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REUSE OF WASTEWATER IN AGRICULTURE, IRRIGATION, AND DOMESTIC USE: A BACKLOOK, AN AHEADLOOK, AND A FORWARDLOOK

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ABSTRACT

Due to population growth and the consolidation of existing states, freshwater resources are becoming increasingly scarce. When there is a shortage of fresh water, an important alternative water source that can be used in gardening is waste water. This is of critical relevance during drought. There have been multiple iterations of irrigation in both developing and developed countries that make use of wastewater. It is recommended that you refrain from utilising untreated rainwater for plant irrigation if at all possible. By implementing proper management practises, such as putting in place the required instruments for treating and watering the soil, it is possible to achieve various benefits while reducing hazards. By utilising these methods, we can achieve this state of equilibrium. The primary difficulties of wastewater irrigation were reviewed, as well as potential solutions that could be implemented in the future to improve wastewater irrigation systems worldwide. This article provides a concise history, overview, and outlook of wastewater reuse and recycling. These articles focus on innovative approaches to the treatment and monitoring of wastewater, such as electrolytic structures, reducing bio filters, membrane bioreactors, and disinfecting tools. Organic matter's impact on pathogen inactivation and nutrient removal are discussed, along with best management practices for biosolids. In sum, the methods presented in this Special Issue range from the most basic to the most advanced approaches to wastewater treatment and reuse.

KEYWORDS: *Biosolids, Wastewater Treatment, Reuse and Recycling*

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INTRODUCTION

As the population of the globe rises, so does the need for water; yet, as supplies become scarcer, water recycling and reuse are becoming an increasingly significant practise. In 2014, metropolitan areas were home to 54% of the global population but were expected to account for only 11% of global water demand. 150 nations are dealing with water scarcity of some kind. It is predicted that by 2025, as much as two-thirds of the global population will experience some form of water stress. It is also anticipated that the number of countries concerned with water issues will increase. Simultaneously, the disposal of a great deal of wastewater from homes and industries places significant demands on the natural environment. These stresses have caused profound changes in the natural world. Annually, more than 400 billion cubic metres of wastewater are discharged worldwide, contaminating about 5500 billion cubic metres of water. Urban wastewater, treated wastewater, and recovered or recycled water are just some of the urban outlets that are used to dispose of wastewater, the quality of which can vary substantially. Wastewater is a valuable water resource for irrigation, especially in arid and semiarid regions, due to the large volumes it carries and the nutritional features (nitrogen and phosphorus) that it possesses. Wastewater is an invaluable resource for agricultural irrigation in dry and semiarid settings. There is a broad variety of wastewater, from its purest to its most diluted forms. Both treated and untreated wastewater can be used for direct irrigation, whereas only treated urban waste water can be used for indirect irrigation. Using wastewater as a consistent and reliable water source helps reduce the price of fertiliser. The amount of precipitation or the change in temperature have little effect on wastewater flow rates. This means that agricultural production can occur year-round, not just during the growing season. In addition, the nutritional content of wastewater can improve crop growth while reducing the amount of chemical fertiliser needed. The quantity of fertiliser required to grow wheat can be cut by as much as 45 percent when using wastewater irrigation, and the amount required for lucerne jumps to 94 percent. However, using sewage for irrigation can pose risks to both human and environmental health. Disease transmission has been linked to heavy metal pollution and parasitic worms in food. Soil hardening, heavy metal enrichment, and shallow groundwater pollution are all potential outcomes of using waste water for irrigation without first treating it. Although wastewater irrigation is essential, it presents a number of challenges that must be overcome before it can be widely used. There has not been a thorough and well-organised examination of the potential problems with wastewater irrigation, nor of its history or current status. The purpose of this research is to analyse how wastewater is recycled for agricultural purposes. The initial purpose of wastewater irrigation was to lessen the need for fertiliser or to stop the development of water contamination during times of severe water shortage. The technique has progressed since then, along with other advances in technology. This article takes a look at the current state of recycling wastewater for use in agricultural irrigation. Key issues and directions for future application of the topic are analysed, and discussion of the impacts on crops and the environment is included. Reusing and recycling wastewater is not a new concept, and neither is our knowledge of how to achieve it. Redirecting human waste away from inhabited areas has long been a motivation for utilising raw municipal wastewater. Land application of domestic wastewater is another time-tested method with a long history of development. Researchers' understanding of processes and treatment technologies has improved, and new benchmarks for water quality have been set.

Domestic wastewater reuse for irrigation dates back to the Bronze Age (3200–1100 BC) and was practised by ancient civilizations such as the Mesopotamians, Indus Valley people, and the Minoans. After that, the land around large cities like Athens and Rome benefited from things like sewage-based irrigation and fertilisation [2]. There is evidence that "sewage farms" were in operation in Bunzlau (Silesia) in the year 1531 and Edinburgh (Scotland) in the year 1650 [3, 4]. "Sewage farms" are defined as the application of wastewater to the land for the purpose of disposal and agricultural use. Some of the "sewage farms" built in the 1800s and 1900s to treat the wastewater of rapidly growing cities in Europe and the United States are still in operation today. In 1872, the borough of Gennevilliers in Paris served as a prototype for sewage farms throughout the city. The city of Melbourne, Australia, also established a significant "sewage farm" in 1897 [citations needed]. [3-5]. The use of land treatment systems remained throughout the twentieth century in central Europe, the United States, and other locations all over the world despite catastrophic public health and environmental implications. Despite their advantages, these systems had not achieved widespread adoption [3] by the end of the first half of the current century because of issues like their large footprint, difficulties in field operations, and meeting stricter cleanliness standards.

To combat the rising squalor caused by industrialization and urbanisation, sophisticated sewage systems were not built until the middle of the nineteenth century. Thousands of Londoners perished in cholera epidemics in 1832, 1849, and 1855 because of water contamination. Furthermore, in 1858, there was a serious odour because untreated human waste was being carried by the River Thames.

In recent years, more nations have seriously contemplated programmes to clean up their wastewater and recycle their effluents. Primary (re)uses of treated wastewater include irrigation (both agricultural and landscape), aquifer recharge, maritime barrier creation, industrial applications, dual-distribution systems for toilet flushing, and other urban purposes. According to the World Bank, the United Nations Food and Agriculture Organisation (FAO), and the World Health Organisation (WHO), the top five countries in the world for the amount of such water that is reused are the United States, China, Japan, Spain, Israel, and Australia. In 2010, only 860 m3/year of California's treated wastewater effluent was recycled, while the remaining 3440 m3/year was discharged into the ocean. In 2030, we hope to recycle 2470 m3/year [7]. Spanish authorities estimate that by 2025 they will have reused 1 billion gallons of cleaned wastewater. Israel recycles more than 80 percent of its treated sewage effluent, mostly for use in agricultural irrigation. Singapore's current water needs [9] are covered by water to the tune of up to 30 percent, and that number might climb to 55 percent by 2060 [10]. Drought across the United States has increased interest in and adoption of direct potable reuse in places like California and Texas. Regulations for both direct and indirect potable reuse were required by the state's governor in 2013. Large-scale direct potable reuse facilities are already operational in the Texas cities of Big Spring and Wichita Falls. Assuming the same treatment trains are used for both indirect and direct potable reuse, the only measurable difference between the two is time. Water quality cannot be improved through the use of environmental buffers such as groundwater injection. In practise, however, environmental buffers provide a response time that scales with the volume of water held. Important control points and online sensor networks are required for the system to respond quickly enough for direct potable reuse. Another issue that has been bothering people who care about water reuse is the potential dangers posed by chemical combinations [11]. In vitro bioassays are increasingly being used for rapid, high-throughput screening of water toxicity [12, 13].

The Development of Irrigating with Disposed of Water

Wastewater irrigation techniques utilised by the ancient Egyptians, Mesopotamians, Cretans, and Indus Valley people are still in use today. 15 This practise has been around for quite some time. In 3500 B.C., the ancient Minoans may have begun using waste water that had been treated for agricultural purposes, as suggested by extensive historical evidence16. Wastewater was first applied in irrigation to preserve crop quality when a paucity of potable water forced its use. Archaeological examinations have shown that its consumption increased beginning somewhere around the year 2600 BC. Since 1700 BC, Crete has been using its wastewater for agricultural uses, such as irrigating and fertilising its crops and fruit trees. This practise dates back to the 17th century. 18 In the course of historical events, collection basins that were positioned outside of towns for the purpose of wastewater irrigation initially developed during the Hellenistic period around 500 BC to the southeast of the Acropolis. These basins were located in the general vicinity of the Acropolis. 16 The Romans are credited with being the first known humans to make use of wastewater. In more recent periods (modern times), the first wastewater irrigation farms were built in Germany in 1531 and Scotland in 1650. Both of these countries are in Europe. Prior to the invention of technologies that could cleanse wastewater, effluent was disposed of in agricultural fields. This practise began at the turn of the previous century and was done to keep wastewater from polluting water bodies. 20 In the early 1900s, it was common practise in Paris to irrigate with sewage that had only been partially purified. This was done in order to save money. 18 A large wastewater irrigation farm that had been established in Australia in 1897 was able to irrigate approximately 10,000 hectares of land with wastewater because it made use of stabilising ponds. 21 In the year 1904, Mexico City created its first extensive wastewater irrigation district in the arid valley of Mexico. This was done so that the city could get rid of the massive volumes of raw sewage that were being produced by urban systems. Mexico is home to one particular neighbourhood.

In recent years, water reuse has grown increasingly common. Volumes of recycled water have increased by 10–29% annually in Europe, the United States, and China, and by as much as 41% annually in Australia. 22

Due to the rapid development and widespread acceptance of technology for the treatment of wastewater, the range of applications for recovered water has significantly grown during the past ten to fifteen years.

Irrigation and indirect and direct potable reuse 23 and 25 are two examples of how developed countries recycle wastewater for agricultural use. This element of wastewater reuse in underdeveloped countries needs more research. More than 80% of Israel's treated wastewater is reused in agricultural irrigation. Here in the Golden State, the Despite this, the Infrastructure Development Finance Corporation reports that 73% of India's urban wastewater is still untreated, and in China, urban wastewater reuse programmes at the national level have been developed slowly. 28 A survey conducted by Bixio29 identified over 3300 water reclamation facilities worldwide.

A total of over 2,600 people from the US and Japan! This highlights the growing gap between poor and developed nations. Emerging economies, with their rapidly growing populations and consequently greater need for grain, must do more to reduce this gap. [1]. Natural treatment approaches, such as land application, have been utilised for decades since they are cost-effective, efficient, and easy to implement. These kinds of tools excel in contexts where qualified labour is scarce. No-discharging efficiency with minimal upkeep [5].

The results indicate that C cycling may be affected by differences in the makeup and/or activity of soil microbial communities in the rhizosphere of different plant species. These findings highlight the importance of plant species in the terrestrial C cycle, which may have consequences for C sequestration and nutrient release [14].

Important biomass output and nutrient recovery (i.e., N and P) are only two examples of the types of things that can be predicted using a partial least squares (PLS) regression model, as was shown in another study. Following the PLS, effluent loading rate, soil salinity, EC, accessible phosphorus (Olsen-P), sodium, calcium, magnesium, potassium, sodium adsorption ratio (SAR), and nitrate-nitrogen were all found to be significant predictors in a multiple regression analysis [15]. The model's prediction abilities were strengthened through historical data validation. This research should lead to more precise planning and monitoring of various agronomic practises, such as land application. Land and vegetation management is another area where this concept will prove valuable [15].

Three types of two-stage hybrid ecological wastewater treatment systems (HEWTS) were studied independently. The effectiveness of these sL, respectively. Systems in removing various contaminants was evaluated by calculating their biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS) [16]. Hybrid systems that included HF and VF or VF and HF were the most effective. In both systems, the NH4+N concentration decreased by 85.5% while the NO3 concentration increased by 91.4 17.6 mg/L and 82.5 17.2 mg/L. While doing so, greater than or equal to E by more than 99.95%. E. coli did not survive [16]. 1. A VMBR that has both an anaerobic and an aerobic zone has been the subject of recent research. The study set aimed to reduce sludge production, find ways to reuse water more effectively, and conform to South Korean water quality laws [17]. It doesn't take much work to get a high removal efficiency for BOD, COD, TSS, and E. coli. The commercial viability of E. coli was demonstrated. The total removal efficiencies of N and P average 79 and 90 percent, respectively. The average energy consumption of the full-scale system was 0.94 kWh/m3 [17].

Nitrification and denitrification biofilter articles are included as well. In order to reduce nitrogen levels and, by extension, to control eutrophication in receiving water bodies, wastewater treatment plants (WWTPs) must employ tertiary denitrification of secondary effluent. The efficiency with which nutrients are removed from water by biofilter systems is proportional to the diameter of the filter medium [18]. Two different DNBFs had secondary denitrification studied using empty bed retention times (EBRTs) of 30, 15, and 7.5 minutes [19]. The grains of sand used to fill each DNBF were between 2 and 4 millimetres in size (DNBFS) and 6 and 10 millimetres in size (DNBFL). During these intervals, the DNBFS biofilter had NO3-N removal rates of 93%, 82%, and 83%, while the DNBFL biofilter had rates of 92%, 68%, and 36%. With lower EBRTs, N removal loading rates dropped. After 30 minutes of EBRT, the DNBFS half-order denitrification coefficient was 0.42 mg/L/min, while it was 0.70 mg/L/min after only 7.5 minutes. There was also little variation in DNBFL concentrations, which fluctuated between 0.22 and 0.25 mg/L/min. The percentage of NO3-N removed after backwashing was less than 5% between the two DNBFs. With DNBFS running, denitrification efficiency was increased despite a decrease in flow rate [19].

To meet the strict microbiological safety criteria for water reuse, conventional wastewater treatment systems frequently use chemical disinfection. In this issue, it was demonstrated that membrane bioreactors (MBRs) may maintain their high level of efficiency with proper preparation and management.

Distribution system microbiological renewal, membrane cleaning, and membrane imperfections or breaches are examples of additional functional components.

Forward osmosis (FO) and bioelectrochemical systems (BES) are two emerging techniques that show promise for treating wastewater with low energy consumption. Recovering bioenergy from organic molecules is made possible by BES thanks to microbial interactions with a solid electron acceptor or donor, and high-quality water is produced by the osmotic pressure inherent in FO. These two methods have enough in common to work together to solve the water-energy nexus. Water recovery (for reuse), electricity generation, and energy transmission to complete cathode operations are all areas where FO can assist BES. BES's capacity to stabilise water flow, dissolve organic pollutants, and supply solutes for a prolonged draw could also benefit FO. New findings demonstrate the complementary nature of BES and FO, as presented by Lu et al. [21]. They look at the synergistic benefits of the two and offer directions for future research. More research is needed to find the optimal way to combine BES and FO into a single, efficient system for treating and recycling wastewater [21].

This special issue also features the work of [22], an AHP that employs the Delphi method to select the best disinfection technique for wastewater reuse projects. The proposed technique is a helpful resource for assessing disinfection strategies according to a variety of criteria and options with the assistance of domain-specific specialists. The relative importance of nine factors was determined after experts were consulted and five different disinfection methods were assessed. This approach works well in practise [22], where several factors must be taken into account when deciding on a disinfection procedure.

This research shows that it is possible to cleanse wastewater from olive mills using a land-based technique. Here, E. can be fixed by using soil that has been farmed traditionally. coli. The physicochemical properties, as well as the contributions to N and P recovery and biomass production, of Camaldulensis [23] and other plant species, are compared and contrasted. When olive mill effluent was put into the soil, the inorganic and organic wastewater components were greatly diminished. The treatment's effectiveness did not rise with soil depth in this setting [24]. Injecting wastewater from an olive mill increased the soil's EC and SAR, but not to harmful levels. The wastewater from the olive mill increased soil fertility, which encouraged the growth of eucalyptus trees that could be harvested for their biomass.

Waterborne illness outbreaks in rural parts of the United States have been linked to the use of biosolids and manure on agricultural land, the topic of the final review article in this special issue [25]. In North America and worldwide, rural water systems are the most common source of waterborne disease [26]. Waterborne epidemics are typically caused by parasites, bacteria, and viruses. Livestock tends to congregate more in rural places. high population density and the lack of modern sewage treatment facilities Livestock farms frequently employ untreated animal faeces as fertiliser. Wastewater treatment operations commonly involve spreading biosolids (treated sewage sludge from cities) on fields in rural areas. Manure, biosolids, and leaking septic systems all include human and zoonotic pathogens that pose a risk to human health if they enter the water supply. This research fills in some of the blanks in our understanding and offers suggestions for enhancing rural water infrastructure [25].

It will become more difficult to both secure water supplies and dispose of wastewater efficiently as the global population grows and more people move into metropolitan areas. The most common method of transporting wastewater nowadays is collection.

The wastewater treatment plant (WWTP) will be sited at the lowest point of the collection system, closest to the eventual disposal destination. However, centralised wastewater treatment plants (WWTPs) often built to send wastewater to these outlying regions make it challenging to reuse water in urban areas [27]. Reuse is becoming less cost-effective as additional infrastructure to store and transfer reclaimed water is required. Decentralised wastewater management systems, which treat wastewater near where it is generated, will require more consideration in the future. Decentralised (satellite) treatment at upstream locations with localised reuse and/or the recovery of wastewater particles is gaining support as an alternative to conveying recovered water from a central WWTP [27].

While biosolids utilisation and disposal remain difficult, especially in dense urban environments, there is significant promise in water reuse to improve water resource portfolios that are already challenged. The public's view of the safety of recycling wastewater and spreading biosolids on farmland is the biggest barrier to these practises. The public's support could be even more difficult to achieve, despite the fact that technical advances have the potential to reduce energy use and increase dependability. Pharmaceuticals and microorganisms resistant to antibiotics are two examples of emerging pollutants that are notoriously challenging to explain to the general public. The public's trust in water reuse is affected by both historical and contemporary cases of water-borne illness transmission, such as cholera and cryptosporidiosis. Understanding how produced, reused water compares to existing source waters can be highly persuasive, even without advanced technologies like online sensors, membranes, and increased oxidation.

The growing concern over combination toxicity adds another layer of complexity to the challenge of working with novel chemical components. Chemicals in the environment are almost never encountered alone, but rather in complex combinations. Studies on animals are useless for answering questions about something's safety because there appears to be a limitless number of possible calculations for mixes. Therefore, rapid biological screening techniques are gaining popularity as a means of rapidly assessing water samples for potentially harmful contaminants. A petri dish is a common tool for such tests. Since there is such a wide range of potential transformation products, bioassays are a useful tool for gaining public and governmental support for new water reuse projects, especially in light of the prevalence of newly discovered compounds.

Growing cities impose a strain on their water supplies that can't be met by natural means alone, such as rain and snow. There are a lot of obstacles that make it hard to win over the public on the topic of water reuse. Scientists could contribute to business development by easing the exchange of complex data and ensuring that recycled water quality is evaluated in comparison to existing municipal water supplies.

Wastewater Irrigation as it Presently Stands

As a byproduct of modern economic and social advancement, waste irrigation has become a crucial component of water reuse. More than 20 million hectares of land are sprayed with untreated or partially treated wastewater per year (Figure 2), as reported by the Food and Agriculture Organisation. More than half of all municipal water reuse projects are used in agricultural operations. In dry and semiarid regions, where wastewater is increasingly being used for irrigation of agricultural and landscape areas, there has been a rise in the number of cutting-edge wastewater treatment plants31, 32.

There are numerous factors that affect how wastewater irrigation influences plant growth, including the water's composition and the physiological systems of the crops themselves. Peas, cabbage, lettuce, alfalfa, and tomatoes, among others, can benefit from wastewater irrigation if it is adequately treated and managed. 11,34,36,37 However, there is no disputing the environmental dangers associated with using wastewater for irrigation. Plants' uptake of chemicals was affected by both the chemical make-up of the compounds and the soil they were growing in. In addition, 42 distinct levels of human exposure called for differing effluent quality. If wastewater that contains contaminants is used to irrigate the soil, a fast accumulation of heavy metals might result. Quantitative analysis and epidemiological research have been utilised to quantify the dangers posed by chemicals and bacteria (references 38, 39). Lines 40 and 41 show that the chemicals had an effect on how well the plants absorbed them.

If we want to lessen our impact on the planet, we need to implement effective irrigation systems. A field can be contaminated by flood irrigation if it is not done properly. 44, whereas wastewater must be treated to at least secondary treatment standards for spray irrigation to be used, and only then is it safe for human and animal use. Subsurface drip irrigation can lessen environmental consequences and nitrate leaching rates (by as much as 70 percent), and it is the most water-efficient method of irrigation.

DIFFICULTIES AND PROSPECTS

Wastewater irrigation can help achieve many societal and environmental goals, including reducing water use and fertiliser use. Although there are obstacles in some regions of the world, the possibility of water reuse through wastewater irrigation is exciting. There will be a greater demand for wastewater treatment and reuse as the world's population and pace of urbanisation rise. Each year, we are able to reuse enough water to irrigate around 20 million acres of land. About 10% of the world's total irrigated area is covered by these systems.

There will inevitably be an uptick in health concerns. The process of collecting and treating wastewater is becoming more difficult and expensive every year. Increasing quantity and quality requirements necessitate further study and development of wastewater treatment systems. We need more decentralised and cost-effective approaches to wastewater treatment19, such as dual distribution and satellite waste-water management systems. By situating irrigated land, wastewater treatment facilities, and disposal places in close proximity to one another, transportation costs can be minimised. However, the efficacy of waste water reuse for irrigation can be improved by applying cutting-edge technology to the utilisation and disposal of biosolids and the use of complex chemical compounds. Water conservation, soil contamination, and health issues, it is hypothesised, may greatly benefit from a simple equilibrium between residential and industrial wastewater output for irrigation.

Adaptable wastewater collection, distribution, and treatment systems are essential for coastal communities as future climate change affects these areas. It's difficult to foresee the repercussions of climate change, and they'll bring with them fresh challenges. In light of this, it is clear that we need to improve our water distribution and collection infrastructure, our soil conservation methods, our wastewater recycling programmes, and our overall system optimisation. Droughts will exacerbate the global water crisis, and rising sea levels will increase the pressure on wastewater disposal infrastructure. 50 This highlights the need for better water distribution and collection systems, soil conservation methods, wastewater recycling initiatives, and general system optimisation.

Finally, we need more stringent regulations on the use of wastewater for irrigation. 52 This practise, which may have some benefits, must be carefully planned and overseen. Farmers did not give the advice the attention it needed, hence it failed. 27 Such instances are rare in China, but they do occur. Data collected by public institutions demonstrates that water recycling has a high probability of success. This study's findings could contribute to the ongoing fight to protect Earth's natural beauties. Although it was predicted that this sector would experience rapid job growth, progress in this area has stalled due to obstacles in the reuse of wastewater. Think about how it could be important to set international benchmarks for water recycling. Particularly in developing countries, the lack of public awareness, collaboration among stakeholders, and economic development of recovered water all pose significant obstacles to wastewater irrigation24. Businesses in developing nations must take great care to plan for the future. Welfare as a long-term economic strategy will always fail. Singapore, Israel, California, and Japan are some of the greatest places to look for examples of water reuse practises and technological advancements.

Irrigation with sewage water is a part of the complex web that connects humans, animals, plants, soil, and air. We'll need creative solutions to the problem of wastewater disposal if our population and economy are to continue growing. More research on agriculture from an academic and scientific perspective is required. Sustainable data gathering and the development of wastewater irrigation systems are both difficult if wastewater is not reused.

FINAL THOUGHTS

Reusing wastewater for agricultural irrigation is a significant step towards solving the world's water crisis. Wastewater irrigation has become widely used, making water scarcity less of a concern in many regions of the world. Nonetheless, it prompts worries for human and environmental survival. Wastewater irrigation has historically been more successful in more developed parts of the world. Both the environment and human health are at risk when untreated wastewater is used for agricultural irrigation. Significant gains are attainable while risks are minimised with the correct treatment and irrigation technology. Careful, proactive management is necessary to secure these benefits while limiting their negative effects. Wastewater irrigation still faces a number of challenges, including the aforementioned growing demands and others. Wastewater reuse for irrigation has the potential to deliver considerable economic, social, and ecological advantages in the near future while also significantly reducing environmental carrying capacity. Around 5,000 years ago [28], the islands of Crete (Hellas) and Mohenjo-Daro (Indus valley) showed signs of recycling water for agriculture. 'Sewage farms' were the earliest large-scale operations of indirect water reuse [1] and were set up between 1500 and 1800 to preserve public health and lessen water pollution. Instead of recycling wastewater for efficient agricultural irrigation, most sewage farms were constructed as dumping grounds to maximise the volume of wastewater applied per unit of surface area. About a century ago, in San Francisco, California, cleaned sewage was used to irrigate Golden Gate Park [29]. This was the first time that water reuse had been done on purpose. In the middle of the nineteenth century, the first state-of-the-art sewage treatment plants were built. Since then, the number of industries that stand to benefit from recycling wastewater has grown dramatically [30]. This includes a wide variety of businesses and government agencies, such as those involved in landscaping, irrigation, car washes, fire departments, and even thermoelectric cooling water.

The authors suggest that research into wastewater treatment should be prioritised on a worldwide scale since it has the potential to provide safe, dependable, and cost-effective technology for reusing effluents. In the not-too-distant future, cutting-edge technologies like online sensors with real-time input will play a significant role in water recycling. Improvements in membrane technology would be required to reduce energy requirements and maximise water recovery. Focusing on these technological developments will guarantee water that is fit for its intended purpose. For purposes such as irrigation, toilet flushing, and laundry, purifying water to an extremely high degree is unnecessary. Therefore, individualised treatment and distributed, networked, and self-managing systems are the way of the future. Defining such research goals is more crucial than ever as the global population grows and urbanisation speeds up. This special issue covers the evolution of wastewater and biosolids management and reuse as well as some of the latest innovations in this field.

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