619–624. [CrossRef]
58. Pekmez, Z. Mining Big Data for Sustainable Water Management. *DIEM* **2019**, *5*, 169–178.
59. Ramos, H.; McNabola, A.; Lopez, A.; Perez-Sanchez, M. Smart Water Management towards Future Water Sustainable Networks. *Water* **2019**, *12*, 58. [CrossRef]
60. Ablanedo-Rosas, J.H.; Guerrero Campanur, A.; Olivares-Benitez, E.; Sánchez-García, J.Y.; Nuñez-Ríos, J.E. Operational Efficiency of Mexican Water Utilities: Results of a Double-Bootstrap Data Envelopment Analysis. *Water* **2020**, *12*, 553. [CrossRef]
61. Chen, F.; Yang, B.; Peng, S.; Lin, T. Applying a deployment strategy and data analysis model for water quality continuous monitoring and management. *Int. J. Distrib. Sens. Netw.* **2020**, *16*, 6. [CrossRef]
62. Liu, F.; Xu, H.; Miao, W. Social water environment governance innovation in China driven by big data: Frontier trends, dilemma challenges and optimization paths. In *IOP Conference Series: Earth and Environmental Science, Volume 612. In Proceedings of the 6th International Conference on Water Resource and Environment, Online Conference, 1 December 2022*; IOP Publishing Ltd.: Tokyo, Japan, 2020.
63. Mukheibir, P.; Jazbec, M.; Turner, A. *Transitioning the Water Industry with the Circular Economy*; Institute for Sustainable Futures: Sydney, Australia, 2020.
64. Ahuja, J. Water Management Is the Wave of the Future. Available online: https://blog.intelex.com/2021/12/29/water-management-is-the-wave-of-the-future/ (accessed on 22 October 2022).
65. Bortoleto, A.; Barbosa, P.; Maniero, M.; Guimaraes, R.; Junior, L. A Water-Energy Nexus analysis to a sustainable transition path for Sao Paulo State, Brazil. *J. Clean. Prod.* **2021**, *319*, 128697. [CrossRef]
66. Mannina, G.; Badalucco, L.; Barbara, L.; Cosenza, A.; Trapani, D.; Gallo, G.; Laudicina, V.; Marino, G.; Muscarella, S.; Presti, D.; et al. Enhancing a Transition to a Circular Economy in the Water Sector: The EU Project Wider Uptake. *Water* **2021**, *13*, 946. [CrossRef]
67. Mbavarira, M.; Grimm, C. A Systemic View on Circular Economy in the Water Industry: Learnings from a Belgian and Dutch Case. *Sustainability* **2021**, *13*, 2–62. [CrossRef]
68. Sankaran, M. The Future of Digital Water Quality Monitoring. Available online: https://www.wqpmag.com/monitoring/article/10959690/the-future-of-digital-water-quality-monitoring (accessed on 22 October 2022).
69. Arndt, J.; Kirchner, J.; Jewell, K.; Schluesener, M.; Wicke, A.; Ternes, T.; Duester, L. Making waves: Time for chemical surface water quality monitoring to catch up with its technical potential. *Water Res.* **2022**, *213*, 118168. [CrossRef]
70. Erlmann, T. Data-Based Decision-Making Processes for WASH. Available online: https://sswm.info/planning-and-programming/decision-making/planning-community/data-based-decision-making-processes-for-wash (accessed on 22 October 2022).
71. Goldin, J.; Nhamo, L.; Ncube, B.; Zvimba, J.; Petja, B.; Mpandeli, S.; Nomquphu, W.; Hlophe-Ginindza, S.; Greeff-Laubscher, M.; Molose, V.; et al. Resilience and Sustainability of the Water Sector during the COVID-19 Pandemic. *Sustainability* **2022**, *14*, 1482. [CrossRef]
72. Sajid, I.; Tischbein, B.; Borgemeister, C.; Florker, M. Assessing Barriers in Adaptation of Water Management Innovations under Rotational Canal Water Distribution System. *Agriculture* **2022**, *12*, 913. [CrossRef]
73. Silva, G.; Campos, D.; Brasil, J.; Tremblay, M.; Mendiondo, M.; Chighlieno, F. Advances in Technological Research for Online and In Situ Water Quality Monitoring—A Review. *Sustainability* **2022**, *14*, 2–28. [CrossRef]
74. Sulaiman, S.; Hamad, O.; Andrea, S. Drivers and Barriers Towards Sustainable Water Management in Erbil Kurdistan Region of Iraq. *World J. Adv. Eng. Technol. Sci.* **2022**, *6*, 10–17. [CrossRef]
75. Baubekova, A.; Kvasha, A. *Implementing Water-Related Sustainable Development Goals*; Routlidge: London, UK, 2019.
76. Oyebode, O.; Babatunde, D.E.; Monyei, C.G.; Babatunde, O.M. Water demand modelling using evolutionary computation techniques: Integrating water equity and justice for realization of the sustainable development goals. *Heliyon* **2019**, *5*, e02796. [CrossRef]
77. D'Odorico, P.; Davis, K.; Rosa, L.; Carr, J.; Chiarelli, D.; Dell'Angelo, J.; Gephart, J.; MacDonald, G.K.; Seekell, D.A.; Suweis, S.; et al. The Global Food-Energy-Water Nexus Paolo. 2018. *Rev. Geophys.* **2018**, *56*, 456–531.
78. Castro Oliveira, M.; Iten, M.; Matos, H.A. Review on Water and Energy Integration in Process Industry: Water-Heat Nexus. *Sustainability* **2022**, *14*, 7954. [CrossRef]
79. Sjöstrand, K.; Lindhe, A.; Söderqvist, T.; Rosén, L. Sustainability assessments of regional water supply interventions–Combining cost-benefit and multi-criteria decision analyses. *J. Environ. Manag.* **2018**, *225*, 313–324. [CrossRef] [PubMed]
80. McConville, J.R.; Künzle, R.; Messmer, U.; Udert, K.M.; Larsen, T.A. Decision Support for Redesigning Wastewater Treatment Technologies. *Environ. Sci. Technol.* **2014**, *48*, 12238–12246. [CrossRef]
81. Garcia, X.; Pargament, D. Reusing wastewater to cope with water scarcity: Economic, social and environmental considerations for decision-making. *Resour. Conserv. Recycl.* **2015**, *101*, 154–166. [CrossRef]
82. Pearce, D.; Turner, K.; Pearce, D.W.; Turner, R.K. Economics of Natural Resources and the Environment. *Am. J. Agric. Econ.* **1991**, *73*, 227–228.

83. Mihai, F.-C.; Minea, I. Sustainable Alternative Routes versus Linear Economy and Resources Degradation in Eastern Romania. *Sustainability* **2021**, *13*, 10574. [CrossRef]
84. Negri, M.; Neri, A.; Cagno, E.; Monfardini, G. Circular Economy Performance Measurement in Manufacturing Firms: A Systematic Literature Review with Insights for Small and Medium Enterprises and New Adopters. *Sustainability* **2021**, *13*, 9049. [CrossRef]
85. McKinsey & Company. *The Circular Economy: Moving from Theory to Practice*; McKinsey & Company: New York, NY, USA, 2016.
86. Ellen MacArthur Foundation. *Towards the Circular Economy: Opportunities for the Consumer Goods Sector*; Ellen MacArthur Foundation: Cowes, UK, 2013.
87. Kirchherr, J.; Reike, D.; Hekkert, M. Conceptualizing the circular economy: An analysis of 114 definitions. *Resour. Conserv. Recycl.* **2017**, *127*, 221–232. [CrossRef]
88. Katz-Gerro, T.; López Sintas, J. Mapping circular economy activities in the European Union: Patterns of implementation and their correlates in small and medium-sized enterprises. *Bus. Strateg. Environ.* **2019**, *28*, 485–496. [CrossRef]
89. Liao, Z.; Chen, Z.; Xu, A.; Gao, Q.; Song, K.; Liu, J.; Hu, H.Y. Wastewater treatment and reuse situations and influential factors in major Asian countries. *J. Environ. Manag.* **2021**, *282*, 111976. [CrossRef] [PubMed]
90. Kravchenko, M.; Pigosso, D.C.; McAloone, T.C. Towards the ex-ante sustainability screening of circular economy initiatives in manufacturing companies: Consolidation of leading sustainability-related performance indicators. *J. Clean. Prod.* **2019**, *241*, 118318. [CrossRef]
91. Jagtap, S.; Skouteris, G.; Choudhari, V.; Rahimifard, S.; Duong, L.N.K. An Internet of Things Approach for Water Efficiency: A Case Study of the Beverage Factory. *Sustainability* **2021**, *13*, 3343. [CrossRef]
92. Rincón-Moreno, J.; Ormazábal, M.; Álvarez, M.J.; Jaca, C. Advancing circular economy performance indicators and their application in Spanish companies. *J. Clean. Prod.* **2021**, *279*, 123605. [CrossRef]
93. Helander, H.; Petit-Boix, A.; Leipold, S.; Bringezu, S. How to monitor environmental pressures of a circular economy: An assessment of indicators. *J. Ind. Ecol.* **2019**, *23*, 1278–1291. [CrossRef]
94. Nobre, G.C.; Tavares, E. The quest for a circular economy final definition: A scientific perspective. *J. Clean. Prod.* **2021**, *314*, 127973. [CrossRef]
95. Ghisellini, P.; Cialani, C.; Ulgiati, S. A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *J. Clean. Prod.* **2015**, *114*, 1–22. [CrossRef]
96. Sheriff, B.; Kachalla, B.; Odeyemi, S.O. Sustainable Implementation of Water and Wastewater Infrastructures in Developing Countries: A Review. *J. Emerg. Trends Eng. Appl. Sci.* **2020**, *10*, 273–281.
97. Al-Zahrani, M.A.; Abo-Monasar, A. Urban residential water demand prediction based on artificial neural networks and time series models. *Water Resour. Manag.* **2015**, *29*, 3651–3662. [CrossRef]
98. Donkor, E.A.; Mazzuchi, T.A.; Soyer, R.; Roberson, J.A. Urban water demand forecasting: Review of methods and models. *J. Water Resour. Plan. Manag.* **2014**, *140*, 146–159. [CrossRef]
99. Bosaq. Long-Term Water Management Plans to Face Future Demand Challenges. Available online: https://bosaq.com/long-term-water-management-plans/ (accessed on 22 October 2022).
100. Haque, M.M.; de Souza, A.; Rahman, A. Water demand modelling using independent component regression technique. *Water Resour. Manag.* **2017**, *31*, 299–312. [CrossRef]
101. Bux, C.; Aluculesei, A.C.; Moagăr-Poladian, S. How to Monitor the Transition to Sustainable Food Services and Lodging Accommodation Activities: A Bibliometric Approach. *Sustainability* **2022**, *14*, 9102. [CrossRef]
102. United Nations. Water Sector Sustainability. Available online: https://sustainabledevelopment.un.org/index.php?page=view&type=99&nr=190&menu=1449 (accessed on 22 October 2022).
103. Shaddel, S.; Bakhtiary-Davijany, H.; Kabbe, C.; Dadgar, F.; Østerhus, S.W. Sustainable sewage sludge management: From current practices to emerging nutrient recovery technologies. *Sustainability* **2019**, *11*, 3435. [CrossRef]
104. Florido, C.; Jacob, M.; Payeras, M. How to Carry out the Transition towards a More Circular Tourist Activity in the Hotel Sector. The Role of Innovation. *Adm. Sci.* **2019**, *9*, 47. [CrossRef]