Desalination and Water Treatment
www.deswater.com
doi: 10.5004/dwt.2020.24949

177 (2020) 167–175
February

An assessment of wastewater pollution, treatment efficiency and management in a semi-arid urban area of Pakistan

Yusra Mahfooz[a,b,*], Abdullah Yasar[a], Liu Guijian[b], Balal Yousaf[b], Muhammad Tayyab Sohail[c], Samina Khan[b], Amtul Bari Tabinda[a], Rizwan Rasheed[a,d], Saleha Mahmood[a], Maryam Khan[a]

[a]*Sustainable Development Study Centre, Government College University Lahore 54000, Punjab, Pakistan, Tel. +92 309 4874365; emails: sdsc8888@gmail.com (Y. Mahfooz), yasar.abdullah@gmail.com (A. Yasar), amtulbaritabinda@gcu.edu.pk (A.B. Tabinda), riz_mian@hotmail.com (R. Rasheed), smenvironmentalist@gmail.com (S. Mahmood), maryamkhan954@gmail.com (M. Khan)*
[b]*Chinese Academy of Science (CAS)-Key Laboratory of Crust-Mantle Materials and the Environments, School of Earth and Space Sciences, University of Science and Technology of China, Hefei 230026, Anhui, China, emails: lgj@ustc.edu.cn (L. Guijian), balal@ustc.edu.cn (B. Yousaf), saminakhan@mail.ustc.edu.cn (S. Khan)*
[c]*School of Management, Xian Jiaotong University, Shaanxi China, email: tayyabsohail@yahoo.com*
[d]*Department of Architecture and Built Environment, University of Nottingham NG7 2RD, UK*

Received 5 May 2019; Accepted 24 September 2019

ABSTRACT

Increased population growth, better living standards and improved economic activity put the upward burden on the world's inadequate water resources. A study was conducted to evaluate the quantity and quality of wastewater generated by industrial and municipal effluent and its treatment efficiency in a semi-arid city Faisalabad, Pakistan. Samples from industries ($n = 60$) and sewage water ($n = 30$) were collected and evaluated for different quality parameters. Physio-chemical including pH, total dissolved solids, suspended solids, biochemical oxygen demand (BOD) and chemical oxygen demand (COD), total coliform and heavy metals including arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), nickel (Ni), and zinc (Zn) were analyzed. Emphasis was made on metal contamination by multivariate indexes including metal pollution index (MPI), degree of contamination (CD) and pollution load of drains. Aquatic macrophytes (*Typha latifolia*, *Brachiaria mutica*, *Poa annua*) were collected from anaerobic ponds of the Chokera wastewater plant. Results showed that all the parameters were higher than the upper limit of Punjab Environmental Quality Standards (PEQs) set by the Environmental Protection Agency (EPA) Pakistan. MPI was found high in textile industrial effluents (MPI > 1,000). The degree of contamination was very high than the maximum contamination level (≥ 3) in industrial effluent (33.85) followed by sewage effluent (14.05). Pollution load was calculated which showed the high BOD (119.34 ton/d) and COD (376.41 ton/d) load in Pharang drain due to excessive discharge of industrial effluent. Treatment efficiency at Chokera wastewater ponds was higher (60%) in summers as compared to winters and through the phytoremediation process. *Typha latifolia* found a most suited plant with a high accumulation coefficient value for metals uptake. Parameters after treatment were still above the PEQs. So, these ponds need to be monitored quarterly for maintenance. The possible environmental benefits can be obtained by introducing such plants in wastewater drains and effluent treatment plants to enhance its efficiency. However, there should be a strict policy to be implemented for the control of industrial discharge by government agencies.

Keywords: Metal pollution; Phytoremediation; Treatment efficiency; Wastewater

* Corresponding author.

1. Introduction

Human activities and speedy industrial expansions lead water bodies facing the burden of metal contamination nowadays [1]. Globally, natural water being contaminated by a variety of chemical disposal and it becoming the major concern coupled with resource scarcity [2,3]. Trace elements are common contaminants of countless concerns as far as their noxious effects and capacities for lasting accumulation in living organisms, sediments and aquatic environments [4]. They bioaccumulate through the ecosystem and present at huge levels in soil, sediments and surface water subsequently entering the food web [5]. The critical factor accountable for the declining of surface water quality is the discharge of untreated industrial effluent augmented with different metals into the riverine environment [6–9]. Effluents from the textile industry have multifaceted chemical composition encompassing oxidable material and suspended solids (SS). This effluent contains different heavy metals (chromium, nickel, and copper, etc.) and chlorinated organic compounds [10]. Amongst the abundant industries, five chief industries including pharmaceutical, petrochemical, coal manufacturing, textile and paper, and pulp have recognized to generate a high threat to the environment and health [11]. Some substantial industries such as batteries, electroplating, metallurgical process, petrochemical processing, mining, pharmaceuticals, paper and pulp, plastic, brewery, and paint release metals (including nickel, copper, zinc, aluminum, lead, and cadmium) in the environment as a by-product [2]. Cd, Pd, and Cu are found frequently in water bodies. Lead exposure can lead to noxious effect on the nervous system, renal, cardiovascular and reproductive system in human beings while in children especially it can cause hyperactivity and mental retardation [12]. Exposure to copper at its higher concentration can lead to lung cancer. A certain enzyme such as acetylcholinesterase produces after interference with cadmium and root causes of behavioral disorders and cholinergic neurotransmission in humans [13,14]. The complexity of different pollutants obstructs effluent treatments to decrease its toxicity and cause treatment more expensive [15]. Tanneries waste is considered as highest polluted effluent among chief industries in any urban area [16]. Efficient methods are essential to abate the environmental influences of industries effluents. To alleviate toxic risks, numerous pre-treatment approaches have been projected and implemented in the recent decade. Regardless of substantial efforts to decrease metal pollution in wastewater, municipal wastewater still carries significant volumes of metals in the ecosystem. The reduction of metal concentrations from agriculture and industrial effluent was carried out through numerous techniques, as they found effective but proved non-eco-friendly and expensive [17]. Numerous wastewater treatment plants (WWTP) were primarily planned to eliminate nutrient load and organic matter but many metals are competently retained in treatment plants [5,18,19]. Wastewater oxidation/stabilization ponds are an appropriate tool to treat the increasing amount of wastewater in tropical and subtropical areas. It mostly depends on periodic maintenance and natural purification that use microorganisms to oxidize the wastewater element [20]. Most of the obnoxious and challenging physiognomies of the domestic wastewater fade through the detention period of bacteria in water [21]. These days, phytoremediation systems through constructed wetlands can be intended to work for field-scale experiments, but their application for reuse industrial effluent still requires to be effectively examined [22]. Numerous wetland plants are being utilized and for contaminant removal in urban areas. *Typha latifolia* is proving effective for phytoremediation [23–25].

In Pakistan, wastewater with an insignificant amount (<5%) is being treated only at primary level and major portions of WWTP were not being operated, as a result, it is predictable around 1% [26]. According to the Pakistan Water Sector Strategy (PWSS) [27], approximation discloses that the entire amount of wastewater generation is 962,335 million gallons per day (MGD). Entire wastewater which releases into the main rivers and water bodies is 392,511 MGD. Table 1 showed the overall wastewater production, generation, collection and usage in large cities of Pakistan. Faisalabad is accounted as it has large industrial units and industrial wastewater is the most important source of pollution in Faisalabad. To overcome the amount of wastewater and meet irrigation scarcity, the Water and Sanitation Authority (WASA) Faisalabad, had entrenched basic wastewater oxidation/stabilization ponds (WSP) in Faisalabad. Different plant species were introduced in these ponds to enhance the pond's treatment efficiency through the phytoremediation process as it endorsed a more reliable and cost-effective technique as describes by other researchers [28–30]. The present study aimed to estimate the status of current water quality of drains, pollution loads of industrial effluent, and to provide a reference for controlling wastewater quality. The present work was conducted through multivariate pollution indexes. Treatment efficiency of waste stabilization ponds and phytoremediation potential were also monitored.

2. Methodology

2.1. Study area

Faisalabad with a rising population accounted for the second largest city of Punjab. Nowadays, Faisalabad City is known as a strong industrial base with many factories including textile manufacturing, dye, fertilizer, industrial chemicals, pulp and paper, printing, industrial goods, agricultural equipment and so on. Most of the industrial effluent (approx. <400 industrial units) discharged as "raw", without any treatment into two main drains which are Pharang drain to the North West and Madhuana drain to the South East. Pharang drain eventually discharges to the Chenab river and Madhuana drain to the Ravi river. These drains are managed by the Irrigation Department. Oxidation ponds established in Faisalabad comprise anaerobic and facultative ponds. It was designed for an inflow of 90,000 m^3/d where untreated wastewater had been used for farming crops, vegetables, and fodder for the past 50 years. The capacity of the treatment plant is 20 MGD (million gallons per day). The design was based on influent biochemical oxygen demand (BOD_5) of 380 mg/L and BOD_5 of treated effluent was 40 mg/L, that is, 90% removal of BOD_5 [31]. In 2012, Water and Sanitation Agency (WASA) Faisalabad with

Table 1
Wastewater generation and collection in megacities of Pakistan

Cities	Annual water production (million m^3)	Sewage generated (million m^3/y)	Wastewater collected (million m^3/y)	Annual water usage (%)				No. of WW treatment plant
				Residential	Commercial	Industrial	NRW	
Lahore	655	556	855	97	2	1% charitable		Nil
Faisalabad	87.10	514.31	390.88	41	13	15	31	01
Gujranwala	91.78	468.3	468.3	60	2	3	35	Nil
Multan	35.51	107.58	107.58	56	32	3	9	Nil
Rawalpindi	97.74	38.40	Nil	41	30	29% others		Nil

Source: (P-WOPs, 2011)

the cooperation of the National Institute of Biotechnology and Genetic Engineering (NIBGE), introduced the floating treatment wetland (FTW) to treat the trace elements naturally from wastewater in anaerobic ponds. Fig. 1a showed the sampling location of sewage and industrial wastewater in the Faisalabad district and 1b sample collection from oxidation ponds.

2.2. Sample collection and laboratory analysis

A total of 60 samples from industrial effluent and 30 samples from sewage water including Madhuana (n = 12) and Pharang drains (n = 18) were collected from Faisalabad to determine the water quality and their impacts on groundwater resources. To check the seasonal variation (summer and winter) and efficiency of the WSP, wastewater samples from WWTP were collected from four locations including inlet, anaerobic pond, facultative pond and outlet for 2017–2018. Some plant/grass samples (*Typha latifolia*, *Brachiaria mutica*, *Poa annua*) were collected from anaerobic ponds of the Chokera wastewater treatment plant. Samples were collected in pre-washed plastic bottles and brought in the laboratory for analysis of selected parameters including physical (pH, total dissolved solids (TDS), SS), chemical (BOD and chemical oxygen demand (COD)), total coliform and trace metals (As, Cd, Cr, Cu, Ni, Pb, and Zn) according to standard method of American Public Health Association [32]. Seven metals (Cu, Cr, Fe, Mn, Ni, Pb, and Zn) were analyzed from plant samples to determine uptake concentrations of these metals.

2.3. Degree of contamination

The degree of contamination (Cd) was used to clarify the level of contamination of any parameter that crossed the maximum limit of pollutants. It was expressed as [33,34]:

$$\mathrm{Cd} = \sum_{i=1}^{n} \mathrm{Cf}_i \tag{1}$$

$$\mathrm{Cf}_i = \frac{C_i}{C_{\mathrm{impl}}} - 1 \tag{2}$$

where Cd is the degree of contamination; Cf_i is the contamination factor of the i-th element, C_i is the investigative value of the i-th element and C_{impl} is the maximum permissible limit of the i-th element. It was expected that if contamination factor (Cf_i) less than 1 then the site considered safe from contamination and if it was more than 1 value than it represents contamination. The contamination index (Cd) is the sum of the contamination factor of the entire selected quality parameters. The additional scale was as Cd less than 1 represents low contamination, Cd more than 1 and less than 3 represent medium contamination and Cd more than 3 present high contamination [34].

2.4. Metal pollution index

The metal pollution index (MPI) was calculated by using the following formula, where W_i is the unit weight of each parameter which is reciprocal of the permissible limit. M_i is the monitored value and S_i is the standard value of each parameter [35].

$$\mathrm{MPI} = \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i=1}^{n} W_i} \tag{3}$$

$$Q_i = \sum_{i=1}^{n} \frac{M_i}{S_i} \times 100 \tag{4}$$

2.5. Pollution load

Pollution load of Madhuana and Pharang drains was calculated with reference to different pollution parameters including BOD, COD, TDS and SS as described by Mahfooz et al. [36] through multiplying the average concentration with flowrate (cusecs) and multiply it with factor 0.002447.

2.6. Removal efficiency of WSP

Wastewater samples were collected from inlet and outlet to check the percentage removal efficiency of WSP of summer and winter for 2 years. Removal efficiency was calculated by using the following formula [36]:

$$\text{Percentage removal efficiency} = \frac{\text{input} - \text{output}}{\text{input}} \times 100 \tag{5}$$

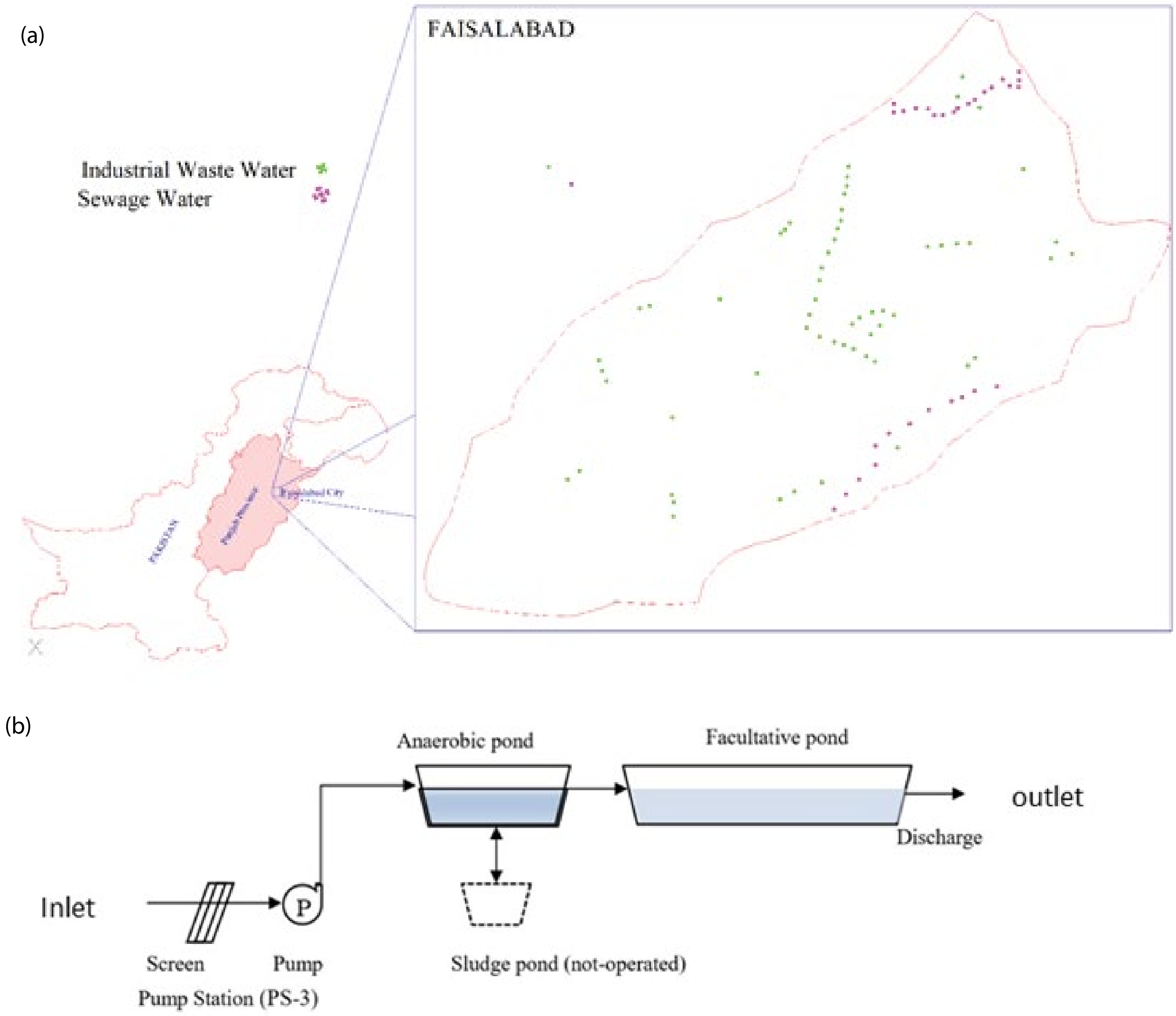

Fig. 1. (a) Study map showing sampling locations of industrial and sewage water and (b) layout of Chokera treatment ponds.

2.7. Accumulation coefficient

AC is a measurement efficiency of a plant species to take up specific elements from water and accumulate in their tissue. Accumulation coefficient (AC) of metals were calculated in wetland plants (*Typha latifolia*, *Brachiaria mutica*, *Poa annua*) by using the following formula [37]:

$$\text{Accumulation coefficient } (\text{AC}) = \frac{C_{\text{plant}}}{C_{\text{wastewater}}} \quad (6)$$

Here C_{plant} is the metal concentration in plants (mg/kg) and $C_{\text{wastewater}}$ is wastewater's metal concentration.

2.8. Statistical analysis

Statistical analysis was performed by using Origin 2017 for principal component analysis other means and standard deviations were drawn through MS Excel 2013.

3. Results and discussion

3.1. General characteristics of wastewater parameters

Industrial effluents (n = 60) and sewage water samples (n = 30), including Madhuana drain (n = 12) and Pharang drain (n = 18) were analysed for physicochemical, biological and metal analysis. Table 2 shows the concentrations of all parameters in sewage and industrial effluent and their comparison with Punjab Environmental Quality Standards (PEQs). pH concentration in industrial and sewage water was 10.2 ± 1.51 and 8.11 ± 0.57, respectively. Average concentration (mg/L) of other parameters including SS (314.7 ± 86.4 and 179.9 ± 33.07), TDS (5,045.35 ± 1,597 and 2,969 ± 874), BOD (955.8 ± 920.3 and 122.06 ± 42.2), COD (3,247.3 ± 3,124.8 and 383.8 ± 126.1) in industrial and sewage water were higher than their permissible limit. Increased value of pH in water may cause decreasing metal toxicity. Municipal wastewater and industrial effluent discharge caused increased TDS in water [38,39]. These high TDS may cause increased BOD and COD in water which eventually influence on dissolved oxygen reduction also indicated the presence of organic and inorganic matter [40–42]. TDS concentration at all sampling stations showed a high value which exceeded the permissible limit for reusing this water in irrigation unless an expensive desalination process is applied. Total coliform (8015 ± 2,584 MPN/100 mL and 8,066 ± 2,318 MPN/100 mL) in industrial and sewage water were many folds higher than PEQs permissible limits. BOD/COD ratio at all sampling stations showed a lower level which implies poor biodegradability. All the metals including As (4.00 ± 2.7 and 1.50 ± 1.31), Cd (1.1 ± 0.8 and 0.80 ± 0.84), Cr (1.42 ± 1.72 and 1.95 ± 0.59), Cu (8.67 ± 5.13 and 1.91 ± 1.02), Pb (2 ± 2.29 and 0.35 ± 0.11), Ni (9.5 ± 4.4 and 3.90 ± 1.65), Zn (10.94 ± 6.47 and 15.7 ± 5.01) in industrial and sewage water were found higher than its permissible limits of PEQs (Table 2). Heavy metals are accountable for lethal and mutagenic activities and can cross the cell membrane [43]. A fertilizer industry in Pakistan was investigated for heavy metal and resulted lead and chromium were found more than their permitted limits and results established that wastewater from industry is potential for varying the chemistry of different water bodies [40]. Yamin et al. [44] investigated the quality of industrial effluent at Faisalabad unfortunately not a single industry had followed the National Environmental Quality Standards (NEQs) for waste disposal. Rivers that pass through Faisalabad are Chenab and Ravi, they gradually becoming polluted due to the discharge of untreated wastewater by Paharang and Madhuana drains. It makes water unsuitable for drinking and causes many health risks for living begins. Al-Musharafi et al. [5] stated in their study that globally, lead and Cadmium are being considered due to their toxicity. Wunderlin et al. [45] stated that different multivariate statistical analysis is used for analyzing of complex and huge data matrices for well understanding of varying water qualities. Figs. 2a and b show the principle component results from 13 different parameters of sewage and industrial wastewater stated variance in parameters. Where BOD and COD closely correlated while TDS and SS showed little variance. In sewage water Zn, Cu and As while in industrial water Cd, As, Cu and Ni correlated with each other. Wastewater treatment is vital to protect the environment and to meet the wastewater effluent standards set by Environmental Protection Agencies (EPAs) [46].

3.2. Degree of contamination (Cd)

The contamination factor and degree of contamination were calculated for industrial and sewage wastewater samples. In industrial effluent Cd, Cu and Ni were found with higher contamination factor (>3) followed by As, Pb, and Zn however, Cr was found in low contamination (>1). In sewage, water Cd was found higher followed by Zn and Ni while As, Cr, and Cu were found in low contamination. However, Pb was found within a safe limit in sewage wastewater (Table 3). Overall, the metals were found with higher contamination levels from the safe limit that can cause detrimental health hazards to the local community. Many farmers living around these drains' areas cultivate their crops with this untreated/contaminated wastewater. Water pollution is the utmost obvious disruption in the area due to the growing invasion of the human settlement and industry [47]. This wastewater posing a higher level of metal toxicity may cause high carcinogenic risk in local inhabitants. The freshwater supply and wastewater treatment facilities are inadequate in the city. So, it considered as infested industrial metropolis. The two drains (Madhuana and Pharang) get 435 million gallon day^{-1} (MGD) wastewater from the city to the Ravi and Chenab rivers, respectively [48]. Samundri drain near Faisalabad put the noxious influence on freshwater resources and analysis exposed the worst groundwater quality more than World Health Organization permissible limits [49].

Table 2
Average concentrations of sewage and industrial effluents

Sr. #	Parameters	Industrial wastewater		Sewage wastewater		PEQs (2016)
		Mean ± SD	Range	Mean ± SD	Range	
1	pH	10.2 ± 1.51	7.4–13.5	8.11 ± 0.57	7.48–9.7	6–9
2	SS (mg/L)	314.7 ± 86.4	140–516	179.9 ± 33.07	119–233	200
3	TDS (mg/L)	5,045.35 ± 1,597	1,856–7,520	2,969 ± 874	1,337–4,083	3,500
4	BOD (mg/L)	955.8 ± 920.3	123–4,061	122.06 ± 42.2	63–219	80
5	COD (mg/L)	3,247.3 ± 3,124.8	415–13,394	383.8 ± 126.1	206–641	150
6	Total coliform (MPN)/100mL	8,015 ± 2,584	3,600–14,400	8,066 ± 2,318	4,000–14,400	–
7	Arsenic (mg/L)	4.00 ± 2.7	1.45–14	1.50 ± 1.31	0.11–6.34	1.0
8	Cadmium (mg/L)	1.1 ± 0.8	0.21–2.42	0.80 ± 0.84	0.04–2.31	0.1
9	Chromium (mg/L)	1.42 ± 1.72	0.11–4.76	1.95 ± 0.59	0.78–2.94	1.0
10	Copper (mg/L)	8.67 ± 5.13	1.75–21.34	1.91 ± 1.02	0.06–4.32	1.0
11	Lead (mg/L)	2 ± 2.29	0.12–7.56	0.35 ± 0.11	0.13–0.59	0.5
12	Nickel (mg/L)	9.5 ± 4.4	1.45–21.2	3.90 ± 1.65	2.13–8.69	1.0
13	Zinc (mg/L)	10.94 ± 6.47	0.97–26.11	15.7 ± 5.01	4.67–23.4	5.0

Industrial wastewater n = 60, sewage wastewater n = 30;
PEQs = Punjab Environmental Quality Standards.

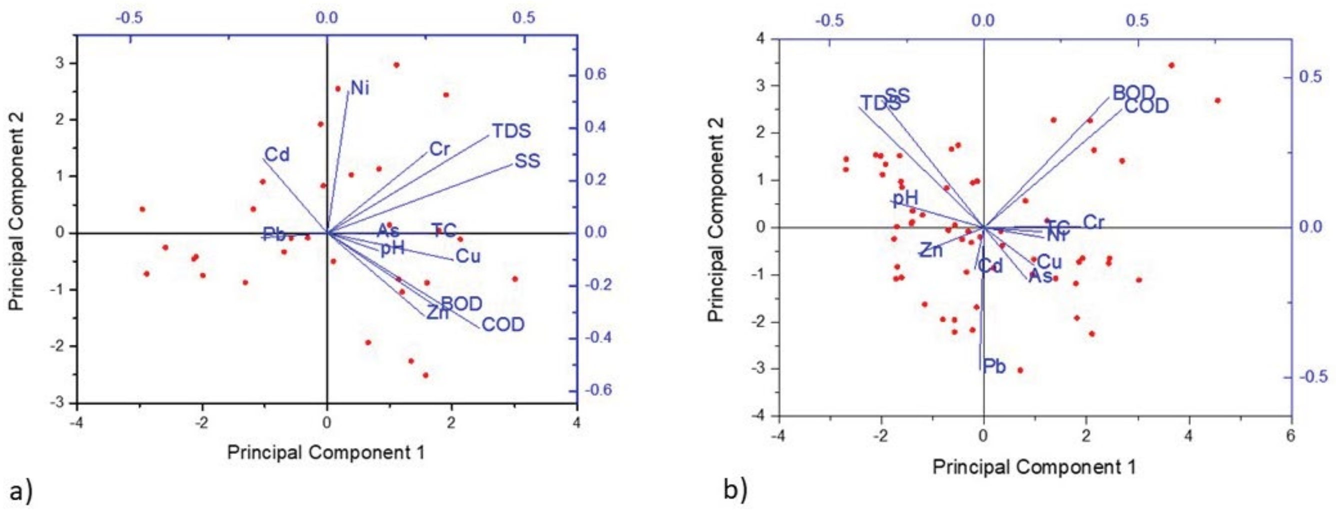

Fig. 2. Principle component analysis of (a) sewage and (b) industrial wastewater.

Table 3
Degree of contamination for industrial and sewage wastewater

Sr #	Water type	Contamination factor (Cf)							Degree of contamination (CI)
		As	Cd	Cr	Cu	Pb	Zn	Ni	
1	Industrial water	3	10	0.42	7.67	3	1.18	8.58	33.85
2	Sewage water	0.42	7	0.95	0.94	–0.3	2.12	2.94	14.05
	Contamination factor > 1 = Contamination exist								
	CI < 1 = Low contamination, CI > 1 < 3 = Medium contamination, CI > 3 = High contamination								

3.3. Metal pollution index

A total of 60 industries were selected for analysis of industrial effluent including metals (As, Cd, Cr, Cu, Ni, Pb, and Zn). The values of all metals in almost all samples increased the permissible limit of PEQs. Out of 60 industries, 25 has a high value of MPI more than 10-folds (<1,000 MPI), 10 has 5–10-folds (500–1,000 MPI), remaining 25 has up to 5-folds (100–500 MPI) higher with maximum level of metals concentrations (Fig. 3). Higher MPI was found in textile, batteries, fertilizers and chemical industries. Kumari et al. [50] evaluated the heavy metal pollution index (HPI) of 2 selected pharmaceutical industries in Lucknow and found 108.7 and 52.14 HPI values respectively, which was less than the present study. Domestic and industrial effluent generates 4.09 m^3/s flow and their toxic pollutants seepage deep into the soil and contaminates groundwater, causing health-related issues in Faisalabad [51–53]. Ravi and Faisalabad industries include textile, dyeing, hospital laboratory, sugar mills, fertilizers, acids, batteries, chemicals, and processing units that discharge their toxic effluent in drains without any prior treatment, even at primary level. Hanif et al. [54] analyzed the heavy metal pollution in industrial wastewater and resulted that the ghee and textile industry has lower metal concentration, tannery, and Ni–Cr plating industry has medium while battery industry (Fe) has highest pollution level crossing the standard limits.

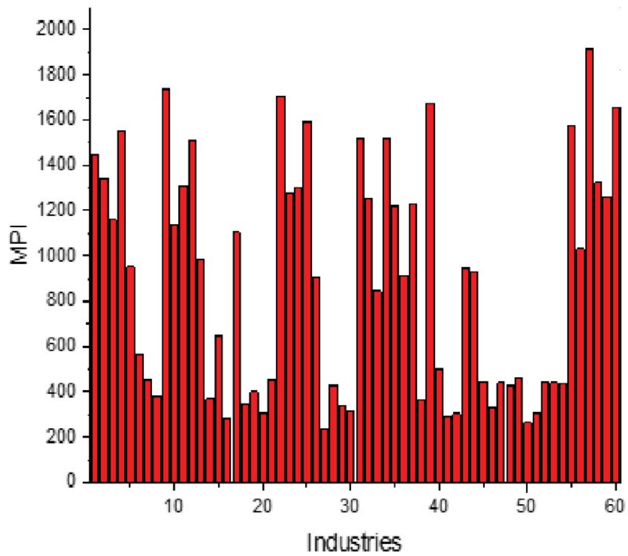

Fig. 3. Metal pollution index of different industries in Faisalabad.

3.4. Pollution load

Pollution load of both drains was calculated with reference to different pollution parameters including BOD, COD, TDS and SS. Table 4 shows that Pharang has high pollution

Table 4
Pollution load of Madhuana and Pharang drains with different pollutants

Drains	Average discharge (cusecs)	Pollution load (ton/d)			
		BOD	COD	TDS	SS
Madhuana	399	93.63	292.41	3,421.82	180.13
Pharang	349.61	119.34	376.41	2,234.46	151.33

load with BOD (119.3 ton/d) and COD (376.4 ton/d) while Madhuana has high SS (180.1 ton/d) load. Two drains in Faisalabad receive 90% of city wastewater. Madhuana has a capacity of 19 m^3/s while Pharang has 30 m^3/s. Pharang receives most of the industrial pollutants with a different chemical composition which increases the COD in the drain while Madhuana mostly receives sewage water. Sixty industries are now discharging their wastewater into open drains and caused high BOD and COD load. Industrial effluent is commonly considered as a main contributor of aquatic contamination [55]. Mahfooz et al. [36] determined the pollution load of four major drains in Lahore, Pakistan and found the drains near the industrial area had a high pollution load with COD and BOD.

3.5. Removal efficiency of WSP

Seasonal variations (summer and winter) in the outlet water sample of Chokera wastewater treatment plants were monitored for two consecutive years (2017 and 2018). High removal efficiency was found in summers than the winter season due to more suitable climatic conditions. High Percentage removal efficiency was found in 2017 summers for Cr (83.5%), followed by Fe (82.3%) then COD (81.8%) as compared to winter, where Cr (68.3%), Fe (78.4%) and COD (47.2%) are observed (Fig. 4). Pollutant reduction was improved by introducing the aquatic-macrophytes for phytoremediation in anaerobic ponds. The phytoremediation technique considered the most cost-effective. In wetlands, plants combine with microbial partners, serve the natural physical, chemical and biological processes to eliminate pollutants from water [48,56]. More efficiency was attained in total coliform and trace metals including Pb, Ni, Cr, Mn in both seasons. Percentage efficiency was lower in 2nd year may due to the non-attendance of monitoring and maintenance at the site.

3.6. Metal concentration in plants and AC

Macrophytes in constructed wetland was conceptualized to design a wetland for remediation of aquatic pollution. These aquatic macrophytes uptake the pollutants from distillery effluent, sewage water, agricultural run-off, industrial effluent and other types of wastewaters through the phytoremediation process. Phytoremediation is further divided into different types (including phytodegradation, rhizo-filtration, phytoextraction, and phytostabilization) depending on the remediation mechanism [28,57]. *Typha latifolia*, *Brachiaria mutica*, *Poa annua* were used in the present study for phytoremediation in anaerobic ponds to enhance the treatment efficiency. Metal concentration of Cu, Cr, Fe, Pb and Zn (4.57, 0.25, 159.06, 0.06 and 16.37 mg/L, respectively) were found higher in *Typha latifolia* while Mn was higher (5.78 mg/L) in *Poa annua* and *Brachiaria mutica* had higher concentration of Ni (0.32 mg/L) (Table 5). The distribution of metals in organs of plants contingent on the biochemical properties of elements and plants itself. More than 1 accumulation value verified previous results for the use of Typha species in phytoremediation [20,58,59]. In Khudia river India, wetland acted as a sink to metals. The wetland containing Typha showed more metal accumulation from

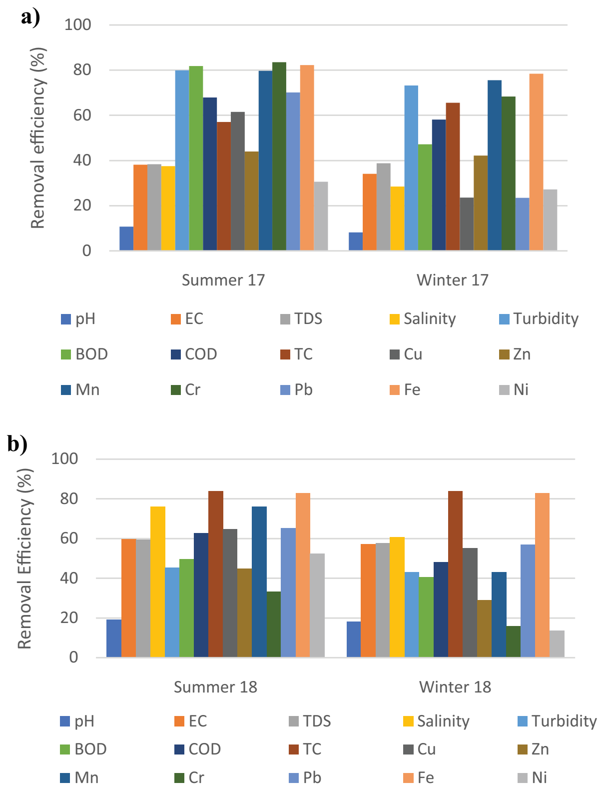

Fig. 4. Percentage removal efficiency in Chokera WWTP in (a) 2017 and (b) 2018.

Table 5
Metal contamination (mg/kg) and accumulation coefficient in macrophytes used in phytoremediation

	Metal concentration						
	Cu	Cr	Fe	Mn	Ni	Pb	Zn
Typha latifolia	4.57	0.25	159.06	3.84	0.31	0.06	16.37
Brachiaria mutica	3.18	0.23	141.07	3.82	0.32	0.04	4.89
Poa annua	2.76	0.17	109.55	5.78	0.29	0.01	12.61
	Accumulation coefficient						
	Cu	Cr	Fe	Mn	Ni	Pb	Zn
Typha Latifolia	1.72	0.18	4.67	0.85	0.12	0.09	1.50
Brachiaria mutica	1.20	0.16	4.14	0.84	0.13	0.06	0.44
Poa annua	1.04	0.12	3.22	1.28	0.11	0.01	1.15

wastewater. Bioconcentration factor (BCF) > 1 was found in phytostabilization and phytoextraction [22–24]. The order for higher metal concentration was as follows *Typha latifolia* > *Poa annua* and *Brachiaria mutica*. AC was found in all three plants for selected metals and AC was found more than 1 for Cu, Fe, and Zn in all three plants (Table 5) which showed that these plants have the ability of phytoremediation [60]. In the present study among all these three plants, *Typha latifolia* has the ability for phytoremediation. Even with the simple setup and formation of FTWs, investigators have stated them to be an extremely operative approach on the way to improving the quality of sewage water [48,61].

4. Conclusion

In water stress country, the management of wastewater pollution from industrial and municipal sources is the most critical issue for the policymakers and government. Wastewater (industrial and sewage) quality of district Faisalabad was investigated through multivariate indexes. Higher concentrations of contaminants (physiochemical and metals) were found in the industrial and sewage wastewater than the permissible limit set by Pakistan EPA (PEQs 2016). Untreated wastewater disposal into drains creating an alarming situation for local people's health and environment. High MPI (MPI > 100) from all industrial samples and a high degree of contamination from industrial (33.85) and sewage (14.05) water showed the discharge of the heavy effluent which is putting pressure on groundwater resources. Chokera waste oxidation ponds were monitored seasonally and resulted in a higher amount of contamination than permissible limits in all parameters even after treatment. Aquatic macrophytes were used to enhance wastewater treatment efficiency. *Typha latifolia* was found the best suited (60% efficient) plant for phytoremediation than others.

In that area, farmers were intended to use this untreated wastewater for agriculture that may cause serious health hazards in the local community. To overcome the amount of water and meet agricultural-water scarcity in a semi-arid area, the reuse of wastewater after treatment is the best practice. There is a dire need to make strict policies and should be implemented on the industries to treat their effluent prior to disposal and farmers for safe use of treated wastewater in agriculture. This study will help to support the implementation of proper monitoring and public policies to ensure integrated and sustainable water development and to minimize the health hazards in the study area.

Conflict of interest

Author(s) declared no conflict of interest

References

[1] W.-X. Wang, K. Pan, Q. Tan, L. Guo, S.L. Simpson, Estuarine pollution of metals in China: science and mitigation, Environ. Sci. Technol., 48 (2014) 9975–9976.

[2] T.G. Kebede, A.A. Mengistie, S. Dube, T.T.I. Nkambule, M.M. Nindi, Study on adsorption of some common metal ions present in industrial effluents by *Moringa stenopetala* seed powder, J. Environ. Chem. Eng., 6 (2018) 1378–1389.

[3] M.T. Sohail, Y. Mahfooz, K. Azam, Y. Yen, L. Genfu, S. Fahad, Impacts of urbanization and land cover dynamics on underground water in Islamabad, Pakistan, Desal. Wat. Treat., 159 (2019) 402–411.

[4] W. Wang, W.-X. Wang, Phase partitioning of trace metals in a contaminated estuary influenced by industrial effluent discharge, Environ. Pollut., 214 (2016) 35–44.

[5] S.K. Al-Musharafi, I.Y. Mahmoud, S.N. Al-Bahry, Heavy metal pollution from treated sewage effluent, APCBEE Procedia, 5 (2013) 344–348.

[6] N. Saha, M.S. Rahman, Multivariate statistical analysis of metal contamination in surface water around Dhaka export processing industrial zone, Bangladesh, Environ. Nanotechnol. Monit. Manage., 10 (2018) 206–211.

[7] A. Benabdelkader, A. Taleb, J.L. Probst, N. Belaidi, A. Probst, Anthropogenic contribution and influencing factors on metal features in fluvial sediments from a semi-arid Mediterranean river basin (Tafna River, Algeria): a multi-indices approach, Sci. Total Environ., 626 (2018) 899–914.

[8] A.M. Odukoya, S.B. Olobaniyi, T.O. Oluseyi, U.A. Adeyeye, Health risk associated with some toxic elements in surface water of Ilesha gold mine sites, southwest Nigeria, Environ. Nanotechnol. Monit. Manage., 8 (2017) 290–296.

[9] C.I. Adamu, T.N. Nganje, A. Edet, Heavy metal contamination and health risk assessment associated with abandoned barite mines in Cross River State, southeastern Nigeria, Environ. Nanotechnol. Monit. Manage., 3 (2015) 10–21.

[10] A.F.S. Costa, C.D.C. Albuquerque, A.A. Salgueiro, L.A. Sarubbo, Color removal from industrial dyeing and laundry effluent by microbial consortium and coagulant agents, Process Saf. Environ. Prot., 118 (2018) 203–210.

[11] J. Tong, X.T. Lu, J.Y. Zhang, Q. Sui, R. Wang, M. Chen, Y. Wei, Occurrence of antibiotic resistance genes and mobile genetic elements in enterococci and genomic DNA during anaerobic digestion of pharmaceutical waste sludge with different pretreatments, Bioresour. Technol., 235 (2017) 316–324.

[12] A. Demayo, M.C. Taylor, K.W. Taylor, P.V. Hodson, P.B. Hammond, Toxic effects of lead and lead compounds on human health, aquatic life, wildlife plants, and livestock, CRC Crit. Rev. Environ. Control, 12 (2009) 257–305.

[13] H. Aydın, Y. Bulut, Ç. Yerlikaya, Removal of copper (II) from aqueous solution by adsorption onto low-cost adsorbents, J. Environ. Manage., 87 (2008) 37–45.

[14] T.G. Kebede, S. Dube, A.A. Mengistie, T.TI. Nkambule, M.M. Nindi, *Moringa stenopetala* bark: a novel green adsorbent for the removal of metal ions from industrial effluents, Phys. Chem. Earth., 107 (2018) 45–47.

[15] D. Prabakar, K.S. Suvetha, V.T. Manimudi, T. Mathimani, G. Kumar, E.R. Rene, A. Pugazhendhi, Pretreatment technologies for industrial effluents: critical review on bioenergy production and environmental concerns, J. Environ. Manage., 218 (2018) 165–180.

[16] U. Tamim, R. Khan, Y.N. Jolly, K. Fatema, S. Das, K. Naher, M.A. Islam, S.M.A. Islam, S.M. Hossain, Elemental distribution of metals in urban river sediments near an industrial effluent source, Chemosphere, 155 (2016) 509–518.

[17] G. Bonanno, G.L. Cirelli, Comparative analysis of element concentrations and translocation in three wetland congener plants: *Typha domingensis*, *Typha latifolia* and *Typha angustifolia*, Ecotoxicol. Environ. Saf., 143 (2017) 92–101.

[18] B. Wu, R. Yin, G. Zhang, C. Yu, S. Zhang, Effects of water chemistry on decolorization in three photochemical processes: pro and cons of the UV/AA process, Water Res., 105 (2016) 568–574.

[19] J.M. Arnal, M.C. León, J. Lora, J.M. Gozálvez, A. Santafé, D. Sanz, J. Tena, Ultrafiltration as a pre-treatment of other membrane technologies in the reuse of textile wastewaters, Desalination, 221 (2008) 405–412.

[20] O. Amahmid, S. Asmama, K. Bouhoum, Urban wastewater treatment in stabilization ponds: occurrence and removal of pathogens, Urban Water J., 4 (2002) 255–262.

[21] M. Farzadkia, M.H. Ehrampoush, S. Sadeghi, M. Kermani, M.T. Ghaneian, V. Ghelmani, E.A. Mehrizi, Performance evaluation of wastewater stabilization ponds in Yazd-Iran, Environ. Health Eng. Manage., 1 (2014) 7–12.

[22] V.A. Riggio, B. Ruffino, G. Campo, E. Comino, C. Comoglio, M. Zanetti, Constructed wetlands for the reuse of industrial wastewater: a case-study, J. Cleaner Prod., 171 (2018) 723–732.
[23] V. Rana, S.K. Maiti, S. Jagadevan, Ecological risk assessment of metals contamination in the sediments of natural urban wetlands in dry tropical climate, Bull. Environ. Contam. Toxicol., 97 (2016) 407–412.
[24] V. Rana, S.K. Maiti, Municipal wastewater treatment potential and metal accumulation strategies of *Colocasia esculenta* (L.) Schott and *Typha latifolia* L. in a constructed wetland, Environ. Monit. Assess., 190 (2018) 328.
[25] V. Rana, S.K. Maiti, Metal accumulation strategies of emergent plants in natural wetland ecosystems contaminated with coke-oven effluent, Bull. Environ. Contam. Toxicol., 101 (2018) 55–60.
[26] Z.A. Soomro, M.I.A. Khokhar, W. Hussain, M. Hussain, Drinking water quality challenges in Pakistan, World Water Day, (2011) 17–28.
[27] Pakistan Water Sector Strategy, Ministry of Water and Power Office of the Chief Engineering Advisor/Chairman Federal Flood Commission, National Water Sector Profile, Volume 5, 2002.
[28] A.O. Ekperusi, F.D. Sikoki, E.O. Nwachukwu, Application of common duckweed (*Lemna minor*) in phytoremediation of chemicals in the environment: state and future perspective, Chemosphere, 223 (2019) 285–309.
[29] V.V. Chandanshive, S.K. Kadam, R.V. Khandare, M.B. Kurade, B.-H. Jeon, J.P. Jadhav, S.P. Govindwar, *In situ* phytoremediation of dyes from textile wastewater using garden ornamental plants, effect on soil quality and plant growth, Chemosphere, 210 (2018) 968–976.
[30] K. Prabakaran, J. Li, A. Anandkumar, Z. Leng, C.B. Zou, D. Du, Managing environmental contamination through phytoremediation by invasive plants: a review, Ecol. Eng., 138 (2019) 28–37.
[31] H.Q. Ali, A. Farooq, M. Ahmed, Monitoring the wastewater treatment efficiency of oxidation ponds at Chokera, Faisalabad, Mehran Univ. Res. J. Eng. Technol., 36 (2017) 987–994.
[32] American Public Health Association (APHA), Standard Methods for the Examination of Water and Waste Water, 17th edition, American Public Health Association, Washington, D.C., 2012.
[33] I.S. Akoteyon, Evaluation of groundwater quality using contamination index in parts of Alimosho, Lagos - Nigeria, Am. Acad. Scholarly Res. J., 4 (2012) 1.
[34] M. Kumar, R. Nagdev, R. Tripathi, V.B. Singh, P. Ranjan, M. Soheb, A. Ramanathan, Geospatial and multivariate analysis of trace metals in tubewell water using for drinking purpose in the upper Gangetic basin, India: heavy metal pollution index, Groundwater Sustainable Dev., 8 (2019) 122–133.
[35] R. Pal, R.K. Dubey, S.K. Dubey, A.K. Singh, Assessment of heavy metal pollution through index analysis for Yamuna water in Agra region, India, Int. J. Curr. Microbiol. Appl. Sci., 6 (2017) 1491–1498.
[36] Y. Mahfooz, A. Yasar, A.B. Tabinda, M.T. Sohail, A. Siddiqua, S. Mahmood, Quantification of the River Ravi pollution load and oxidation pond treatment to improve the drain water quality, Desal. Wat. Treat., 85 (2017) 132–137.
[37] A.S. Al-Farraj, T.G. Al-Otabi, M.I. Al-Wabel, Accumulation Coefficient and Translocation Factor of Heavy Metals Through *Ochradenus Baccatus* Plant Grown on Mining Area at Mahad Ad'dahab, Saudi Arabia, Conference proceeding of Ecosystems and Sustainable Development, 2009, pp. 459–468.
[38] M.W. Aktar, M. Paramasivam, M. Ganguly, S. Purkait, D. Sengupta, Assessment and occurrence of various heavy metals in surface water of Ganga river around Kolkata: a study for toxicity and ecological impact, Environ. Monit. Assess., 160 (2010) 207–213
[39] A. Rim-Rukeh, O.G. Ikhifa, A.P. Okokoyo, Effects of agricultural activities on the water quality of Orogodo River, Agbor Nigeria, J. Appl. Sci. Res., 2 (2006) 256–259.
[40] U. Younas, S. Iqbal, A. Saleem, M. Iqbal, A. Nazir, S. Noureen, K. Mehmood, N. Nisar, Fertilizer industrial effluents: physico-chemical characterization and water quality parameters evaluation, Acta Ecologica Sinica., 37 (2017) 236–239.
[41] P.N. Patil, D.V. Sawant, R.N. Deshmukh, Physico-chemical parameters for testing of water — a review, Int. J. Environ., 3 (2012) 1194.
[42] M.R. Mahananda, B.P. Mohanty, N.R. Behera, Physico-chemical analysis of surface and ground water of Bargarh District, Orissa, India, Int. J. Res. Rev. Appl. Sci., 2 (2010) 284–295.
[43] A.M. Farag, T. May, G.D. Marty, M. Easton, D.D. Harper, E.E. Little, L. Cleveland, The effect of chronic chromium exposure on the health of Chinook salmon (*Oncorhynchus tshawytscha*), Aquat. Toxicol., 76 (2006) 246–257.
[44] M. Yamin, A. Nasir, M. Sultan, W.I.W. Ismail, R. Shamshiri, F.N. Akhbar, Impact of sewage and industrial effluents on water quality in Faisalabad, Pakistan, Adv. Environ. Biol., 9 (2015) 53–58.
[45] D.A. Wunderlin, M.P. Diaz, M.V. Ame, S.F. Pesce, A.C. Hued, M.A. Bistoni, Pattern recognition techniques for the evaluation of spatial and temporal variations in water quality. A case study: Suquia river basin (Cordoba, Argentina), Water Res., 35 (2001) 2881–2894.
[46] D. Davereya, P. Pandey, S. Verma, V. Verma, K. Shah, K. Dutta, Arunachalam, Recent advances in energy efficient biological treatment of municipal wastewater, Bioresour. Technol. Rep., 7 (2019) 100252.
[47] M.K. Daud, M. Nafees, S. Ali, M. Rizwan, R.A. Bajwa, M.B. Shakoor, M.U. Arshad, S.A.S. Chatha, F. Deeba, W. Murad, I. Malook, S.J. Zhu, Drinking water quality status and contamination in Pakistan, Biomed. Res. Int., (2017). https://doi.org/10.1155/2017/7908183.
[48] A. Ijaz, G. Shabir, Q.M. Khan, M. Afzal, Enhanced remediation of sewage effluent by endophyte-assisted floating treatment wetlands, Ecol. Eng., 84 (2015) 58–66.
[49] A. Nasir, M.S. Nasir, I. Shauket, S. Anwar, I. Ayub, Impact of samanduri drain on water resources of Faisalabad, Adv. Environ. Biol., 10 (2016) 155–160.
[50] V. Kumari, A.K. Tripathi, A. Kannan, Evaluation of heavy metals toxicity of pharmaceuticals industrial wastewater by pollution indexing and chemometric approaches, Int. J. Chem. Tech. Res., 10 (2017) 718–730.
[51] K. Rehman, S. Ashraf, U. Rashid, M. Ibrahim, S. Hina, T. Iftikhar, S. Ramzan, Comparison of proximate and heavy metal contents of vegetables grown with fresh and wastewater, Pak. J. Bot., 45 (2013) 391–400.
[52] J.T. Srinivasan, V.R. Reddy, Impact of irrigation water quality on human health: a case study in India, Ecol. Econ., 68 (2009) 2800–2807.
[53] WWF, Pakistan's Water at Risk, WWF, Pakistan, 2007.
[54] M.A. Hanif, R. Nadeem, U. Rashid, M.N. Zafar, Assessing pollution levels in effluents of industries in city zone of Faisalabad, Pakistan, J. Appl. Sci., 5 (2005) 1713–1717.
[55] J. Romo, M. Chaudhary, T.R. Walker, Baseline assessment of contaminants in marine biota prior to remediation of industrial effluent impacted sediments in a former tidal estuary in Nova Scotia, Canada, Mar. Pollut. Bull., 145 (2019) 641–648.
[56] C.B. Zhang, W.L. Liu, X.C. Pan, M. Guan, S.Y. Liu, Y. Ge, J. Chang, Comparison of effects of plant and biofilm bacterial community parameters on removal performances of pollutants in floating island systems, Ecol. Eng., 73 (2014) 58–63.
[57] W.H.T. Ting, I.A.W. Tan, S.F. Salleh, N.A. Wahab, Application of water hyacinth (*Eichhornia crassipes*) for phytoremediation of ammoniacal nitrogen: a review, J. Water Process Eng., 22 (2018) 239–249.
[58] S. Ong, K. Uchiyama, D. Inadama, Y. Ishida, K. Yamagiwa, Treatment of azo dye Acid Orange 7 containing wastewater using up-flow constructed wetland with and without supplementary aeration, Bioresour. Technol., 101 (2010) 9049–9057.
[59] M.V.T. Gomes, R.R. Souza, V.S. Teles, É.A. Mendes, Phytoremediation of water contaminated with mercury using *Typha domingensis* in constructed wetland, Chemosphere, 103 (2014) 228–233.
[60] A. Aihemaiti, J. Jiang, D. Li, N. Liu, M. Yang, Y. Meng, Q. Zou, The interactions of metal concentrations and soil properties on toxic metal accumulation of native plants in vanadium mining area, J. Environ. Manage., 222 (2018) 216–226.
[61] J. Lynch, L.J. Fox, J. Owen, D.J. Sample, Evaluation of commercial floating treatment wetland technologies for nutrient remediation of stormwater, Ecol. Eng., 75 (2015) 61–69.