Review Article

Wastewater Irrigation Possess a Risk on Food Chain, Health, and its Treatment with Constructed Wetlands

Hasnain Raza[1]*, Maryam Maqsood[2], Muhammad Muzamil Nazir[1], Iqra Tariq[1], Kaynat Ahmed[1], Qurat-ul-Ain[1], Ali Raza[2], Huda Bilal[3], Muhammad Bilal Shoukat[1], Attiq ur Rehman[1], Awais Rasheed[1] and Muhammad Zeshan Gulzar[1]

[1]Department of Soil and Environmental Sciences, MNS-University of Agriculture, Multan, Pakistan; [2]Department of Food Science and Technology, MNS-University of Agriculture, Multan, Pakistan; [3]Institute of Plant Protection, MNS-University of Agriculture, Multan, Pakistan.

Abstract | Currently, wastewater irrigation is increasing to combat the depletion of freshwater resources and the water stress caused by climate change. In many countries, wastewater irrigation has been highlighted as a serious environmental concern due to heavy metal buildup in soils and food crops, as well as potential health hazards to humans from ingesting these foods. Human health hazards are becoming more crucial as wastewater irrigation increases because exposure to a variety of toxins must be evaluated against the advantages to food security and livelihoods. By irrigating treated wastewater, the danger of human exposure to heavy metal contamination can be considerably minimized. Innovative solutions to this universal problem are being provided through eco-technologies, such as constructed wetlands (CWs). CWs are among the most widely used natural water management options. CWs can be used for phytoremediation, which acts as a natural sink for toxins. The present paper aims to provide a brief discussion on wastewater health risks, CWs, and its phytoremediation attributes as a plant-based cleanup solution for wastewater remediation.

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***Correspondence** | Hasnain Raza, Department of Soil and Environmental Sciences, MNS-University of Agriculture, Multan, Pakistan; **Email:** Hasnainraza662@gmail.com
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1. Introduction

In 2050, the global population is predicted to reach 9.5 billion people, requiring an additional 60% increase in food production (Mbow *et al.*, 2019). Freshwater scarcity is a global issue, with 60% of the world's population expected to face a shortage by 2025 (Alexandratos and Bruinsma, 2012). Between 2006 and 2017, Pakistan's per capita water availability decreased from 1100 to 908 m^3 (Imran *et al.*, 2018). To meet the demands, agriculture must cut off its share of freshwater usage and search for alternative supplies, due to the growing imbalance between supply and demand, as well as the expected effects of climate change. Agricultural use of water and wastewater is currently the highest in the world, accounting for over 70% of total water usage (Winpenny *et al.*, 2010).

Wastewater reuse is becoming more popular as a way to fulfill the growing demand for water. This resource, in general, comprises significant concentrations of both helpful nutrients and hazardous contaminants, which present both prospects and challenges for agriculture (Alghobar and Suresha, 2017). As a result, irrigation with municipal or industrial wastewater for a long time may result in a heavy metal deposition in soils and plants (Singh *et al*., 2010). Since heavy metals are non-biodegradable and have a lengthy biological half-life, they can accumulate in body parts, their contamination in soils and crops has been considered a serious environmental hazard (Khan *et al*., 2010; Muhammad *et al*., 2011).

The removal of pollutants from wastewater is extremely important to minimize the threat to public health and the environment. The wastewater is treated through various conventional and non-conventional methods including reverse osmosis (Al-Alawy and Salih, 2017), chemical precipitation (Huang *et al*., 2017), adsorption, and solvent extraction (Burakov *et al*., 2018), are some of the conventional and non-conventional technologies used to treat wastewater. However, for the removal of unwanted toxic materials, most of these approaches are very expensive, inefficient, time-consuming, and need a large capital investment (Bolisetty *et al*., 2019). An environment-friendly and cost-effective indigenous wastewater treatment system is urgently needed to treat wastewater contaminated with heavy metals and pollutants (Ashraf *et al*., 2018). For wastewater treatment in developing countries like Pakistan, constructed wetlands (CWs) are an environmentally friendly, energy-efficient, and low-cost option.

1.1 Wastewater irrigation a global health challenge

Wastewater irrigation of food crops is a common practice in urban, suburban, and rural areas around the world, and it has gained popularity in recent years in water-scarce areas (Hajjami *et al*., 2013). Its continued usage on agricultural fields has the potential to contaminate and compromise the safety of the food crops produced (Hu *et al*., 2013), it poses a significant risk to humans through feeding on contaminated food crops. The generation of worldwide wastewater is projected to be 1500 billion m^3 per year (Kachenko and Singh, 2006). Wastewater is used to irrigate approximately 20 million hectares of land in 50 countries (Abaidoo *et al*., 2010).

Pakistan generates 6.414 billion m^3 of wastewater annually, receiving 4.953 billion m^3 from municipal and 0.395 billion m^3 from industry (Yamin *et al*., 2015). In agriculture, 0.876 billion m^3 of wastewater from the total wastewater produced is being used for crop production (Murtaza *et al*., 2010), by irrigating about 32500 ha of land. Almost one-tenth of the crops in the world is irrigated with untreated wastewater (Qadir *et al*., 2007). Untreated wastewater contains a wide variety of pollutants from agricultural, municipal, and industrial sources. Farmers, their families, people living near wastewater irrigation, and consumers of wastewater-irrigated crops are all at risk from excreta-related infections, skin irritants, and hazardous compounds originating from these sources (Qadir *et al*., 2007). Heavy metal exposure from contaminated foods or inhalation of irrigated soil or occupational ingestion has been related to a wide range of chronic health problems, including cadmium, arsenic, lead, and mercury poisoning.

Table 1: Effects of heavy metals on humans.

Heavy metals	Toxic form	Effects on Humans	References
Cr	Cr^{+6}	Cancer of respiratory tract, nose ulcers, and multi-organ toxicity	(Medda and Mondal, 2017)
Hg	Methylmercury (Me Hg)	Neurotoxicity, nephrotoxicity, Gastrointestinal and carcinogenesis	(Azevedo *et al*., 2018); (Gardner *et al*., 2010)
Cd	Cd^{+2}	Renal dysfunction, risk of lung cancer, bone demineralization and impair lung function	(Loi *et al*., 2018)
Pb	Pb^{+2}	Damage to the reproductive system, affect CNS and PNS and kidney failure	(Zhou *et al*., 2018)
As	As^{+3}	Portal fibrosis, neurologic, cardiovascular, developmental anomalies, carcinoma, and hematologic disorders	(Signes-Pastor *et al*., 2019); (Abbas *et al*., 2018)
Ni	Ni salts and dust	Diarrhea, lungs and nasal cancer, vomiting, and dermatitis	(Ahmad and Ashraf, 2012)
Zn	Zn^{+2}	Cytotoxicity, Hematological change, Detrimental effect on neuronal development, immunity, and growth	(Maurya *et al*., 2019); (Plum *et al*., 2010)
Cu	Cu salts and fumes	Kidneys and liver damage, hypotension, gastrointestinal discomfort, hematemesis, and melena	(Sheldon and Menzies, 2005)

Food contamination with heavy metals is a major contributing channel to human exposure (more than 90%), surpassing other paths such as dermal contact and inhalation (Loutfy *et al*., 2006). Heavy metals have a negative impact on human and animal populations even at low concentrations (Uzu *et al*., 2011a, b) by causing nervous, cardiovascular, mental impairment, kidney and bone diseases (Yargholi *et al*., 2008). Acute and chronic exposure can result in dermal, cardiovascular, respiratory, gastrointestinal, renal, hematological, neurological, hepatic, developmental, immunological, reproductive, genotoxic, carcinogenic, and mutagenic effects e.g., liver cancer (Lin *et al*., 2013). The detail about effects of heavy metals on human are given in (Table 1).

1.2 Impact of heavy metals in soils

Due to the tremendous expansion of the industry sector, more effluents are being released into the environment, contaminating soil and water, and accumulating in living organisms. Heavy metals can't be degraded into less harmful forms, they have long-term environmental impacts when they are discharged haphazardly into the soil and rivers (Dixit *et al*., 2015). Heavy metal pollution of soil is a worldwide issue that affects human health and agricultural production (Liu *et al*., 2018). Heavy metals are found in agricultural soils due to natural and anthropogenic sources (Rahimi *et al*., 2017; Ratul *et al*., 2018).

Agricultural soil becomes contaminated when wastewater is used to irrigate it (Hajjami *et al*., 2013). Long-term wastewater application causes a heavy metal build-up in soil and crops, which affects crop toxicity, soil functioning, food chain contamination, and vegetable nutritional quality (Chen *et al*., 2010; Singh *et al*., 2010). Heavy metals bio accumulate into vegetables, crops, and humans as a result of continual ingestion.

1.3 Toxicity of heavy metals and their bioaccumulation through food chain contamination

Anthropogenic activities, such as industrial processes, release Heavy metals into the environment, resulting in the accumulation of heavy metals toxicity in living organisms (Koivula *et al*., 2011). Agrochemicals, industrialization, and fossil fuel burning discharge a variety of heavy metals, which are the primary source for pollution such as mercury (Hg), arsenic (As), cobalt (Co), copper (Cu), nickel (Ni), zinc (Zn), lead (Pb), chromium (Cr) and cadmium (Cd) into water channels and soils (Kumar *et al*., 2019a; b). Bioaccumulation occurs when Heavy metals are ingested by plants and subsequently biomagnified when top consumers consume them (Pollard *et al*., 2014). Once heavy metals enters the food chain, they can't be removed easily from the top of the chain, and they're spread out across the entire food web.

There are several hyper-accumulated plants that are used as food by humans and animals alike. As heavy metals have a potential to persist in the environment, produce a variety of negative impacts because plants carry them from the soil to humans. The extent of contamination in crops is determined by the effectiveness of the soil-to-plant transfer. Possibly harmful health effects could result from the consumption of contaminated crops containing heavy metals (Clemens and Ma, 2016). Vegetables are an essential part of the human diet because they contain essential nutrients and minerals (Nankishore, 2014). Unfortunately, plants can absorb and store heavy metals in both edible and inedible parts of their bodies, exceeding the permissible limits (Tasrina *et al*., 2015). In the last few years, high quantities of heavy metals have been detected in vegetables (leaves, roots, and fruits) (Wai *et al*., 2017) in detailed (Table 2). During the transition from one sector of the food chain to the next, several heavy metals have the potential to accumulate in the tissues of top consumers (liver, feathers, muscles, kidneys, and other organs).

1.4 Constructed wetlands an efficient option for wastewater treatment

Constructed wetlands (CWs) are an efficient wastewater treatment systems that use physical, chemical, and biological processes which are similar to those found in natural treatment wetlands (Uysal, 2013). CWs have been used to reduce pollution in the environment by eliminating various contaminants from wastewater, including heavy metals, organic compounds, nutrients, suspended solids, and pathogens (Gikas and Tchobanoglous, 2009). Over the last 50 years, the use of CWs is a common wastewater treatment technique in many countries.

Furthermore, it is a viable alternative treatment technology to traditional wastewater treatment methods due to their high pollution removal efficiency, low energy requirements, ease of operation and maintenance, high water recycling rate, and potential for providing significant natural habitat for flora and

Table 2: Heavy metals bioaccumulation in different vegetable organs.

Vegetables	Plant organ Analyzed	Heavy metals	Concentration (mg/kg)	Reference
Coriandrum sativum, Lepidium sativum, Spinacia olarecea	Leaves	Co, Ni, Cu, Zn, As, Pb, Cd, and Cr	Co– 0.005-0.21 Ni – 0.04-0.81 Cu – 0.59-2.23 Zn – 1.7 - 6.7 As–0.018-0.126 Pb – 0.2-4.7 Cr – 0.1-1.87 Cd – 0.02-0.52	(Souri *et al.*, 2018)
Solanum Lycopersicum, Brassica oleracea, Capsicum annuum	Edible parts	Pb and Cd	Pb – BDL-0.05, Cd – 0.01-0.07	(Ametepey *et al.*, 2018)
Anolis lividus, Basella alba, Trichosanthes cucumerina, Cucurbita moschata, Spinacia oleracea	Edible parts	Ni, Cu, Cd, Pb, Cr, and Zn	Zn - 19.762 Pb - 3.699 Cu - 9.373 Ni - 2.92 Cd - 0.168 Cr - 1.127	(Ratul *et al.*, 2018)
Solanum melongena	Edible parts	Cd, Ni, and Pb	Cd – 0.07-11.14 Ni – 0.01-4.82 Pb – 0.88-42.7	(Youssef and Abd El-Gawad, 2018)
Cucumis melo, Solanum melongena, Pinacia oleracea	Edible parts	Mn, Cd, Cr, Ni, Cu, Fe, and Zn	Cr – 2.7-3.7 Mn – 18.7-137 Cu – 22.2-65 Cd – 0.05-0.39 Ni – 1.8-5.05 Zn – 19.5-41 Fe – 129-968	(Latif *et al.*, 2018)
Cucurbita maxima, Solanum lycopersicum	Fruits	Pb, Zn, Cu, and Cd	Cu – 0.38-7.7 Zn – 1.1-128.5 Pb –up to 14.2 Cd – up to 2.2	(Zafarzadeh *et al.*, 2018)
Lactuca sativa	Leaves, Roots, and Shoots	Cu	Cu – 0.5-2.3	(Shiyab, 2018)
Lycopersicon esculentum, Abelmoschus esculentus	Fruits	Pb, Cd, Ni, and Zn	Cd – 0.01-0.05 Pb – 0.53-1.39 Zn – 0.02-0.09 Ni – 0.31-0.86	(Ali *et al.*, 2017)

fauna (Kadlec and Wallace, 2008). Different aquatic floating plants play an important role in the detoxification process in CW by absorbing pollutants directly into their tissues. To remove toxins from wastewater, these plants use physicochemical and biological methods (DalCorso *et al.*, 2019), which help in the remediation process (Khan and Faisal, 2018).

The main functions of plants in constructed wetlands are, provision of physical effect through its roots which helps some physical treatment in a wetland such as filtering effect, velocity reduction, promotion of sedimentation, decreased resuspension, prevention of medium clogging, improved hydraulic conductivity (Uysal, 2013), plants roots are used as a base for microorganisms, under this function plants provide a surface for microbial attachment and release of gas and exudates, also plant roots release oxygen that increased aerobic degradation and supports precipitation of heavy metals (Shelef *et al.*, 2013). Metal uptake is done through phytoremediation processes, (in detailed Table 3) also plants increase evapotranspiration that accelerates water loss in the wetland (Dalcorso *et al.*, 2019). Plants provide microclimatic conditions such as light attenuation that reduces algal growth, insulation from frost in the winter, insulation from radiation in the spring, reduced wind velocity as well as stabilization of the sediment surface (Chao *et al.*, 2014). The major aquatic plants that are used for the treatment of wastewater in constructed wetlands are *Pistia stratiotes* (water cabbage), *Typha latifolia* (cattail), Pistia stratiotes (Water lettuce), *Lemna gibba* (duckweed), common reed (Phragrmites), *Eichhornia crassipes* (Water hyacinth), *Centella Asiatica* (Pennywort) and *Alternanthera philoxeroides* (Alligator weed) (Wang *et al.*, 2015).

Table 3: Potential of constructed wetlands by using plants for the removal of heavy metals.

Type of constructed wetlands	Plants species	Contaminants treated	Reference
Floating treatment wetlands	*Typha domingensis*	Cu, Zn, Pb, and Cd	(Bauer *et al.*, 2021)
Constructed wetlands microcosms	*Typha latifolia*	Fe, Cu	(Meitei and Prasad, 2021)
Horizontal subsurface flow constructed wetlands	*Hydrilla verticillata, Water hyacinth, T. latifolia and Echornia crassipes*	Cu, Pb, Cd, and Cr	(Wang *et al.*, 2021)
Horizontal subsurface flow constructed wetlands	*Phragmites australis*	Pb, As, and Fe	(Lizama-Allende *et al.*, 2021)
Natural Wetlands	*P. australis*	Cr, Fe, Zn, and Pb	(Attili, 2020)
Free water surface constructed wetlands	*L. paucicostads*	V, Cd, Pb, and Cr	(Ekperusi *et al.*, 2019)
Natural wetlands	*S. polyrhiza, Echornia crassipes and Pistia stratiotes*	Cu, Fe, Zn, Cd, Cr, and N	(Rai, 2019)
Constructed wetlands microcosms	*Alocasia puber*	Zn, Cd, Cu, Cr, and Ni	(Thani *et al.*, 2019)
Horizontal subsurface flow constructed wetlands	*Aster amellus, Tagetes patula, Gaillardia grandiflora and Portulaca grandiflora*	Mn, Cu, and Fe	(Chandanshive *et al.*, 2018)
Horizontal constructed wetlands	*P. australis Cav. Trin. ex Steud, Canna indica L. T. latifolia L., and Hydrocotyle umbellata L.*	Pb, Cu, Mg, Co, Zn, and Cd	(Ali *et al.*, 2018)
Vertical surface flow constructed wetlands	*T. latifolia, Cyperus alternifolius, and Cynodon dactylon*	Cr, Cu, Zn, Cd, Pb, and Fe	(Mustapha *et al.*, 2018)
Horizontal subsurface flow constructed wetlands	*P. australis*	Cd, Pb, and Cr	(Šíma *et al.*, 2017)
Free water surface constructed wetlands	*T. latifolia, P. australis*	Cd, Pb, Cu, and Zn	(Gill *et al.*, 2017)
Horizontal subsurface flow constructed wetlands, vertical flow constructed wetlands	*P. australis, T. latifolia*	Cu, Zn, Pb, and Cr	(Papaevangelou *et al.*, 2017)
Free water surface constructed wetlands	*Azolla pinnata*	Mg, Fe, Mn, Zn, and Pb	(Akinbile *et al.*, 2016)
Horizontal flow constructed wetlands	*V. zizanioides*	Ni, Cr, Pb, and Zn	(Bakhshoodeh *et al.*, 2016)
Vertical flow constructed wetlands	*Erianthus arundinaceus, Typha angustifolia and P. australis.*	Cu, Zn, Mn, Ni, Fe, and Cd	(Arivoli *et al.*, 2015)
Horizontal subsurface flow constructed wetlands	*T. latifolia, P. australis*	Cr, Cd, Pb, Hg, and As	(He *et al.*, 2015)
Horizontal subsurface flow constructed wetlands	*T. latifolia, P. australis*	Cu, Zn, and Pb	(Kumari and Tripathi, 2015)
Vertical flow constructed wetlands	*V. zizanioides*	Mg, Ni, and Zn	(Mudhiriza *et al.*, 2015)
Horizontal subsurface flow constructed wetlands	*T. latifolia, P. australis*	Cu, Cr, Zn, Pb, and As	(Rai *et al.*, 2015)
Vegetative submerged bed constructed wetlands	*Phragmites karka and Veteveria nigritana*	Fe, Pb, Mn, Zn, Cr, and Mg	(Badejo *et al.*, 2015)

Conclusions and Recommendations

Water resources are under threat because of the growing population. Wastewater treatment is one of many countries' major concerns, as rising levels of unwanted or unknown pollutants are extremely hazardous to human health and the environment. We looked at the environmental and public health concerns related to the use of untreated wastewater in agriculture in this paper. There is a significant correlation between wastewater irrigation and concentrations of heavy metals and their existence (retention) in soil and accumulation in the crops, vegetables, and plants. Therefore, wastewater irrigation poses a health risk by contaminating the food chain through the consumption of contaminated crops and vegetables. We have focused on the current state of affairs concerning wastewater treatment with the constructed wetland with phytoremediation. Constructed wetland is an efficient, reliable, and active biogeochemical method for the removal of pollutants from wastewater. Several processes such as sedimentation volatilization, microbial activity, adsorption, filtration, and phytoaccumulation are used in CW to remove contaminants. In CW different aquatic floating plants plays a vital role in the enhancement of decontamination process by directly accumulating pollutants in their tissues. These plants utilize some physiochemical and biological processes to remove contaminants from wastewater, which help in remediation process.

Novelty Statement

Wastewater reuse is becoming more popular as a way to fulfill the growing demand of water for irrigation purpose. We have focused on the current state of affairs concerning wastewater treatment with the constructed wetland with phytoremediation. Constructed wetland is an efficient, reliable, and active biogeochemical method for the removal of pollutants from wastewater.

Author's Contribution

Hasnain Raza, Muhammad Muzamil Nazir, Muhammad Bilal Shoukat, and Attiq ur Rehman planed the work and gather the information related to the constructed wetland, and Iqra Tariq Kaynat Ahmed, Qurat-ul-Ain, Awais Rasheed, and Muhammad Zeshan Gulzar wrote the portion of the water scarcity of the manuscript Maryam Maqsood and Ali Raza has done the portion of Food chain and health. Huda Bilal reviewed this article and gave fruitful suggestions and format the manuscript according to the journal.

Conflict of interest

The authors have declared no conflict of interest.

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