Chapter

Potential of Aquatic Plants for Pesticide Removal in Wastewater: A Case Study on Pentachlorophenol

Rim Werheni Ammeri, Faiza Souid, Feryell Hajjeji, Saifeddine Eturki and Mohamed Moussa

Abstract

Today, soil and water pollution by pesticides is a serious problem worldwide. Compared with conventionally expensive, invasive, and sometimes ineffective techniques for pentachlorophenol (PCP) dealing, such as excavation, dredging and some chemical methods, in situ treatment strategies are more effective at reducing risk and decreasing expenditures on management. Among the in situ treatments, bioremediation (microbial remediation and phytoremediation) is thought to be capable in permanent pollutants elimination at low cost. Therefore, phytoremediation has received more attention in the last decade. Phytoremediation is applicable owing to its esthetic value, environment friendly, manipulation in situ and economic benefit. However, the previous phytoremediation studies mostly focused on the use of terrestrial plants and remediation of heavy metals. Sediments in aquatic environment are regarded as ultimate sink of organic contaminants, but little information is available on the possibility of use of aquatic macrophytes for remediation of organic toxicants in aquatic environment. It is, therefore, necessary to develop phytoremediation method of PCP by using aquatic macrophytes.

Keywords: pentachlorophenol, soil, wastewater, plant

1. Introduction

The pollution of water is one of the most important troubles of the whole globe, because of the unsuitable discharge of used water of the industries into the environment, excessive usage of chemical fertilizers in agricultural fields, production of roads, buildings, etc. [1, 2]. Further, the population growth is very expeditious, which harms the availability of drinking water to everyone [3]. Especially, industrialization and urbanization, pollution of water have accelerated on a large scale [4]. There are many chemical industries, which are dealing with the dyes and among them, the large quantity of dye utilization and wastewater discharge after the process is being done by the textile industries exclusively. The utilization of such dangerous substances has been ensuing in water pollution and environmental contamination. The water launched after the material guidance includes dissolved solids, color, harmful metals (chromium), production gums (pentachlorophenol, detergents), appropriating retailers (trisodium polyphosphate and sodium hexametaphosphate, chlorine, azo dyes), and stain removers (CCl4, residual chlorine, solving retailers similar; formaldehyde and benzidine). Maximum of the aforementioned chemical compounds are dangerous and a danger to the surroundings [5, 6]. From this time, the wastewater is wanted to be handled nicely earlier than it's far discharged into the environment or used for different purposes [7]. Thus, to minimize the toxicity, pollution, and to protect the environment, it is important to treat the dye wastewater before discharge [8]. Phytoremediation is a good and significantly hired environmental cleanup biotechnology primarily based totally on volatilization, stabilization, degradation, or extraction of pollution with the aid of using plants and their related microorganisms [9, 10]. Over the previous couple of decades, phytoremediation strategies had been elaborately studied and seemed as a effective tool for eliminating and degrading many unfavorable contaminants, which include antibiotics, HMs, landfill leachate, fabric dyes, pesticides, hormones, petroleum, explosives, or even poisonous gases [11, 12]. Phytoremediation is turning into an increasing number of famous in authorities corporations and industries because the cost-powerful and the restricted investment for environmental governance [13]. The phytoremediation procedure is pushed with the aid of using sun strength and might offer ecological landscapes for rehabilitated areas, which additionally has esthetic value at the same time as treating pollutants [11]. It provides a sustainable method for nutrients recovery and poisonous contaminants elimination. Numerous hydrophytes with distinct species had been applied for the control of LW, for example, Spirodela polyrhiza, Lemna minor, Polygonum hydropiper, Lemna gibba, Eichhornia crassipes, Pistia stratiotes, Scenedesmus quadricauda, Typha latifolia, Phragmites australis, Limnobium laevigatum, Chlamydomonas reinhardtii, Myriophyllum aquaticum, Coelastrella sp., Lemna aequinoctialis [14–23]. The main objective in this study to evaluate the Potential of aquatic plants for Pesticide removal in Wastewater: A case study on pentachlorophenol. Also, to discuss some example of phytoremediation process for pesticide removal.

2. Phytoremediation process

Biological methods using plants for treatment of polluted environment may also provide an alternative to traditional techniques [23, 24]. Phytoremediation (phyto = plant, remediation = correct evil) means re-vegetation of land which is spoiled by toxic substances and phytoremediation might be successful when plant using for phytoremediation material can accumulate high concentration of heavy metals in their shoots parts [23–28]. Phytoremediation as a brand new remedy approach for environmental pollutants communally anticipated to advantage all contemporary crises in better performance and decrease environmental effect in addition to economically feasible. This rising inexperienced technology, were won many severe anthropogenic pollutants. Fair evaluation required for risks, which associated with this approach. Even specifying it for a selected waste remedy inclusive of municipal wastewater [29] may also supply the reply key for consciousness on benefits and the accent risks. Aquatic macrophytes are vegetation that stay in water or moist soil and develop generously in lakes and waterways. This vegetation offer numerous ecological niches (meals, shelter), significantly contribute to biodiversity on the atmosphere level, and maintain meals chains. Besides their big position in nutrient cycle, oxygen balance, purification of water [30], and a source of some biologically

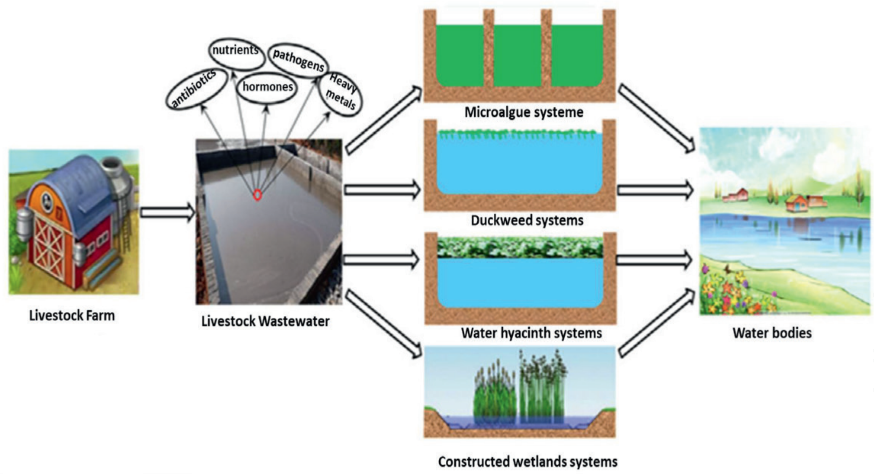

Figure 1.
Diagram of the different uses of phytoremediation techniques [37].

active substances like antibacterial and antifungal agents [31]. Emergent aquatic macrophytes constitute a numerous institution of flora with a giant cappotential for removal/degradation of a lot of toxic objects and pollutants [32]. Besides, aquatic macrophytes are greater appropriate for wastewater preparation than different terrestrial flora because of their quicker growth, manufacturing of greater biomass and a relative better cappotential of pollutant approval [33]. Phytoremediation is a rapidly developing method that uses plants to reduce, degrade, assimilate and metabolize environmental pollutants such as hydrocarbons, pesticides, etc. [34].

The main mechanisms of phytoremediation included phytoextraction, rhizofiltration, phytostabilization, phytodegradation, and phytovolatilization [13]. Generally, vegetation selected for phytoremediation had the possibility to concentrate on a wide range of or specific contaminants [35]. Phytoremediation is the direct use of living green plants and is an effective, cheap, non-invasive, and environmentally friendly technique used to transfer or stabilize all the toxic metals and environmental pollutants in polluted soil or ground [35, 36]. Furthermore, phytoremediation is concerned with the potential of a plant species to accumulate high concentrations of toxic pollutants in their tissues. A number of plant metabolic processes come into play to degrade various organic compounds. There are many types of phytoremediation for agricultural land and water Plants bodies, e.g., phytotransformation, rhizosphere bioremediation, phytostabilization, phytoextraction (phyto-accumulation), rhizofiltration, phytovolatization, phytodegradtion, and hydraulic control (**Figure 1**) [38–40]. After more than 20 years of development, phytoremediation has become mature and widely employed to refine contaminated soil, water, and atmosphere. Also, the achievement of phytoremediation relies upon upon a plant's potential to tolerate and to build up excessive portions of the contaminant, even as yielding a big plant biomass [25]. In herbal and man-made filtering systems, macrophytes play an crucial function withinside the biochemical approaches of water remedy in view that their presence should exert a few high quality outcomes on this environment [41].

3. Type of phytoremediation

Aquatic macrophytes are categorized into three principal classes, submerged, floating, and emergent macrophytes associated with vegetation' role concerning the

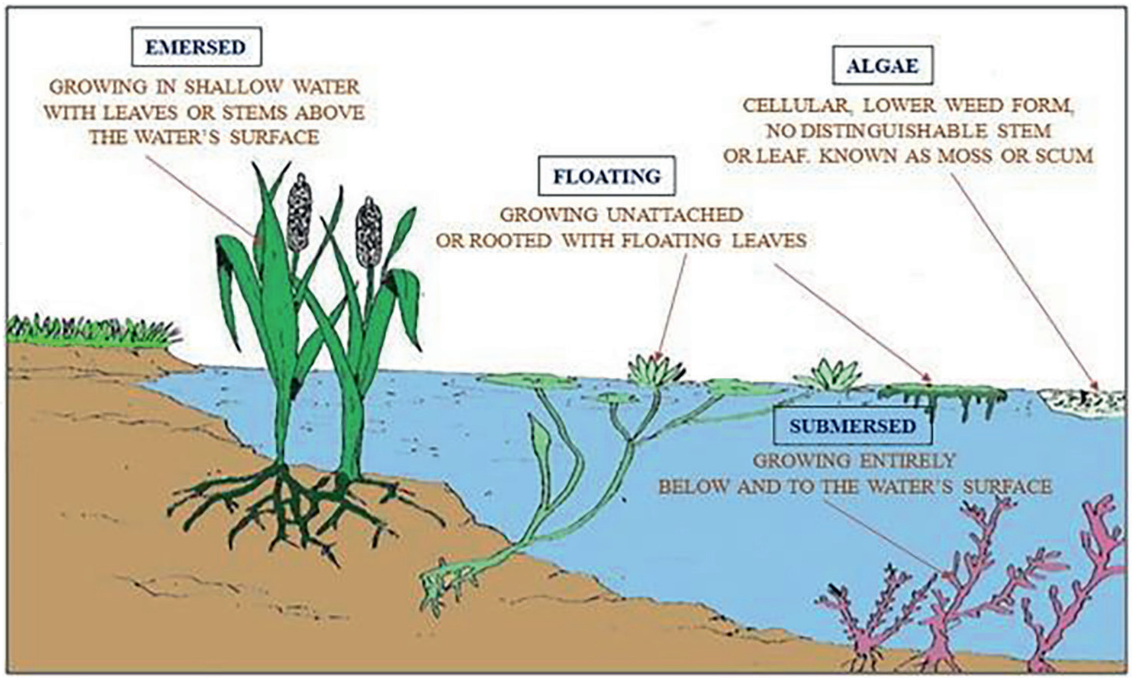

Figure 2.
Different types of the Phytoremediation process [45].

water floor (**Figure 2**). Submerged macrophytes: consist of vegetation completely submerged below the water surface without a vegetative components rising from the water floor (e.g., Myriophyllum spicatum and Najas marina). They are characterized through their particular morphological and anatomical constructions, which assist adapt to residing below the water floor. The increase and distribution of those vegetation are encouraged through numerous factors, which include water level, environmental condition, plant connections, and herbivory [42]. Floating macrophytes: consist of vegetation that develop at intermediate depths; a number of them (e.g., Eichhornia crassipes) are free-floating with roots that grasp unanchored with inside the water column, however others (which include Nymphaea lotus L.) are rooted withinside the soil with floating leaves. They are in large part unaffected through modifications in ranges and intensity of water and substratum characteristics [43]. Emergent macrophytes: consist of vegetation-rooted with inside the sediment with their essential vegetative components above the water floor (e.g., Typha sp.). They are impartial of water for aid and are characterized through their excessive increase price and biomass formation [44]. Lagoons cowl about 4% of the earth's continental ground.

4. Pesticide use in the world

The agrochemical enterprise has drastically improved over the last few years because of tremendous agricultural exercises [46]. Pesticides are the chemical materials that generally steady the rural commodities through controlling the extensive array of pests and insects [47]. Numerous styles of insecticides generate pollutants of air, soil, groundwater, and floor water, and unfavorable to human properly being as they are discharged into the ecosystem due to runoff from farming and civic areas [48, 49]. Among these pollutants, pesticides are of great concern because of

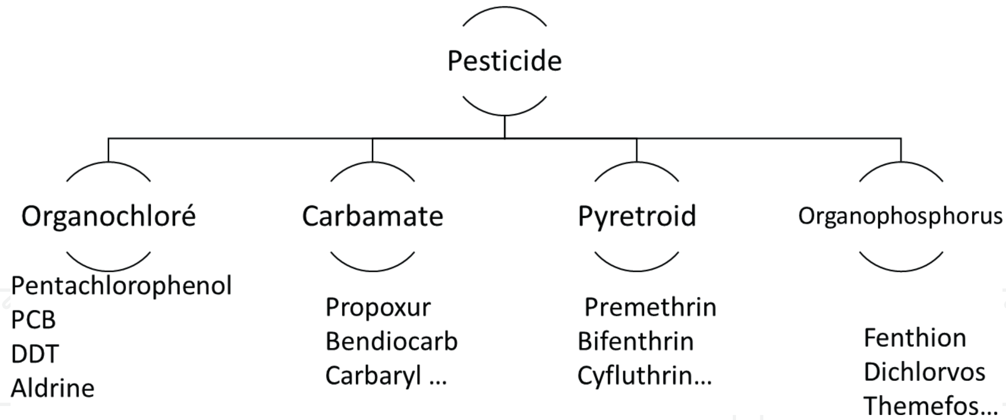

Figure 3.
Different types of pesticides based on chemical composition [60].

their broad use and persistence in the environment for up to decades [50], bringing negative impacts on ecosystems and human health [51, 52]. In the last century, organochlorine pesticides (OCPs), have been extensively used worldwide (**Figure 3**) [53], raising environmental concerns due to their toxicity, persistence, bioavailability, endocrine-disrupting properties and long-range transportation [54, 55]. Despite their worldwide ban between the 1970s et 1990s, concentrations of these pollutants remain in the environment, being a threat to the ecosystem and human health [56].

Pesticides are the second one largest potable water pollutant and posture the best danger [57]. A pesticide must be dangerous to the supposed pests however now no longer to non-supposed species like people and many different creatures. Nevertheless, because of the lack of precision, it's far toxic to each supposed and non-supposed species. The major reason for humans, fishes, birds, and bee's infection was the non - specific pesticide toxicity [58]. Phenol and chlorophenols (CPs) are representative examples of a wider group of phenolic pollutants. Their presence in the environment is due to intensive historical use, drinking water chlorination, biodegradation of organochlorinated chemicals, and their importance in the chemical industry [59].

5. Pentachlorophenol

Pentachlorophenol (PCP) is one of the World's worst chemical ever produced [61]. PCP was developed in the 1930s as one of the first synthetic organic wood preservatives [62]. PCP (C_6Cl_5OH) is well known as a highly chlorinated organic pollutant with stable aromatic ring structure and as highly persistent in the soil system [63]. The U.S. Environmental Protection Agency [64] regulates PCP as one of the priority pollutants. PCP pollutants has been released in large quantities into the environment as a wood preservative, pesticides, insecticides, fungicides and solvents [65]. PCP is also formed as a by-product during disinfection of water by chlorinated oxidants [66]. It is a synthetic organochlorine pesticide, a conjugate acid of pentachlorophenolate and a member of pentachlorobenzenes, which comprises aromatic fungicides and a chlorophenol (CPs) [67]. PCP is also a metabolite of lindane and other polychlorinated phenolic compounds [68]. Due to its stable aromatic ring structure and high chlorine content, PCP is chemically stable and not prone to degradation [69]. It is a significant environmental contaminant due to its widespread

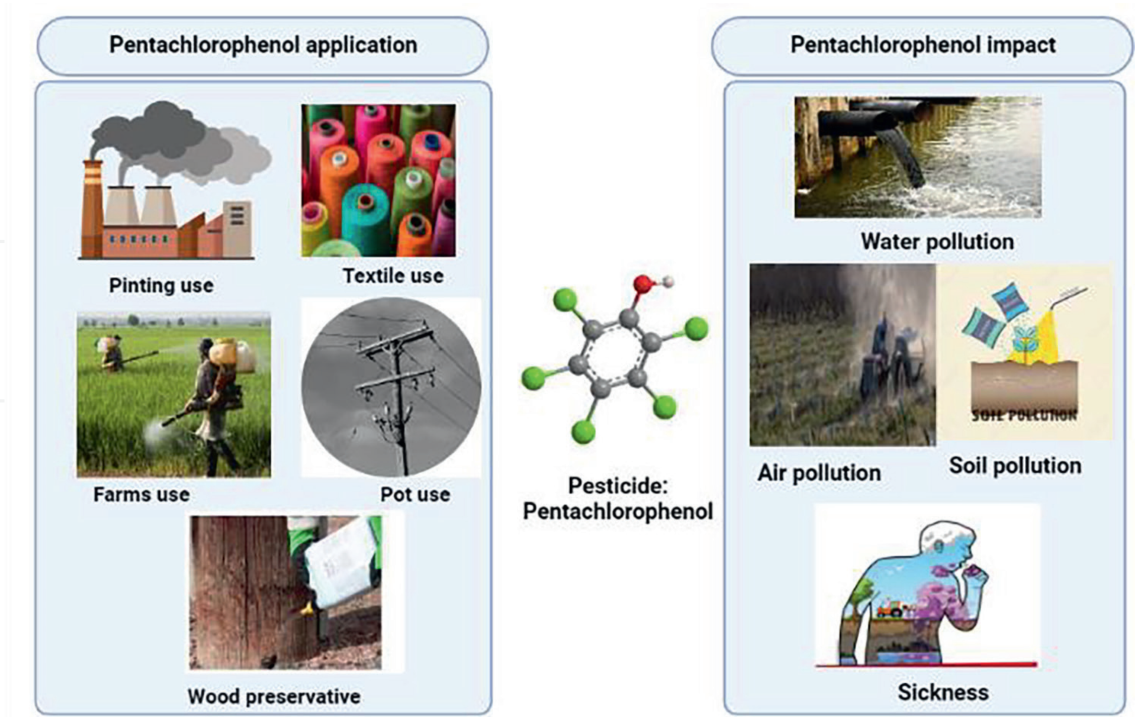

Figure 4.
Pentachlorophenol application and impact description.

use and chemical stability, persistency, and high toxicity. Human exposure to PCP occurs through inhalation, absorption through the skin, and consumption of contaminated water and food (**Figure 4**) [70]. It, therefore, has a very long half-life in the environment. PCP accumulates in the environment due to its lipophilicity and contaminates water and soil [71]. PCP used as a fungicide, insecticide, herbicide, and bactericide [72, 73]. that is widely employed as a wood preservative, especially for logs and wooden utility poles. There are many reports on the toxicity of PCP, including cases with fatal outcomes [70, 74]. The liver, thyroid, immune system, and reproductive system are the primary targets of PCP toxicity [70]. PCP inhibits spermatogenesis and has adverse effects on reproductive and inter-renal system at environmentally relevant concentrations [75].

In addition, PCP exposure is associated with renal, neurological, and carcinogenic effects. Several epidemiological studies suggest that PCP exposure is linked to human cancer [76]. PCP accelerates the incidence of hematopoietic cancer, multiple myeloma, lymphoma, soft tissue sarcoma, leukemia, and aplastic anemia [77]. This results in bioaccumulation of PCP in human testes, kidney, prostate gland, liver, and adipose tissue [78]. PCP is classified as possible human carcinogen (class 2B) by the International Agency for Research on Cancer [79]. PCP concentration at contaminated sites has been reported between 100 and 500 mg kg^{-1} in soil and 10–1000 mg L^{-1} in groundwater [80].

6. Pentachlorophenol wastewater treatment

For counteracting PCP pollution, wastewater-containing pesticides are commonly treated using biological and physico-chemical approaches [81]. The increasing of the accumulation of pollutants in the aquatic environment generated and activated many investigations concerning their removal and their biological treatment [82]. Unlike physical and chemical methods based techniques that are expensive and producing environmental side effects, biological methods could be useful for cost-effective and environmentally friendly approaches [83].

In addition, the bioremediation of PCP contaminated soil or water were widely examined in diferent research work, including phytoremediation [84] biostimulation [85] and bioaugmentation [64].

7. Example of pentachlorophenol phytoremediation

7.1 Typha genus

The Typha genus as a macrophyte always shows the advantage of development and growth under various climatic conditions, and function as bio-filters to protect lakes, estuaries and varied water bodies (**Table 1**) [86]. However, although it has been shown that Typha can tolerate and remove various xenobiotics: chlorinated benzenes, carbamazepine, diazinon, permethrin, chlorpyrifos and metformin (**Figure 5**) [87]. The two processes of phytoremediation and bioaugmentation are both biological methods used in PCP remediation process. Phytoremediation is a rapidly developing method that uses plants to reduce, degrade, assimilate and metabolize environmental pollutants such as hydrocarbons, pesticides, etc. [88].

Several studies have successfully evaluated phytoremediation of pollutants (i.e. nutrients, heavy metals, polycyclic aromatic hydrocarbons, polychlorinated biphenyls) by mangroves [89].

7.2 Duckweed

This technology is suitable for sites with shallow contaminants [90]. They indicate that fullscale and pilot studies are going to demonstrate the promise and drawbacks of plant application for remediating hazardous waste in terrestrial and sediments. Aquatic media have been presented high quality and effective responses for phytoremediation especially for organic contamination.

Ant species	Polluants	Location	Reference
Lemna giba	PCP	Wastewater	[65]
Typha angustifolia	PCP	Wastewater	[64, 65]
Typha latifolia	Arsenic	Dringing water	[94]
Phragmites australis	Organic pollutants and pesticide	Constracted watland	[95]
Phragmites Australis	Organic pollutants	Contaminated aquifers	[96]
Phragmites Australis and *Typha latifolia*	Metalic elements	River water	[97]

Table 1.
Examples of plants use in phytoremediation process.

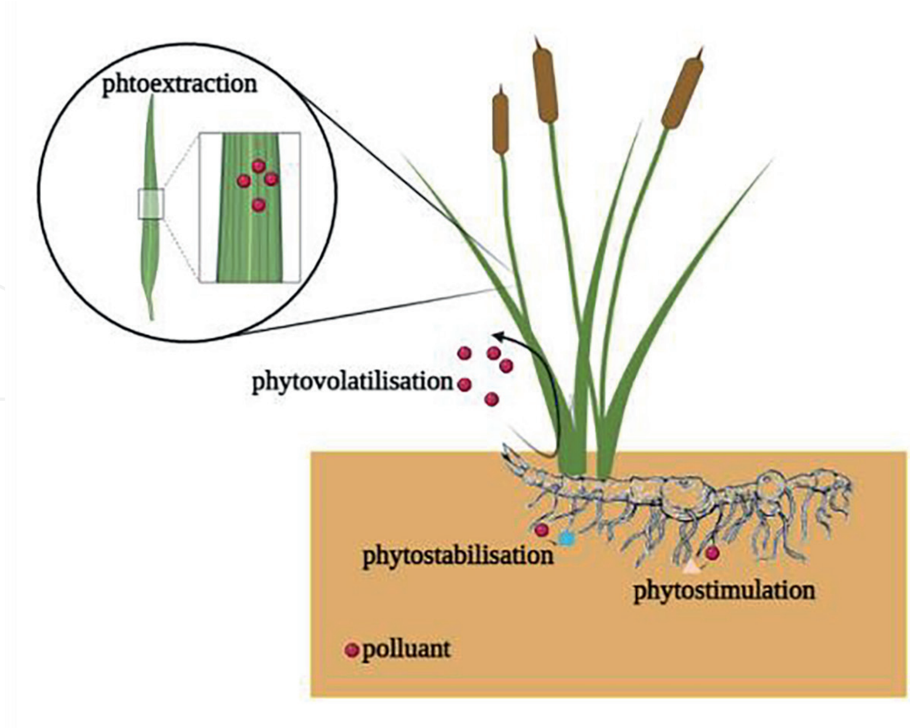

Figure 5.
Different phenomena of phytoremediation for Typha angustifolia plant.

Duckweed is composed of one or few leaves called fronds and a single root or rootlet with no stem, and the next generation generate through vegetative propagation [91]. Therefore, Lemnaceae is tremendously suitable for the phytoremediation of sewage. Duckweed is a highly efficient accumulator of various pollutants in surface water bodies and extensively used for xenobiotics, inorganic matters, HMs and pathogens removal from LW [10, 16, 23, 91]. Above all, duckweed needs plenty of nutrients to maintain its growth and development, which is beneficial for nitrogen and phosphorus recovery from LW. For example, Lemna sp. could remove 90% of PCP in constructed wetland with typha angustifolia [65].

7.3 Phytoremediation by microalgae

Microalgae could be adapted to a variety of water bodies and were extensively used to treat effluent [9]. Microalgae-based systems can absorb organic matter and nutrients from water bodies to meet their own growth needs [16]. Meanwhile, microalgae store various high value-added nutrients and chemical raw materials such as proteins, lipids, polysaccharides, vitamins, and beta-carrots, which could produce high-addition products such as biofuels and health products after purification [92]. Microalgae are also successfully employed to remove various antibiotics from LW. Initially, photobioreactors based on microalgae could remove 95% of doxycycline (DOX) and 93% of OTC from piggy wastewater [93]. In recent years, various studies have a smack at removing hormones and pathogens from LW via microalgae.

Phytoremediation by aquatic plants Aquatic plants have confirmed to be available materials for phytoremediation research, and dissimilar kinds of hydrophytes such as duckweed, water lettuce, water hyacinth, and watermilfoil were widely applied to phytoremediation of LW [10, 16].

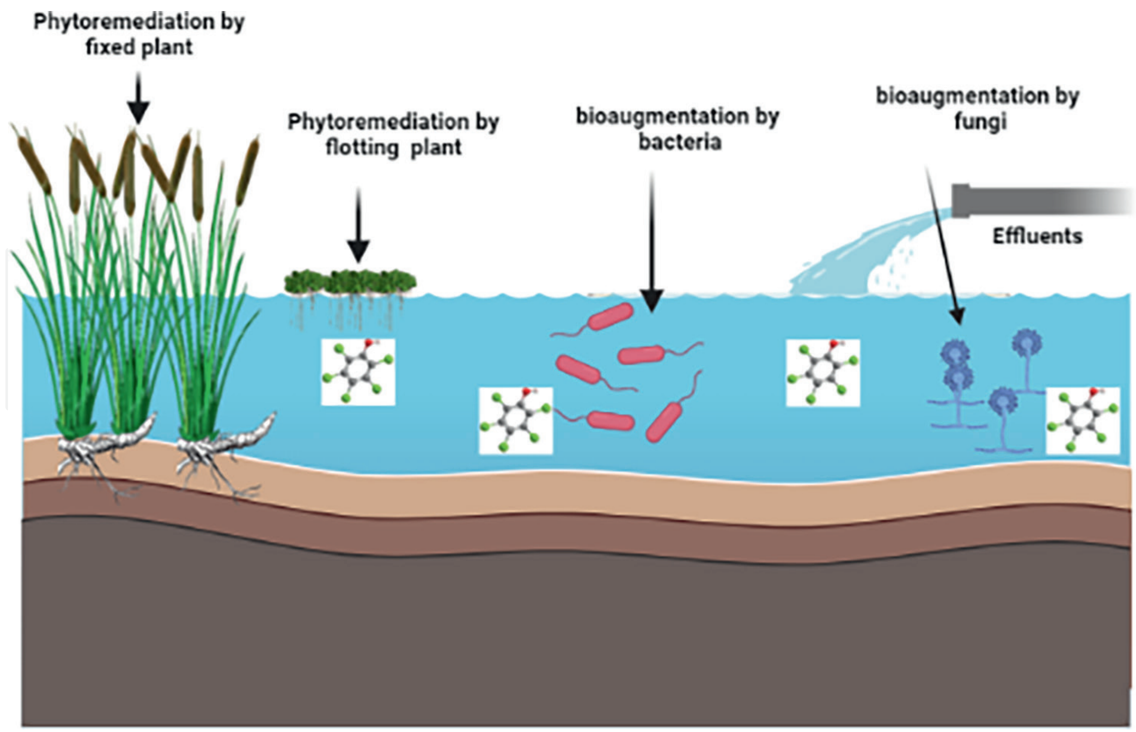

Figure 6.
The main mechanisms of phytoremediation- bioaugmentation process; case of constructed wetland.

7.4 Phytoremediation by constructed wetlands

Biological, physical, and chemical processes interactions between water and substrate, macrophytes, and associated microorganisms are the foundation of erasing pollutants from wastewater in constructed wetlands (CWs) (**Figure 6**) [98]. Eventually, although wetland plants could widely involve in removing organic matters from LW, research by [99] showed that the elimination performance of that did not alternate considerably in seasons while plants increase became reserved. It may be concluded that the elimination of natural topics from LW special from nutrients, which relies upon at the participation of microorganisms that distribute withinside the rhizosphere of vegetation and substrate of CWs. The organic technique is the important pathway to remove HMs from LW in CWs, and the performance of metals elimination via way of means of CWs varies extensively related to the neighborhood weather conditions, plant species, concentrations, and species of heavy metals [100].

In the end, the aerobic condition is more efficient than anaerobic on the biodegradation of antibiotics and hormones, and benefit from this, antibiotics and hormones in LW can be greatly reduced [101]. In order to hold the sustainable improvement of the ecological environment, the usage of aquatic plant life that applied to manipulate LW is rather important. Foremost, macrophytes including duckweed and water hyacinth had been used for farm animals feed because of better degrees of proteins, starches, and celluloses, and accomplished outstanding results.

8. Advantages of a Phytoremediation technology

The phytoremediation is an eco-friendly, maintainable, and hopeful method. Firstly, as compared with conventional organic and physical–chemical methods, phytoremediation is pushed through sun electricity and does now no longer require extra electricity matters, which leads to this manner is decrease cost, much less equipment, and clean to operate [102]. Secondly, the process of phytoremediation is multifaceted since aquatic plants can absorb substances from wastewater indiscriminately, which results in hydrophytes that can remove nutrients and hazardous chemicals such as heavy metals, antibiotics and hormones concurrently [16, 23].

Furthermore, aquatic plants applied for phytoremediation can use nutrients uptake from wastewater to synthesis a variety of high-value nutrients, so as to achieve the purpose of resource recovery [18, 19, 103].

Besides, aquatic macrophytes are more suitable for wastewater treatment than other terrestrial plants due to their faster growth, production of more biomass and a relative higher ability of pollutant [33]. Further, the success of phytoremediation depends upon a plant's capacity to tolerate and to accumulate high quantities of the pollutant, while yielding a large plant biomass [104, 105]. Due to their adaptive techniques to extraordinary environmental conditions, aquatic macrophytes can colonize numerous kinds of aquatic ecosystems. These plant life inhabit the littoral zone, wherein they turn out to be crucial additives affecting ecological methods in numerous ways, which includes 3 major categories (outcomes on network structure, the interplay among aquatic organisms, and limnological outcomes) [106].

In natural and man-made filtering systems, macrophytes play an important role in the biochemical processes of water treatment since their presence could exert some positive effects in this environment.

Overgrowth of aquatic macrophytes has a considerable impact on ecosystem processes [107], including constituting oxygen depletion, decreasing the phytoplankton production, interfering with navigation, increasing water pollution, and health hazards by providing an ideal breeding place for mosquitoes larvae and displace more desired species. The efficiency of full scale phytoremediation in natural condition significantly lower than lab-scale researches meanwhile, advantages of this treatment method cause concerning high attention and requests for future environmental cleaning strategies [108].

The cost of phytoremediation is highly variable and there a high correlation between cost of phyto-treatment and contaminant concentration, types, properties of soil and/water, site circumstances and importance of pollutant as a hazardous effect in the food chain. Anyway, phytoremediation is the most cost effective treatment methods with high social acceptance worldwide [109]. The value of decontamination could be growth approximately 7 times, whilst metal factors blended with natural pollutants [110]. Ligand software including glutamate affect reason growing phytoremediation (via the 30 days [111]. It shows that augmentation or modification system via the phytoremediation approach may also make contributions better efficiency, however it must be explored because the value of augmentation and associated environmental impacts [112]. The maximum appealing element of phytoremediation belongs to wastewater remedy and destiny of this software may also alternate the coverage of municipal wastewater remedy withinside the world [29].

In situ treatment method and easy large-scale applicability [113], generally applied in conjunction with other cleanup approaches [114], or augmentation such as adsorbents [115] nutrients, organic amendments [116] for effectively gaining with current environmental pollution. The plants applied to phytoremediation should possess a faster growth rate, high biomass, extensive fiber root system, easy to regulate, high tolerance to pollutants, and easy to cultivate and harvest [117]. On reason of their extraordinary metabolic and extraction capabilities, plants have been given an unparalleled decontamination capacity [12]. Meanwhile, the leaves, roots, and stems of plants provide residences for a variety of microbes, which can heighten the treatment process by synchronous decompose pollutants [12]. Over the past two decades, a fair amount of studies had been invested in the phytoremediation of LW [16].

9. Disadvantages of a Phytoremediation technology

Any disability, failure unknown reaction might also additionally divert as make a contribution a component to plant species and it additionally might also additionally motive growing dangers of phytoremediation. Literature suggests that infection concentration, toxicity and bioavailability and Plant preference and pressure tolerance are the primary dangers of phytoremediation, which include following tips:

- Accumulation of pollutant in fruit and different fit to be eaten elements of crop and vegetables.
- So a ways developing of phytoremediator plants (hyperaccumulators).
- Low biomass manufacturing in phytoremediators, so numerous planting and harvesting required for decontamination [118].
- Generally, precise selective specific accumulation of 1 metal detail in hyperaccumulator [119]
- Environmental pollution caused by chelate–enhanced phytoremediation [120]
- Very slow and seasonally effective treatment method [121]
- Handling and disposing contaminated plants through the phytoremediation is the major footprint of this green technology [122].
- Mobilization of radionuclides through the translocation in plants [123]
- Not applicable for all compounds [124]
- Dissolved contaminant in groundwater are not suitable case for aquatic phytoremediation [125].
- Originally, phytoremediation is a slow process that requires numerous hours, and extreme environmental weather conditions could also result in the death of hydrophytes and disturb management efficiency [126].

The plants cannot withstand higher contaminant levels [16]. Meanwhile, a few aquatic plant life with large quantity and quicker uptake price can gather the absorbed toxic and pernicious contaminants withinside the body. Although this will enhance the effluent best of wastewater, it'll additionally endanger the secondary usage of hydrophytes. Additionally, phytoremediation of wastewater requires a wide range of land, which is inexecutable in some regions, especially in areas with high population density and scarce land resources [127]. Ultimately, how to maintain the long-term effective and sustainable operation of the management systems still faces a variety of challenges.

10. Conclusion

Remedying technique for decontamination or pollutant elimination from the human surroundings. Advantages and downsides of this approach partially rely on challenge on vegetation as important main organisms via the remedy method, in the meantime maximum of hazards associated with right utility of this ecofriendly surroundings-cleansing technique. In different word, each performance advert blessings of phytoremediation noticeably associated with appropriate operation of remedy method. Combination with different remedy technique as sharpening or submit remedy method, crop plant utility for quicker pollution elimination, transgenic engineered plant species with expert cappotential in pollutant elimination in addition to appropriate utility of hyperaccumulator vegetation species will lead destiny researches to offering a clean image for blessings of this fee powerful technique. Furthermore, eligibility of phytoremediation for municipal wastewater were noticeably showed for destiny imaginative and prescient in wastewater remedy. Cost performance of phytoremediation, optimizing method of remedy and first-class mixture junction with different remedy strategies in phytoremediation has not been completely addressed and might keep in mind as destiny research objectives.

Author details

Rim Werheni Ammeri*, Faiza Souid, Feryell Hajjeji, Saifeddine Eturki and Mohamed Moussa
Eremology and Combating Desertification, Arid Regions Institute of Medenine, Tunisia

*Address all correspondence to: rimwerheni@gmail.com

References

[1] Kaur R, Kaur H. Solar driven photocatalysis – An efficient method for removal of pesticides from water and wastewater. Biointerface Research in Applied Chemistry. 2021;**11**(2):9071-9084

[2] Sharma S, Bhattacharya A. Drinking water contamination and treatment techniques. Applied Water Science. 2017;**7**(3):1043-1067

[3] Ahmed SF, Mofijur M, Nuzhat S, Chowdhury AT, Rafa N, Uddin A, et al. Recent developments in physical, biological, chemical, and hybrid treatment techniques for removing emerging contaminants from wastewater. Journal of Hazardous Materials. 2021;**416**:125912

[4] Saha D, Martuza RL, Rabkin SD. Macrophage polarization contributes to glioblastoma eradication by combination immunovirotherapy and immune checkpoint blockade. Cancer Cell. 2017;**32**(2):253-267

[5] Durmusoglu E, Taspinar F, Karademir A. Health risk assessment of BTEX emissions in the landfill environment. Journal of hazardous materials. 2010;**176**(1-3):870-877

[6] Ananthashankar R, Ghaly A. Effectiveness of photocatalytic decolourization of reactive red 120 dye in textile effluent using UV/H sub (2) O sub (2). American Journal of Environmental Sciences. 2013;**9**:-322

[7] Fallis D. Information ethics for twenty-first century library professionals, Library Hi Tech. 2007;**25**(1):23-36. DOI: 10.1108/07378830710735830

[8] Morelli L, Capurso L. FAO/WHO guidelines on probiotics: 10 years later. Journal of Clinical Gastroenterology. 2012;**46**:S1-S2

[9] Luo J, Chen LS, Duan HZ, Gong YG, Hu S, Ji J, et al. TianQin: A space-borne gravitational wave detector. Classical and Quantum Gravity. 2016;**33**(3):035010

[10] Zhang L, Ho CT, Zhou J, Santos JS, Armstrong L, Granato D. Chemistry and biological activities of processed Camellia sinensis teas: A comprehensive review. Comprehensive Reviews in Food Science and Food Safety. 2019;**18**(5):1474-1495

[11] Markou G, Wang L, Ye J, Unc A. Using agro-industrial wastes for the cultivation of microalgae and duckweeds: Contamination risks and biomass safety concerns. Biotechnology Advances. 2018;**36**(4):1238-1254

[12] Pilon-Smits E. Phytoremediation. Annual Review of Plant Biology. 2005;**56**:15-39

[13] Vymazal J. Constructed wetlands for wastewater treatment: Five decades of experience. Environmental Science & Technology. 2011;**45**(1):61-69

[14] Chen S, Rotaru AE, Liu F, Philips J, Woodard TL, Nevin KP, et al. Carbon cloth stimulates direct interspecies electron transfer in syntrophic co-cultures. Bioresource Technology. 2014;**173**:82-86

[15] Ekperusi AO, Sikoki FD, Nwachukwu EO. Application of common duckweed (Lemna minor) in phytoremediation of chemicals in the environment: State and future perspective. Chemosphere. 2019;**223**:285-309

[16] Hu R, Zhang J, Kuang Y, Wang K, Cai X, Fang Z, et al. A Janus evaporator with low tortuosity for long-term solar

desalination. Journal of Materials Chemistry A. 2019;**7**(25):15333-15340

[17] Kumari M, Tripathi BD. Efficiency of Phragmites Australis and Typha Latifolia for heavy metal removal from wastewater. Ecotoxicology and Environmental Safety. 2015;**112**:80-86

[18] Liu Y, Cao X. Characteristics and significance of the pre-metastatic niche. Cancer Cell. 2016;**30**(5):668-681

[19] Li P, Qian H. Water resources research to support a sustainable China. International Journal of Water Resources Development. 2018;**34**(3):327-336

[20] Mishra VK, Tripathi BD. Accumulation of chromium and zinc from aqueous solutions using water hyacinth (*Eichhornia crassipes*). Journal of Hazardous Materials. 2009;**164**(2-3):1059-1063

[21] Sudiarto SIA, Renggaman A, Choi HL. Floating aquatic plants for total nitrogen and phosphorus removal from treated swine wastewater and their biomass characteristics. Journal of Environmental Management. 2019;**231**:763-769

[22] Zheng H, Wang Z, Deng X, Herbert S, Xing B. Impacts of adding biochar on nitrogen retention and bioavailability in agricultural soil. Geoderma. 2013;*206*:32-39

[23] Zhang H, Wang J, Zhou B, Zhou Y, Dai Z, Zhou Q, et al. Enhanced adsorption of oxytetracycline to weathered microplastic polystyrene: Kinetics, isotherms and influencing factors. Environmental Pollution. 2018;**243**:1550-1557

[24] Siwek GT, Dodgson KJ, de Margarida MS, Bartelt LA, Kilborn SB, Hoth PL, et al. Invasive zygomycosis in hematopoietic stem cell transplant recipients receiving voriconazole prophylaxis. Clinical Infectious Diseases. 2004;**39**(4):584-587

[25] Maher BA, Ahmed IA, Karloukovski V, MacLaren DA, Foulds PG, Allsop D, et al. Magnetite pollution nanoparticles in the human brain. Proceedings of the National Academy of Sciences. 2016;**113**(39):10797-10801

[26] Zhang B, Zheng J, Sharp R. Phytoremediation in engineered wetlands: Mechanisms and applications. Procedia Environmental Sciences. 2010;**2**:1315-1325

[27] Yahaghi Z, Shirvani M, Nourbakhsh F, De La Pena TC, Pueyo JJ, Talebi M. Isolation and characterization of Pb-solubilizing bacteria and their effects on Pb uptake by brassica juncea: Implications for microbe-assisted phytoremediation. Journal of Microbiology and Biotechnology. 2018;**28**:1156-1167

[28] Parmar S, Singh V. Phytoremediation approaches for heavy metal pollution: A review. Journal of Plant Science and Research. 2015;**2**:135

[29] Liu K, Guan X, Li C, Zhao K, Yang X, Fu R, et al. Global perspectives and future research directions for the phytoremediation of heavy metal-contaminated soil: A knowledge mapping analysis from 2001 to 2020. Frontiers of Environmental Science & Engineering. 2022;**16**(6):1-20

[30] Haroon O, Rizvi SAR. Flatten the curve and stock market liquidity–an inquiry into emerging economies. Emerging Markets Finance and Trade. 2020;**56**(10):2151-2161

[31] Haroon M, Daboor S. Nutritional status, antimicrobial and anti-biofilm

activity of Potamogeton nodosus Poir. Egyptian Journal of Aquatic Biology and Fisheries. 2019;**23**(2):81-93

[32] Dhir B, Sharmila P, Saradhi PP. Potential of aquatic macrophytes for removing contaminants from the environment. Critical Reviews in Environmental Science and Technology. 2009;**39**(9):754-781

[33] Ali F, Omar R, Amin M. An examination of the relationships between physical environment, perceived value, image and behavioral Intentions: A SEM approach towards Malaysian resort hotels. Journal of Hotel and Tourism Management. 2013;**27**(2):9-26

[34] Materac M, Wyrwicka A, Sobiecka E. Phytoremediation techniques of wastewater treatment. Environmental biotechnology. 2015;**11**(1):10-13

[35] Achref H, Foudil M, Cherif B. Higher buckling and lateral buckling strength of unrestrained and braced thin-walled beams: Analytical, numerical and design approach applications. Journal of Constructional Steel Research. 2019;**155**:1-19

[36] Saleem M, Ali S, Rehman M, Rana M, Rizwan M, Kamran M, et al. Influence of phosphorus on copper phytoextraction via modulating cellular organelles in two jute (*Corchorus capsularis* L.) varieties grown in a copper mining soil of Hubei Province, China. Chemosphere. 2020;**248**:126032

[37] Hua H, Lia X, Wua S, Yanga C. Sustainable livestock wastewater treatment via phytoremediation: Current status and future perspectives. Bioresource Technology. 2020;**315**:123809

[38] Muszynska E, Hanus-Fajerska E. Why are heavy metal hyperaccumulating plants so amazing? Journal of Biotechnology, Computational Biology and Bionanotechnology. 2015;**96**:265-271

[39] Liu X, Fu JW, Da Silva E, Shi XX, Cao Y, Rathinasabapathi B, et al. Microbial siderophores and root exudates enhanced goethite dissolution and Fe/As uptake by As-hyperaccumulator Pteris vittata. Environmental Pollution. 2017;**223**:230-237

[40] Usman K, Al-Ghouti MA, Abu-Dieyeh MH. Phytoremediation: Halophytes as promising heavy metal hyperaccumulators. Heavy Metal. 2018

[41] Chen J, Shafi M, Li S, Wang Y, Wu J, Ye Z, et al. Copper induced oxidative stresses, antioxidant responses and phytoremediation potential of Moso bamboo (*Phyllostachys pubescens*). Scientific Reports. 2015;**5**:13554

[42] Carr VJ, Lewin TJ, Webster RA, Kenardy JA, Hazell PL, Carter GL. Psychosocial sequelae of the 1989 Newcastle earthquake: II. Exposure and morbidity profiles during the first 2 years post-disaster. Psychological Medicine. 1997;**27**(1):167-178

[43] Adeniji SA, Emovon EU. Competitive alkali-metal flame reactions. Part 5. Reactions of potassium atoms with fluorobenzene, fluoroanisoles, and t-butyl chloride and of potassium and cesium atoms with p-alkylchlorobenzenes. Journal of the Chemical Society, Perkin Transactions. 1979;**2**(3):239-242

[44] Symmoens JJ, Burgis M, Gaudet, JJ. The ecology and utilization of African Inland waters. SI LWorkshop. UNEP Proceedings. Girgiri, Kenya. 1981:191. ISBN: 9280710280

[45] Haroon AM, Abd Ellah RG. Variability response of aquatic macrophytes in inland lakes: A case study

of Lake Nasser. The Egyptian Journal of Aquatic Research. 2021;**47**(3):245-252

[46] Barka N, Abdennouri M, Makhfouk ME. Removal of Methylene Blue and Eriochrome Black T from aqueous solutions by biosorption on Scolymus hispanicus L.: Kinetics, equilibrium and thermodynamics. Journal of the Taiwan Institute of Chemical Engineers. 2011;**42**(2):320-326

[47] Amer MW, Awwad AM. Removal of As(V) from aqueous solution by adsorption onto nanocrystalline kaolinite: Equilibrium and thermodynamic aspects of adsorption. Environmental Nanotechnology, Monitoring & Management. 2018;9:37-41. DOI: 10.1016/j.enmm.2017.12.001

[48] Hassan AF, Elhadidy H, Abdel-Mohsen AM. Adsorption and photocatalytic detoxification of Diazinon using iron and nanotitania modified activated carbons. Journal of the Taiwan Institute of Chemical Engineers. 2017;**75**:299-306

[49] Hossaini H, Moussavi G, Farrokhi M. Oxidation of Diazinon in cns-ZnO/LED photocatalytic process: Catalyst preparation, photocatalytic examination, and toxicity bioassay of oxidation by-products. Separation and Purification Technology. 2017;**174**:320-330

[50] Guo D, Mitchell RJ, Withington JM, Fan PP, Hendricks JJ. Endogenous and exogenous controls of root life span, mortality and nitrogen flux in a longleaf pine forest: Root branch order predominates. Journal of Ecology. 2008;**96**(4):737-745

[51] Grung M, Lin Y, Zhang H, Steen AO, Huang J, Zhang G, et al. Pesticide levels and environmental risk in aquatic environments in China—A review. Environment International. 2015;**81**:87-97

[52] Aiyesanmi AF, Idowu GA. Organochlorine pesticides residues in soil of cocoa farms in Ondo State Central District, Nigeria. Environment and Natural Resources Research. 2012;**2**(2):65

[53] Blyth S, Chape S, Fish L, Fox P, Spalding M. 2003 United Nations list of protected areas. 2003

[54] El-Shahawi MS, Hamza A, Bashammakh AS, Al-Saggaf WT. An overview on the accumulation, distribution, transformations, toxicity and analytical methods for the monitoring of persistent organic pollutants. Talanta. 2010;**80**(5):1587-1597

[55] Bayen S. Occurrence, bioavailability and toxic effects of trace metals and organic contaminants in mangrove ecosystems: A review. Environment International. 2012;**48**:84-101

[56] Wang S, Yu M, Jiang J, Zhang W, Guo X, Chang S, Campbell M. Evidence aggregation for answer re-ranking in open-domain question answering. arXiv preprint arXiv:1711.05116, 2017.

[57] Mahmood I, Imadi SR, Shazadi K, Gul A, Hakeem KR. Effects of Pesticides on Environment. In: Hakeem K, Akhtar M, Abdullah S, editors. Plant, Soil and Microbes. Cham: Springer; 2016. pp. 253-269. DOI: 10.1007/978-3-319-27455-3_13

[58] Devi KP, Nisha SA, Sakthivel R, Pandian SK. Eugenol (an essential oil of clove) acts as an antibacterial agent against Salmonella typhi by disrupting the cellular membrane. Journal of Ethnopharmacology. 2010;**130**(1):107-115

[59] Kravos A, Žgajnar Gotvajn A, Lavrenˇciˇc Štangar U, Malinoviˇc BN, Prosen H. Combined analytical study on chemical transformations and detoxification of model phenolic

pollutants during various advanced oxidation treatment processes. Molecules. 1935;**2022**:27. DOI: 10.3390/molecules27061935

[60] Ajiboye TO, Kuvarega AT, Onwudiwe DC. Recent strategies for environmental remediation of organochlorine pesticides. Applied Sciences. 2020;**10**:6286

[61] Zeng L, Li H, Wang T, Gao Y, Xiao K, Du Y, et al. Behavior, fate, and mass loading of short chain chlorinated paraffins in an advanced municipal sewage treatment plant. Environmental Science & Technology. 2013;**47**(2):732-740

[62] Morrell JJ. Protection of Wood-Based Materials. Handbook of Environmental Degradation of Materials. 2018;343-368. DOI: 10.1016/b978-0-323-52472-8.00017-4

[63] Ammeri RW, Simeone GDR, Hassen W, Ibrahim C, Ammar RB, Hassen A. Bacterial consortium biotransformation of pentachlorophenol contaminated wastewater. Archives of Microbiology. 2021. DOI: 10.1007/s00203-021-02589-9

[64] Werheni WR, Hassen W, Hidri Y, Di Rauso Simeone G, Hassen A. a. Macrophyte and indigenous bacterial co-remediation process for pentachlorophenol removal from wastewater. International Journal of Phytoremediation. 2021;1-12. DOI: 10.1080/15226514.2021.1933897

[65] Werheni Ammeri R, Simeone GDR, Hassen W, Smiri M, Sadf N, Hidri Y, et al. Aspergillus sydowii and Typha angustifolia as useful tools for combined bio-processes of PCP removal in wastewater. International Journal of Environmental Science and Technology. 2021. DOI: 10.1007/s13762-021-03853-7

[66] Michałowicz J, Duda W. Phenols--sources and toxicity. Polish Journal of Environmental Studies. 2007;**16**(3):347-362

[67] Kim Y, Dyer C, Rush AM. Compound probabilistic context-free grammars for grammar induction. arXiv preprint arXiv:1906.10225. 2019

[68] Engst R, Macholz RM, Kujawa M, Lewerenz HJ, Plass R. The metabolism of lindane and its metabolites gamma-2, 3, 4, 5, 6-pentachlorocyclohexene, pentachlorobenzene, and pentachlorophenol in rats and the pathways of lindane metabolism. Journal of Environmental Science & Health Part B. 1976;**11**(2):95-117

[69] Okeke BC, Paterson A, Smith JE, Watson-Craik IA. Comparative biotransformation of pentachlorophenol in soils by solid substrate cultures of Lentinula edodes. Applied Microbiology and Biotechnology. 1997;**48**(4): 563-569

[70] Harkins DK, Susten AS. Hair analysis: Exploring the state of the science. Environmental Health Perspectives. 2003;**111**(4):576-578

[71] Maenpaa T, Pietikäinen M. Classification with color and texture: Jointly or separately? Pattern Recognition. 2004;**37**(8):1629-1640

[72] Kolata GB. Love Canal: False Alarm Caused by Botched Study: In the opinion of many experts, the chromosome damage study ordered by the EPA has close to zero scientific significance. Science. 1980;**208**(4449):1239-1242

[73] Zheng Z, Tai T, Thorp JS, Yang Y. A transient harmonic current protection scheme for HVDC transmission line. IEEE Transactions on Power Delivery. 2012;**27**(4):2278-2285

[74] Gray DM, Landine PG, Granger RJ. Simulating infiltration into frozen prairie soils in streamflow models. Canadian Journal of Earth Sciences. 1985;*22*(3):464-472

[75] Maheshwari N, Khan FH, Mahmood R. Pentachlorophenol-induced cytotoxicity in human erythrocytes: enhanced generation of ROS and RNS, lowered antioxidant power, inhibition of glucose metabolism, and morphological changes. Environmental Science and Pollution Research. 2019;**26**(13):12985-13001

[76] Ziemsen B, Angerer J, Lehnert G. Sister chromatid exchange and chromosomal breakage in pentachlorophenol (PCP) exposed workers. International Archives of Occupational and Environmental Health. 1987;**59**(4):413-417

[77] Demers A, Gehrke J, Hong M, Riedewald M, White W. Towards expressive publish/subscribe systems. In: International Conference on Extending Database Technology. Berlin, Heidelberg: Springer; 2006. pp. 627-644

[78] Wagner RG, Radosevich SR. Neighborhood predictors of interspecific competition in young Douglas-fir plantations. Canadian Journal of Forest Research. 1991;**21**(6):821-828

[79] Bunker PR, Epa VC, Jensen P, Karpfen A. An analytical ab initio potential surface and the calculated tunneling energies for the HCl dimer. Journal of Molecular Spectroscopy. 1991;**146**(1):200-219

[80] Cort JC. Christian Socialism: An Informal History, with an New Introduction by Gary Dorrien. Orbis Books; 2020

[81] Hincapie M, Maldonado MI, Oller I, Gernjak W, Sa'nchez-Pe'rez JA, Ballesteros MM, et al. Solar photocatalytic degradation and detoxification of EU priority substances. Catalysis Today. 2005;**101**:203-210. DOI: 10.1016/j.cattod.2005.03.004

[82] Grandclément C, Seyssiecq I, Piram A, Wong-Wah-Chung P, Vanot G, Tiliacos N, et al. From the conventional biological wastewater treatment to hybrid processes, the evaluation of organic micropollutant removal: A review. Water Research. 2017;**111**:297-317

[83] Hosokawa T, Omukai K. Evolution of massive protostars with high accretion rates. The Astrophysical Journal. 2009;**691**(1):823

[84] Ali V, Singh K, Vishwakarma A, Krishnan C, Chinnusamy V, Tyagi A. Starch accumulation in rice grains subjected to drought during grain filling stage. Plant Physiology and Biochemistry, 2019;**142**:440-451

[85] Chandra R, Castillo-Zacarias C, Delgado P, Parra-Saldívar R. A biorefinery approach for dairy wastewater treatment and product recovery towards establishing a biorefinery complexity index. Journal of Cleaner Production. 2018;**183**:1184-1196

[86] Milam JE. Posttraumatic growth among HIV/AIDS patients 1. Journal of Applied Social Psychology. 2004;**34**(11):2353-2376

[87] Cui H, Tsuda K, Parker JE. Effector-triggered immunity: From pathogen perception to robust defense. Annual Review of Plant Biology. 2015;**66**:487-511

[88] Materac M, Wyrwicka A, Sobiecka E. Phytoremediation techniques of wastewater treatment. Environmental biotechnology. 2015;**11**(1):10-13

[89] Qiu W, Chu C, Mao A, Wu J. The impacts on health, society, and economy

of SARS and H7N9 outbreaks in China: a case comparison study. Journal of environmental and public health. 2018:1-7

[90] Schnoor JL, Light LA, McCutcheon SC, Wolfe NL, Carreia LH. Phytoremediation of organic and nutrient contaminants. Environmental Science & Technology. 1995;**29**(7):318A-323A

[91] Hu H, Li X, Wu S, Yang C. Sustainable livestock wastewater treatment via phytoremediation: Current status and future perspectives. Bioresource Technology. 2020;**315**:123809

[92] Li C, Yang Y, Ren L. Genetic evolution analysis of 2019 novel coronavirus and coronavirus from other species. Infection, Genetics and Evolution. 2020;**82**:104285

[93] Pérez-Lemus N, López-Serna R, Pérez-Elvira SI, Barrado E. Analytical methodologies for the determination of pharmaceuticals and personal care products (PPCPs) in sewage sludge: A critical review. Analytica Chimica Acta. 2019;**1083**:19-40

[94] Elless MP, Poynton CY, Willms CA, Doyle MP, Lopez AC, Sokkary DA, et al. Pilot-scale demonstration of phytofiltration for treatment of arsenic in New Mexico drinking water. Water Research. 2005;**39**(16):3863-3872

[95] Sun T, Jackson S, Haycock JW, MacNeil S. Culture of skin cells in 3D rather than 2D improves their ability to survive exposure to cytotoxic agents. Journal of Biotechnology. 2006;**122**(3):372-381

[96] Braeckevelt M, Mirschel G, Wiessner A, Rueckert M, Reiche N, Vogt C, et al. Treatment of chlorobenzene-contaminated groundwater in a pilot-scale constructed wetland. Ecological Engineering. 2008;**33**(1):45-53

[97] Doumett S, Lamperi L, Checchini L, Azzarello E, Mugnai S, Mancuso S, et al. Heavy metal distribution between contaminated soil and Paulownia tomentosa, in a pilot-scale assisted phytoremediation study: Influence of different complexing agents. Chemosphere. 2008;**72**(10):1481-1490

[98] Shao S, Wu X. Microbial degradation of tetracycline in the aquatic environment: A review. Critical Reviews in Biotechnology. 2020;**40**(7):1010-1018

[99] Luo S, Gao L, Wei Z, Spinney R, Dionysiou DD, Hu WP. Xiao R. Kinetic and mechanistic aspects of hydroxyl radical-mediated degradation of naproxen and reaction intermediates. Water research. 2018;**137**:233-241

[100] Rezania S, Din MFM, Taib SM, Dahalan FA, Songip AR, Singh L, et al. The efficient role of aquatic plant (water hyacinth) in treating domestic wastewater in continuous system. International Journal of Phytoremediation. 2016;**18**(7):679-685

[101] Garcia-Rodríguez A, Matamoros V, Fontàs C, Salvadó V. The ability of biologically based wastewater treatment systems to remove emerging organic contaminants—a review. Environmental Science and Pollution Research. 2014;**21**(20):11708-11728

[102] Ma B, Peng Y, Zhang S, Wang J, Gan Y, Chang J, et al. Performance of anammox UASB reactor treating low strength wastewater under moderate and low temperatures. Bioresource Technology. 2013;**129**:606-611

[103] Liu Y, Xu H, Yu C, Zhou G. Multifaceted roles of duckweed in aquatic phytoremediation and

bioproducts synthesis. Gcb Bioenergy. 2021;**13**(1):70-82

[104] Ali F, Omar R, Amin M. An examination of the relationships between physical environment, perceived value, image and behavioural Intentions: A SEM approach towards Malaysian resort hotels. Journal of Hotel and Tourism Management. 2013;**27**(2):9-26

[105] Grcman H, Persolja J, Lobnik F, Lestan D. Modifying lead, zinc and cadmium bioavailability in soil by apatite and EDTA addition. Fresenius Environmental Bulletin. 2001;**10**(9):727-729

[106] Gasith A, Hoyer MV. Structuring role of macrophytes in lakes: changing influence along lake size and depth gradients. In The structuring role of submerged macrophytes in lakes. New York, NY: Springer; 1998:381-392

[107] Uka UN, Chukwuka KS. Effect of water hyacinth infestation on the physicochemical characteristics of AWBA reservoir, Ibadan, South-West, Nigeria. 2007:**7**(2):282-287. DOI: 10.3923/jbs.2007.282.287

[108] Gomes B, Calanzani N, Curiale V, McCrone P, Higginson IJ. Effectiveness and cost-effectiveness of home palliative care services for adults with advanced illness and their caregivers. Cochrane Database of Systematic Reviews. 2013;(6)

[109] Raskin I, Ensley BD. Phytoremediation of Toxic Metals: Using Plants to Clean up the Environment. John Wiley & Sons, Inc., New York. 2000:53-70

[110] Lasat MM, Pence NS, Garvin DF, Ebbs SD, Kochian LV. Molecular physiology of zinc transport in the Zn hyperaccumulator Thlaspi caerulescens. Journal of Experimental Botany. 2000;**51**(342):71-79

[111] Doumett S, Fibbi D, Azzarello E, Mancuso S, Mugnai S, Petruzzelli G, et al. Influence of the application renewal of glutamate and tartrate on Cd, Cu, Pb and Zn distribution between contaminated soil and Paulownia tomentosa in a pilot-scale assisted phytoremediation study. International Journal of Phytoremediation. 2010;**13**(1):1-17

[112] Römkens MJ, Helming K, Prasad SN. Soil erosion under different rainfall intensities, surface roughness, and soil water regimes. Catena. 2002;**46**(2-3):103-123

[113] Willscher S, Mirgorodsky D, Jablonski L, Ollivier D, Merten D, Büchel G, et al. Field scale phytoremediation experiments on a heavy metal and uranium contaminated site, and further utilization of the plant residues. Hydrometallurgy. 2013;**131**:46-53

[114] Guo L, Lu M, Li Q, Zhang J, Zong Y, She Z. Three-dimensional fluorescence excitation–emission matrix (EEM) spectroscopy with regional integration analysis for assessing waste sludge hydrolysis treated with multi-enzyme and thermophilic bacteria. Bioresource Technology. 2014;**171**:22-28

[115] Mojiri A, Ziyang L, Tajuddin RM, Farraji H, Alifar N. Co-treatment of landfill leachate and municipal wastewater using the ZELIAC/zeolite constructed wetland system. Journal of Environmental Management. 2016;**166**:124-130

[116] Park CK, Xu ZZ, Liu T, Lü N, Serhan CN, Ji RR. Resolvin D2 is a potent endogenous inhibitor for transient receptor potential subtype V1/A1, inflammatory pain, and spinal cord synaptic plasticity in mice: Distinct roles of resolvin D1, D2, and E1. Journal of Neuroscience. 2011;**31**(50):18433-18438

[117] Jabeen R, Ahmad A, Iqbal M. Phytoremediation of hea. 2009

[118] Pilipović A, Zalesny Jr, RS, Rogers ER, McMahon BG, Nelson ND, Burken JG, Lin CH. Establishment of regional phytoremediation buffer systems for ecological restoration in the Great Lakes Basin, USA. II. New clones show exceptional promise. Forests. 2021;**12**(4):474

[119] Xi Z, Ramirez JL, Dimopoulos G. The Aedes aegypti toll pathway controls dengue virus infection. PLoS Pathogens. 2008;**4**(7):e1000098

[120] Melo R, Verde SC, Branco J, Botelho ML. Gamma radiation induced effects on slaughterhouse wastewater treatment. Radiation Physics and Chemistry. 2008;**77**(1):98-100

[121] Chintakovid W, Visoottiviseth P, Khokiattiwong S, Lauengsuchonkul S. Potential of the hybrid marigolds for arsenic phytoremediation and income generation of remediators in Ron Phibun District, Thailand. Chemosphere. 2008;**70**(8):1532-1537

[122] Ghosh M, Singh SP. A review on phytoremediation of heavy metals and utilization of it's by products. Asian Journal of Energy Environ. 2005;**6**(4):18

[123] Popa P, Timofti M, Voiculescu M, Dragan S, Trif C, Georgescu LP. Study of Physico-Chemical Characteristics of Wastewater in an Urban Agglomeration in Romania. The Scientific World Journal. 2012:1-10. DOI: 10.1100/2012/549028

[124] Trapp S, Karlson U. Aspects of phytoremediation of organic pollutants. Journal of Soils and Sediments. 2001;**1**(1):37-43

[125] Van Den Bos E, Jeannerod M. Sense of body and sense of action both contribute to self-recognition. Cognition. 2002;**85**(2):177-187

[126] Khandare RV, Govindwar SP. Phytoremediation of Textile Dyes and Effluents: Current Scenario and Future Prospects. Biotechnology Advances, 2015;**33**:1697-1714. DOI: 10.1016/j.biotechadv.2015.09.003

[127] Cheng Z, Ding Y, He X, Zhu L, Song X, Kankanhalli M. An Adaptive Aspect Attention Model for Rating Prediction. Proceedings of the Twenty-Seventh International Joint Conference on Artificial Intelligence. 2018:3748-3754. DOI: 10.24963/ijcai.2018/521