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Review

Towards Sustainable Application of Wastewater in Agriculture: A Review on Reusability and Risk Assessment

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Abstract: The use of marginal-quality waters, not limited to brackish/saline and treated sewage effluent (TSE), is called reclaimed water. Reclaimed water is a sustainable source in the future for use in agriculture, essentially required to offset the food demand of a rapidly growing population. Moreover, the sustainable recovery of reclaimed water is essential for humanity to satisfy extreme sanitation and water-supply demands. To increase access to water supply, alternate water resources' use, existing water resources' degradation, and improved water-use efficiency are imperative. There is a high potential to address these factors by using reclaimed water as an alternative source. The reclaimed water treated at a tertiary level has the potential for use in crop production, especially for forage crops, irrigating urban landscapes, recreational and environmental activities, industry, and aquifer recharge to increase strategic water reserves in water-scarce countries. This way, we can save precious freshwater that can be utilized for other purposes. Eminently, freshwater applications for industrial and agronomic sectors account for 20% and 67%, respectively, depleting freshwater resources. The use of reclaimed water in agriculture can significantly reduce pressure on freshwater. However, if the quality of reclaimed water does not comply with international standards, it may cause serious health risks (diseases) and soil pollution (heavy metals).

Keywords: agriculture; health risks; food security; pollution; reclaimed water

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1. Introduction

The largest consumer of total freshwater withdrawals (~70%) is the agriculture sector [1], and it is one of the major drivers for ensuring global food security [2]. Globally there are 1500 million hectares of cropland, in which 250 million hectares (17%) were irrigated, contributing 40% of the world's food production. The other 1250 million hectares (83%) were rain-fed agriculture, contributing 60% of the remaining food production. An estimated 310 million hectares of land (agricultural land and others) was irrigated worldwide, from which 20% (62 million hectares) was severely affected due to salinity and sodicity, contributing to the worldwide economic deprivation of US$27.3 billion per year [3,4]. It was also projected that, in the last 20 years, an average of 2000 hectares of irrigated arid and semiarid terrestrial across 75 countries had been tainted by high salinity [3]. These statements show that improper use of highly salted water for crop irrigation can cause a large farming area to be salinized and the farm to, thus, be abandoned. Therefore, an alternative source such as reclaimed water can potentially supplement the saline/brackish water or freshwater to restore the agricultural needs of long-term sustainable crop production [5].

Irrigated agriculture is the major contributor to food security and keeping up with the ever-increasing food demand of the growing population [6]. For instance, irrigation caused up to a 400% increase in crop yields, and, nonetheless, there has been a manifold increase in water use that has intensified competition among consumptive water users (i.e., urban, industry, and irrigation) and environmental water demands. Several factors, such as prolonged dry periods, frequent episodes of drought, heatwaves, and changes in precipitation patterns, have also increased the water security challenges in many parts of the world [7]. Focusing on just one water source for food production due to freshwater depletion and rapidly growing population may cause severe risk to sustainable irrigation practices. The world population will be about 9.2 billion by 2050, with large pressure on available fresh resources of water [8,9]. In 2010, the global groundwater use was about 800 km^3, and the increase in groundwater extraction is expected to be 1100 km^3 per year by 2050 [9,10]. The supply of freshwater may be more limited, as it is consumed ignorantly, and, worldwide, these problems may be more severe in the future at regional levels [11,12].

In Gulf Cooperation Council (GCC) countries, where water scarcity is a major limiting factor for open-field agriculture, reclaimed-water application can solve this limitation of water stress and scarcity for agro-economic activities. In Bahrain, the total water evacuated was 357.4 million m^3, three major water sectors, i.e., groundwater (238.7 Mm^3), desalinated (102.4 Mm^3), and treated sewage (16.3 Mm^3) (Table 1). The traditional water resources are considered to be 34% of total water withdrawal, and almost 90% is utilized for crop irrigation. Egypt was estimated to have 78,000 Mm^3, i.e., 67,000 Mm^3 (86% for agriculture purposes), 9000 Mm^3 (12% for municipalities), and 2000 Mm^3 (3% for industrial) [13]. In Lebanon, total withdrawal has been estimated to be 1310 million m^3. Only 0.2% of reclaimed water is reused for agriculture, and 60–70% of water is utilized in the industry through groundwater and surface water resources (Table 1).

Table 1. Demography, agricultural contribution (%GDP), groundwater usage, and non-conventional water resources info from some of the representative Middle Eastern countries [14,15].

Country	Population	Surface Area	Agriculture Value	Total Water Withdrawals	Produced Water	Treated Wastewater	Treated Wastewater Reuse
	Population	(km^2)	(% GDP)	(10^6 m^3/year)	Non-Conventional Water Sources (10^6 m^3/year)		
Bahrain	1,569,439	778	0.3	357.4	44.9	61.9	16.3
Egypt	98,423,595	1,001,450	11.2	78,000	7078	4013	1300
Jordan	9,956,011	89,320	5.6	940.9	-	107.4	83.5
Kuwait	4,137,309	17,820	0.5	913.2	244	250	78
Oman	4,829,483	309,500	2.2	1321	90	37	37
Qatar	1,569,439	11,610	0.2	444	55	58	43
KSA	33699947	2,149,690	2.2	23,666	20,826	547.5	166
UAE	9630959	83,600	0.7	3998	500	289	248
Lebanon	6,848,925	10,450	2.9	1310	310	4	2

Treated municipal wastewater irrigation for cultivation can be applied directly to specific cases in different countries or in combination with freshwater [16,17]. Moreover, cyclic saline/brackish water application combined with reclaimed water can reduce the salinity effect on the crop production decline [18]. The unprecedented population growth with massive urbanization and industrialization have enforced the water authorities to think of this ever-increasing wastewater as a resource and explore the ways to utilize it in different sectors, such as agriculture and urban uses [19,20]. Although wastewater (reclaimed water) irrigation is mostly practiced in low-income countries after basic water treatment, the high-income countries apply reclaimed water after the tertiary level of water treatment for irrigation in arid region agriculture [21]. Over 20 million hectares of agricultural land was irrigated by using reclaimed water attained from treated wastewater [22].

Exploring the reuse of wastewater is a more effective, low-cost alternative than establishing a new desalination system that requires more land and other capital investments [23,24], and treated-sewage-irrigated agriculture is a substantial source of revenue along with the contribution of supplying food products for these poor urban farmers [25,26]. Moreover, the treated-wastewater reuse has reduced the pressure utilizing high-cost desalinated water, especially in gulf countries for agriculture proposed to irrigate the field crops, and the UAE has widely used the wastewater for irrigation in Sharjah city to attenuate the water scarcity for future sustainability and environment protection [27–29].

The application of treated wastewater improves soil fertility status. It contains organic matter; essential elements such as N, P, and K; and micronutrients, i.e., Fe, Mn, Zn, and Cu, required for plant growth [30]. However, the improperly treated waste may accumulate nutrients and create environmental hazards [31]. Therefore, an effective treatment system is recommended to reduce salinity and provide suitable irrigation water management practices to improve soil fertility [32]. Reclaimed water, rather than non-renewable groundwater, has lessened the adverse effects on the environment. Therefore, adequate and controlled wastewater reuse in farm management practices has been revealed for the quality of crop and other irrigation applications through wastewater reuse [33,34]. The human health risks and ecosystem protection can be achieved through suitable treatment [35,36].

Reclaimed irrigation water can provide greater certainty of water supply for agriculture, as its quantity will increase with the rising population. In addition to being a water source, it contains valuable nutrients that reduce fertilizer application and contribute to enhancing crop production. Therefore, applying reclaimed water with the proper treatment processes for agriculture and elsewhere can safely replace freshwater consumption, nutrients' availability, and energy recovery that can be helpful in agricultural adaptation to climate change [37,38]. Therefore, this article aims to highlight the significance of treated wastewater as a possible solution to meet the water shortages, especially in water-scarce regions. Furthermore, this comprehensive study of reclaimed wastewater discusses economic, environmental, and social issues that need to be addressed through scientific evidence.

This study also provides insight into the following research questions (RQs):

RQ1: What is reclaimed wastewater, how is it produced, and how can it be utilized in agriculture?

RQ2: What types of risks, challenges, and management approaches are associated with reclaimed water?

2. Materials and Methods

To accomplish our objectives and find answers to our research question (RQs), we gathered information from peer-review full-length papers, review articles, and research articles that were published from the years 2000 to 2022. These peer-review articles were selected from well-known journals found in Scopus, Elsevier's, MDPI, Springer, Web of Science, and other databases. Therefore, to fulfill research objectives and to resolve research questions, the review paper was divided into four major parts:

(1) Definition of wastewater and its types;
(2) Reclaimed-water uses in agriculture and its prospects;
(3) Risk associated with wastewater usage;
(4) Management approaches for sustainable wastewater treatment systems.

These major parts were further divided into subsections. The first part is focused on defining wastewater, different types of wastewaters, their resources, and salient characteristics of different wastewater. Further in this section, reclaimed wastewater production and its related historical information are discussed. In the second part, a comprehensive study of reclaimed-water uses in agriculture is performed.

Likewise, in the third part of the article, the risks associated with the reclaimed water, such as microbial risks to public health, chemical risks to human health and plants, and environmental risk hazards, are discussed in complete detail. Furthermore, the standard limits and threshold limits of wastewater reuse for irrigation purposes are also discussed.

In the fourth and last part of this article, management approaches for sustainable wastewater treatment systems are discussed, and, finally, to improve quality, readability, and consistency, the authors checked and scanned the titles, highlights, abstracts, keywords, materials, and methods and double-checked the papers' references.

3. Results and Discussion

3.1. Brief historical Perspectives of Wastewater

Over the past 4000 years, domestic wastewater has been the source of irrigation for agriculture production [39]. For many years in past centuries, human urine and fecal waste were utilized to replenish the soil nutrients in the Indo Pak sub-continent, as there were no direct sanitation facilities at home. Additionally, in the mid-nineteenth century, municipal wastewater was utilized to irrigate crops in many cities of the US and Europe [35]. This usage of domestic sewage was considered a source of agricultural fertilizer and a means of reducing river pollution due to its direct disposal [16,40]. However, the concern for public health and disease transmission through the agricultural products cultivated from untreated sewage led to a gradual decrease to complete closure of farming and using alternative sources in many Western countries [16].

After World War II, systematic investigations on wastewater applications were started in different countries. Meanwhile, a group of researchers from the US explored the harmful influence of wastewater on public health and showed the necessity for health-risk assessment caused by the microbes [41,42]. Owing to the legislative support with management services, agricultural irrigation practices by community sewage have become the most effective sewage-handling method in the UK and USA, rather than being disposed of directly. On the other hand, Pakistan only treats urban sewage (2%) (IWMI 2003), as does and West Africa (<10%), and it is received through piping networks [25]. In the early 20th century, many reuse projects were often handled wrongly, with poor regulation and lack of funds, eventually resulting in closure. The poor knowledge of wastewater treatment methods was another reason to discourage such projects. With the advancement of wastewater treatment technologies, the reuse of wastewater is gaining recognition of its value for multiple uses, especially its use in agriculture. Furthermore, the global decline of freshwater has raised the need for an alternative source to avoid water pollution to save more water for agro-economic use in water-scarce regions.

3.2. Wastewater as Reclaimed Water

Wastewater refers to the water polluted and degraded by several forms of waste coming from homes, industries, agriculture, and other resources [43,44]. Domestic wastewater mostly includes household materials, while industrial wastewater includes food pulps, papers, pharmaceuticals, chemicals, and heavy metals enriched with organic and inorganic contents [45]. However, it can be reused or reutilized in irrigation, industrial usage, or even for drinking by eliminating pollutants, and it is called reclaimed or recycled water. Furthermore, this wastewater contains many dissolved and suspended solids that can be classified based on the source, such as black, gray, and storm. Different sources of wastewater are shown in Figure 1.

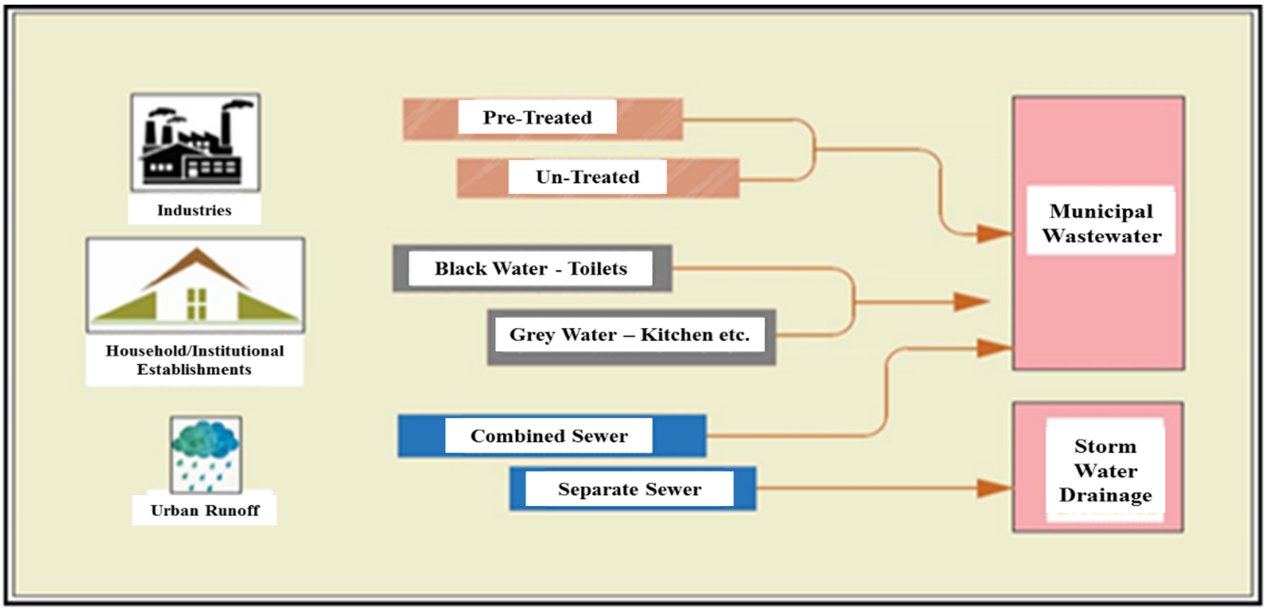

Figure 1. Different sources, i.e., industrial, domestic, and urban runoff; types of wastewaters; and their potential reuse modified from Reference [46].

3.2.1. Blackwater

'Blackwater' refers to the wastewater received from lavatory and toilets and the solid content in black water, which significantly contains nutrients such as phosphorus and nitrogen [47]. Blackwater can be classified into urine and wastewater derived from feces. The annual discharges of nitrogen (N) and phosphorous (P) by human urine were estimated at 4 and 0.4 kg, respectively, and 0.55 and 0.18 kg through feces [48]. Only a few nutrients are retained by the body, and the remaining approximately 100% is wasted as excreta [49]. Therefore, returning to soil is an efficient, sustainable approach to increasing soil fertility. At present, only a few amounts are recycled, while the remaining is discharged with no end value. The characteristics of black wastewater are presented in Table 2.

Table 2. Characteristics of black wastewater [50–52].

Parameter	Unit	Domestic	Urban	Industrial
pH	-	7.7–8.1	7.08–8.24	7.16–8.1
EC	µS/cm	-	165–3680	-
COD	mg/L	515–1450	460–5490	835–1680
BOD_5	mg/L	-	290–3480	420–1420
NH_4-N	mg/L	120–155	-	109.30–171.48
TKN	mg/L	140–187	9.55–142.88	117–178
Total Nitrogen	mg/L	117.2–178.40	-	-
TDS	mg/L			716–983
TSS	mg/L	270–800	375–5400	212–486
VSS	mg/L	190–590	-	-
Total Phosphate	mg/L	-	2.36–40.33	17.9–35.4
Alkalinity, $CaCO_3$	mg/L	580–740	-	-
Turbidity	NTU	-	-	80–205
COD/TKN	-	3.7–7.8	-	-

3.2.2. Graywater

The discharged water from the laundry, kitchen, and shower can be termed 'graywater'. The high percentage of solids and greasy substances in graywater may cause serious environmental and human health risks if used untreated. The pollutant loads in gray and black water depend on the time of activities (peak and off-peak) related to their corresponding source. The characteristics of gray and black wastewaters are given in Table 3.

Table 3. Salient characteristics of gray and black wastewater [53,54].

Parameter	Unit	Black Wastewater		Gray Wastewater	
		Concentration Levels (* Low to ** High)			
COD	mg/L	900–1500	806–3138	200–700	495–685
BOD_5	mg/L	300–600	410–1400	40–100	350–500
Nitrogen	mg/L	100–300	130–180	8–30	8–11
Phosphorus	mg/L	20–40	21–58	2–7	4.6–11
Potassium ***	mg/L	40–90	40	2–6	8–10

COD = chemical oxygen demand; BOD_5 = 5-day biochemical oxygen demand; * low values can be due to high water consumption; ** high values result from low water consumption or high pollution load from the kitchen; *** exclusive of the content in the water supply.

3.2.3. Stormwater

After precipitation (rain, melted ice or snow, etc.) the runoff water from the road, paved area, and house roof is called stormwater. When the stormwater is so overwhelming that the catchment and conveyance (stormwater carrying paths) are unable to carry it off, it may cause flash floods in urban settlements. The volume of stormwater depends on the quantity of precipitation, land-use pattern, and inclination of the land surface. However, stormwater contains lesser loads of pollutants than black and graywater. Still, the diversified nature of pollutants and debris get washed away while flowing above the surface, influencing the waste contents in stormwater [55]. The features of stormwater are presented in Table 4.

Table 4. Characteristics of stormwater [56–58].

Parameter	Unit	Domestic	Urban	Industrial
pH	-	6.9–8.1	-	-
EC	S/cm	34–224	-	-
COD	mg/L	10.7–79.2	-	-
BOD_5	mg/L	1.7–6.4	-	-
TDS	mg/L	20–86	-	-
TSS	mg/L	22.6–231	112.07–142.76	35.57–50.84
Total Phosphate	mg/L	0.5–2	0.13–0.17	0.09–0.12
Total Alkalinity	mg/L	9–50	-	-
Turbidity	NTU	36–188	-	-
TOC	mg/L	0–19	2.04–2.33	1.50–2.03
Calcium	mg/L	4–24	-	-
Sodium	mg/L	1.7–5	-	-
Potassium	mg/L	1.7–4.5	-	-
Magnesium	mg/L	0.2–1	-	-
Zinc	mg/L	0–0.4	0.2–0.21	0.38–0.45
Copper	mg/L	0–0.1	0.2–0.21	0.03–0.09
Iron	mg/L	0.1–0.7	1.88–3.0	1.24–1.89
Lead	mg/L	0–0.2	-	
TN	mg/L		1.11–1.85	1.08–1.61
NO_3-N	mg/L		0.29–0.72	0.58–0.61
NH_4-N	mg/L		0.11–0.27	0.07–0.42

3.3. How Is Reclaimed Water Produced?

One way of addressing the environmental and health risk challenges involved in wastewater irrigation is to consider the risks along the wastewater production pathway and food supply chain from producers to the consumers and farm to the fork. Reclaimed water is a byproduct of domestic and municipal sewage treatment plants; however, the water produced by some industries may or may not be suitable for agricultural use.

Primarily in wastewater treatment, suspended and heavy materials are removed by using meshes through the settling process, and then the effluent is transferred for the secondary treatment-settlement process, which is used for the degradation of organic compounds to settable products allowed to settle down for further treatment. This secondary effluent can be discharged to natural waterways if further disinfection and advanced treatment are unavailable. Otherwise, the secondary effluent would be disinfected and treated but unqualified for direct or domestic use without tertiary, as shown in Figure 2. Tertiary treatment involves an advanced mechanism to separate the effluent from volatile fatty acids, dissolved solids, and macro- and micropollutants, including a higher degree of disinfection against infectious pathogens [59]. The tertiary effluent should be disinfected before discharge or reuse.

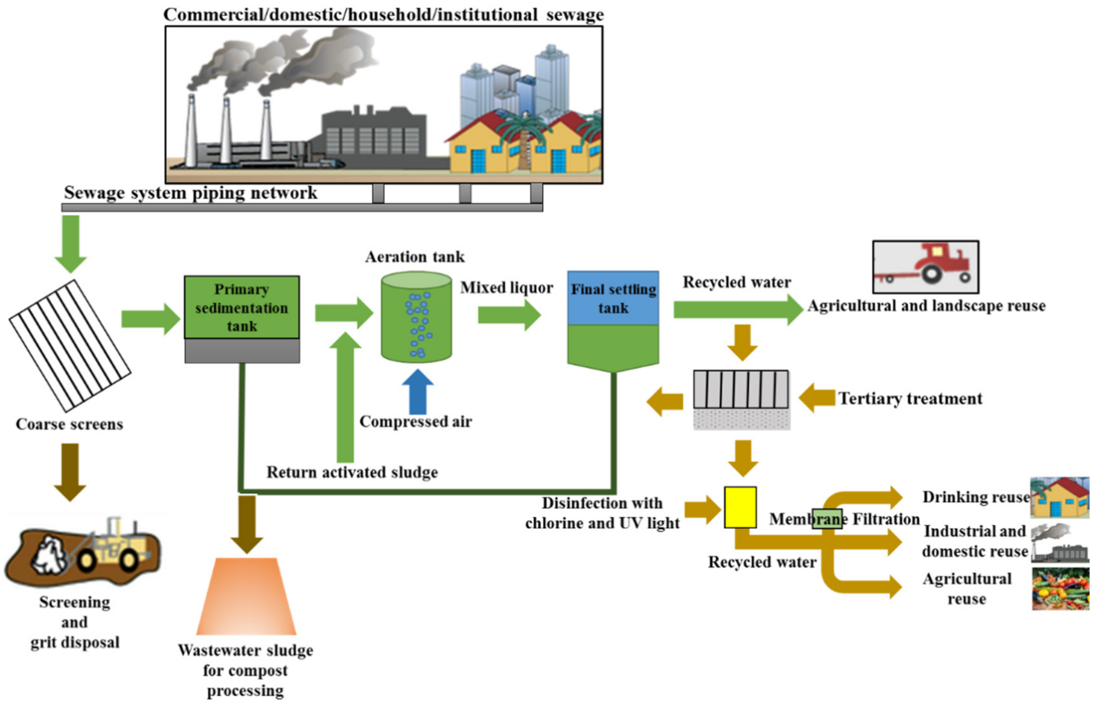

Figure 2. Water-reclamation process at the treatment facility modified from [60,61].

The possibility of water renewal was investigated through hybrid coagulation by polyaluminium chloride (PACl) with membrane bioreactor (MBR) process to treat the dairy wastewater. It resulted in effective reductions in turbidity (98.95%) at the optimum dosage of PACl (900 mg/L) and a pH of 7.5. Furthermore, the MBR reduced high COD, indicating that the hybrid system is suitable for the wastewater treatment to be used as a reclaimed-water source [62,63].

The jar-test coagulation (coagulants: alum and ferric chloride) was applied for the industrial wastewater with the doses from 10 to 80 mg/L, at a pH of 5 to 6.5. It resulted in the reduction of the total organic carbon from 6.1 to 4.0 mg/L and dissolved organic carbon from 5.1 to 4.0 mg/L. Therefore, the coagulation can be an effective treatment process to achieve reclaimed water from the industrial wastewater sources [64]. The fenton process aided by UV irradiation treatment was reported for the treatment of pesticide-contaminated post-irrigation water. The combined process effectively removed the pesticides and improve the quality of the wastewater for reclamation [65].

Another study also reported that integrated processes such as isoelectric precipitation/ultrafiltration/nanofiltration and lactic acid fermentation have been used for dairy wastewater treatment and recovered it as a reclaimed water source for its reuse applications [66].

The advanced techniques for sewage to reclaimed water may adopt these procedures for efficient treatment:

- Bio-physicochemical treatment protocols for removing usable nitrogenous and phosphate compounds and advanced oxidation processes using chemical procedures and mechanisms for the removal of organic components [67,68].
- Filtration reverses osmosis, ion exchange to remove different solids such as suspended, dissolved, and volatiles solids contents [69,70].
- Oxidative removal of organic chemicals with hydrogen peroxide (H_2O_2) or ozone (ozonation) [71,72].

3.4. Reclaimed-Water Uses in Agriculture and Its Prospects

Treated sewage is a promising safe alternative for agriculture irrigation, and effective planning and management can make it more beneficial for society [73,74]. Reclaimed-water (RW) use in the agriculture sector can be significantly understood by considering the rising global demand for feedstock and fiber. Therefore, the RW reuse in agriculture can be considered the largest user, despite its treatment [75]. GCC regions utilized greater than one-third of reclaimed water to irrigate many non-edible crops such as fodder, including landscape irrigation [22]. It has been reported that provisionally 50% of sewage-water treatment and recycling may fulfill the demand across GCC's total water need, which is about 11% that may persuade 14% of irrigation water demand for agriculture water use. It would decrease fossil water pumping and could save more than 15% by 2020 [76].

Furthermore, GCC countries have identified that no more than 43% of treated sewage is used as recycled wastewater, which is contributing to supplying water for landscape, industrial propose, and many other non-edible irrigations [76]. Among GCC countries, about 43% of wastewater is used for landscape irrigation, supplying around 1.8% of total water demands [77]. However, in GCC countries, reclaimed water is the best alternative for reuse; therefore, it could be more effective for gardening, vegetable growth, oil-seed, food, and non-food crops to reduce the demand for freshwater; thus, it may decrease the water-scarcity issues for more agriculture demand and its production [78,79]. In Lebanon, the applications of sewage influent and reclaimed water as irrigation were found to be a very common practice for vegetables and agricultural production [80]. In Egypt, certain crops were irrigated with reclaimed water under the Egypt Decree 44/2000 to control and manage the water-quality standards and safe agricultural production [81]. In Jordan, the two major cities (i.e., Amman and Zarqa Governorate) have the largest facility for wastewater treatment. Around 20 to 30 farmers were alternatively using 77% reclaimed water to cultivate forages, sorghum, and other crops from the As-Samra treatment plant [82,83]. In contrast to uncertain rainfall patterns and intensities, the wastewater is considered a reliable and readily available irrigation water source, resulting in better cropping intensity and higher crop yields in countries with low water reserves [84,85]. Several findings were organized in Pakistan and Senegal, which have shown similar outcomes in the yields of agricultural crops [86]. This usage can ensure enhanced crop production and higher savings, which can improve the farmer's livelihood, lead to better education, and result in access to better healthcare facilities. The use of RW use for irrigating vegetables and the major crops could result in the collective advantage of a balanced and nutritional diet, and it has improved the nutritional level of more than 200,000 people in Accra through their consumption of vegetables produced while applying reclaimed water as irrigation [87].

It is well-known that the daily city requirement of dairy, meat, and related products that come from urban livestock is very important for the urban food cycle [88]. Arid and semiarid regions rely on natural grasslands for their livestock, nourished with low precipitation. In such cases, wastewater irrigation to fulfill livestock demand can be a helpful alternative to support the food security of farming communities in the developing world [89].

Reclaimed water can be a better source of multiple nutrients and organic matter than chemical fertilizers. Reclaimed water is essential for plant growth, as it is rich in several micronutrients, such as Mn, Co, Fe, Cu, Zn, and Mo. Approximately 1000 cubic meters of RW is used for the irrigation of the land of 1 hectare, which may provide nitrogen, phosphorus, potassium, calcium, magnesium, and sodium with 16–62, 4–24, 2–69, 18–208, 9–110, and 27–182 kg, respectively [90]. Thus, these nutrients required by the crops present in the RW can reduce the pressure on farmers to use the expensive chemical fertilizers and reduce the cost of production. To offset the P requirement of crops in P-deficient farm soils, the excreta and RW can be used [91]. However, it should be noted that the excessive N quantities in wastewater may cause excessive vegetative growth, favoring the insect/pest attacks, crop lodging, and unwanted ripeness, and this may reduce the crop quality [90,92]. Higher concentrations of trace metals may result in plants being unsafe for the consumer and may risk human health [42]. The prospects of the reuse of wastewater protecting environmental health risks are shown in Figure 3.

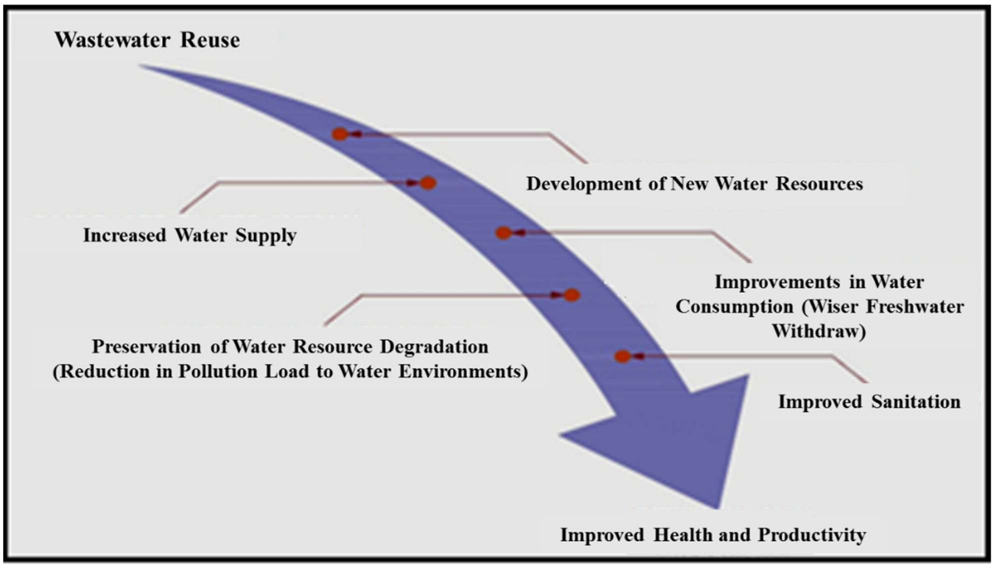

Figure 3. Prospects of reuse of wastewater or sewage/domestic water protecting environmental health risks modified from [93].

A financial assessment of the nutrient application from using RW in Guanajuato, Mexico, showed that US$135 was saved when irrigated by wastewater to supply phosphorous needed for each hectare of land [84]. Likewise, a similar financial benefit on RW reuse was reported in studies in India and Pakistan [94,95]. Regardless of the lesser financial studies and uniformity of study methodology, it is evident that wastewater irrigation can provide substantial economic gain at the farmer's level. Moreover, establishing a high monetary value of nutrient-rich wastewater compared to normal wastewater can open new business avenues with significant profitability [92]. The benefits may return to these farmers' peers, and stakeholders associated with wastewater business and supply chain, including consumers, can also benefit from it [96,97]. Due to low capital costs and quick returns, wastewater irrigation can resolve water scarcity problems and the economic loss of farmers at large [98,99].

Wastewater irrigation for agriculture can provide low-cost handling of nutrients that are over the trace limit and remove contaminants. Similarly, injection and infiltration of treated wastewater in deep wells can help in aquifer recharge to increase groundwater reserves [92].

Other important reasons were the presence of organic nutrients as fertilization, using sewage; the vicinity of municipal arcades; and the consistent availability of water supply [100]. However, reducing surface-water pollution due to wastewater discharge in water bodies is a noteworthy environmental benefit of wastewater irrigation. It will enable the planning of systematic application of freshwater when wastewater is used for irrigation, especially in water-scarce regions. Moreover, the application of chemical fertilizer will be controlled and reduced. Additionally, the source of irrigation and nutrients, the organic contents present in wastewater, will benefit soil conservation and structure development, leading to reduced erosion losses and sand-dune stabilization.

3.5. Risks Associated with Wastewater Use for Agriculture

Reclaimed water needs a higher degree of treatment than tertiary effluent because its application may cause danger to public health due to the direct contact of reclaimed water without further dilution by surface water. Wastewater irrigation can be considered for substantial benefits. However, considerable risks to human health are evident if the water is not properly treated before application [42]. The potential hazards of reclaimed-water reuse for irrigation purposes are shown in Table 5. Therefore, before applying the sewage water for crop production as irrigation, certain risks should be assessed to comprehensively protect public health and the environment for better management and safe use [101].

Table 5. Different types of risks supplementary with domestic sewage use as irrigation in the developing countries globally [75,102,103].

Hazard	Exposure Route	Relative Importance
Excreta-related pathogens		
Bacterial infections (i.e., *E-coli*, *Vibrio-cholera*, *Shigella* spp., and *Salmonella* spp.)	Contact; food intake	Low–high
Helminths	Contact; food intake	Low–high
• Soil transmitting pathogens (*Ascaris*, *Taenia* spp., and hookworms)	Contact; food intake	Nil–high
• *Schistosoma* spp.	Contact	Low–medium
Protozoa-pathogens (*Giardia-intestinalis*, *Cryptosporidium*, and *Entamoeba* spp.)	Contact; food intake	Low–medium
Viruses (i.e., hepatitis A, hepatitis E, adenovirus, rotavirus, and norovirus)	Contact; food intake	Low–high
Skin irritants and infections		
Vector borne-pathogens (*Filaria* spp., Japanese encephalitis-virus, and *Plasmodium* spp.)	Vector contact	Nil–medium
Chemicals		
Trace elements and heavy metals (e.g., As, Pb, Cd, and Hg)	Food intake	Generally low
Halogenated hydrocarbons (dioxin, furan, and PCBs)	Food intake	Low
Pesticidal infections (aldrin-DDT)	Contact; food intake	Low

3.6. Mitigating the Risks Associated with Wastewater Reuse

There are many options to decrease the risks associated with wastewater reuse in agriculture. The essential approach to decreasing irrigation-related dangers is the decay of infections over time [101]. The investigations on lettuce showed that irrigation before harvesting can prevent microbial contamination by utilizing treated wastewater. Additionally, the chemical contaminants (such as antibiotic absorption and organic compounds) must be reduced because of their impacts on animals and humans and their fate in agricultural fields. The study has been reported that antibiotics were successfully eliminated by artificial wetlands [102]. Furthermore, advanced oxidation techniques such as ozonation, improved oxidation, activated carbon, microfiltration, ultrafiltration, and nanofiltration are highly recommended [103]. On-site wastewater filtration can reduce the farmland contamination. Moreover, violet devices can also be utilized in conjunction with these advanced processes to lower the pathogen concentrations prior to irrigation-water applications [104]. Different types of wastewater risk-mitigation methods are presented in Table 6.

Table 6. Different types of risk-mitigation methods.

Hazard	Mitigation	Reference
Excreta-related pathogens • Bacterial infections • Viruses • Protozoa pathogens	• Disinfection technologies, primarily filtration systems, are effective in removing bacteria and *E. coli*. • Viruses are more resistant to treatment methods than bacteria; hence, filtration and disinfection are important alternatives for viruses. • Physical treatment procedures such as filtration and stabilizing ponds can remove protozoa-pathogens. • In the creation of the risk assessment, WHO standards use assumptions from underdeveloped countries.	[105]
Skin irritants and infections • Vector-borne pathogens	• Existing rules, such as the World Health Organization's wastewater reuse guidelines and Sanitation Safety Plans (SSPs).	[106]

3.7. Microbial Risks to Public Health

Microbial risks through pathogenic bacteria are raised by the direct application of domestic wastewater without treatment with particular microbes, and it may cause severe health issues for individuals who eat the produce raw and uncooked (Table 7). Many infections are investigated by direct use of untreated wastewater through farming activities and then consumers.

Table 7. Microbial contamination using domestic wastewater for irrigation proposes [107].

Type	Reuse	Visible Groups [a]	Colonic Nematodes (No. of Eggs per Liter) [b]	Fecal Coliforms (No. of Eggs per 100 mL) [c]	Sewage-Treated Anticipated Microbial Quality
A	Irrigated crops, uncooked food consumption, sports fields, and public parks	Workers, consumers, public	1	1000 [d]	Stabilized ponds indicated with quality microbes for the treatment
B	Cereal, fodder, pasture, trees, and industrial crops	Workers	1	No standard recommended	A total of 8–10 days retention time may increase the treatment for removing fecal coliform removal
C	Locally irrigated crops	None	Not applicable	Not applicable	Treatment techniques may reduce from primary sedimentation

[a] In definite cases, local epidemiology and sociocultural environmental conditions as the guidelines, modified accordingly; Ascaris-Trichuris and Hookworms; [b] depending on the type of excreta, weights may be used instead of volumes: 100 mL of wastewater equals 1–4 g of total solids; 1 litre equals 10–40 g of total solids. The required *E. coli* numbers per unit of weight would be the same; [c] crop irrigation within acceptable limits (<200 fecal coliforms per 100 mL) to protect public health; [d] fruit trees recommended picking once irrigation system properly closed irrigation and no fruit and sprinkler irrigation should not be used.

In recent growing countries, the threat level increased because of the different diseases caused by these microbes; that is, bacteria and viruses percolated through untreated wastewater irrigated crops. Across the last five decades, farmers irrigated their crops with this unconstrained domestic wastewater, causing epidemic and endemic diseases for the many food consumers. Higher diarrheal infections were investigated in the farming community, using wastewater in Pakistan [108]. A higher occurrence of hookworms/roundworms was reported from using direct sewage irrigating agricultural lands [109]. It was found that the excreta-pathogenic bacterial infections are the main cause of diarrheal diseases, including worm contagions [84]. Untreated wastewater use exposed individuals to helminthic diseases, especially for the farmworkers, while eating raw vegetables, causing viral infections such as diarrhea and cholera [42]. A different source of graywater has shown the microbial presence as fecal and total coliform contamination (Table 8).

Table 8. Bacterial indications and presence of microbes in the grey wastewater (log_{10}/100 mL) [110,111].

Water Source	Total Coliform	Fecal Coliform	Thermotolerant Coliforms	Fecal Enterococci	Fecal Streptococci	*E. coli*	References
Clothes wash	8.5–8.9	0.9–1.6	-	-	1–1.3	-	[112]
Clothes rinse	1.9–1.5	3.5–7.1	-	-	1–1.23	-	[112]
Washing	7	7.28	-	-	-	-	[113]
Laundry	3.4–5.5	1.1–10.9	2.0–3.0	1.4–3.4	2.3–2.4	-	[113]
Hand basin/shower	2.7–7.4	-	2.2–3.5	1.9–3.4		4.4	[114]
Graywater	7.9	-	5.8	2.4		3.2–5.1	[111]
Laundry—wash	1.9–5.9	1.99	1.0–4.2	1.5–3.9	1.26		[115,116]
Laundry—rinse	2.3–5.2	5.6	0–5.4	0–6.1	2.5		[116,117]
Kitchen sink	-	-	7.6	7.7		7.4	[116]

It has also been reported that the untreated wastewater microbes include various types of pathogens, viruses, protozoa, and water infected helminths, total and fecal coliform that could cause more viral infection in humans as public health risks [118]. These sources may cause potential risks to public health through microbial growth, and initial numbers could form large colonies of total coliform bacteria from 0 to 10,000 (CFU) units in 100 mL^{-1} [119]. The microbial treatment process for wastewater reuse (i.e., fit for irrigation) is certainly needed to be avoided from the identified potential risks and other pathogenic issues [120].

Different types of untreated residential and commercial graywater fecal contamination have been detected with a mean value of 3.3 to 8.1 µg/L (Table 9), having an equal composition of 10,000 µg/L in the wastewater, fecal loads have been also investigated, i.e., 0.04 to 65 g per capita per day is caused for this contamination [121]. The standard limits for the reuse of wastewater for irrigation propose the fecal coliform count recommended for food crops (<1000 CFU/100) mL [122,123].

Table 9. Micro-organism and fecal presence in household untreated graywater [111].

Microbes	Concentration per Liter (Untreated Wastewater)	Microbes	Concentration (Mean Values) (log_{10} 100 mL^{-1})	Reference
Fecal coliforms	10^6–10^{10}	Total coliform	8.1	[124]
Enteroviruses	1–1000	*E. coliform*	6.0	[125]
Rotaviruses	50–5000	Fecal enterococci	4.4	[126]
Cryptosporidium	1–10,000	*C. perfringens* spores	3.3	[127]

3.8. Chemically Risks to Human Health

Recent developing countries are exposed to more risks because of wastewater from industries being released into the domestic sewerage pipelines, thus polluting the community wastewater. The major chemical toxins presented in industrial sewage, i.e., trace elements, heavy metals, and pesticide wastes/traces, may harm human health, while also accumulating in soil and being taken up by the plants. Moreover, these toxic pollutants can seriously cause cancer and are difficult to attribute to the application of sewage water [128]. Chemical risks are largely caused by the higher concentration of trace and heavy elements, i.e., Pb, Hg, and Cd, because of the poisonous composites of organics. It was reported that cadmium intake rates were above their recommended minimum residual levels in leafy vegetables irrigated with wastewater. In contrast, Cu, Ni, Cr, and Pb had daily intakes above 40% of their maximum residual limits, so consumers' health was at risk long term [129]. Therefore, the health risks were incomprehensible because of their complexity; however, the developed countries have shown great concern in controlling anthropogenic activities to prevent pharmaceuticals and personal-care products. Several studies (Table 10) have been reported for the chemical and heavy-metals toxins in the three different crops, i.e., potato, tomato, and cucumber, the average level of Pb has been shown to be greater than the levels of both Cr and Cu; the resulting ranges can be used to advance the reuse of wastewater through proper treatment for further contamination [130]. Moreover, chemical toxins, major heavy metals, trace elements, and micro-organisms could pose more public health risks through wastewater-irrigated crops [118,131].

Table 10. Heavy-metal concentrations (mg/kg dry wt.) of three different vegetables grown in three countries, i.e., lead (Pb), copper (Cu), chromium (Cr), and zinc (Zn), irrigated through reclaimed water [102,132,133].

Crops	Algeria				Egypt				Saudi Arabia			
	Pb	Cr	Cu	Zn	Pb	Cr	Cu	Zn	Pb	Cr	Cu	Zn
Potato	1.79	0.89	3.02	0.60	0.1	-	0.83	7.16	1.51	-	6.41	17.65
Tomato	12.46	6.23	3.03	0.61	0.26	-	1.83	7.79	2.78	-	7.46	22.91
Cucumber	9.34	4.67	2.46	0.49	0.19	-	5.69	9.90	6.98	-	7.18	22.30

3.9. Plant Health Risks

Plant health risks impact the food quality and can cause decreased crop yields, especially when the sewage water for irrigation contains higher levels of boron (B) and other salts, heavy metals, nitrogen, and sodium, as well as many other industrial pollutants. Plant health risks may be reduced by avoiding the mixing of industrial wastewater into normal domestic sewage; however, whatever the case may be, the five parameters, namely B, N, SAR (sodium adsorption ratio), pH, and salinity levels, must be regularly monitored throughout the crop season, and if any parameter exceeds the threshold limit, appropriate action must be taken to rectify the problem to avoid any negative effects on the crop productivity and food quality [131]. Several studies have identified the pharmaceuticals contamination for non-potable reuse of wastewater for both influent and effluent through TQD-MS (Triple Quadrupole Mass Spectrometer) distributed with an electrospray ionization system (ESI) (Table 11).

Table 11. Identification of pharmaceuticals (antibiotics) present in the influents and effluents [120,132].

Chemical Constituents	Concentrations (ng/L)		Acceptable Limits	Reference
	Influent (Avg.)	Effluent (Avg.)	(µg/kg-day)	
Sulfapyridine	251.7	99.9	4.8	[133]
Sulfamethazine	23.7	11.0	9.5	[134]
Sulfamethoxazole	161.8	75.1	3.8	[135]
Ciprofloxacin	862.7	543.4	0.48	[136]
Ofloxacin	845.9	510.8	1.9	[133]
Risperidone	244.8	13.2	3.3	[137]

The standard limits (B) and ammonium nitrogen through seasonal threshold values of (B) have been reported, and it has been explained that higher ranges could affect plant health, i.e., (0.22–0.45) and (0.2–22.6) mg/L, respectively [138]. Additionally, microbial biofilm formation, accumulation of heavy metals, and other trace elements could cause the depletion of nutrients in the plant roots and rhizosphere; therefore, it highly affects plant health [139,140]. It has been reported that treated sewage as reclaimed water can be utilized for agricultural irrigation to ensure plant health [140] after proper physical cleaning of microbes through different treatment processes, i.e., chlorination [141] and ultra-violet (UV) treatment [142], including advanced oxidation processes [143,144]. Various chemicals have been reported that could harm the environment and plant health, i.e., pharmaceutical drugs such as Ibuprofen, Gemfibrozil, and Carbamazepine, having different concentrations of 0.37, 0.40, and 2.1 µg/L, respectively, through untreated wastewater [120].

3.10. Environmental Risks

Irrigation water application for agricultural farms by using untreated wastewater could pose serious threats for groundwater and soil contamination. Most of the harmful microbes may be retained at the top surface of soils; however, a few hydrogeological states form limestone structures [145]. However, chemicals such as nitrate and boron, including household cleansing agents, have deteriorated the quality of fresh groundwater resources. Hence, efficient and well-established wastewater treatment techniques and controlling programs are needed to prevent this chemical risk that may severely affect the plans, public, and environment [146]. Therefore, for low-income countries, these technologies must be given special attention in order to protect them from recent and future risks through the proper applications of proposed treatment systems. Wastewater irrigation, i.e., treated or untreated, may cause groundwater contamination through seepage, and supply system leakages could pollute the natural groundwater aquifers [118]. The Pakistan Research Council of Water Resources conducted studies in Faisalabad city regarding domestic wastewater use for agriculture in the peri-urban area, and the results showed that vegetable crops irrigated with untreated wastewater were contaminated with Cr, Pb, Cd, and Fe [147]. The studies carried out on a range of vegetables and other edible corps showed Cd accumulation from high to very low concentration uptake by the type of crops (Table 12).

The impact of these treated wastewater toxicants (metals and pesticides) on the environmental quality of the disposal areas is assessed in terms of their elevated levels in different media samples, such as water, soil, crops, vegetation, and food grains. The biological samples collected from exposed areas indicated that the long-run disposal of these toxicants and their higher concentrations may build up and will be hazardous for the surrounding population. The study reported that the metals and organo-chlorine pesticides harm the whole environment. The analytical data generated from various environmental studies for exposed and unexposed areas showed the environmental problem. Therefore, the toxicants have definite adverse impacts on the environmental quality of the disposal areas [148].

Wastewater in semiarid region represents a valuable resource for irrigation and agricultural production. It contributes to the irrigation supply and considerable nutrients for farming soil. Nevertheless, negative environmental effects may result from long-term wastewater application, due to heavy-metal accumulation in soils; increasing amounts can mobilize the heavy and trace metal fractions, as well as crops' uptake. These environmental risks emphasize the importance of minimizing the public health risks and environmental pollution [149].

The environmental and health impacts of untreated or inadequately treated wastewater effluents may cause serious harm to water bodies. The untreated or inadequately treated wastewater effluent may lead to eutrophication in receiving water bodies and also create environmental conditions that favor proliferation of waterborne pathogens of toxin-producing cyanobacteria. Therefore, to achieve unpolluted wastewater discharge into receiving water bodies, careful planning, adequate and suitable treatment, regular monitoring, and appropriate legislations are necessary [150].

Table 12. Accumulation of cadmium (Cd) levels exposed to edible crops in various vegetables [151].

High Uptake	Moderate Uptake	Low Uptake	Very Low Uptake
Lettuce	Kale	Cabbage leaves	Snap beans
Spinach	Collard	Sweet corn	Chickpea
Chard	Beets	Broccoli plant	Melon family
Escarole	Turnips	Cauliflower	Tomato crop
Endive	Radish globe	Brussels sprouts	Pepper plant
Cress	Mustard plants	Celery	Eggplant
Turnip, green	Potatoes	Berry fruit	Fruits plants
Beet, green		Onion	

The Cd is considered a potential source of toxicity evaluation with the food chain mobility for human and plant health [152]. This report further indicated that even fish reared by using groundwater showed excessive levels of heavy metals, except for Cd and Mn. An investigation conducted on some toxic pollutants for three different crops, i.e., potato, tomato, and cucumber, in µg/kg, found Pb (0.16, 1.56, 1.72), Cr (0.15, 0.83, 0.86), Cu (0.10, 2.31, 4.45), and (0, 2.45, 3.22) [153], respectively. Salinity levels > 3000 µS/cm can effectively raise the soil salinity more significantly, so solids concentration and SAR ranges should be under permissible limits (Table 13), i.e., (<450 mg/L and <3 meq/L), respectively, to reduce the harmful effects towards the environment and plant health. Therefore, it is necessary to apply the irrigation under permissible limits, as treated/untreated wastewater may cause more salinity, as well as less crop production.

Table 13. Standard limits for irrigation-water-application guidelines restricted degrees for pollutants by World Health Organization (WHO) [118,151].

Parameters	Fit for Irrigation	Moderate Fit	Unsuitable for Irrigation
Salinity levels (EC), µS/cm	<700	700–3000	>3000
TDS, mg/L	<450	450–2000	>2000
SAR, $(mmoles/L)^{0.5}$	<3	3–9	>9
Chlorides (Cl^-), mg/L	<4	4–10	>10

4. WHO Permissible Limits for Micro-Organisms Treated Sewage for Agriculture

The World Health Organization (WHO) initiated a Sanitation Safety Planning (SSP) and guidelines for water reuse [154,155]. The permissible limits of microbial presence have been reported, i.e., total coliform and fecal coliform bacteria from treated and untreated wastewater irrigation, presenting three different threshold limits: fit for irrigation (≤1000 fecal coliform), highly restricted limit (≤105 fecal coliform), and acceptable limits (≤103 fecal coliform for irrigation). Slightly treated wastewater irrigation exposed more health risks through microbes, using vegetables, i.e., cabbage, carrot, green tomatoes, red tomatoes, onion, chili, lettuce flowers, radish fruit, cucumber fruit, and coriander plant (104 fecal coliform) [156]. The threshold values of various toxins are presented in Table 14 for the application of wastewater irrigation water directly to the irrigated crops and are also demonstrated by Public Health and Environment [157].

Table 14. Threshold limits of wastewater for reuse applications standardized by the World Health Organization (WHO), United States Environmental Protection Agency (USEPA), Oman, UAE, Egypt, and Algerian Standards guidelines [118,157–159].

Parameters	Units	WHO	USEPA	Oman	UAE	Jordan	Egypt	Algerian	EU
Electrical Conductivity (EC)	µS/cm	2225	≤700	-	-	-	≤700	-	≤1000
Hydrogen Ions (pH)	-	4–8.6	6.9	6–9	7–9.2	6–9	6.5–8.5	6.5–8.5	6.5–8.4
TDS	mg/L	2500	-	1000	100–1000	1500	-	-	-
TSS	mg/L	40	-	10	-	50	≤15	30	35–60
Turbidity	NTU	2	≤2	2	4	10	≤10	-	≤10
Sodium (Na^+)	mg/L	250	-	70	150	230	-	-	-
Calcium (Ca^{2+})	mg/L	450	-	-	-	230	-	-	-
Magnesium (Mg^{2+})	mg/L	80	-	30	0.4	100	-	-	-
Potassium (K^+)	mg/L	100	-	-	12	-	-	-	-

Table 14. *Cont.*

Parameters	Units	WHO	USEPA	Oman	UAE	Jordan	Egypt	Algerian	EU
BOD_5	mg/L	40	≤10	10	5	30	≤15	30	25
COD	mg/L	100	-	50	50	100	≤30	90	125
NH_3-N	mg/L	50	-	1	0.5	-	-	30	-
NO_3^-	mg/L	30	-	-	50	30	-	-	-
NO_2^-	mg/L	-	-	-	3	-	-	-	-
Ammonium-Ion (NH_4^+)	mg/L	5	-	30	-	-	-	-	-
Phosphate (PO_4^{2-})	mg/L	25	-	20	2.2	30	≤2	2	15
Sulfates (SO_4^{2-})	mg/L	-	-	200	250	500	-	-	-
Boron (B)	mg/L	0.70	0.75	1	2.4	1	0.5	-	-
Aluminum (Al)	mg/L	5	5	1	0.2	5	-	-	5.0
Lithium (Li)	mg/L	2.5	2.5	2.5	-	2.5	-	-	2.5
Cadmium (Cd)	mg/L	0.01	0.01	0.01	0.003	0.01	0.001	-	0.01
Arsenic (As)	mg/L	0.1	0.1	0.05	0.01	0.1	0.01	-	0.1
Chlorides (Cl^-)	mg/L	-	-	250	250	400	-	-	-
Fluorides (F^-)	mg/L	1	1	1	1.5	1.5	0.5	-	1.0
Nickel (Ni)	mg/L	0.2	0.2	0.2	0.07	0.2	0.2	-	0.2
Fe	mg/L	5	5	1	0.2	5	0.5	-	5.0
Cr	mg/L	0.1	0.1	0.1	0.5	0.1	0.05	5	0.1
Pb	mg/L	5	5	0.1	0.1	5	0.01	10	5.0
Zn	mg/L	2	2	2	5	5	0.01	10	2.0
Cu	mg/L	0.2	0.2	0.2	1	0.2	0.01	0.5	0.2
Mercury (Hg)	mg/L	-	-	0.001	0.006	0.002	0.001	-	-
Beryllium (Be)	mg/L	0.1	0.1	0.1	-	0.1	-	-	0.1
Cobalt (Co)	mg/L	0.05	0.05	0.1	-	0.05	-	-	0.05
Manganese (Mn)	mg/L	0.2	0.2	0.2	-	0.2	0.2	-	0.2
Molybdenum (Mb)	mg/L	0.01	0.01	0.01	-	0.01	0.07	-	0.01
Selenium (Se)	mg/L	0.02	0.02	-	-	0.05	0.01	-	0.02
Temperature (T)	°C	-	-	30	25	30	-	30	-
TKN	mg/L	-	-	5	-	45	-	30	2
TOC	mg/L	-	-	20	1	-	≤3.5	-	-
Hardness-$CaCO_3$ (TH)	mg/L	-	-	-	300	400	-	-	-
Free Chlorine (FRC)	mg/L	-	-	0.5	0.2–0.5	-	-	-	-
Total-Coliform (*T. Coli*)	MPN/100 mL	≤1000 CFU		≤200 CFU		100	≤10 CFU	-	≤100

5. Challenges in Wastewater Irrigation

Wastewater is frequently discharged into natural water bodies, with little or no treatment, causing them to become highly polluted. Farmers in nearly all developing countries' urban and peri-urban areas who require water for irrigation frequently have no other option but to use wastewater. It also provides nutrients as a cheaper source [73]. This practice can cause serious harm to human health and the environment, primarily due to associated pathogens, heavy metals, and other undesirable constituents [90]. Furthermore, in many countries, farmers, consumers, and some government agencies are unaware of the potential consequences of wastewater irrigation [160]. Similarly, there is a lack of technical and financial resources for wastewater reclamation in developing countries. Furthermore, more than 90% of unprocessed sewage water is discharged into rivers-oceans without any control [161]. Moreover, treatment to the highest safety standards (ultrafiltration and desalination) to drinking-water quality standards is available but not economical in most developing countries, due to technological constraints and the very high cost of treatment. Furthermore, some trends that were linked to climate change showed that the disaster was spreading slowly but with a large impact, and various applications are needed to manage the sewage water that is discharged as domestic, household, and commercial wastewater. In addition, wastewater irrigation in municipalities may affect human health by food intake and considerably impact the environment.

6. Management Approaches for Sustainable Wastewater Treatment Systems

6.1. Natural Purification and Green Economy

In the natural and biological community system, the waste is generated by humans, plant biota, and living organisms such as fecal compounds, dried leaf clutter, and organic and food wastes, including dead biomass. More often, freshwater lagoons and various water bodies in streams and rivers flowing through natural forests carry outstanding water quality, while purifying the water through natural processes. This natural purification mechanism may deliver a sustainable management system for wastewater and stormwater treatment. The direct use of domestic sewage and stormwater over the limits may be harmful to the environment because nitrates and phosphate may be accumulated as pollutants that the ecosystem will not absorb. The accretion of organic compounds in the biological community requires oxygen to process the treatment obtained from the atmosphere; otherwise, anaerobic conditions ascend [162]. The management of these wastewater resources may resolve serious impacts and also may enhance the green economy for a green sustainable environment [163]. Conversely, it would help for nutrients' recovery options by providing organic fertilizer for agriculture and, more importantly, where land base treatment and disposal are possible, especially for more covered area metropolitan cities with limited space challenges.

6.2. Crop Selection and Diversification

Nutrient management and the farming community may escape the unbalanced use of sewage water for agriculture, while crop selection may also help to avoid various risks and may benefit from the inclusion of essential nutrients, i.e., N, P, and high N content may require for leafier vegetables. Additionally, some of the green leave crops that are well established in supplying high nutrients such as grass–alfalfa through sewage water, as scavengers will be transferred to the soil by using a continuous supply of wastewater [160].

6.3. Soil Amendments

Likewise, soil mixed options are not only enough to provide these essential nutrients but also depend on crop type, local clay type, and site conditions. For instance, medium/fine-textured clay can hold more nitrogenous contents than sandy clays. Thereby, it would be recommended to release less wastewater, which may strain through sandy clay and cause serious groundwater contamination. Hence, continuous monitoring is required, especially for shallow depths and the water which is used as a drinking source for humans and animals. In the regions where farmers are unable to cultivate their crops, the high nutrient levels while irrigation may pass through the system, and this nutrient load can convert into large biomass. The wastewater with freshwater as an optional source for supplying irrigation to decline the nutrient load concentrations may benefit from using increased volumes with less biomass. This preference might have resilient periodic dimensions, which are only possible where the sewage-water watercourses are detached from surface-water bodies.

6.4. Public Awareness

People in developing countries are unaware of the harmful effects of wastewater on their health. Many farmers also lack knowledge about proper food hygiene practices. Therefore, the awareness programs related to types of wastewaters and their reclamation can solve health problems. Similarly, inspection and certification programs must promote consumer safety on vegetables and other products [164].

6.5. Promotion of Research and Outreach Programs

Farmers could better use the nutrients present in wastewater if they had more information about nutrient levels in the water, nutrient availability in soils, and crop demands. In this regard, researchers and public institutions may help solve challenges and provide opportunities by providing data on the present condition and applicability of reclaimed water. Hence, the public may gain more benefits by using wastewater in agriculture. The data regarding wastewater quality and its geographical distribution may help design policies regarding reclaimed water to improve its quality and human health [160]. Multi-criteria decision-making procedures are strategies that assist the decision-maker to select suitable treatment options when faced with an issue with multiple alternatives [165].

7. Conclusions

Extended urbanization, industrial development, and excessive use of freshwater at the domestic or agricultural level is causing the depletion of precious freshwater resources rapidly. The use of treated water or reclaimed water in agriculture is a sustainable approach to conserving the freshwater. Reclaimed water in crops is a low-cost approach to providing essential macro- and micronutrients to crops, and it compensates for the scarcity of irrigation water. Reclaimed water is the best alternative to agricultural-irrigation water demands and solves the disposal issues, especially for arid and semiarid regions. Improving the reuse applications according to reuse standards for agriculture, treated effluent, and reclaimed water may improve wastewater management facilities and be the best alternative to increasing wastewater use without endangering public health.

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