sustainability

Article

Wastewater Treatment with Technical Intervention Inclination towards Smart Cities

Shivam Pandey [1], Bhekisipho Twala [2,*], Rajesh Singh [3,4], Anita Gehlot [3,4], Aman Singh [5,6], Elisabeth Caro Montero [4,5,7] and Neeraj Priyadarshi [8]

1 School of Applied and Life Science, Uttaranchal University, Dehradun 248007, India
2 Digital Transformation Portfolio, Tshwane University of Technology, Staatsartillerie Rd, Pretoria West, Pretoria 0183, South Africa
3 Uttaranchal Institute of Technology, Uttaranchal University, Dehradun 248007, India
4 Department of Project Management, Universidad Internacional Iberoamericana, Campeche 24560, CP, Mexico
5 Higher Polytechnic School, Universidad Europea del Atlantico, C/Isabel Torres 21, 39011 Santander, Spain
6 Department of Engineering, Universidad Internacional Iberoamericana, Arecibo, PR 00613, USA
7 Department of Project Management, Universidade Internacional do Cuanza, Estrada Nacional 250, BairroKaluapanda, Cuito-Bie P.O. Box 841, Angola
8 Department of Electrical Engineering, JIS College of Engineering, Kolkata 741235, India
* Correspondence: twalab@tut.ac.za

Abstract: At this time, efforts are being made on a worldwide scale to accomplish sustainable development objectives. It has, thus, now become essential to investigate the part of technology in the accomplishment of these Sustainable Development Goals (SDGs), as this will enable us to circumvent any potential conflicts that may arise. The importance of wastewater management in the accomplishment of these goals has been highlighted in the study. The research focuses on the role of fourth industrial revolution in meeting the Sustainable Goals for 2030. Given that water is the most important resource on the planet and since 11 of the 17 Sustainable Goals are directly related to having access to clean water, effective water management is the most fundamental need for achieving these goals. The age of Industry 4.0 has ushered in a variety of new solutions in many industrial sectors, including manufacturing, water, energy, healthcare, and electronics. This paper examines the present creative solutions in water treatment from an Industry-4.0 viewpoint, focusing on big data, the Internet of Things, artificial intelligence, and several other technologies. The study has correlated the various concepts of Industry 4.0 along with water and wastewater management and also discusses the prior work carried out in this field with help of different technologies. In addition to proposing a way for explaining the operation of I4.0 in water treatment through a systematic diagram, the paper makes suggestions for further research as well.

Keywords: Industry 4.0; wastewater treatment; Internet of Things; artificial intelligence; big data; cloud computing

check for updates

Citation: Pandey, S.; Twala, B.; Singh, R.; Gehlot, A.; Singh, A.; Montero, E.C.; Priyadarshi, N. Wastewater Treatment with Technical Intervention Inclination towards Smart Cities. *Sustainability* **2022**, *14*, 11563. https://doi.org/10.3390/su141811563

Academic Editors: Jiangyong Hu, Say-Leong Ong, Jie Han and Jun Dong

Received: 18 August 2022
Accepted: 10 September 2022
Published: 15 September 2022

1. Introduction

Within the framework of its Global Sustainable Development Goals (SDGs), the United Nations has set a target date of 2030 for providing universal and equitable access to potable water that is both safe and cheap for all people. For both public health and the economy, it is of the highest importance to be cognizant of the possible threat presented by wastewater that is polluting water bodies. Thus, to achieve sustainable water supplies, water treatment is one of the most crucial components [1–3]. Water is an important resource which is threatened by a fast-rising population which is polluting surface and groundwater with agricultural, industrial, and urban pollutants. Climate change, biodiversity loss, and unsustainable use of resources have led to low river flow, low groundwater levels and drying up of river bodies. The treatment of water and wastewater plays a significant part in the development of the circular economy. The circular economy concept is designed to ensure that products, commodities, and raw materials remain useful in the economy for as long as feasible. In addition, it mandates that waste be treated and repurposed as raw material again [4,5]. What allows wastewater treatment plants to contribute to the circular economy is its ability to recover nutrients and energy and reuse water [6].

Worsening water quality exacerbates water shortages and endangers human health. Wastewater originates from different sources of sewage, industrial, agricultural, and commercial waste, and can be differentiated by its physical appearance, chemical composition, and microbiological load [7]. Wastewater results from normal life activities too, and domestic wastewater along with agricultural, industrial, and commercial waste, have emerged as major sources of wastewater [8–10]. Industries need water of high quality, but, in exchange, a massive amount of contaminated and polluted water is produced and discharged into enormous bodies of water, polluting them [11,12]. A complex matrix, wastewater is made up of 99.9 percent water and the remaining 0.1 percent is made up of suspended solids, organic and inorganic solids, dissolved biodegradable organics, and other particulate matter [13].

Since the Sustainable Development Goals were established in 2015, several studies have been conducted to evaluate the contribution that wastewater treatment plants make to the goals [14–16]. However, most of this research was focused on either contributing to one of the Sustainable Development Goals, i.e., 6, which deals with clean water and sanitation, or performing a multi-criteria decision analysis to assess emerging wastewater solutions, or analyses of various case studies [17–19]. Therefore, there is a need to understand the correlation of Sustainable Development Goals with Industry 4.0 and understand their need in the area. Thus, the major focus of the present study is:

- To understand the role of Industry 4.0 (I4.0) in accomplishing the Sustainable Development Goal—2030 of safe and secure drinking water for everyone.
- To co-relate Sustainable Development Goals and Industry 4.0.
- To review use of prior work of Industry 4.0 in treatment of wastewater.
- To give advice for improving the positive aspects of wastewater treatment's position in the SDGs with respect to various newly developed technologies.

The first section provides a concise introduction to the industry 4.0 and SDGs and establish a relation between them. The next step is to provide various approaches to wastewater treatment and the steps for treatment. It is then followed by use of Industry 4.0 in wastewater treatment facilities. The last is the future prospects and conclusion.

2. Overview of Sustainable Development Goals (SDGs) and Industry 4.0 (I4.0)

Sustainable practices have received an increasing amount of attention from academics, corporations, and governments during the last few decades [20,21]. This tendency has accelerated due to the pledges made to decrease greenhouse gases, handle resource limitations, and rethink the management of waste [22,23]. In addition, international norms and agreements are demanding sustainability-related operations as a contract obligation, which converts adherence to efforts into an advantageous market position [24]. The Sustainable Development Goals are a unified plan for the development of sustainable practices and solutions which aims to address the most pressing issue confronting our society today. There are 17 Sustainable Development Goals in all. Industry 4.0 (I4.0) is an emerging concept that is gaining prominence because of its capacity to implement systematic reforms and contribute to the attainment of the Sustainable Development Goals [25].

The term "Industry 4.0" was first used at Hannover Messe in 2011 where Prof. Wolfgang Wahlster (Director, German Research Centre for Artificial Intelligence) talked about the industrial revolution which will be driven by the internet. The term "I4.0" alludes to a profound shift toward an intelligent industry that is characterized by industrial systems that are both autonomous and linked [26]. According to Drath and Horch, the objective of Industry 4.0 is to link businesses to the internet to make manufacturing facilities more cost-effective, intelligent, and efficient [27]. According to Ramakrishna et al., this novel technological scenario will cause a sea change in the standard operating procedure of the industrial sector as it is currently practiced [28]. Furthermore, Hofmann and Rüsch hypothesized that this new technological scenario will impact all industries by causing a shift in how products and materials are designed, operated, and transported and it also refers to the utilization of integrative and interconnected technologies for the purpose of optimizing production [29]. The Internet of Things (IoT), big data (BD), cyber physical systems (CPS), cloud computing (CC), augmented reality (AR), systems integration, cybersecurity, simulation, and autonomous robots are some other sophisticated technologies that fall under the umbrella of Industry 4.0; see Figure 1 [30–33]. Thus, Industry 4.0 offers new prospects for waste prevention, reduction, and even elimination in certain sectors; resource-recovery advancement; and high treatment and disposal standards, which leads to significant pollution reduction. Technology such as IoT, artificial intelligence, machine learning, cloud computing, big data, robotics and drones, and the Metaverse can all be employed for treating water and wastewater.

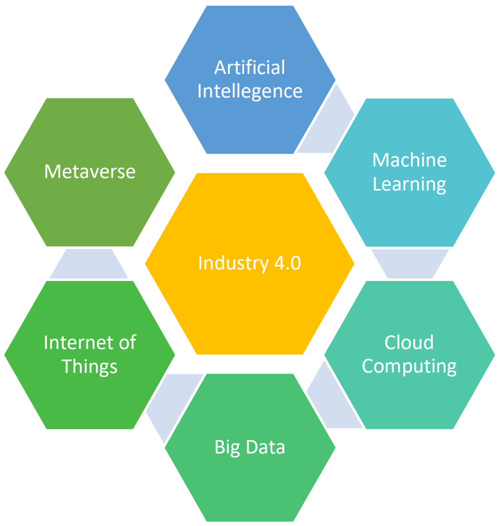

Figure 1. Industry 4.0 in brief.

3. Wastewater Treatment or Processing

The term “industrial wastewater processing” refers to the processes and methods that are used to treat wastewater which is a product of an industrial or commercial activity. This kind of wastewater must be treated before being discharged back into the environment. After going through the processes, water that has been contaminated by industrial waste (also known as effluent) may be reused or disposed of, through a sewage system or surface water. The most recent recommendations in the industrialized world are to steer clear of such items or to find ways to recycle wastewater produced in the production process; most industries still generate certain types of wastewaters. Despite this, a great number of industries are still dependent on the treatment of wastewater. The various wastewater treatment plants are as follows.

3.1. Effluent Treatment Plants (ETPs)

ETPs are used in chemical- and pharmaceutical-related industries. These industries use water-purification technologies for the elimination of dangerous and harmless chemicals. In the production of medicines, contaminants and effluents are generated which need to be treated before being discharged into the water bodies. The medication’s pollution, dust, debris, polymers, and grain are collected from treatment facilities [34,35]. The plant uses the process of drying and evaporation to treat wastewater. Wastewater treatment facilities are structured as such to minimize the danger of contamination [36].

3.2. Septic/Sewage Treatment Plants (STPs)

Sewage wastewater treatment refers to the process of removing contaminants from wastewater produced from human activities. Chemical, physical, and biological processes are used to eliminate natural and physiological contaminants. Pre-treatment processes aid in the elimination of untreated wastewater components. Stress is applied to sewage water, and other contaminants are removed from the sewage flow. This results in the production of clean water that can be used in homes or business properties for different purposes [37].

3.3. Common and Combined Wastewater Treatment Facilities (CETP)

CETP is utilized when tiny industrial units are placed because bigger systems cannot be employed. The CETP is situated in small industrial units. The primary objective of the CETP is to lower the costs of dealing with small enterprises [38,39]. CETP systems aid small industries to process wastewater with little expenditure.

4. Treatment of Wastewater

Recent years have seen a surge in wastewater output, which has become a serious concern for the environment and its ecosystems. Therefore, proper wastewater treatment has become crucial for water reuse and environmental restoration [40]. The biological treatment of wastewater involves two aerobic processes, i.e., suspended growth and fixed film. Activated sludge is often used for suspended growth systems. Anaerobic bacteria present in wastewater convert the organic material into biogas. When the organic content of effluent becomes too dissolved, anaerobic treatment is advised [41]. The quantity of the pollutant that needs to be removed and the technology being used generally determines the number of stages required to treat wastewater [42].

The first step in wastewater treatment is the elimination of large and heavy particles by preliminary treatment. Screening the particles and removal of grit are typically the steps of preliminary treatment. The process of screening removes floating trash such as papers and plastics. Removal of grit then takes place, which removes inorganic particles such as sand and other particulate matters [43]. The primary treatment of wastewater also consists of a sedimentation process that eliminates suspended debris. Sedimentation of the particles takes place in large tanks where it is allowed to settle for several hours, enabling suspended particles to settle or form smut, which is then skimmed off and the sludge is removed [44]. To remove organic toxins from wastewater, millions of actively growing microorganisms are utilized to oxidize organic contaminants. Using the processes of nitrification and absorption, secondary treatment removes nutrients such as nitrogen and phosphorus [45]. The tertiary or the final stage of treatment involves removing residual organic and inorganic matter from the effluents, which is followed by disinfection of the treated sewage by using chemicals such as chlorine or sodium hypochlorite, or radiation such as ultraviolet or ozone, prior to being released into the environment; see Figure 2 [46].

Wastewater can be treated by using nanomaterials such as nanoparticles or nanomaterials. Nanomaterials combine various features to generate multifunctional materials such as nanocomposite, nanofibers and membranes. Ma et al. created nanofibrous aerogels that can clean themselves and proved that the composite material may be utilized to monitor a variety of human functions in real time [47]. Similar work was carried out by many by constructing super hydrophilic nanofibers with antifouling and visible-light-induced self-cleaning properties [48,49]. Nanomaterials may be used extensively in the treatment and remediation of water because of their raised surface area, useful chemical performance, mechanical properties, cheap cost, and low power consumption. When supported by intelligible and controllable morphologies of appropriate size and porosity, these compounds have the potential to be used as adsorbents [50,51].

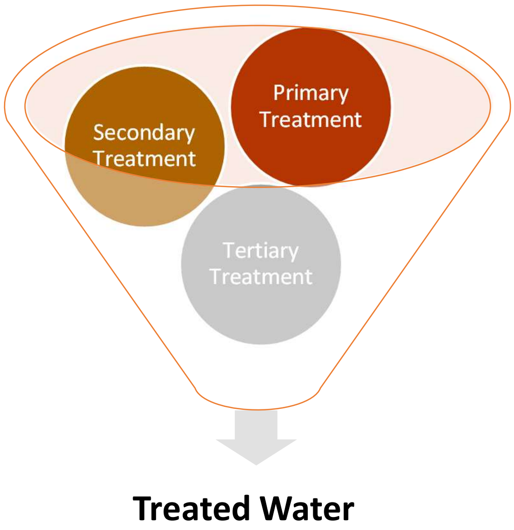

Figure 2. Treatment of Wastewater.

Nanomaterials' huge surface area helps them operate well. However, nanomaterials have several limits. Functionalizing materials with NPs may also leak NPs into the environment which harms them. Due to their high expense, nano-engineered water technologies are seldom used on an industrial basis. In addition, there are certain additional difficulties that are connected to the size of these materials. One of these difficulties is the major difficulty of separating nano-adsorbents from aqueous solutions. Additionally, the availability of large quantities of low-cost nano-adsorbents for water-treatment purposes is also a significant problem for commercial usage. In addition, controlling the discharge of utilized nanomaterial into the environment is a difficult task because of the nanoparticles' ability to accumulate over extended periods of time [52,53].

5. Utilization of Industry 4.0 in Wastewater Treatment

Industry 4.0 has six important technical aspects. The integration and incorporation of these aspects into interoperable production systems has the potential to connect global value chains, making the world more adaptable, responsive, and productive. It can assist in the interconnection of water utilities and the creation of vast data repositories. Using big-data analytical techniques and machine learning, engineers and scientists can provide valuable knowledge on the behavior of the shared environment and common physical assets which can enhance the industry, environment, and society. Industry 4.0 can deliver scope and scale efficiencies throughout the whole water industry that were inconceivable during the earlier industrial revolution. Wastewater Treatment 4.0, or water treatment digitalization, contains the same characteristics as Industry 4.0, including the networking of equipment and systems, Internet of Things, connectivity of smart devices, big data, and interconnection of water management systems. It is anticipated that this will produce and make accessible massive amounts of data pertinent to water management, data analysis, processing, and the generation of knowledge with added value. For this idea or implementation to be effective on a global scale, the water sector must install the proper monitoring equipment (i.e., the correct water infrastructure and sensors) in order to capture or gather the data needed to make educated decisions. For the water industry, this is where the factors of Industry 4.0 come into play.

5.1. IoT

IoT refers to everything from doors and fans to coolers and washing machines as "interconnected items" which, with help, may establish communication with one another. Similarly to the Internet of Things, which is an interconnected network of computer devices embedded in everyday items that allows them to communicate and exchange data, the internet is a means or method for connecting individuals who are geographically separated. Kevin Ashton coined the phrase "IoT" in 1999 during a presentation to Proctor and Gamble (P&G). In the beginning, he coined the term "internet for things", which subsequently evolved into the term "Internet of Things" [54]. The IoT in water treatment plants can monitor the different types of sewage treatment networks, which are connected by an automated control system. Online control of pipe valves by Internet-of-Things-controlled nodes is another potential solution to the problems with the current paradigm of sewage treatment. Establishing a wastewater treatment system based on an Internet-of-Things system has the potential to achieve real-time control of treatment production of all different resources by using predetermined arrangements [55]. In addition to this, such a system has the potential to further improve operational response speed during times of crisis, standardize management, reduce energy consumption, and increase economic efficiency. The primary functions of the IoT system in the plant is to collect wastewater data, control remotely the quality of water after treatment, supervise the operation state of equipment, maintain staff schedules, monitor data management centers, and many other services; see Figure 3 [56].

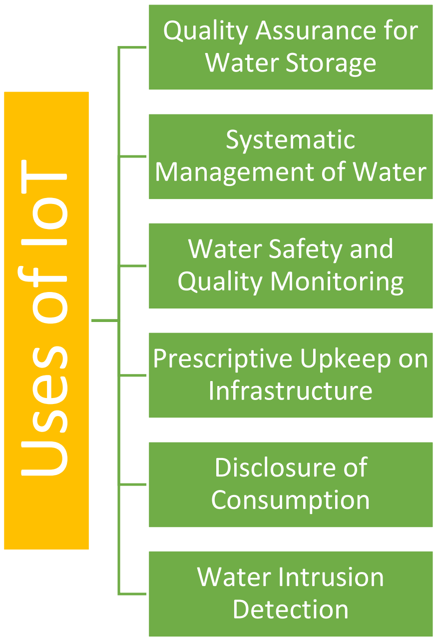

Figure 3. Use of IoT in treatment plants.

In recent years, the concept of Internet of Things paired with software technologies such as service-oriented architecture and cloud computing has led to the development of SWQMS, i.e., smart water-quality monitoring systems [57]. These SWQMSs combine the knowledge, functionality and technology of biology, chemistry, nanoscience, and other disciplines with the technologies and components of electric, mechanical, optical, and fluid devices. Wireless sensor networks (WSNs) are also a potential technology in wastewater treatment due to their quick deployment and capacity to receive, analyse, and send data from several dispersed sample stations. The application of wireless sensor networks to water-quality management has created a new research route toward the creation of decentralized SWQMSs that adapt to changing wastewater infrastructures [58]. Decentralized SWQMS offers cost reduction, permits precise matching of increasing wastewater capacity needs, takes advantage of the homogeneousness of wastewater streams, and does not require large sewer systems for distributing treated water. In addition, the failure probability is lower than that of centralized systems [59].

5.2. Cloud Computing and Big Data

As an alternative to establishing a direct connection to a server, cloud computing enables information technology (IT) services and resources to be stored on and retrieved from the internet. It is possible to store one's files not only on local storage devices but also on cloud-based storage systems. The term "cloud computing" refers to a type of distributed computing that offers customers access to computing capabilities and resources on an as-needed, pay-per-use basis [60,61]. The utilization of computing infrastructure on demand, known as "elastic cloud" or "infrastructure as a service" (IaaS), is an additional technical strategy that has enabled the fast spread of big-data applications. This depends on increasing or decreasing the size of a cluster, storage, or processing capacity according to the current requirements of the operations being performed. This considerably reduces the cost of the infrastructure since it facilitates distribution of resources just "as needed" [62,63]. Various industries and services—including banking, insurance, internet user behavior comprehension and customization, and environmental research—employ big-data analysis effectively [64,65].

PinkiSaha et al. presented an underwater monitoring system that utilized IoT's big-data storage. Using an Arduino-based sensor for temperature, pH and turbidity, they assessed the physical and chemical properties of water and stored the results in a large database. For communication between the client and server, the webserver employed HTTP to configure remote-calling methods for the client and the server [66]. Donovan et al. formed a data-collection system based on cloud computing for wastewater plants. He, along with his colleagues, formed a system to collect data from Irish wastewater systems that can be used to monitor and analyze the waste being generated [67]. A study by Quang Ly presented a dependable and precise method for forecasting the quality of wastewater effluent, which is an essential component in terms of the socio-economic elements of wastewater management, using big data [68]. Similar works have been carried out by many researchers, where they proposed models for analyzing water and wastewater by using cloud computing and big-data analytics. The big data generated from wastewater and water treatment plants were stored on the cloud for analyzing and monitoring the effluents and various substances in it; see Figure 4 [69–73].

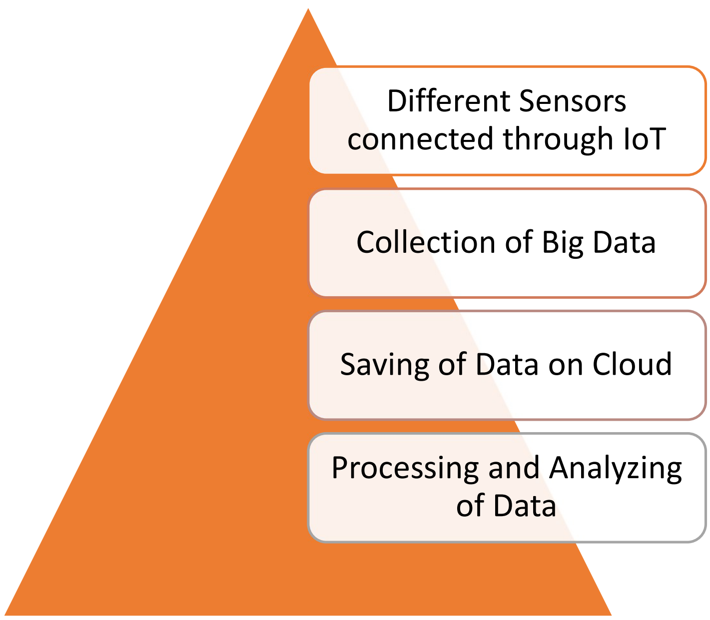

Figure 4. Use of big data and cloud computing in treatment plants.

5.3. Artificial Intelligence (AI) and Machine Learning (ML)

Several water and wastewater treatment facilities have benefited tremendously from the use of computer and online sensor technologies, which have led to a significant increase in overall plant efficiency. Numerous strategies have been developed to monitor and manage the quality of wastewater analysis more precisely. These strategies include anticipating environmental time series via the use of predictive modelling, in addition to the application of neural networks. In recent years, there has been an increased emphasis placed on the development of real-time data-collecting techniques, which also include the combination of sensor technology and information science [74,75]. Models based on artificial intelligence are emerging as useful new tools for the construction of prediction models [76]. A computational artificial intelligence using artificial neural networks, also known as ANNs, can process a wide range of information because they contain billions of neurons that are connected to one another [77,78]. Artificial-intelligent models application tools include things such as artificial neural networks (ANNs), artificial neuro-fuzzy inference systems (ANFIS), support vector machine (SVM), reinforcement learning (RL), and hybrid and expert systems (HS&ES), etc. [79–81]. The process of treating wastewater has benefited greatly from the global development of supervisory tools and the implementation of dependable real-time controls. ANNs have shown to be the most effective tool for forecasting and prediction in situations where the intended ratio of input to output is established by the external and supervised change in system parameters [82].

Way back in their 2007 study, titled "Prediction of azo dye decolorization by UV/H_2O_2 using artificial neural networks", A. Aleboyeh and colleagues made use of multilayer feedforward neural networks [83]. The implementation of AI models in electrochemical processes for the treatment of water and wastewater has also been shown by a few recent studies to have a respectable degree of accuracy [84,85]. The wastewater treatment plant's procedures can also be optimized and predicted using an AI system. Numerous studies have been conducted to make predictions using genetic algorithms, multilayer preceptors, and artificial neural networks (ANN), etc. [86]. K. Golzar et al. used the ANN approach and Monte Carlo sensitivity analysis to make their prediction about the temperature of the WWTP influent. Their findings demonstrated that the ANN model carried out its functions adequately. The capacity of an ANN model to estimate the amount of removal of fecal chloroform in a sequential batch reactor (SBR) of a wastewater treatment plant was validated by Khatri et al. [87,88]. Mohammad et al. found that the prediction of the multilayer artificial neural network with a genetic algorithm outpaced other structures developed for the removal of chlorophenol from water [89]. Kiiza et al. proposed an increase in the availability of water by analyzing measures such as water consumption, reduction, reclamation, and by using sustainable water treatment according to the circular and digital economy by AI; see Figure 5 [90].

5.4. Block Chain

Due to erroneous or missing information supplied by companies globally, the data on wastewater management are murky. However, unified information, such as data supplied by many government agencies, reveals that the management of wastewater production is inadequate. Nevertheless, monitoring treatment plants (WWTPs) is a difficult task. The monitoring of treatment plants has become achievable with the advent of the Industrial Internet of Things (IIoT). Sensor-generated data storage is a basic difficulty in the process. Various kinds of sensors, such as titrimetric and biosensors, are used for gathering information on various factors when treating wastewater and, subsequently, the data is kept in a database for analysis and monitoring. This data is very susceptible to being tampered with by hackers or misinterpreted by other parties [91]. Research is now being performed in blockchain technology, since it represents a possible solution to the problem; see Figure 6. Recent years have seen the publication of research looking at various facets of blockchain technology and IIoT for treatment plants [92,93]. The integration of blockchain technology inside IIoT applications and the creation of strong frameworks are the primary focuses of significant research for solving crucial issues related to the Internet of Things [94,95]. Hakak et al. proposed the use of blockchain technology for treating wastewater being generated by industries and households. They proposed an entire mechanism of a number of steps to analyze and monitor the waste being generated. Some of the primary benefits of using the system were the real-time monitoring of water being consumed and the wastewater being discharged [96].

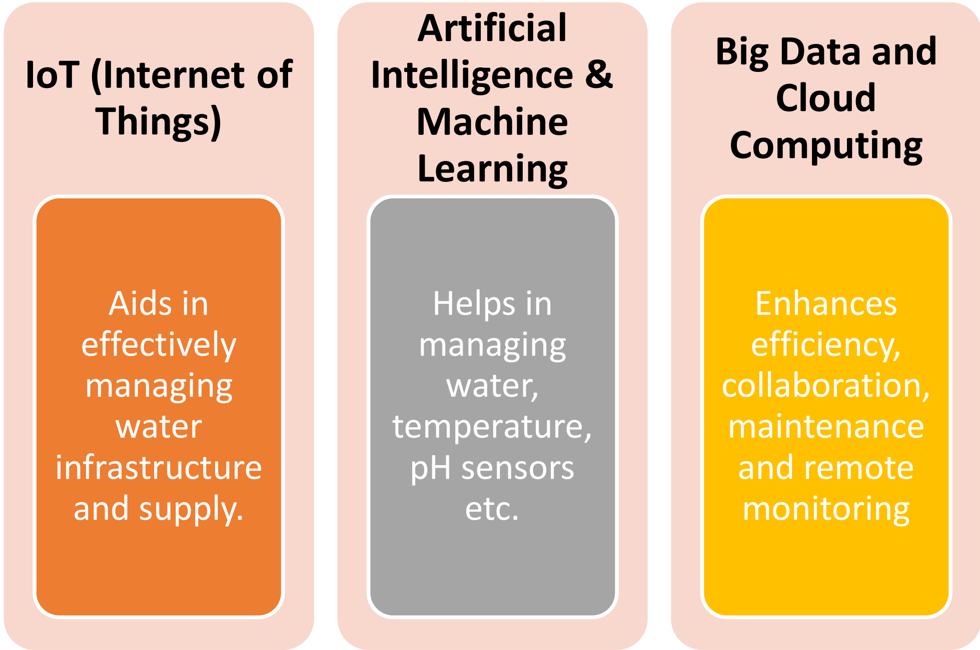

Figure 5. Use of different technologies in wastewater treatment.

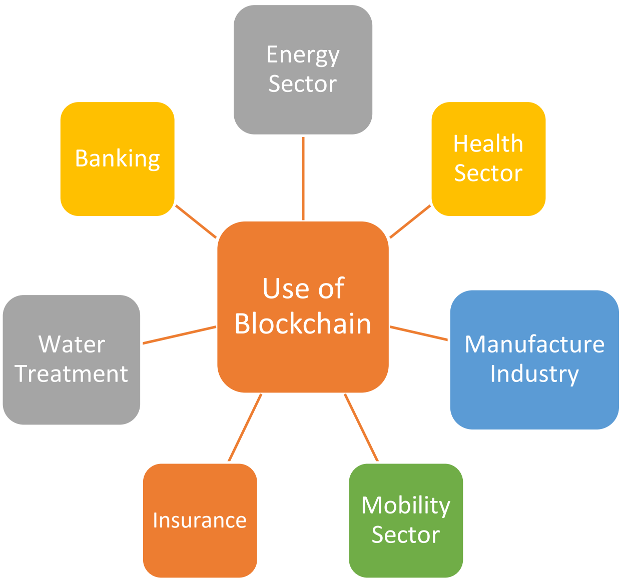

Figure 6. Use of blockchain in other industries.

5.5. Robotics and Drones

Small drones may now be equipped with chemical-sensing payloads for application in atmospheric chemistry, the monitoring of industrial pollution, environmental law enforcement, agriculture, chemical industries, and wastewater treatment facilities. Wastewater treatment plants (WWTPs) are now experimenting using drones to reduce the costs and risks associated with walkover surveys using hand-held detectors. This is performed to reduce the frequency with which walkover surveys must be undertaken [97]. Regular odor monitoring is conducted at wastewater treatment facilities to check the efficacy of smell abatement systems, detect escapee emissions, and forecast and minimize off-site odor effects [98,99]. Even in small concentrations, compounds having unpleasant odors produce problems for human settlements [100,101]. Drones are used for the purpose of ensuring worker safety by inspecting sections of wastewater treatment plant's infrastructure for difficulties such as cracks or a multitude of other problems. In most cases, drones are able to shoot video of a good quality in a very short amount of time. If a drone were to discover significant issues, a maintenance manager would be able to determine how to distribute available resources and take preventative measures before disaster struck. The usefulness of tiny drones for monitoring odor in WWTPs and oil-refinery facilities using drones and robotics with electrochemical sensors for odorous substances such as hydrogen sulfide or ammonia has been studied [102].

6. Discussion and Future Prospects

The purification of water and wastewater has been significantly aided by technological advancements. These techniques have made extensive use of a variety of technology-based procedures, such as electrochemical treatment, coagulation, and the purification of water via the use of RO and UV technologies, amongst others. The purification of water and wastewater has been made slightly simpler as a result of these technologies; however, these technologies now need to be modified as time goes on. The most crucial thing that has to be taken care of right now is the technological improvement that will come with time. As we have seen and discussed, Industry 4.0 possesses potential to play a major part in achieving the Sustainable Development Goals' aim for clean water. Industry 4.0 has the potential to facilitate the creation of brand-new options for the prevention, reduction, and even elimination of waste from certain industries and streams. This will result in the acceleration of resource recovery, the achievement of high standards of treatment and disposal, and a significant reduction in pollution. Cutting-edge technologies, such as cloud computing (Cloud), artificial intelligence (AI), Internet of Things (IoT), machine learning (ML), robotics and drones, etc., are already being explored by a variety of industries. These technologies can be used in water treatment plants as given below. The big data obtained from different sensors connected through IoT can be stored to a cloud from where it can be easily accessed for further study and analysis or can be used for artificial intelligence or machine learning. The data can be further utilized through the Metaverse and augmented reality for various applications such as water quality monitoring or analyzing contaminants, etc.; see Figure 7.

The most recent technological advancements and disciplines, such as artificial intelligence, deep learning, robotics, big data, Internet of Things, drones, augmented and virtual reality, and more, have enabled the development of pilot programs and prototypes to test their potential application in waste treatment facilities. However, in future, these technologies can play a significantly vital role as follows:

- Technologies such as the Internet of Things and automation make it feasible for organizations to play a larger role in the waste management arena by lowering or eliminating tasks that are "hazardous." Artificial intelligence will make it possible to determine the composition of raw materials (trash) and to maintain constant mass balance throughout the selection process. It will also help in maintaining and controlling the temperature, pH and water sensors being used. Machine learning will offer increased traceability for all chosen commodities, improved stock and warehouse management, and overall logistics efficiency.
- Real-time conditions will be monitored by sensor networks established throughout supply, collection, treatment, and distribution activities and processes. Anywhere and at any time, data and information will be accessible through the cloud and mobile devices. The combination of data analytics and machine learning will make machines and gadgets intelligent, allowing for the autonomous execution of prescriptive actions based on data-driven predictions.
- Big data and Internet of Things (IoT), combined with artificial intelligence, will allow governments to construct individualized analytics dashboards, which can assist in achieving a deeper comprehension of waste streams and the development of more

effective resource recovery initiatives. The combination of technologies might be simply used to automate the processes involved in recycling. Industries can use data from the Internet of Things (IoT) and other technologies to understand usage and disposal patterns better and to plan waste management with respect to environment.

- Within the next ten years, robotic recycling will enter the mainstream, bringing with it increased accuracy, improved flexibility, and faster market adaptation, as well as transforming the materials recovery facilities of the future. Drones outfitted with various sensors, such as vision or odor, and even integrating artificial intelligence, will enhance plant inspection, maintenance, anomaly detection, and health and safety. The use of robotics systems for maintenance and cleaning jobs will increase asset availability and enhance treatment capacity. Dual systems of modern robotics and artificial intelligence can also enhance capacity for trash selection, thus enhancing the working environment.
- Automation will replace mundane, manual operations with jobs that optimize performance and provide more value. In-situ monitoring devices will detect and send alerts about events such as water level rises, pressure spikes or dips, the presence of contaminants, loss of flow, out-of-specification water quality, etc., allowing preventive intervention and shifting the risk paradigm from consequence containment to prevention. The meter-to-cash payment procedure will be smooth.
- Application of virtual reality will help to learn and simulate for maintenance, breakdowns, and personnel training prior to operation. Augmented reality can help the allocation of equipment, as an interface for maintenance management, and as a self-protection and safety enhancement system for employees. It will ease onboarding and minimize the expense and time away from the office required for destination training events.
- However, just as every coin has two faces, these technologies possess some limitations too. One thing that really needs attention is that these wireless technologies and interoperability have done away with the necessity of people to individually handle the controls that run the water and wastewater systems. In the past, humans were responsible for the personal monitoring of these controls. As a direct consequence of this, interconnected water and wastewater systems are now susceptible to sophisticated attacks that the sector has never before seen. Anyone with nefarious intentions might access the network and perhaps poison it or put an end to the process of treating and distributing water if suitable cybersecurity measures are not in place. Many water and wastewater plants are small or medium-sized, and they lack the security skills necessary to detect and repel any attack directed against them.
- The fact that cybercriminals will only become more talented over time is a fact. As a consequence of this, there is a genuine possibility that an enemy—such as a nation state, hacker, or cyber terrorist—may seize control of a system or network. The aftermath of an advanced persistent threat might lead to the contamination of the water supply with chemicals, or overflowing of streets with untreated sewage, etc. The harm caused would not be restricted to a small area, since these systems are now networked with one another. Instead, an attack might disrupt the supply chain of water throughout the nation, leading to the seizure of the most important resource and putting the lives of the general population in danger.

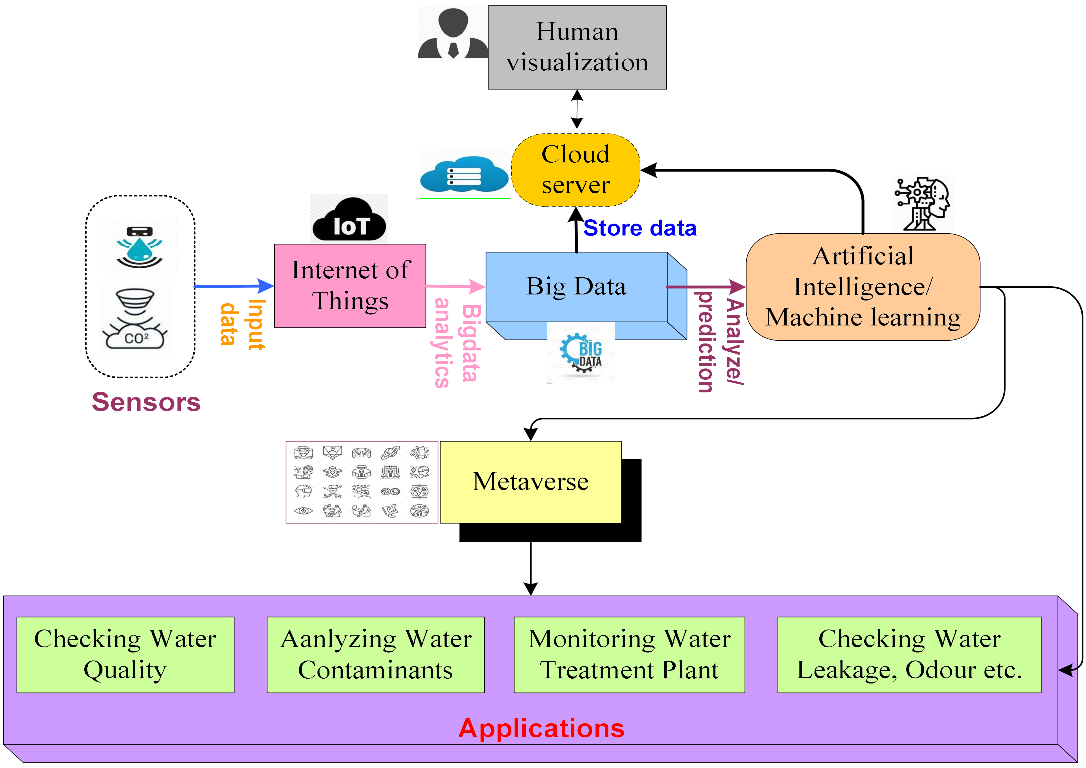

Figure 7. Proposed use of I4.0 for water treatment plants.

7. Conclusions

The global initiative known as Agenda 2030 was conceived of as a tool to facilitate increased participation in solving the world's most serious problems. The 17 Sustainable Development Objectives (SDG) are an interrelated collection of various goals, targets, and indicators that were developed to steer governments, institutions, and civil society towards sustainable development. At the same time, the creation of I4.0 and the transition to CE are presently in the process of getting underway. Considering this context, the purpose of this study was to understand the combination of I4.0 and SDGs in the accomplishment of these goals, as well as to connect these two themes of I4.0 and SDGs via the process of a systematic literature review. It is now essential that, to meet the goals, the water industries adopt Industry 4.0 and upgrade its systems. This necessitates the complete digitization of all activities and the integration of not just technologies but also people and processes in order to accomplish complete digitalization. It also entails deploying the key technological components of Industry 4.0 to create an interoperable water management network that employs near-real-time data and analytics to provide actionable insights that enable short- and long-term responses to changes in monitored systems, such as water and waste water. In conclusion, the themes that this study focuses on are relatively new; it is possible that future systematic studies with similar aims may be able to highlight the SDGs reactions to the further expansion of the I4.0 nexus.

Author Contributions: Conceptualization, R.S. and A.G.; methodology, S.P.; software, E.C.M.; validation, N.P. and A.S.; formal analysis, E.C.M.; investigation, B.T.; resources, R.S.; data curation, A.S.; writing—original draft preparation, S.P.; writing—review and editing, S.P.; visualization, A.G.; supervision, R.S.; project administration, A.S.; funding acquisition, B.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding. The APC was funded by Tshwane University of Technology, South Africa.

Data Availability Statement: Not applicable.

Acknowledgments: The authors are thankful to the Department of Research and Innovation, Uttaranchal University for their support and guidance. In addition, we are thankful to Ajay Singh for helping us to prepare detailed authors responses.

Conflicts of Interest: The authors state no conflict of interest of any kind.

References

1. Fighir, D.; Teodosiu, C.; Fiore, S. Environmental and energy assessment of municipal wastewater treatment plants in Italy and Romania: A comparative study. *Water* **2019**, *11*, 1611. [CrossRef]
2. Padilla-Rivera, A.; Güereca, L.P. A proposal metric for sustainability evaluations of wastewater treatment systems (SEWATS). *Ecol. Indic.* **2019**, *103*, 22–33. [CrossRef]
3. Maria, F.D.; Daskal, S.; Ayalon, O. A methodological approach for comparing waste water effluent's regulatory and management frameworks based on sustainability assessment. *Ecol. Indic.* **2020**, *118*, 106805. [CrossRef]
4. 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.* **2016**, *114*, 11–32. [CrossRef]
5. Shehata, N.; Mohamed, O.A.; Sayed, E.T.; Abdelkareem, M.A.; Olabi, A.G. Geopolymer concrete as green building materials: Recent applications, sustainable development and circular economy potentials. *Sci. Total Environ.* **2022**, *836*, 155577. [CrossRef] [PubMed]
6. Neczaj, E.; Grosser, A. Circular economy in wastewater treatment plant–Challenges and barriers. *Multidiscip. Digit. Publ. Inst. Proc.* **2018**, *2*, 614.
7. Ritter, L.; Solomon, K.; Sibley, P.; Hall, K.; Keen, P.; Mattu, G.; Linton, B. Sources, pathways, and relative risks of contaminants in surface water and groundwater: A perspective prepared for the Walkerton inquiry. *J. Toxicol. Environ. Health Part A* **2002**, *65*, 1–142.
8. Rajasekhar, B.; Nambi, I.M.; Govindarajan, S.K. Human health risk assessment of ground water contaminated with petroleum PAHs using monte carlo simulations: A case study of an Indian metropolitan city. *J. Environ. Manag.* **2018**, *205*, 183–191. [CrossRef]
9. Rodriguez-Proteau, R.; Grant, R.L. Toxicity evaluation and human health risk assessment of surface and ground water contaminated by recycled hazardous waste materials. *Water Pollut.* **2005**, *2*, 133–189.
10. Ahmad, H.R.; Aziz, T.; Zia-ur-Rehman, M.; Sabir, M.; Khalid, H. Sources and composition of waste water: Threats to plants and soil health. In *Soil Science: Agricultural and Environmental Prospectives*; Springer: Cham, Switzerland, 2016; pp. 349–370.
11. Jassby, D.; Cath, T.Y.; Buisson, H. The role of nanotechnology in industrial water treatment. *Nat. Nanotechnol.* **2018**, *13*, 670–672. [CrossRef]
12. Rout, P.R.; Mohanty, A.; Sharma, A.; Miglani, M.; Liu, D.; Varjani, S. Micro-and nanoplastics removal mechanisms in wastewater treatment plants: A review. *J. Hazard. Mater. Adv.* **2022**, *6*, 100070. [CrossRef]
13. Warwick, C.; Guerreiro, A.; Soares, A. Sensing and analysis of soluble phosphates in environmental samples: A review. *Biosens. Bioelectron.* **2013**, *41*, 1–11. [CrossRef] [PubMed]
14. Alcamo, J. Water quality and its interlinkages with the sustainable development goals. *Curr. Opin. Environ. Sustain.* **2019**, *36*, 126–140. [CrossRef]
15. Tortajada, C. Contributions of recycled wastewater to clean water and sanitation sustainable development goals. *NPJ Clean Water* **2020**, *3*, 22. [CrossRef]
16. Obaideen, K.; Shehata, N.; Sayed, E.T.; Abdelkareem, M.A.; Mahmoud, M.S.; Olabi, A.G. The role of wastewater treatment in achieving sustainable development goals (SDGs) and sustainability guideline. *Energy Nexus* **2022**, *7*, 100112. [CrossRef]
17. Delanka-Pedige, H.M.K.; Munasinghe-Arachchige, S.P.; Abeysiriwardana-Arachchige, I.S.A.; Nirmalakhandan, N. Evaluating wastewater treatment infrastructure systems based on UN sustainable development goals and targets. *J. Clean. Prod.* **2021**, *298*, 126795. [CrossRef]
18. Palme, U.; Lundin, M.; Tillman, A.M.; Molander, S. Sustainable development indicators for wastewater systems–Researchers and indicator users in a co-operative case study. *Resour. Conserv. Recycl.* **2005**, *43*, 293–311. [CrossRef]
19. Sayed, E.T.; Abdelkareem, M.A.; Obaideen, K.; Elsaid, K.; Wilberforce, T.; Maghrabie, H.M.; Olabi, A.G. Progress in plant-based bioelectrochemical systems and their connection with sustainable development goals. *Carbon Resour. Convers.* **2021**, *4*, 169–183. [CrossRef]
20. Sadhukhan, J.; Dugmore, T.I.; Matharu, A.; Martinez-Hernandez, E.; Aburto, J.; Rahman, P.K.; Lynch, J. Perspectives on "game changer" global challenges for sustainable 21st century: Plant-based diet, unavoidable food waste biorefining, and circular economy. *Sustainability* **2020**, *12*, 1976. [CrossRef]
21. Stahel, W.R. Sustainable development and strategic thinking. *Chin. J. Popul. Resour. Environ.* **2007**, *5*, 3–19. [CrossRef]
22. Nascimento, D.L.M.; Alencastro, V.; Quelhas, O.L.G.; Caiado, R.G.G.; Garza-Reyes, J.A.; Rocha-Lona, L.; Tortorella, G. Exploring industry 4.0 technologies to enable circular economy practices in a manufacturing context: A business model proposal. *J. Manuf. Technol. Manag.* **2018**, *30*, 607–627. [CrossRef]
23. Zhang, A.; Venkatesh, V.G.; Liu, Y.; Wan, M.; Qu, T.; Huisingh, D. Barriers to smart waste management for a circular economy in China. *J. Clean. Prod.* **2019**, *240*, 118198. [CrossRef]

24. Juste Ruiz, J. The process towards a global pact for the environment at the United Nations: From legal ambition to political dilution. *Rev. Eur. Comp. Int. Environ. Law* **2020**, *29*, 479–490. [CrossRef]
25. Dantas, T.E.; De-Souza, E.D.; Destro, I.R.; Hammes, G.; Rodriguez, C.M.T.; Soares, S.R. How the combination of circular economy and industry 4.0 can contribute towards achieving the sustainable development goals. *Sustain. Prod. Consum.* **2021**, *26*, 213–227. [CrossRef]
26. Bai, C.; Dallasega, P.; Orzes, G.; Sarkis, J. Industry 4.0 technologies assessment: A sustainability perspective. *Int. J. Prod. Econ.* **2020**, *229*, 107776. [CrossRef]
27. Drath, R.; Horch, A. Industrie 4.0: Hit or hype? [Industry forum]. *IEEE Ind. Electron. Mag.* **2014**, *8*, 56–58. [CrossRef]
28. Ramakrishna, S.; Ngowi, A.; Jager, H.D.; Awuzie, B.O. Emerging industrial revolution: Symbiosis of industry 4.0 and circular economy: The role of universities. *Sci. Technol. Soc.* **2020**, *25*, 505–525. [CrossRef]
29. Hofmann, E.; Rüsch, M. Industry 4.0 and the current status as well as future prospects on logistics. *Comput. Ind.* **2017**, *89*, 23–34. [CrossRef]
30. Berawi, M.A. The role of industry 4.0 in achieving sustainable development goals. *Int. J. Technol.* **2019**, *10*, 644–647. [CrossRef]
31. Wang, Y.; Ma, H.S.; Yang, J.H.; Wang, K.S. Industry 4.0: A way from mass customization to mass personalization production. *Adv. Manuf.* **2017**, *5*, 311–320. [CrossRef]
32. Lu, Y. Industry 4.0: A survey on technologies, applications and open research issues. *J. Ind. Inf. Integr.* **2017**, *6*, 1–10. [CrossRef]
33. Zhong, R.Y.; Xu, X.; Klotz, E.; Newman, S.T. Intelligent manufacturing in the context of industry 4.0: A review. *Engineering* **2017**, *3*, 616–630. [CrossRef]
34. Raha, D. Exploring artificial neural networks (ANN) modelling for a biological nutrient removal (BNR) sewage treatment plant (STP) to forecast effluent suspended solids. *Indian Chem. Eng.* **2007**, *49*, 205.
35. Soller, J.A.; Eftim, S.E.; Nappier, S.P. Direct potable reuse microbial risk assessment methodology: Sensitivity analysis and application to State log credit allocations. *Water Res.* **2018**, *128*, 286–292. [CrossRef]
36. Kundu, P.; Debsarkar, A.; Mukherjee, S.; Kumar, S. Artificial neural network modelling in biological removal of organic carbon and nitrogen for the treatment of slaughterhouse wastewater in a batch reactor. *Environ. Technol.* **2014**, *35*, 1296–1306. [CrossRef] [PubMed]
37. Bagheri, M.; Mirbagheri, S.A.; Ehteshami, M.; Bagheri, Z. Modeling of a sequencing batch reactor treating municipal wastewater using multi-layer perceptron and radial basis function artificial neural networks. *Process Saf. Environ. Prot.* **2015**, *93*, 111–123. [CrossRef]
38. Farhaoui, M.; Hasnaoui, L.; Derraz, M. Optimization of drinking water treatment process by modeling the aluminumsulfate dose. *Br. J. Appl. Sci. Technol.* **2016**, *17*, 1–14. [CrossRef]
39. Kesari, K.K.; Soni, R.; Jamal, Q.M.S.; Tripathi, P.; Lal, J.A.; Jha, N.K.; Siddiqui, M.H.; Kumar, P.; Tripathi, V.; Ruokolainen, J. Wastewater treatment and reuse: A review of its applications and health implications. *Water Air Soil Pollut.* **2021**, *232*, 208. [CrossRef]
40. Ahmadi, F.; Zinatizadeh, A.A.; Asadi, A.; McKay, T.; Azizi, S. Simultaneous carbon and nutrients removal and PHA production in a novel single air lift bioreactor treating an industrial wastewater. *Environ. Technol. Innov.* **2020**, *18*, 100776. [CrossRef]
41. Deshpande, B.D.; Agrawal, P.S.; Yenkie, M.K.N.; Dhoble, S.J. Prospective of nanotechnology in degradation of wastewater: A new challenges. *Nanostruct. Nano-Objects* **2020**, *22*, 100442. [CrossRef]
42. Yaqoob, A.A.; Parveen, T.; Umar, K.; Ibrahim, M.N.M. Role of nanomaterials in the treatment of wastewater: A review. *Water* **2020**, *12*, 495. [CrossRef]
43. Templeton, M.R.; Butler, D. *Introduction to Wastewater Treatment*; Bookboon: London, UK, 2011.
44. Kalfa, A.; Shapira, B.; Shopin, A.; Cohen, I.; Avraham, E.; Aurbach, D. Capacitive deionization for wastewater treatment: Opportunities and challenges. *Chemosphere* **2020**, *241*, 125003. [CrossRef]
45. Verlicchi, P.; Aukidy, M.A.; Zambello, E. Occurrence of pharmaceutical compounds in urban wastewater: Removal, mass load and environmental risk after a secondary treatment—A review. *Sci. Total Environ.* **2012**, *429*, 123–155. [CrossRef]
46. Bora, T.; Dutta, J. Applications of nanotechnology in wastewater treatment—A review. *J. Nanosci. Nanotechnol.* **2014**, *14*, 613–626. [CrossRef]
47. Ma, W.; Jiang, Z.; Lu, T.; Xiong, R.; Huang, C. Lightweight, elastic and superhydrophobic multifunctional nanofibrous aerogel for self-cleaning, oil/water separation and pressure sensing. *Chem. Eng. J.* **2022**, *430*, 132989. [CrossRef]
48. Cao, W.; Ma, W.; Lu, T.; Jiang, Z.; Xiong, R.; Huang, C. Multifunctional nanofibrous membranes with sunlight-driven self-cleaning performance for complex oily wastewater remediation. *J. Colloid Interface Sci.* **2022**, *608*, 164–174. [CrossRef]
49. Ma, W.; Ding, Y.; Li, Y.; Gao, S.; Jiang, Z.; Cui, J.; Huang, C.; Fu, G. Durable, self-healing superhydrophobic nanofibrous membrane with self-cleaning ability for highly-efficient oily wastewater purification. *J. Membr. Sci.* **2021**, *634*, 119402. [CrossRef]
50. Pérez-Page, M.; Yu, E.; Li, J.; Rahman, M.; Dryden, D.M.; Vidu, R.; Stroeve, P. Template-based syntheses for shape controlled nanostructures. *Adv. Colloid Interface Sci.* **2016**, *234*, 51–79. [CrossRef]
51. Nasrollahzadeh, M.; Sajjadi, M.; Iravani, S.; Varma, R.S. Carbon-based sustainable nanomaterials for water treatment: State-of-art and future perspectives. *Chemosphere* **2021**, *263*, 128005. [CrossRef]
52. Alalwan, H.A.; Alminshid, A.H.; Mohammed, M.M.; Mohammed, M.F. Reviewing of using nanomaterials for wastewater treatment. *Pollution* **2022**, *8*, 995–1013.

53. Nasrollahzadeh, M.; Sajjadi, M.; Iravani, S.; Varma, R.S. Green-synthesized nanocatalysts and nanomaterials for water treatment: Current challenges and future perspectives. *J. Hazard. Mater.* **2021**, *401*, 123401. [CrossRef]
54. Internet of Things Wikipedia. Available online: https://en.wikipedia.org/wiki/Internet_of_things (accessed on 17 August 2022).
55. Su, J.J.; Ding, S.T.; Chung, H.C. Establishing a smart farm-scale piggery wastewater treatment system with the internet of things (IoT) applications. *Water* **2020**, *12*, 1654. [CrossRef]
56. Kshirsagar, P.R.; Tirth, V.; Islam, S.; Qaiyum, S.; Al Duhayyim, M.; Waji, Y.A. IOT based smart wastewater treatment model for industry 4.0 using artificial intelligence. *Sci. Program.* **2022**, *2022*, 5134013.
57. Geetha, S.; Gouthami, S.J.S.W. Internet of things enabled real time water quality monitoring system. *Smart Water* **2016**, *2*, 1. [CrossRef]
58. Malhotra, V. IoT-based smart water quality monitoring system to expand sensors life and battery power. In *Sustainable Communication Networks and Application*; Springer: Singapore, 2022; pp. 153–162.
59. Dhruba, A.R.; Alam, K.N.; Khan, M.; Saha, S.; Khan, M.M.; Baz, M.; Masud, M.; AlZain, M.A. IoT-based water quality assessment system for industrial waste waterhealthcare perspective. *J. Healthc. Eng.* **2022**, *2022*, 3769965. [CrossRef]
60. Davia, C.; Gowen, S.; Ghezzo, G.; Harris, R.; Horne, M.; Potter, C.; Pitt, S.P.; Vandenberg, A.; Xiong, N. Cloud computing services and architecture for education. *Int. J. Cloud Comput. 1* **2013**, *2*, 213–236. [CrossRef]
61. Abolfazli, S.; Sanaei, Z.; Ahmed, E.; Gani, A.; Buyya, R. Cloud-based augmentation for mobile devices: Motivation, taxonomies, and open challenges. *IEEE Commun. Surv. Tutor.* **2013**, *16*, 337–368. [CrossRef]
62. Bhardwaj, S.; Jain, L.; Jain, S. Cloud computing: A study of infrastructure as a service (IAAS). *Int. J. Eng. Inf. Technol.* **2010**, *2*, 60–63.
63. Subashini, S.; Kavitha, V. A survey on security issues in service delivery models of cloud computing. *J. Netw. Comput. Appl.* **2011**, *34*, 1–11. [CrossRef]
64. Azeem, M.; Haleem, A.; Bahl, S.; Javaid, M.; Suman, R.; Nandan, D. Big data applications to take up major challenges across manufacturing industries: A brief review. *Mater. Today Proc.* **2021**, *49*, 339–348. [CrossRef]
65. Cooper, J.; Noon, M.; Jones, C.U.; Kahn, E.; Arbuckle, P. Big data in life cycle assessment. *J. Ind. Ecol.* **2013**, *17*, 796–799. [CrossRef]
66. Saha, P.; Vinnarasi, M.R. Smart underwater monitoring system through IoT using big data. *Int. J. Pure Appl. Math.* **2018**, *120*, 1893–1901.
67. O'Donovan, P.; Coburn, D.; Jones, E.; Hannon, L.; Glavin, M.; Mullins, D.; Clifford, E. A cloud-based distributed data collection system for decentralised wastewater treatment plants. *Procedia Eng.* **2015**, *119*, 464–469. [CrossRef]
68. Ly, Q.V.; Truong, V.H.; Ji, B.; Nguyen, X.C.; Cho, K.H.; Ngo, H.H.; Zhang, Z. Exploring potential machine learning application based on big data for prediction of wastewater quality from different full-scale wastewater treatment plants. *Sci. Total Environ.* **2022**, *832*, 154930. [CrossRef] [PubMed]
69. Stankov, S.P. Big data in water supply and sewerage systems. *ActaTechnicaCorviniensis-Bull. Eng.* **2022**, *15*, 21–25.
70. Sundarasekar, R.; Shakeel, P.M.; Baskar, S.; Kadry, S.; Mastorakis, G.; Mavromoustakis, C.X.; Samuel, R.D.J.; Gn, V. Adaptive energy aware quality of service for reliable data transfer in under water acoustic sensor networks. *IEEE Access* **2019**, *7*, 80093–80103. [CrossRef]
71. Matheri, A.N.; Mohamed, B.; Ntuli, F.; Nabadda, E.; Ngila, J.C. Sustainable circularity and intelligent data-driven operations and control of the wastewater treatment plant. *Phys. Chem. Earth Parts A/B/C* **2022**, *126*, 103152. [CrossRef]
72. Verma, A.; Wei, X.; Kusiak, A. Predicting the total suspended solids in wastewater: A data-mining approach. *Eng. Appl. Artif. Intell.* **2013**, *26*, 1366–1372. [CrossRef]
73. Arridha, R. Classification extension based on IoT-big data analytic for smart environment monitoring and analytic in real-time system. *Int. J. Space-Based Situated Comput.* **2017**, *7*, 2. [CrossRef]
74. Martínez, R.; Vela, N.; El Aatik, A.; Murray, E.; Roche, P.; Navarro, J.M. On the Use of an IoT integrated system for water quality monitoring and management in wastewater treatment plants. *Water* **2020**, *12*, 1096. [CrossRef]
75. Edmondson, V.; Cerny, M.; Lim, M.; Gledson, B.; Lockley, S.; Woodward, J. A smart sewer asset information model to enable an 'Internet of Things' for operational wastewater management. *Autom. Constr.* **2018**, *91*, 193–205. [CrossRef]
76. Irfan, M.; Waqas, S.; Arshad, U.; Khan, J.A.; Legutko, S.; Kruszelnicka, I.; Ginter-Kramarczyk, D.; Rahman, S.; Skrzypczak, A. Response surface methodology and artificial neural network modelling of membrane rotating biological contactors for wastewater treatment. *Materials* **2022**, *15*, 1932. [CrossRef]
77. Ganguly, P.; Das, P. Integral approach for second-generation bio-ethanol production and wastewater treatment using peanut shell waste: Yield, removal, and ANN studies. *Biomass-Convers. Biorefinery* **2022**, 1–11. [CrossRef]
78. Agatonovic-Kustrin, S.; Beresford, R. Basic concepts of artificial neural network (ANN) modeling and its application in pharmaceutical research. *J. Pharm. Biomed. Anal.* **2000**, *22*, 717–727. [CrossRef]
79. Shokry, A.; Vicente, P.; Escudero, G.; Pérez-Moya, M.; Graells, M.; Espuña, A. Data-driven soft-sensors for online monitoring of batch processes with different initial conditions. *Comput. Chem. Eng.* **2018**, *118*, 159–179. [CrossRef]
80. Jana, D.K.; Bhunia, P.; Adhikary, S.D.; Bej, B. Optimization of effluents using artificial neural network and support vector regression in detergent industrial wastewater treatment. *Clean. Chem. Eng.* **2022**, *3*, 100039. [CrossRef]
81. Zhao, L.; Dai, T.; Qiao, Z.; Sun, P.; Hao, J.; Yang, Y. Application of artificial intelligence to wastewater treatment: A bibliometric analysis and systematic review of technology, economy, management, and wastewater reuse. *Process Saf. Environ. Prot.* **2020**, *133*, 169–182. [CrossRef]

82. Zaghloul, M.S.; Iorhemen, O.T.; Hamza, R.A.; Tay, J.H.; Achari, G. Development of an ensemble of machine learning algorithms to model aerobic granular sludge reactors. *Water Res.* **2021**, *189*, 116657. [CrossRef]
83. Aleboyeh, A.; Kasiri, M.B.; Olya, M.E.; Aleboyeh, H. Prediction of azo dye decolorization by UV/H2O2 using artificial neural networks. *Dye. Pigment.* **2008**, *77*, 288–294. [CrossRef]
84. GholamiShirkoohi, M.; Tyagi, R.D.; Vanrolleghem, P.A.; Drogui, P. Artificial neural networks and genetic algorithms: An efficient modelling and optimization methodology for active chlorine production using the electrolysis process. *Can. J. Chem. Eng.* **2021**, *99*, S389–S403.
85. Farzin, S.; Chianeh, F.N.; Anaraki, M.V.; Mahmoudian, F. Introducing a framework for modeling of drug electrochemical removal from wastewater based on data mining algorithms, scatter interpolation method, and multi criteria decision analysis (DID). *J. Clean. Prod.* **2020**, *266*, 122075. [CrossRef]
86. Ye, Z.; Yang, J.; Zhong, N.; Tu, X.; Jia, J.; Wang, J. Tackling environmental challenges in pollution controls using artificial intelligence: A review. *Sci. Total Environ.* **2020**, *699*, 134279. [CrossRef] [PubMed]
87. Golzar, F.; Nilsson, D.; Martin, V. Forecasting wastewater temperature based on artificial neural network (ANN) technique and montecarlo sensitivity analysis. *Sustainability* **2020**, *12*, 6386. [CrossRef]
88. Khatri, N.; Khatri, K.K.; Sharma, A. Artificial neural network modelling of faecal coliform removal in an intermittent cycle extended aeration system-sequential batch reactor-based wastewater treatment plant. *J. Water Process Eng.* **2020**, *37*, 101477. [CrossRef]
89. Mohammad, A.T.; Al-Obaidi, M.A.; Hameed, E.M.; Basheer, B.N.; Mujtaba, I.M. Modelling the chlorophenol removal from wastewater via reverse osmosis process using a multilayer artificial neural network with genetic algorithm. *J. Water Process Eng.* **2020**, *33*, 100993. [CrossRef]
90. Kiiza, C.; Pan, S.-Q.; Bockelmann-Evans, B.; Babatunde, A. Predicting pollutant removal in constructed wetlands using artificial neural networks (ANNs). *Water Sci. Eng.* **2020**, *13*, 14–23. [CrossRef]
91. Xie, S.; Zheng, Z.; Chen, W.; Wu, J.; Dai, H.-N.; Imran, M. Blockchain for cloud exchange: A survey. *Comput. Electr. Eng.* **2020**, *81*, 106526. [CrossRef]
92. Rathee, G.; Sharma, A.; Kumar, R.; Iqbal, R. A secure communicating things network framework for industrial IoT using blockchain technology. *Ad Hoc Networks* **2019**, *94*, 101933. [CrossRef]
93. Bai, L.; Hu, M.; Liu, M.; Wang, J. BPIIoT: A light-weighted blockchain-based platform for industrial IoT. *IEEE Access* **2019**, *7*, 58381–58393. [CrossRef]
94. Reyna, A.; Martin, C.; Chen, J.; Soler, E.; Diaz, M. Onblockchain and its integration with IoT. Challenges and opportunities. *Future Gener. Comput. Syst.* **2018**, *88*, 173–190. [CrossRef]
95. Khan, M.A.; Salah, K. IoT security: Review. Blockchain solutions. and open challenges. *Future Gener. Comput. Syst.* **2018**, *82*, 395–411. [CrossRef]
96. Moin, S.; Karim, A.; Safdar, Z.; Safdar, K.; Ahmed, E.; Imran, M. Securing IoTs in distributed blockchain: Analysis, requirements and open issues. *Future Gener. Comput. Syst.* **2019**, *100*, 325–343. [CrossRef]
97. Hakak, S.; Khan, W.Z.; Gilkar, G.A.; Haider, N.; Imran, M.; Alkatheiri, M.S. Industrial wastewater management using blockchain technology: Architecture, requirements, and future directions. *IEEE Internet Things Mag.* **2020**, *3*, 38–43. [CrossRef]
98. Emran, B.J.; Tannant, D.D.; Najjaran, H. Low-altitude aerial methane concentration mapping. *Remote Sens.* **2017**, *9*, 823. [CrossRef]
99. Zarra, T.; Naddeo, V.; Belgiorno, V.; Reiser, M.; Kranert, M. Odour monitoring of small wastewater treatment plant located in sensitive environment. *Water Sci. Technol.* **2008**, *58*, 89–94. [CrossRef]
100. Naddeo, V.; Zarra, T.; Giuliani, S.; Belgiorno, V. Odour impact assessment in industrial areas. *Chem. Eng.* **2012**, 30.
101. Martí, V.; Jubany, I.; Pérez, C.; Rubio, X.; De Pablo, J.; Giménez, J. Human health risk assessment of a landfill based on volatile organic compounds emission, immission and soil gas concentration measurements. *Appl. Geochem.* **2014**, *49*, 218–224. [CrossRef]
102. Byliński, H.; Gębicki, J.; Namieśnik, J. Evaluation of health hazard due to emission of volatile organic compounds from various processing units of wastewater treatment plant. *Int. J. Environ. Res. Public Health* **2019**, *16*, 1712. [CrossRef]