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Wastewater Problems Analysis and Their Treatment Using Eco-friendly Techniques: An Overview

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Authors' contributions

This work was carried out in collaboration among all authors. Author JS designed the study and wrote the first draft of the manuscript. Author APS wrote the protocol and managed the analyses of the study. Authors AKG, RG and YPS managed the literature searches. All the authors contributed for approval of the manuscript.

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Review Article

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ABSTRACT

In the current changing environment where almost all activities involve the use of clean water, waste water is discharged in a huge amount, which not only pollutes the environment but also causes many diseases in human as well as in animal. The scarcity of the most limited natural resource, "clean water" for daily use is decreasing day by day. So, the present study was done to assess various harmful effects of wastewater and techniques to overcome these effects through different plant-based wastewater treatment methods. There are few researches conducted to overcome the problem of wastewater biologically, the researchers used different plans to treat wastewater which absorb toxic substances up to a greater extent and clean the water efficiently. In

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the current study, some environmentally friendly wastewater treatment techniques—such as seaweed-based flocculants, mangrove plants, phyto-accumulation, Phyto remediation etc.—are discussed in order to better understand how they work and to advocate for their widespread use.

Keywords: Phyto-accumulation; eco-friendly; wastewater treatment; scarcity; water pollution.

1. INTRODUCTION

Water is one of the most important natural resource for the survival of all kind of life on the earth. However, this limited natural resource is decreasing rapidly due to uncontrolled and unbounded utilization of fresh water by various activities performed by human, such as in food processing industries, leather factories, drug manufacturing units, domestic use, etc. These industries use large amounts of water, and their wastes, which contain hazardous and occasionally toxic substances, are discharged with water in canals, rivers, and other bodies of water, which severely pollutes the natural water resources and upsets the natural balance [1]. Due to the harmful impacts of municipal, industrial, and hospital wastewater on water, soil, air, and agricultural products, wastewater treatment and the proper disposal of the produced sludge are crucial from the standpoint of environmental safety [2]. According to Zhang Q.H. et al. [3], efficient wastewater treatment has significant economic effects on water conservation and reducing wasteful water losses. Water consumption has increased in dry and semiarid nations like Iran, and yearly rainfall is also low in parts of North Africa, Southern Europe, and big nations like Australia and the United States. Hence, recycling sewage is the most long-term and environmentally friendly way to address the issue of water scarcity [4,5]. The population of the planet will get more than double in the ensuing 30 years. A fairly constant amount of water is currently distributed among the oceans, glaciers, polar ice, groundwater, lakes, and rivers. The fundamentals of the water cycle's physics and hydrology are covered in this chapter. Water reserves are over 1.4 billion km3, of which 35 million km3 are fresh water resources, 91,000 km3 of which can be used for daily consumption. This translates to approximately 12,000 litres for each of the 7.5 billion people that occupy the planet today [6]. According to Jaffar Abdul Khaliq S. et al. [7], wastewater reuse necessitates treatment and installation of suitable wastewater treatment technologies. The employment of straightforward, affordable, and user-friendly wastewater treatment techniques in developing nations has been the subject of more research in recent years [8,9]. For the treatment of wastewater and removal of physical, chemical, and biological contaminants, systems and processes like activated sludge, aerated lagoons, stabilisation ponds, natural and artificial wetlands, trickling filters, and rotating biological contactors (RBCs) have been used [10,11]. Microbial agents are among the various wastewater contaminants that are growing more significant, and the effectiveness of their removal in various wastewater treatment systems should be documented [12,13]. Several types of bacteria, including faecal coliforms and Escherichia coli, Salmonella, Shigella, and Vibrio cholerae, as well as parasitic cysts and eggs, viruses, and fungus, are biological pollutants in wastewater. Depending on the quality and quantity, they are all potentially harmful to the environment and to human health [14,15]. For instance, viruses can cause hepatitis and protozoa can cause diarrhoea [Ajonina, C. *et al*., 2015] [16]. Bacteria in wastewater also cause cholera, typhoid fever, and tuberculosis. If wastewater is not properly treated and released into the environment, such as river water, green space, and crops, many microbiological agents linked to suspended particles pose a risk to humans and aquatic organisms [17,18].

2. PROBLEM ANALYSIS

The implementation of suitable wastewater treatment technologies that optimize water quality standards for safe release has eliminated or significantly reduced the potential adverse impacts of wastewater reuse on human health and the environment in few developed economies/nations. For instance, treated water is used to irrigate city parks in Madrid, Spain. UV devices are used to treat wastewater in reducing the health risk of the population. In developing nations, where access to even basic treatment is minimal, such highly technical wastewater treatment methods are available in theories and debates only. It probably leads to the use of raw (untreated) wastewater. Therefore, farmers are forced to use polluted water as their only source of input, ignoring the potential harm to human health due to the high risk of disease infection (such as hookworm, ascaris, diarrheal disease, giardia intestinalis infection) and food contamination (such as cholera, typhoid, ascaris infection) [19]. In India, it is quite widespread practice to use both treated and untreated wastewater in urban and peri-urban agricultural activities. Unfortunately, harmful and infectious chemicals are frequently found in foods those are produced through wastewater irrigation. However , Indian law does not control the use of recycled/treated water for irrigation [20]. Hence, to assist the farmers, it becomes necessary to develop feasible wastewater management procedures and practices on the basis of strong and relevant scientific information [20]. In Indian cities, the municipal sewer system does not cover the most part of the urban areas. Furthermore, the infrastructure is unsuitable, deficient and in poor condition, aggravates the problem. As a consequence, a large proportion of the domestic wastewater is either discharge directly in natural drains or in some cases is directed to decentralized treatment systems. In fact, it is estimated that about 29% of the India's population uses septic tanks [21]. However, it's crucial to reiterate what Water Aid India has said in the past. To achieve the Millennium Development Goals (MDG) in India, major investments in sewage and waste disposal infrastructure are needed. Additionally, they pointed out that if the MDG was accomplished, neither slum dwellers nor rural poor people would be impacted by these policies. Therefore, working with India's urban regions presents a difficult context. It's necessary to provide infrastructure, but it's also important to address the inequalities that encourages the poorest residents to live in slums.

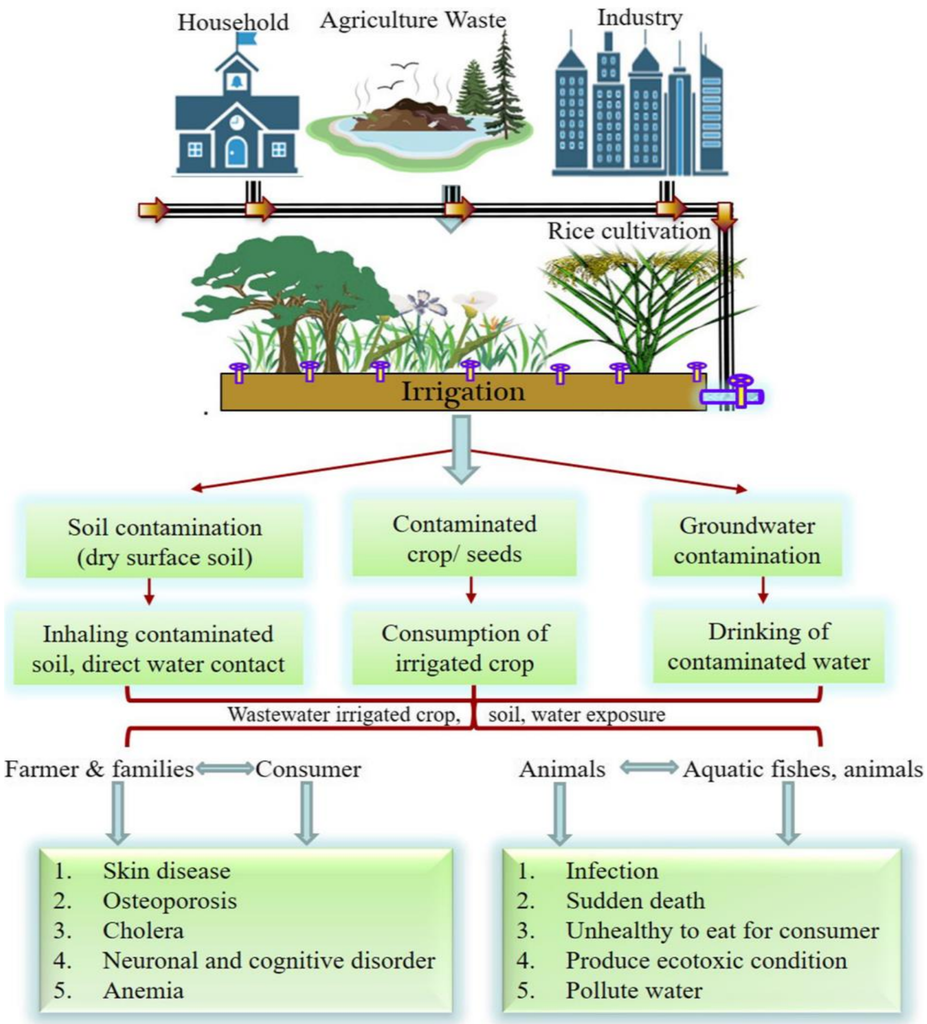

Fig. 1. Exposure pathway representing serious health concerns from wastewater-irrigated crops [42]

Despite the fact that freshwater supplies are rapidly running out and demand is rising, wastewater reclamation or reuse is one of the most crucial requirements of the present situation. 92% of the world's total water consumption is used for agriculture [22,23,24] of which 70% of freshwater, which is derived from subterranean water sources and rivers, is used for irrigation [25] [WRI, 2020]. The data indicate grave concern for the nations experiencing a water shortage. According to Shen *et al*. [26], 40% of the world's population lives in basins with high water stress, which highlights the water issue for agriculture.Thus, using wastewater for agriculture instead of freshwater is a great resource [27]. The majority of the time, treated wastewater is used for non-potable activities like construction, firefighting, groundwater replenishment, irrigation, vehicle washing, and golf course irrigation. It can also be utilised in thermal power plants for cooling purposes [28,29,30,31]. Treated wastewater irrigation helps millions of smallholder farmers throughout the world support their livelihoods and increase agricultural output [32]. Reusing treated wastewater for agriculture around the world varies greatly, from 1.5 to 6.6% [32,33]. More than 10% of people worldwide consume agricultural goods that are grown using wastewater irrigation (WHO, 2006). In China, the USA, and Europe, volumes of reused treated wastewater have climbed by 10 to 29% annually, and by up to 41% in Australia [34]. China stands out as the top Asian nation for wastewater reuse, with an estimated 1.3 million hectares (ha) of land, ahead of Vietnam, India, and Pakistan [35]. Currently, it is estimated that just 37.6% of India's urban wastewater is treated [36]. Israel is the biggest user of treated wastewater for agriculture land irrigation, using 90% of reclaimed water [37]. Most often in developing nations, irrigation uses partially treated or untreated wastewater [38]. The direct use of wastewater for irrigation has serious health consequences (WHO, 2006). Communities (farmers, agricultural workers, their families, and product consumers) are at risk for health problems as a result of these toxins. Residing near sewage streams and locations where untreated sewage is used to grow crops [39]. Wastewater also contains a large diversity of organic compounds. Several of them harm an embryo because they are carcinogenic or poisonous [40,41]. Fig. 1 depicts the flow of untreated wastewater utilized for irrigation and the resulting health implications.

3. WATER SCARCITY

The limited and constrained access to sufficient water supplies for human and environmental needs is referred to as "water scarcity" [43]. As a result, there are two ways to approach the idea of water scarcity: socioeconomically and physically. The expanding population and conflicting demands for water could be seen as the cause of socioeconomic scarcity [44]. The limited water is shared among several stakeholders because of the high pressure demands. The world population is expected to grow by 40–50% over the next four to five decades, and these numbers are considerably more pronounced in India. The continuously increasing water requirement is caused by the population's growth and concentration in particular places. In addition, socioeconomic development and rising living standards lead to greater water use in cities, which puts agriculture in competition with it. Since, agricultural yields must ensure food security, it should have less competition with the

Table 1. Water requirement for various sectors

Sector	Water Demand in km^2 or Cubic Meter/year								
	Standing Sub-Committee of availability and requirement of water (MOWR)			National Commission on Integrated Water Resources Development (NCIWRD)					
	2010	2025	2050	2010		2025		2050	
				Low	High	Low	High	Low	High
Drinking water	56	73	102	42	43	55	62	90	111
Irrigation	688	910	1072	543	557	561	611	628	807
Energy	5	15	130	18	19	31	33	63	70
Industry	12	23	63	37	37	67	67	81	81
Other	52	72	80	54	54	70	70	111	111
Total	**813**	**1093**	**1447**	**693**	**710**	**784**	**843**	**973**	**1180**

other sectors. A constant rise in water consumption is anticipated over the coming years, as seen in Table 1. Until 2050, agriculture's projected growth ranges from 16% (Standing Sub-Committee for Assessment of Availability and Requirement of Water, MOWR) to 55% (National Commission on Integrated Water Resources Development, NCIWRD). However, the projected growth of all other types of uses is significantly higher, such as: increase in drinking water from 82% (MOWR) to 164% (NCIWRD).

4. BIOLOGICAL WASTEWATER TECHNOLOGIES

4.1 Mangrove Plants

A group headed by Professor Tong Yen Wah of Department of Chemical and Biomolecular Engineering, National University of Singapore, Singapore is working continuously to create aquaporin-based biomimetic membranes that are inspired by the natural water purification mechanisms of human kidney and mangrove plants [45]. According to Tong Yen Wah, aquaporins are "extremely selective" in terms that they exclusively permit the transfer of water molecules while rejecting all other molecules [45].

Professor Tong Yen Wah further explained that they are trying to imitate the cell by incorporating the aquaporin water channel molecules into an impermeable barrier, just like a cell membrane. Thus, seawater or wastewater can be purified by using these channels, since water and only water can pass through this membrane swiftly [45].

The technique incorporates additional barrier components from roots of mangrove plants to reinforce the membrane, making it even more strong and resilient. To extend the membrane's lifespan even further, the team embeds the aquaporin proteins in vesicles structuring like a cell, which protect the proteins from deterioration. Common reed (Phragmites australis), reed canary grass (Phalaris arundinacea), cattail (Typha angustifolia, Typha latifolia), manna grass (Glyceria maxima), sedges (Carex sp.), and yellow iris (Iris pseudacorus) are the plants most frequently employed for wetland treatment [Fig. 2].

The natural aesthetic element of artificial and natural wastewater treatment systems may be small ponds, using mainly rain but also treated wastewater, planted with water lilies (*Nymphaea spp*), *Nuphar luteum* and around the shores aesthetically looking kinds of littoral species of plants (yellow iris *Iris pseudacorus*, rushes *Juncus sp*., sedge *Carex sp., Lythrum salicaria*, reed canary grass *Phalaris arundinacea* - form *Picta*, cattail *Typha spp.*, etc.). Plants significantly contribute to nutrient depletion and pollution, significantly contribute to water evaporation, enrich water with oxygen and in winter prevent continuous ice cover (more islets in the wind), which allows the survival of fish [Fig. 3].

Fig. 2. Arrangement of small Treatment pond with water and wetland vegetation [46]

Fig. 3. Small natural wastewater treatment plant without outflow (final treating tank with floating islands with yellow hyacinth) forms an aesthetic element in the garden [46]

Fig. 4. Fast-growing floating aquatic plant *Pistia stratiotes* in the final treating tank Iris and Water [47]

4.2 Phyto-remediation

Diverse inorganic and organic contaminants are deteriorating water quality day by day. The technique of phytoremediation utilising aquatic plants is the most preferable of the different tactics created so far. Due to the inflow of contaminating elements, aquatic ecosystems are under a great deal of stress and are being severely depleted. However, some aquatic macrophyte species may survive under these demanding circumstances, even when there is a significant concentration of different organic and inorganic pollutants in the water. These species are useful in polluted water treatment through phytoremediation or bioremediation technologies. Among the various aquatic plant species, Azolla, Eichhornia, Lemna, Potamogeton, Spirodela, Wolfifia, and Wolfifialla have been reported as phytoremediators and also they are highly efficient in reducing aquatic contamination through bioaccumulation of contaminants in their body tissues. Among the various aquatic species, water hyacinth (Eichhornia) is highly resistant and can tolerate the toxicity of heavy metals, phenols, formaldehydes, formic acids, acetic acids and oxalic acids even in their high concentrations. Likewise some other species of the family Lemnaceae are very effificient to reduce the percentage of biochemical oxygen demand (BOD), chemical oxygen demand (COD), as well as impact of HMs (heavy metals), and various ionic forms of nitrogen and phosphorus. Here in this review we are providing up-to-date information regarding the utilization of these aquatic plants for the bioremediation of contaminated waters. The review is primarily focused on the specific capabilities of aquatic plants and as an important tool in phytotechnologies in the management of contaminants in aquatic environment [48].

4.3 Seaweed-based Flocculent

Another fascinating project is being developed by the Norwegian company Sorbwater Technology, which has evolved a flocculent process technology based on seaweed to aid in the recovery of water having oil waste. The technique involves adding the company's patented Sorbfloc flocculent, an alginate made from seaweed, to water that has been contaminated by oil droplets or other contaminants [46]. Seaweeds are important marine resources with numerous applications in contemporary agriculture. Since many years ago, extracts from various seaweeds have been utilised in agriculture to promote plant development and increase production. Currently, the over use of synthetic fertilisers and chemicals presents a threat to global health and pollutes agricultural fields all over the world. Thus, encouraging the use of natural fertilizers and plant growth regulators, such as seaweeds, is advised because of their potential benefits. Additionally, seaweed extract-based biostimulants that can promote plant growth as well as increase a plant's overall resilience are greatly desired [49].

4.4 Phyto-accumulation

Potato (*Solanum tuberosum*): The widespread potatoes are herbaceous perennial plants that produce white, pink, blue, or purple flowers depending on the variety. According to research done in Europe, potatoes are exceptional accumulators of aluminium (Al). However, entire plant should be harvested because it has accumulated this heavy metal in the roots, leaves, and tubers. Contaminated aquatic environment disturbs the entire aquatic ecosystems which intern alter the life of animals, plants and microorganisms. The detrimental effects always occur at species level as well as at the community level of the aquatic ecosystem due to water pollution. Water contamination occurs mainly due to agricultural fertilizers, industrial and household waste waters, acid rains, heavy metals (HMs), pesticides, oil and many other inorganic and organic chemical compounds [50].

Kenaf (*Hibiscus cannabius*): Originating from Africa, kenaf is an annual herbaceous plant. Kenaf leaves are edible and the woody stalks are frequently used as fuel, despite the fact that they are traditionally produced for rope making in Africa and Asia. Researches in the production and potential applications of the plants have been heavily influenced by the economic and cultural significance of kenaf to emerging nations. There is research being conducted in Nigeria to find the most effective way for plant-based extraction of cadmium using kenaf.

Water Hyacinth (*Eichhornia crassipes*): The only major aquatic plant that can float on water without being linked to the bottom is water hyacinth. They float on inflated hollow leaf stalks filled with air, with roots trailing behind them in a thick mat. Arsenic, cadmium, chromium, copper, nickel, and selenium are six trace elements that the water hyacinth can absorb and move around. Shoots and roots had the highest concentrations of cadmium (371 and 6,103 mg/kg dry weight, while chromium concentrations were 119 and 3,951 mg/kg dry weight Apart from these, selenium accumulated more in the shoots, whereas cadmium, chromium, copper, nickel, and arsenic were accumulated in significant amounts in the roots. Water quality metrics are improved by using Eichhornia crassipes [51] [Hussain et al., 2010]. According to the findings of numerous studies, water hyacinth is a moderate Cd and Zn accumulator. Additionally, hexavalent chromium (CrVI)-contaminated streams are treated with plants [52].

Duckweed (*Lemna minor*): One of the most common of the duckweed, *Lemna minor*, often known as lesser duckweed, is found all over the world. According to studies, duckweed is a powerful mercury absorber and after 3 days under the high concentration of mercury water had 2,000 ppm of mercury in it. The metal concentration factor (i.e., the ratio of metals in the plant to the growth media) for duckweed kept in a solution containing copper at 8 ppm was 51 after 14 days water affected with huge copper metal concentration. The value of this factor was recorded 27 when there was an equal concentration of iron present, suggesting that iron had an impact on the rate at which copper was absorbed. Heavy metals, phenols, formaldehydes, formic acids, acetic acids, and oxalic acids are harmful, yet they are resistant to them and can tolerate them even at large concentrations. similar to some other family species. According to Saha et al. [52], plants are also utilised to clean up waters that have been contaminated with the hazardous metal hexavalent chromium (CrVI). According to Uysal Y. [53], Lemna minor has the capacity to eliminate soluble Pb, Ni, and Cr (VI) [54-56].

5. CONCLUSION

Hence, it is clear from the above facts that waste water is becoming a serious problem of the world which can be effectively tackled by using biological wastewater techniques at lower costs. Plants like, mangrove, water hyacinth, duckweed, potato, kenaf, and sea-weed, etc. should be utilized for the removal of toxic substances from water bodies and protect water, soil and environment by hazards caused due to metals released from factories with waste water. All kinds of life forms depend on water as a vital medium to survive. Due to numerous anthropogenic activities, the water is continuously contaminated; as a result, it would pose a direct threat to the continued existence of all living things. To stop this difficult scenario, the regulatory agencies and authorities need to act right away. Using aquatic macrophytes as a cost-effective bio-remediation technology could be a crucial strategy for the cleanup of contaminated waters.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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