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CASE STUDY

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Phytoremediation of pollutants from wastewater using hydrophytes: A case study of Islamabad, Pakistan

Shehryar Khan[1], Mohammad Eshaq Faiq[2], Samreen Elahi[3], Safeerul Islam Hashmi[4], Shamim Akhtar[5], Asad jamil[6], Misbah Sharif[7], Sajid Ullah[*8], Zakerullah[9], Sadaf Mansoor[10], Rabia Nazir[11]

[1]*School of Environmental Sciences and Engineering, Northeast Normal University, Jilin, China*

[2]*Department of Marine Biology, Ocean University of China, Qingdao, China*

[3]*School of Environment, Tsinghua University, Beijing, China*

[4]*Department of Environmental Engineering, University of Engineering & Technology, Taxila, Pakistan*

[5]*Department of Earth Sciences, University of Sargodha, Sargodha, Pakistan*

[6]*Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan*

[7]*Department of Botany, University of Agriculture, Faisalabad, Pakistan*

[8]*Department of Water and Environmental Engineering, Nangarhar University, Jalalabad, Afghanistan*

[9]*Department of Disaster Management, Sharq Institute of Higher Education, Kabul, Afghanistan*

[10]*Department of Environmental Sciences, International Islamic University, Islamabad, Pakistan*

[11]*Department of Wildlife Management, PMAS-Arid Agriculture University Rawalpindi, Pakistan*

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Abstract

In this study, phytoremediation technique using two hydrophytes such as Common Duckweed (*Lemnoideae*) and Water Lettuce (*Pistia stratoites*) were used to treat the waste water generated from Chakshahzad, Islamabad. Physico-chemical parameters, including pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Turbidity, Hardness, Bicarbonates, Calcium, Calcium Carbonate, Chloride and Magnesium were assessed before and after the treatment. For this purpose, Common Duckweed (*Lemnoideae*) and Water Lettuce (*Pistia stratoites*) were planted in four different tubs (two tubs for each specie) to find their removal efficiency. The selected Physico-chemical parameters were tested through the initial Pre-test, while after the adding of these species to waste water three Post-test were done. Result shows that more changes were reported in the values of selected parameters at five (5) days interval. These results were compared with the standard values set by Pakistan-National Environmental Quality Standards (PAK-NEQs). The values of all Physico-chemical parameters were reduced to the permissible limits of PAK-NEQs. Although, some parameters were much closed to the threshold level. Results proposed that both species Water Lettuce (*Pistia stratoites*) and Common Duckweed (*Lemnoideae*) have a potential to treat the wastewater. Moreover, Common Duckweed (*Lemnoideae*) showed a better pollutants removal and have a greater efficiency than Water Lettuce (*Pistia stratoites*). However, such type of wastewater without any treatment may cause the pollution of surface and ground water. Therefore, it is recommended that the government and responsible agencies must take formal actions and to make laws and policies to regularly monitor water quality and also awareness programs should be launched.

***Corresponding Author:** Sajid Ullah ✉ sajidjalwan@gmail.com

Introduction

Bioremediation is a biological technique in which we use biological treat agents, such as plants and microbes to clean up contaminated water and soil (Strong and Burgess, 2008). Bioremediation may also be defined as a process, which relies on biological mechanisms to reduce, or degrade the concentration of pollutants to a completely harmless state (Kumar *et al.,* 2016). This process of pollutants removal depends mainly on the type and chemical characteristics of the pollutants, such as: chemicals used for farming, chlorinated compounds, dyes, greenhouse gases, heavy metals, hydrocarbons, nuclear waste, plastics, and sewage etc (Folch *et al.,* 2013). Actually, taking into consideration site of application, bioremediation techniques can be two types as ex-situ or in-situ. In-situ techniques polluted substances are treated at the site of pollution and this bioremediation techniques is primarily used to treat any polluted site which are polluted by chlorinated solvents, dyes, heavy metals, and hydrocarbons (Alvarez *et al.,* 2017). While in the ex-situ techniques the pollutants are excavated, from their sites at which the contamination occurred and then subsequently transported to another site for treatment. Some the selection criteria that are thought out while choosing any bioremediation technique are pollutants nature, depth and degree of pollution, type of environment, location, cost, and environmental policies (Raghunandan *et al.,* 2018).

Apart from selection criteria, performance criteria in which the process of bioremediation largely depend are oxygen and nutrient concentrations, temperature, pH, and other abiotic factors that determine the success of bioremediation processes are also given major considerations prior to bioremediation technique (Mgbeahuruike, 2018). Although bioremediation techniques are diverse, most studies on bioremediation are focused on hydrocarbons and account of frequent pollution of soil and ground water with this particular type of pollutant (Frutos *et al.,* 2010; Chen *et al.,* 2015; Singh and Gupta, 2016).

There are three different types of bioremediation as phytoremediation, myco remediation, and Microbial remediation. Myco remediation is that type of bioremediation which occur through the use fungi. In this process fungi release a specific digestive enzyme through the action of which the degradation of waste occurs. Microbial remediation uses microorganisms to break down contaminants by using them as a food source (Elias *et al.,* 2014; Raghunandan *et al.,* 2014) . They break down contaminants in or out of the contaminated sites by releasing specific type of enzymes. Phytoremediation involves the use of plants to bind, extract, and clean up contaminants in a contaminated site. This is an in-situ type of bioremediation (Soda *et al.,* 2012; Ferraro *et al.,* 2015).

Phytoremediation is the use of hydrophytes to remove the pollutants, present in wastewater or in contaminated soil (Song *et al.,* 2014). The idea of using metal or their pollutants accumulating plants to remove heavy metals and other compounds were first introduced in 1983, but the concept has actually implemented for the last 300 years (Spacil *et al.,* 2011). The generic term “Phytoremediation” consists of the Greek prefix phyto (plant), attached to the Latin word remedian (to correct or remove an evil) (Prasad, 2004). It is mainly applied to sites with surface contamination of organic, nutrient, or metal contaminants. Phytoremediation processes are of four type, such as Phyto-extraction, Rhizo-filtration (Naghipour *et al.,* 2016), Phyto-stabilization (Salt *et al.,* 1995) and Phyto-transformation/Phyto-degradation (Susarla *et al.,* 2002). Using hydrophytes for the treatment of wastewater is very attractive and low-cost method as compared to other methods. Phytoremediation is also called green-remediation, botano-remediation, agro-remediation and vegetative -remediation (Erakhrumen, 2007). Phytoremediation is eco-friendly, cost-effective, aesthetically environmental pollutants removal approach making this more suitable for developing countries especially Pakistan, India and Bangladesh (Pivertz, 2001).

Phytoremediation is a biological treatment and is considered as more attractive alternative. It is the use of different floras besides associated microbes to reduce, remove, immobilize or degrade the environmental contaminants from water and soil, for the restoration of polluted sites to comparatively nontoxic and clean sites. Phytoremediation consist of numerous techniques and all of them are cost-effective, environmental friendly and promising strategies. Different types of contaminated waters can be treated through hydrophytes, as municipal and sewage WW, industrial WW, drainage water, ground plumes, landfill leachate, coal pile runoff and main drainage (Pilon-Smits and Freeman, 2006).

Hydrophytes perform some important natural processes in the treatment of wastewater. These processes are direct accumulation of pollutants in tissues, and a catalytic role to enhance the purification reactions which normally take place in plant's rhizosphere (Jenssen *et al.,* 1993). In rhizosphere, through the interaction of soil/ sediments and microorganisms' plants induce some biological and physiochemical processes to remove pollutants from the WW (Stottmeister *et al.,* 2003).

Several factors are responsible to affect the remediation of contaminated water like pH of sediment and water, sequestration and compartmentalization within root, uptake and mobilization from soil, xylem loading and transport (transfer factor) efficiency, storage and sequestration in the leaf cells, metal sinks distribution in the aerial parts transpiration rates and plant growth (Khan *et al.,* 2017; Hadad *et al.,* 2006).

In this research, two different hydrophytes such as Water Lettuce (*Pistia stratoites*) and Common Duckweed (*Lemnoideae*) were used in order to evaluate the performance of these two hydrophytes against Chak Shahzad waste water and find out the maximum removal efficiency of each species for pollutants removal.

Materials and methods

Study Area Description

For this research, wastewater samples were taken from Chakshahzad, Islamabad, Pakistan.

The latitude and longitude of Chakshahzad is 33.6910° N, 73.1324° E respectively. Chakshahzad has recently evolved into a mix of urban and rural population. It is also considered as a home for some important landmarks including National Agricultural Research Center, Health Services Academy (HSA), and COMSATS University. Fig. 1 shows the study area (Chakshahzad, Islamabad).

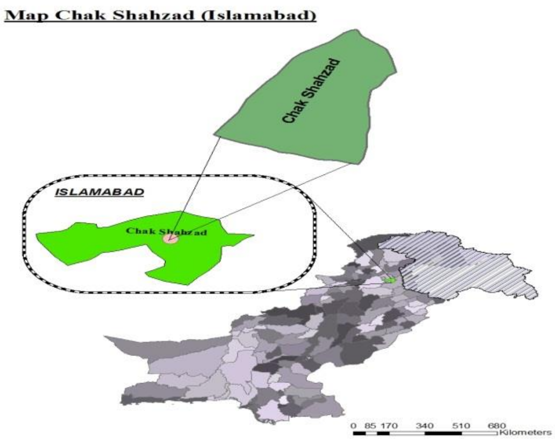

Fig. 1. Map of Pakistan showing the study area (Chakshahzad).

Collection of Hydrophytes and Cultivation

In current research, two different species of hydrophyte such as Water Lettuce (*Pistia stratoites*) and Common Duckweed (*Lemnoideae*) were taken from the local lake ecosystem, of National Agriculture Research Center (NARC), Islamabad, Pakistan. The used species were selected due to distinct features like rapid growing, great resistance to pollutants and maximum uptake of pollutants.

These species were planted and adapted into the open tubs at average temperature of 20 °C±0.02 with mean pH of 7.2 under sunlight for 19 d. The collected waste water of Chakshahzad were used for irrigation of these hydrophytes. Water Lettuce (*Pistia stratoites*) and Common Duckweed (*Lemnoideae*) were used in this study for pollutants removal as shown in Fig. 2 (a) and Fig.2 (b).

Water Quality Analysis

The wastewater samples taken from Chakshahzad were analyzed using physico-chemical parameters such pH, EC, TDS, CO_3^{-2}, BCO_3^{-1}, Hardness, Ca^{+2}, Mg^{+2}, sulfates, Nitrates and BOD.

Fig. 2(a). Shows Water Lettuce (*Pistia stratoites*) and Fig. 2(b): shows and Common Duckweed (*Lemnoideae*) used in this study.

Method to Determine pH

pH is a measure of acidity or basicity (alkaline) of a solution. pH is the abbreviation of pondus hydrogenii and means the weight of hydrogen. The pH scale covers the active concentration of the H^+ ions and OH^- ions and therefore the pH value is defined as the negative common logarithm of the active hydrogen ion concentration in an aqueous solution.

$$pH = \frac{1}{\log hydrogen\ ion\ concentration \frac{mole}{litter}}\ Eq.1$$

$$pH = \frac{1}{\log hydrogen\ ion\ concentration\ (mol\ L^{-1}}\ Eq.2$$

If the H^+ ion concentration changes by a factor of ten, the pH value changes by one unit.

$$pH = \frac{1}{log10}\ Eq.3$$

pH of the samples were recorded using pH meter LA Lutron WA-2015. During this process stirred the sample vigorously using clean glass stirring rod and the pH was recorded after the water pH stable for some time.

Method to Determine TDS

Total dissolved solids (TDS) are defined as all inorganic and organic substances contained in water that can pass through a 2-micron filter. Samples were taken in few beakers and recorded using the electrode LA Lutron WA-2015. During this process stirred the sample vigorously using clean glass stirring rod and the stable reading was recorded.

Method to determine EC

Electrical conductivity (EC) is a measure of the ease with which electrical current can pass through water. It can be measure accurately in the field using a portable conductivity probe and meter. EC of the samples were recorded using a Mettler Toledo MC 226 conductivity meter. The EC meter was switched on and its probe dipped into the sample contained in a beaker. The electrical conductivity was read directly and recorded in (μS)/cm.

Method to Determine Turbidity

Turbidity is a measure of water clarity i.e. the degree to which the water loses its transparency due to the presence of suspended particulates. The more total suspended solids in the water, the murkier it seems and the higher the turbidity. Sample (25 mL) was taken in cuvette of turbidity analysis. Placed the vial /cuvette in turbidity meter and read the measurement and note down using a turbidity meter.

Method to Determine Cl^{-1}

Chlorides are basically salts resulting from the combination of the gas chlorine with a metal. About 25 mL sample was taken in a titration flask by using pipette. Then added 2-3 drops of indicator potassium chromate into the sample. Silver nitrate solution was taken using burette and the initial reading was recorded. Titrate the sample against the silver nitrate until the color changed. The final reading was then noted down. Chloride amount in water sample can be calculated by using the following equation.

Calculations

$$Chloride\ in \frac{mg}{L} = \frac{ml\ of\ AgNO3\ usedx0.014x35.5x1000}{ml\ of\ sample}\ Eq.4$$

Where, 0.014= Normality of the $AgNO_3$

35.5= Mol. wt of chlorine

Method to Determine Ca^{+2}

The chemicals required for Calcium determinations are NaOH 1 mL, Meuroxide indicator (pinch of) and EDTA as required. Take 10 mL sample in titration flask. Add 1 mL NaOH (1 molar) and a pinch of meuroxide as an indicator. Now titrate this solution against EDTA solution. Take the difference of initial and final reading of EDTA used.

Calculations

$$Ca^{+2}\ in \frac{mg}{L} = \frac{ml\ of\ EDTA\ used}{ml\ of\ sample} x400.5x1.05\ Eq.5$$

Where,

$$mL\ of\ EDTA\ used = Final\ reading - Initial\ reading\ Eq.6$$

Method to Determine Mg^{+2}

Magnesium is calculated by putting values in equation;

$$Mg^{+2}\ in \frac{mg}{L} = (A - B)X0.244\ Eq.7$$

Where,

$$A = Total\ Hardness$$

$$B = \frac{ml\ of\ titrant\ for\ Ca^{+2}}{ml\ of\ sample} x1000x1.05\ Eq.8$$

Method Do determine HCO_3^{-1}

Bicarbonates are commonly calcium bicarbonate, Ca $(HCO_3)^2$; sodium bicarbonate, $(NaHCO_3)$; or magnesium bicarbonate, Mg $(HCO_3)^2$. For this purpose, 25 mL sample was taken in a titration flask by using of pipette. Added indicator methyl orange (2-3 drops) in to sample. Sulfuric acid solution was taken in a burette and the initial reading was noted down. Titrate the sample against the sulfuric acid until the color of sample changed. The final reading was then noted down. It can be calculated as follow

Calculations

Using following formula amount of Carbonates in given sample can be calculated:

$$HCO_3^{-1} = \frac{ml\ of\ sulfuric\ acid\ used}{ml\ of\ sample} x1000\ Eq.9$$

Where,

$$ml\ of\ sulfuric\ acid = Final\ reading\ on\ Burette - Initial\ reading\ on\ Burette$$

For carbonates, permissible limit is 10 mg/L. For Bicarbonate permissible limit is 200 mg/L.

Method to Determine Total Hardness

Hard water is high in dissolved minerals, both calcium, and magnesium. As water moves through soil and rock, it dissolves small amounts of these naturally occurring minerals and carries them into the ground water supply. Water is a great solvent for calcium and magnesium, so if the minerals are present in the soil around well and its water supply, it will end up with hard water.

$$Total\ Hardness \left(\frac{mg}{L}\right) = Ca^{+2}\ hardness \left(\frac{mg}{L}\right) + Mg^{+2}\ hardness \left(\frac{mg}{L}\right)\ Eq.10$$

The chemicals required for calculating hardness are hardness Buffer, EBT (Erichrome Black T) indicator, and EDTA as required. Wash all glass wares. Take 10mL sample in clean titration flask. Add 1 mL hardness Buffer and a pinch of EBT as an indicator. Now titrate this solution against EDTA solution. Take the difference of initial and final reading of EDTA used.

Calculations

$$Total\ Hardness\ in \frac{mg}{L} = \frac{ml\ of\ EDTA\ used}{ml\ of\ sample} x1000\ Eq.11$$

Where,

$$ml\ of\ EDTA\ used = Final\ reading - Initial\ reading$$

Data Analysis

The results of experimental work were analysed with statistical package (SPSS), for graphs making Origin Pro was used, while Arc Geographic Information System (ArcGIS) was used for study area map.

Results and discussion

Physico-Chemical Parameters

In physico-chemical analysis, different parameters (pH, EC, TDS, DO, Hardness, turbidity, carbonates, Bicarbonates, Calcium, and Magnesium) were tested as shown in Tab. 1. Sampling was done with five (5) days interval from 5 August to 25 August, 2021 at 32ºC and 35ºC. The samples were taken from Chakshahzad, Islamabad. Two (2) different species named Water Lettuce (*Pistia stratoites*) and Common Duckweed (*Lemnoideae*) were added to waste water in four (4) separate tubs (two for each specie). All the samples were tested in the laboratory of National Institute of Bioremediation (NIB) at (NARC) Islamabad. Significant results were obtained from physico-chemical analyses which are described in Tab. 1.

pH

Control pH value of the samples were recorded as 5.51. After the addition of hydrophytes in waste water samples, the pH value increased and it changed from acidity towards basicity. The pH value reported for Common Duckweed (*Lemnoideae*) on 19 d was 8.02, whereas the pH value recorded for Water Lettuce (*Pistia stratoites*) on 19 d was 7.66 see Fig. 3 and Tab. 3.

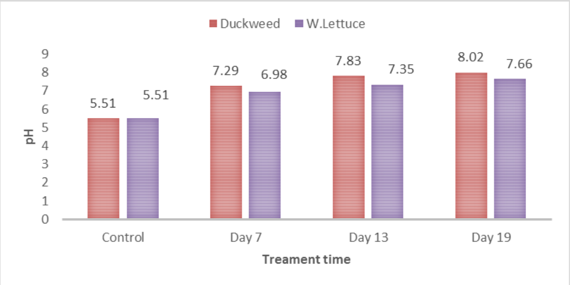

Fig. 3. Variations in pH values at five (5) days interval by adding Common Duckweed (*Lemnoideae*) and Water Lettuce (*Pistia stratoites*).

The permissible limit for pH set by Pakistan-NEQs is 6-10 pH (acidity/basicity). If this limit exceeds than the pH of water affects the solubility of many toxic and nutritive chemicals; as acidity increases; most metals become more water soluble and more toxic (Fontanili *et al.,* 2016). The ideal pH range for soil is from 6 to 6.5 because most plant nutrients are in their most available state. Nitrogen, for example, has its greatest solubility between soil pH 4 and pH 8 and the pH value <3 and >9 cause reduced plant growth (Maine *et al.,* 2009).

Total Dissolved Solids

Control value for TDS is recorded to be 741 parts per million (ppm) see Tab. 1. After the addition of hydrophytes to waste water there were significant changes occur in this value. The TDS value was recorded after 19 d for Common Duckweed (*Lemnoideae*) was 500 ppm whereas for Water Lettuce (*Pistia stratoites*) it was 520ppm as shown in Fig. 4.

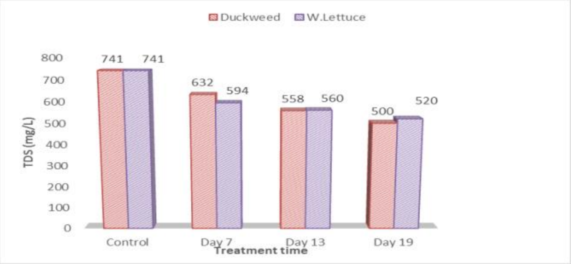

Fig. 4. Variations in TDS values at five (5) days interval by adding Common Duckweed (*Lemnoideae*) and Water Lettuce (*Pistia stratoites*).

The Environmental protection Agency (EPA) effluent standards for reuse in irrigation are 500 ppm. If the mentioned level exceeds then without leaching and drainage, salts may be redistributed towards the soil surface by the upward movement of water associated with evaporation (Shukla and Rao, 2017).

Electrical Conductivity

Control value of EC was recorded about 1.121µs/cm. The high EC values of the sample showed, that these effluents contain a high concentration of mobile and valence inorganic ions (Tan and Ting, 2012). With the addition of Common Duckweed (*Lemnoideae*) and Water Lettuce (*Pistia stratoites*) significant changes occurred in EC value. The EC value recorded for Common Duckweed (*Lemnoideae*) was 0.74, whereas for Water Lettuce (*Pistia stratoites*) it was recorded to be 0.82 as shown in Fig. 5. The effluent standard limits for wastewater reuse in irrigation for EC is 800µs/cm (Karna *et al.,* 2017).

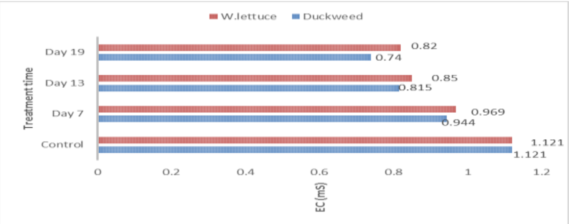

Fig. 5. Variations in EC values at five (5) days interval by adding Common Duckweed (*Lemnoideae*) and Water Lettuce (*Pistia stratoites*).

Turbidity

The turbidity values showed great variations among all samples in which the hydrophytes were added. The control turbidity value for the sample was 34.04 NTU. After the addition of Common Duckweed (*Lemnoideae*) and Water Lettuce (*Pistia stratoites*), a significant changes occurred in the turbidity for all samples. After completion of 19 d, the turbidity value for Common Duckweed (*Lemnoideae*) was 5.02, while for Water Lettuce (*Pistia stratoites*), the turbidity value was recorded about 4.70 see Fig. 6. These values showed that the samples after treatment through these species still contain impurities which may include finely divided inorganic and soluble colored organic compounds (Ma *et al.,* 2016).

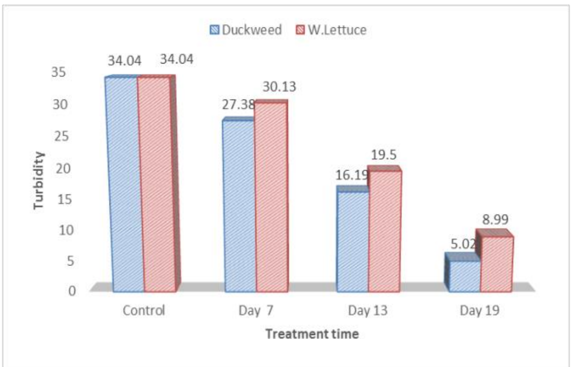

Fig. 6. Variations in turbidity values at five (5) days interval by adding Common Duckweed (*Lemnoideae*) and Water Lettuce (*Pistia stratoites*).

Chloride

The Chloride values show great changes among all the tested samples. For chloride, the control value was reported 120.91 mg/L. While after the addition of Common Duckweed (*Lemnoideae*) and Water Lettuce (*Pistia stratoites*) in waste water samples significant changes were founded. By adding Common Duckweed (*Lemnoideae*), the Chloride value after 19 d was reported 120.91 mg/L, whereas for Water Lettuce (*Lemnoideae*), after 19 d the values was reported 109.2 mg/L as given in Fig. 7.

The chlorides mostly affect the soil pH. Soil pH ($CaCl_2$) of 5.2 to 8.0 provides optimum conditions for most agricultural plants. Microbial activity in the soil also affected by soil pH with most activity occurring in soils of pH 5.0 to 7.0. Where the extremities of acidity or alkalinity occur, various species of earth worms and nitrifying bacteria disappear (Fang *et al.,* 2011).

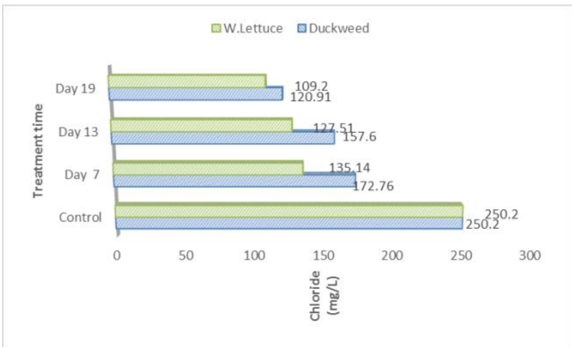

Fig. 7. Variations in Chloride values at Five (5) days interval by adding Common Duckweed (*Lemnoideae*) and Water Lettuce (*Pistia stratoites*).

The standard value of Chloride for irrigation is 250 mg/L (Taştan *et al.*, 2012). Chloride does not absorb to soil particles (as do ammonium and phosphorous) generally it does not form complexes with other compounds and it does not undergo biological transformation (as do nitrate and ammonium). Additionally, chloride is one of the few ions, along with nitrate that travels at the same rate as ground water (Fang *et al.,* 2011).

Total Hardness

The control value of the samples for its total hardness were recorded about 500 mg/L. After the addition of species waste water, important changes occurred. On 19 d the total hardness value was recorded 239.54 for Common Duckweed (*Lemnoideae*) while for Water Lettuce (*Pistia stratoites*) it was recorded 250.67 mg/L see in Fig. 8.

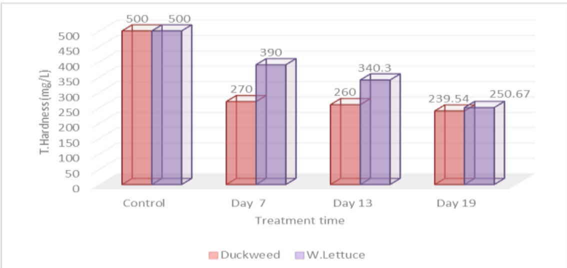

Fig. 8. Variations in Total Hardness values at five (5) days interval by adding Common Duckweed (*Lemnoideae*) and Water Lettuce (*Pistia stratoites*).

The highest value recorded for the Water Lettuce (*Pistia stratoites*) which was 390 mg/L on d seven (7) as shown in Tab. 2. The waste water seeps through the ground and increase the hardness of ground water. The standard classifications of hard water are moderate (60-120 mg/L), hard (120-180 mg/L) and very hard more than (180 mg/L) (Shukla and Rao, 2017).

Magnesium

The Control value for Magnesium was recorded about 52.86 mg/L. However, after the addition of Common Duckweed (*Lemnoideae*) and Water Lettuce (*Pistia stratoites*), major changes were occurred. For Common Duckweed (*Lemnoideae*) after 19 d the value was recorded 7.56 mg/L, while for the Water Lettuce (*Pistia stratoites*), the value was recorded 15.67 mg/L as shown in Fig 9. According to the literature Common Duckweed (*Lemnoideae*) have the greater capability to extract Magnesium from waste water.

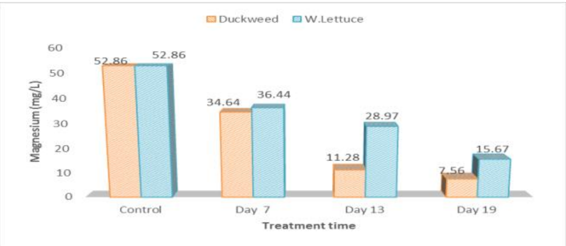

Fig. 9. Variations in Magnesium values at five (5) days interval by adding Common Duckweed (*Lemnoideae*) and Water Lettuce (*Pistia stratoites*).

Calcium

The Control value for Calcium on sampling day was recorded 113.54 mg/L. However, Common Duckweed (*Lemnoideae*) and Water Lettuce (*Pistia stratoites*), significant changes were founded. For Common Duckweed (*Lemnoideae*) after 19 d the value was reported 74.66 mg/L, whereas for the Water Lettuce (*Pistia stratoites*), the value was recorded 76.56 mg/L as shown in Fig. 10.

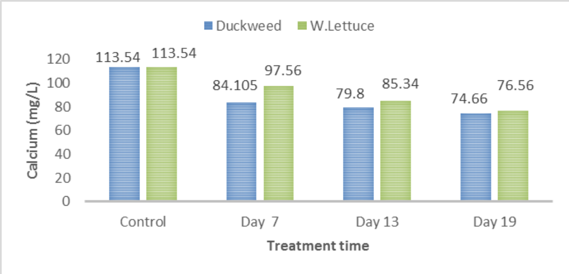

Fig. 10. Variations in Calcium values at five (5 days) interval adding Common Duckweed (*Lemnoideae*) and Water Lettuce (*Pistia stratoites*).

Calcium Carbonate

The control value for Calcium carbonate for the waste water was recorded 283.5 mg/L. After the addition of hydrophytes such as adding Common Duckweed (*Lemnoideae*) and Water Lettuce (*Pistia stratoites*) to waste water, significant changes were founded in the $CaCO_3$. On d 13 and 19 the $CaCO_3$ value recorded for Common Duckweed (*Lemnoideae*) was 186.42 and 120 mg/L, while for Water Lettuce (*Pistia stratoites*) it was recorded 195.54 and 160.7 mg/L as shown in Fig. 11 and Tab. 3.

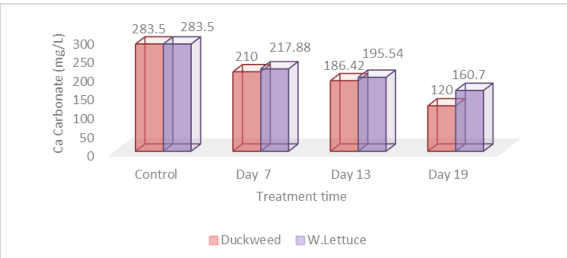

Fig. 11. Variations in Calcium Carbonate values at five (5) days interval by adding Common Duckweed (*Lemnoideae*) and Water Lettuce (*Pistia stratoites*).

Table 1. Physico-chemical parameter values of waste water samples tested on d first (1).

SN	Parameter	Control	Duckweed	Water Lettuce	Permissible Value
1	pH	5.51			6-10
2	TDS (ppm)	741			500 mg/L
3	EC (mS)	1.121			800mS/cm
4	Turbidity (NTU)	34.04			>5 NTU
5	Calcium (mg/L)	113.54			75 mg/L
6	Chloride (mg/L)	250.20	Same as mentioned in Control		250 mg/L
7	T. Hardness (mg/L)	500			200 mg/L
8	CaCO3 (mg/L)	283.5			600 mg/L
9	Magnesium	52.86			50 mg/L

Table 2. Physico-chemical parameter values of waste water samples tested on d seven (7).

SN	Parameter	Control	Duckweed	Water Lettuce
1	pH	5.51	7.29	6.98
2	TDS (ppm)	741	632	594
3	EC (mS)	1.121	0.944	0.969
4	Turbidity (NTU)	34.04	27.38	30.13
5	Calcium(mg/L)	113.54	84.105	97.56
6	Chloride(mg/L)	250.20	172.76	135.14
7	T. Hardness	500	270	390.00
8	CaCO3 (mg/L)	283.5	210	217.88
9	Magnesium	52.86	34.64	36.44

Table 3. Physico-chemical parameter values of waste water samples tested on d thirteen (13).

SN	Parameter	Control	Duckweed	Water Lettuce
1	PH	5.51	7.83	7.35
2	TDS (ppm)	741	558	0.850
3	EC (mS)	1.121	0.815	19.50
4	Turbidity (NTU)	34.04	16.19	85.34
5	Calcium(mg/L)	113.54	79.80	127.51
6	Chloride(mg/L)	250.20	157.6	340.30
7	T. Hardness	500	260.00	195.54
8	CaCO3 (mg/L)	283.5	186.42	28.97
9	Magnesium	52.86	11.28	15.67

Table 4. Physico-chemical parameter values of waste water samples tested on d nineteen (19).

SN	Parameter	Control	Duckweed	Water Lettuce
1	pH	5.51	8.02	7.66
2	TDS	741	500	520
3	EC	1.121	0.740	0.820
4	Turbidity	34.04	5.02	8.99
5	Calcium	113.54	74.66	76.56
6	Chloride	250.20	120.91	109.2
7	T. Hardness	500	239.54	250.67
8	CaCO3	283.5	120.00	160.7
9	Magnesium	52.86	7.56	15.67

Discussion

Bioremediation is not a new concept but this process was first discovered around 600 BC by the Romans, to clean the waste water. Much later, in the 1960's, bioremediation was officially invented by George Robinson. During the late nineteenth century, waste water treatment plants were developed, and along with the first intentional application of biological processes to treat waste and wastewater. For at least 300 years, the ability of plants to remove contaminants from the environment has been recognized and taken advantage of its applications such as land farming of waste. Over time, the use of plants has been evolved to the construction of treatment wetlands or even the planting of trees to stabilize air pollution. In more recent years, as recognition grew of the damage resulting around the world from decades of an industrial economy and extensive use of chemicals, so did interest in finding technologies that could address the residual contamination, among them phytoremediation (Maine *et al.,* 2009). Research into and application of phytoremediation has flourished over the last 15 years. Phytoremediation has been implemented as a component of the selected remedy at 18 superfund sites in the United States (Taştan *et al.,* 2012). Phytoremediation has been increasingly used to clean up contaminated soil and water systems because of its lower costs and fewer negative effects than physical or chemical engineering approaches (Fang *et al.,* 2011). In Pakistan, as there is plenty of abundant and agriculture based lands, therefore, these techniques for waste water treatment can be used for safe disposal of contaminated water.

Many researchers have used different plant species for treating the waste water like Water Hyacinth, Water Lettuce, Duckweed, Bulrush, Vetiver Grass, and Common Reed for the treatment of wastewater. In many cases, especially in tropical or subtropical areas, invasive plants such as the Duckweed and Water Lettuce were used in phytoremediation water systems (Soda *et al.,* 2012).This is because, compared to other native plants, these plants species show a much higher nutrient removal efficiency with their high nutrient uptake capacity, fast growth rate, and big biomass production (Reddy and Sutton, 1984). In this study of phytoremediation, we have used the Common Duckweed (*Lemnoideae*) and Water Lettuce (*Pistia stratoites*) based on their growth patterns, nutrient uptake rates and the fact that they are native to the study region.

Common Duckweed (*Lemnoideae*) also known as (water lens) are small aquatic plants belonging to the botanical family named as Lemnaceae are flowering plants which float on or just beneath the surface of still or slow moving bodies of fresh water and wetlands.

In recent years a commonly occurring aquatic plant, "Duckweed", has become prominent, because of its ability to concentrate minerals on heavily polluted water such as that arising from sewage treatment facilities. However, it has also attracted the attention of scientists because of its apparent high potential as a feed resource for livestock (Ferraro *et al.,* 2015). Due its capability of rapid propagation through consuming dissolved nutrients from the waste water make Common Duckweed (*Lemnoideae*) an excellent candidate for waste water treatment.

Most of the research has been done on the use of Common Duckweed (*Lemnoideae*) in waste water treatment systems because of their great potential to remove mineral contaminants from waste waters emanating from sewage works, intensive animal industries or from intensive irrigated crop production. The minimum water temperature allowing their use in waste water treatment is reported to be 7 °C (Kumar *et al.,* 2016). A second critical soil parameter is pH for the growth of Common Duckweed (*Lemnoideae*). The optimum pH for Common Duckweed (*Lemnoideae*) growth ranges between 4.5 and 7.5. Other authors report a narrower pH optimum ranging from 6.5 to 7.5 (Folch *et al.,* 2013). Therefore, highly acid and alkaline soils are unsuitable for Common Duckweed (*Lemnoideae*) cultivation. Alkaline conditions favor, in particular, the transformation of ammonium to ammonia which is harmful to Common Duckweed (*Lemnoideae*). As described in this study that Common Duckweed (*Lemnoideae*) increases the pH value of the selected waste water from pH 5.51 to 8.02.

Pistia stratiotes common name of Water Lettuce is a floating perennial commonly belonging to the family Araceae. It floats on the surface of the water, and its roots hanging underwater beneath floating leaves. Water Lettuce (*Pistia stratoites*) is non-winter-hard plant, having a minimum growth at temperature 15 °C. Fonkou *et al.* (2002) stated that Water Lettuce (*Pistia stratoites*) doubles its biomass in just over 5 d, triples it in 10 d, quadruples in 20 d and has its original biomass multiplied by a factor of 9 in less than one month. This evolution indicates that 25 d is the maximum period to allow the plant in the system. Lu *et al.* (2010) also reported that low concentration of nutrients may reduce the performance of plant in removing nutrients. A 200- fold difference in dry weight of Water Lettuce (*Pistia stratoites*). Most of the studies conducted on the use of Water Lettuce (*Pistia stratoites*) for the treatment of waste water that Alkaline pH was changed to the neutral through the application of this plant. Similarly like that of other studies this study also shows that the pH of the selected wastewater is increased from 5.51 to 7.66 which is slightly alkaline and is near to neutral through the use Water Lettuce (*Pistia stratoites*). The reduction in pH is due to absorption of nutrients and other salts by plants or by simultaneous release of H^+ ions with the uptake of metal ions.

Preliminary study by Lu *et al.* (2010), revealed that Water Lettuce (*Pistia stratoites*) growth decreased the EC in the treatment plot due to salt removal from the waters by plant uptake or root adsorption and it was concluded that water quality in ponds was improved by phytoremediation with Water Lettuce (*Pistia stratoites*). As the present study shows that that the EC value of waste water was decreased from 1.121 (uS/cm) to (0.82 uS/cm) by using Water Lettuce (*Pistia stratoites*) and show lower reduction as compared to the decrease showed by the Common Duckweed (*Lemnoideae*) which was EC 0.74 (uS/cm). From this study it was concluded that the efficiency of Water Lettuce (*Pistia stratoites*) for the treatment of waste water was lower than Common Duckweed (*Lemnoideae*), used for the treatment of sewage waste water of Chakshahzad, Islamabad.

Conclusions

Phytoremediation is one of the recent cleaning concept that use plant species to clean the polluted environments. In this study two different hydrophytes such as Common Duckweed (*Lemnoideae*) and Water Lettuce (*Pistia stratoites*) were used to remove the pollutants from waste water of Chakshahzad, Islamabad. Hydrophytes are suitable for waste water treatment because they play an inspiring role and show a tremendous capacity for absorbing nutrients and remove other contaminants from waste water. Results showed that Common Duckweed (*Lemnoideae*) and Water Lettuce (*Pistia stratoites*) have more effects on the removal of different contaminants from waste water. However, the Common Duckweed (*Lemnoideae*) showed good removal efficiency as compared to Water Lettuce (*Pistia stratoites*) and have been recommended for waste water treatment because it shows the capability of rapid growth on a wide range of pH and cold tolerable to grow throughout the year instead of that of other aquatic plants.

Common Duckweed (*Lemnoideae*) produces biomass faster than any other hydrophytes and has more potential for the removal of different contaminants and may be helpful in future research studies and phytoremedial approaches.

References

Aghunandan K, Mchunu S, Kumar A, Kumar KS, Govender A, Permaul K, Singh S. 2014. Biodegradation of glycerol using bacterial isolates from soil under aerobic conditions. Journal of Environmental Science and Health, Part A **49,** 85-92.

Alvarez A, Saez JM, Costa JSD, Colin VL, Fuentes MS, Cuozzo SA, Benimeli CS, Polti MA, Amoroso MJ. 2017. Actinobacteria: current research and perspectives for bioremediation of pesticides and heavy metals. Chemosphere **166,** 41-62.

Chen J, Zhou HC, Wang C, Zhu CQ, Tam NFY. 2015. Short-term enhancement effect of nitrogen addition on microbial degradation and plant uptake of polybrominated diphenyl ethers (PBDEs) in contaminated mangrove soil. Journal of Hazardous Materials **300,** 84-92.

Elias SH, Mohamed M, Ankur A, Muda K, Hassan M, Othman MN, Chelliapan S. 2014. Water hyacinth bioremediation for ceramic industry wastewater treatment-application of rhizofiltration system. Sains Malaysiana **43,** 1397-1403.

Erakhrumen Agbontalor Andrew. 2007. Phytoremediation: an environmentally sound technology for pollution prevention, control and remediation in developing countries. Educational Research and Review **2(7),** 151-156.

Fang L, Wei X, Cai P, Huang Q, Chen H, Liang W, Rong X. 2011. Role of extracellular polymeric substances in Cu (II) adsorption on Bacillus subtilis and Pseudomonas putida. Bioresource technology **102,** 1137-1141.

Ferraro A, Van Hullebusch ED, Huguenot D, Fabbricino M, Esposito G. 2015. Application of an electrochemical treatment for EDDS soil washing solution regeneration and reuse in a multi-step soil washing process: case of a Cu contaminated soil. Journal of environmental management **163,** 62-69.

Ferraro A, Van Hullebusch ED, Huguenot D, Fabbricino M, Esposito G. 2015. Application of an electrochemical treatment for EDDS soil washing solution regeneration and reuse in a multi-step soil washing process: case of a Cu contaminated soil. Journal of environmental management **163,** 62-69.

Folch A, Vilaplana M, Amado L, Vicent R, Caminal G. 2013. Fungal permeable reactive barrier to remediate groundwater in an artificial aquifer. J Hazard Mater **262,** 554-560. doi: 10.1016/j.jhazmat. 2013.09.004.

Fonkou T, Agendadia P, Kengne I, Akoa A, Nya J. 2002. Potentials of water lettuce (*Pistia stratiotes*) in domestic sewage treatment with macrophytic lagoon systems in Cameroon. In: Proc. of International Symposium on Environmental Pollution Control and Waste Management, Tunis 709-714.

Fontanili L, Lancilli C, Suzui N, Dendena B, Yin YG, Ferri A, Ishii S, Kawachi N, Lucchini G, Fujimaki S. 2016. Kinetic analysis of zinc/cadmium reciprocal competitions suggests a possible Zn-insensitive pathway for root-to-shoot cadmium translocation in rice. Rice **9,** 1-13.

Hadad HR, Maine MA, Bonetto CA. 2006. Macrophyte growth in a pilot-scale constructed wetland for industrial wastewater treatment. Chemosphere **63(10),** 1744-1753.

Jenssen PD, Maehlum T, Krogstad T. 1993. Potential use of constructed wetlands for wastewater treatment in northern environments. Water Science and Technology **28(10),** 149-157.

Karna RR, Luxton T, Bronstein KE, Hoponick Redmon J, Scheckel KG. 2017. State of the science review: Potential for beneficial use of waste by-products for in situ remediation of metal-contaminated soil and sediment. Critical Reviews in Environmental Science and Technology **47,** 65-129.

Khan S, Shamshad I, Waqas M, Nawab J, Ming L. 2017. Remediating industrial wastewater containing potentially toxic elements with four freshwater algae. Ecological Engineering **102,** 536-541.

Kumar A, Chanderman A, Makolomakwa M, Perumal K, Singh S. 2016. Microbial production of phytases for combating environmental phosphate pollution and other diverse applications. Critical Reviews in Environmental Science and Technology **46,** 556-591.

Lu Q, He ZL, Graetz DA, Stoffella PJ, Yang X. 2010. Phytoremediation to remove nutrients and improve eutrophic storm waters using water lettuce (*Pistia stratiotes* L.). Environ. Sci. Poll. Res **17,** 84-96.

Ma Y, Oliveira RS, Freitas H, Zhang C. 2016. Biochemical and molecular mechanisms of plant-microbe-metal interactions: relevance for phytoremediation. Frontiers in plant science **7,** 918.

Maine MA, Sune N, Hadad H, Sánchez G, Bonetto C. 2009. Influence of vegetation on the removal of heavy metals and nutrients in a constructed wetland. Journal of Environmental Management **90,** 355-363.

Mgbeahuruike LU. 2018. An investigation into soil pollution and remediation of selected polluted sites around the globe. Manchester Metropolitan University.

Naghipour D, Gharibi H, Taghavi K, Jaafari J. 2016. Influence of EDTA and NTA on heavy metal extraction from sandy-loam contaminated soils. Journal of environmental chemical engineering **4,** 3512-3518.

Pilon-Smits EA, Freeman JL. 2006. Environmental cleanup using plants: biotechnological advances and ecological considerations. Frontiers in Ecology and the Environment **4(4),** 203-210.

Pivertz E, Bruce. 2001. Phytoremediation of Contaminated Soil and Ground Water at Hazardous Waste Sites. Environmental Research Services Corporation. EPA/540/S- 01/500.

Prasad MNV. 2004. Phytoremediation of metals in the environment for sustainable development. Proc. Indian natn. Sci. Acad., B **70(1),** 71-98.

Raghunandan K, Kumar A, Kumar S, Permaul K, Singh S. 2018. Production of gellan gum, an exopolysaccharide, from biodiesel-derived waste glycerol by *Sphingomonas* spp. 3 Biotech **8,** 71.

Salt DE, Blaylok M, Nanda-Kumar PBA, Dushenkov V, Ensly BD, Chet I, Raskin I. 1995. Phytoremediation: A novel strategy for the removal of toxic elements from the environment using plants. Bio-Technology **13,** 468-475.

Shukla SK, Rao TS. 2017. The first recorded incidence of Deinococcus radiodurans R1 biofilm formation and its implications in heavy metals bioremediation. bioRxiv 234781.

Singh S, Gupta VK. 2016. Biodegradation and bioremediation of pollutants: perspectives strategies and applications. International Journal of Pharmacology and Biological Sciences **10,** 53.

Soda S, Hamada T, Yamaoka Y, Ike M, Nakazato H, Saeki Y, Kasamatsu T, Sakurai Y. 2012. Constructed wetlands for advanced treatment of wastewater with a complex matrix from a metal-processing plant: bioconcentration and translocation factors of various metals in Acorus gramineus and Cyperus alternifolius. Ecological engineering **39,** 63-70.

Song HL, Liang L, Yang KY. 2014. Removal of several metal ions from aqueous solution using powdered stem of Arundo donax L. as a new biosorbent. Chemical Engineering Research and Design **92,** 1915-1922.

Spacil MM, Rodgers JRJH, Castle JW, Chao WY. 2011. Performance of a pilot-scale constructed wetland treatment system for selenium, arsenic, and low-molecular-weight organics in simulated fresh produced water. Environmental Geosciences **18,** 145-156.

Stottmeister U, Wießner A, Kuschk P, Kappelmeyer U, Kästner M, Bederski O, Moormann H. 2003. Effects of plants and microorganisms in constructed wetlands for wastewater treatment. Biotechnology advances **22(1-2),** 93-117.

Strong PJ, Burgess JE. 2008. Treatment methods for wine related ad distillery wastewaters: a review. Biorem. Jou **12,** pp 7087.

Susarla S, Medina VF, Mccutcheon SC. 2002. Phytoremediation: An ecological solution to organic chemical contamination. Ecol. Eng **18,** 647-658.

Tan WS, Ting ASY. 2012. Efficacy and reusability of alginate-immobilized live and heat-inactivated Trichoderma asperellum cells for Cu (II) removal from aqueous solution. Bioresource technology **123,** 290-295.

Taştan, BE, Duygu E, Dönmez G. 2012. Boron bioremoval by a newly isolated Chlorella sp. and its stimulation by growth stimulators. water research **46,** 167-175.