Article

Comparative assessment of physico-chemical parameters of waste water effluents from different industries in Lahore, Pakistan

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Abstract

The magnitude of wastewater generation in Lahore city is increasing due to urbanization and industrialization. Wastewater is being thrown directly into rivers and canals without proper treatment. This study examines the physico-chemical characteristics of wastewater which is being discharged from different industries in Lahore. Samples were collected from the outlet of five industries before they discharge into Hudyra drain. Physical characteristics of wastewater were analyzed based on TDS and TSS concentration. TDS and TSS concentration was measured in the laboratory using Evaporation and Gravimetric method respectively. Chemical characteristics of wastewater were analyzed based on pH, BOD, COD, and metal concentration. pH value of wastewater collected from five sampling stations was measured using pH meter. Biological oxygen demand was determined using respirometric method and Lovibond meter while COD was determined using the Open reflux method and Back titration. The concentration of heavy metals (Cr, Hg, Ba, Fe, Mn, Cl^-, B) was measured by using ICP-OES (Inductively Coupled Plasma-Optical Emission Spectrometry). All parameters after analysis were compared with standard of Punjab Environmental Quality Standard (PEQS). Experimental results show that the quality of wastewater varies from site to site and at some sampling stations values of water quality parameters exceeded maximum permissible limit of PEQS. Pearson correlation matrix for physico-chemical parameters at all sampling sites was developed to identify the possible relationships between concentrations of these parameters. The increasing level of physico-chemical parameters above permissible limit clearly shows that such type of wastewater if directly discharged into fresh water bodied may contaminate ground as well as surface water.

Keywords physico-chemical; metal concentration; solid concentration; wastewater; pollution loading.

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1 Introduction

Soil, air and water are necessary wealth of life, without these survivals of life is impossible. These natural resources are being spoiled in developing countries due to industrialization and urbanization (Tripathi et al., 2010). Water pollution is a major universal issue affecting human health and causing deaths worldwide. The disposal of untreated wastewater is a global issue as it is affecting water quality of freshwater bodies and human health (Su et al., 2014). Urbanization and industrial development in metropolitan area not only increase the demands of fresh water but also release toxic elements (Cr, Fe, Mn, etc.) in the environment. These toxic substances seep in the soil and affect groundwater resources (Srinivasan and Reddy, 2009; Tiwari, 2011; Su et al., 2014).

Lahore is a mega city of Punjab province, which is facing many issues related to water, including discharges of wastewater into River Ravi without proper treatment. Currently there are 2,700 registered industries are working in Lahore, out of which 2025 industries are considered as large scale factories. Total generation of wastewater in Lahore is estimated about 8.0 million cubic meter per days and almost all is discharged into the River Ravi without proper treatment (Agency, 2010; Agency, 2013). Some small scale industries disposed their wastewater effluent on land which affects the groundwater quality. For safe disposal of wastewater generating from industries and domestic sources, Water and Sanitation Agency (WASA) has installed twelve pumping stations having total discharge capacity of 5.7 million cubic per day. In peri-urban areas of Lahore mostly farmers are growing vegetables and fruit with untreated wastewater which are lying to heavy metal contamination. The disposal issues of untreated wastewater have remained uncontrolled because there are no incentives for industries to treat wastewater before throwing into water bodies (WWF, 2007).In Lahore, only three out of hundred industries are treating their effluents. Industrial and unlined sewerage wastewater is contaminating the surface as well as ground water resources in Lahore city (Rehman et al., 2013). Industrial effluents containing chemicals and other harmful products affect the soil, plants and wild life(Asamudo et al., 2005; Nayyef and Sabbar, 2012).These impurities especially heavy metals existing in industrial waste when discharge into water bodies contaminate the fresh water resources and cause water pollution (Dembitsky and Rezanka, 2003; Nasir, 2016). Heavy metals existing in industrial wastewater are proved to be most hazardous type of chemicals causing human health problems. Disposal of wastewater into water bodies without appropriate treatment, pollute surface water and groundwater causing negative influences on land area and aquatic system (Thilakar et al., 2012). Nowadays, fresh water channels are being considered as dumping sites for disposal of wastewater (Aboulroos et al., 2006).

Many research have been conducted all over the world to assess the physico-chemical characteristics of wastewater effluents from different kinds of industries(Abrha and Chen, 2017; Kudłak et al., 2016; OLUGBUYIRO, 2011; Parveen et al., 2017; Popa et al., 2012; Rohit and Ponmurugan, 2013; Warner et al., 2013; Wolfgang et al., 2013; Younas et al., 2017). Fig.1 shows the review studies that have been conducted to analyze the physico-chemical characteristics of wastewater. Al-Farraj et al. (2013) have assessed the behavior of heavy metals released from industrial effluents. Outcomes of their research have indicated that at some monitoring sites water quality parameters exceeded the acceptable limit of USEPA. Gyamfi et al. (2012) have analyzed the chemical characteristics of potable water collected from Accra, Ghana. The results of their study clearly indicated that the concentration of some chemical parameters exceeded the permissible limit of WHO. There is a need of time to analyze the characteristics of wastewater generated from different industries in Lahore city, so that their impacts on the environment can be judged and proper treatment planning can be formulated. Moreover wastewater after treatment if reused for agriculture production not only save 3.7×10^{17} sej/year of emergy cost but also reduce pollution load on environment (Arshad, 2017).

The objectives of this study were 1) To analyze the characteristic of effluents discharged from different industries by analyzing their pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), chloride (Cl-), Iron (Fe), Manganese (Mn) and many other parameters (2) To compare effluent properties with standard of Punjab Environmental Quality Standard(3) To analyze pollution loading of heavy metals and organic material.

Fig. 1 Spatial distribution of review studies.

2 Study Area and Methodology

2.1 Study area

This study was conducted to analyze characteristics of wastewater effluents from five industries located in Lahore (Fig. 2 and Table 1). Lahore is a second most populated city of Punjab province. It is located at latitude 31^{o} 15' and longitude 74^{o} 10' with a mean elevation of 213 m from sea level. The mean maximum and mean minimum temperature in winter is 25 ^{o}C and 0 ^{o}C while in summer it reaches up to 48 ^{o}C and 38 ^{o}C respectively. The Lahore district is situated in Chaj Doab with geographical area of 1,771 Km^2 (Punjab, 2004). In this city there are many historical buildings including Lahore Fort, Badshahi mosque, Shalimar Garden and Jahangir tomb. The main industries of this city are textile, silk goods, carpets and metal work. There are also large scale ice factories, cotton mills, and flour mills, several small scale factories of mineral water, soaps and oils.

2.2 Study design

The study involved sampling of wastewater from five-industry, which mainly discharge their untreated effluents into Hudyra drain and finally to River Ravi. All the samples were collected from their outlets before they discharge their effluent into Hudyra drain. Detail description of sub units working in five industries is given in Table 1.

Table 1 Sample collection from five industries in Lahore.

Sampling ID	Industries	Sub units
1	Nishat Mills Limited	Dyeing, cutting, knitting, pressing and garments
2	Comfort Knitwear (Pvt.) Limited	Knitting, Packing, Dispatch
3	Taiga Apparel (Pvt.) Limited	Printing and Dyeing
4	Hunbul Tex Pvt. Limited	Printing and Dyeing
5	Pensy Garments (Pvt.) Limited	Printing and Dyeing

2.3 Material and lab instruments

1. Glassware
2. Chemical and reagents
3. Electronic balance
4. pH meter
5. Whatsman filter paper
6. UV visible spectrophotometer
7. Lovibond meter
8. Water measuring beaker
9. ICP-OES
10. Analytical balance

2.4 Sample collection

Wastewater samples were collected from the outlet of five different industries including Nishat Mills Limited (Apparel Division), Comfort Knitwear (Pvt.) Limited, Pensy Garments (Pvt.) Limited, Taiga Apparel (Pvt.) Limited and Humbul Tex (Pvt.) Limited. Polythene bottles having a volume of 1.5 L were used to collect water samples. Before sampling bottles were cleaned with HCl, washed with distilled water and then dipped into wastewater at sampling station. Small gap for air was left at the top portion of the bottle. The sampling bottles were wrapped with paraffin wax to make it free from outside disturbance. For the analysis of metal concentration (e.g., Hg, Mn and Fe) 10 ml solution of (2M HNO_3) was taken to protect samples from pathogenic attack. These samples were placed into an icebox (light proof) to protect them from sun radiations and then finally shifted to the laboratory for physico-chemical analysis.

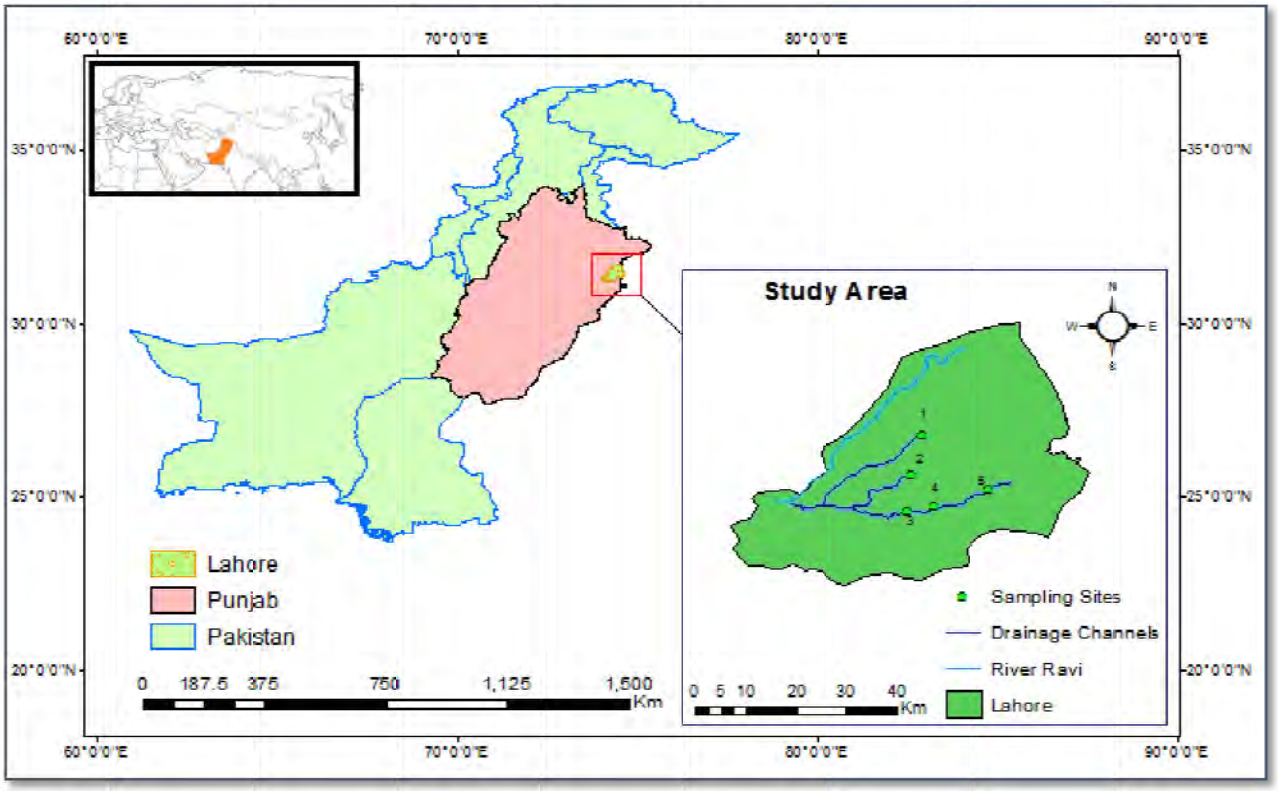


Fig. 2 Shows map of sampling sites in study area.

2.5 Physico-chemical analysis of wastewater

Wastewater samples were collected and analyzed for physical and chemical characteristics according to Standard Methods for the Examination of Water and Wastewater 21st Edition, American Public Health Association, American Water Works Association, Water Environment Federation USA (2005). The Physical characteristics of wastewater samples judged based on TDS and TSS while chemical characteristics judged based on pH, Biological Oxygen Demand, Chemical Oxygen Demand and metal contents. The pH value of water samples was determined by taking 50 mL of water in a beaker having 100 mL capacity. Electrode of pH meter was immersed into samples and readings were recorded. Total dissolved solid (TDS) is the measure of total inorganic salts which measured by using evaporation method and total suspended solid (TSS) were measured by using gravimetric analysis.

Chemical parameters of wastewater such as COD, BOD and metals contents were determined according to the standard analytical methods (Greenberg, 2005). COD was determined using open reflux method. 50ml of water samples was taken into 500ml refluxing flask and 1g mercuric sulphate, 5ml sulphuric acid and 25 ml 0.25 N potassium dichromate were added in it. Refluxing flax was attached to condenser and turned on cooling water. Back titration method was used to find the value of COD by using ferrous ammonium sulfate and ferroin as indicator. BOD was determined by respirometric method by taking 100 ml of water sample in a glass bottles. Samples were placed in four bottles, first bottle for test, second bottle for replicate, and third bottle for standard and fourth bottle for blank sample. Samples were placed in Lovibond Trintometer at 20^{o}C for 5 days and BOD reading was noted after 5 days. Heavy metals (Cr, Hg, Ba, Fe, Mn and B) were determined by using ICP-OES (Inductively coupled plasma-Optical emission spectrometry) by taking 50 mL sample in a beaker of 250 mL volume. 5% Nitric acid was added in each waste water sample and then placed them in microwave digester. After digestion, all digested samples were shifted to ICP for determination metals concentration. Table 2 illustrates the methods and apparatus used in laboratory for physico-chemical analysis of wastewater.

2.6 Data analysis

After physico-chemical analysis, data were compiled and tabulated. GIS, SPSS and Microsoft Office Excel software were used for analysis and presentation of data in comprehensive way. Statistical analysis of data was carried out using Pearson correlation matrix to identify the possible relationship between all parameters. Different charts, tables and graphs, etc. were prepared for the presentation of results. All analyzed parameters were then compared with standard of Punjab Environmental Quality Standard (PEQS).

Table 2 Methods and instruments used for analysis.

Physico-chemical parameters	Methods and instrument
pH value (H+)	pH meter
BOD	Respirometric method, Lovibond meter
COD	Open reflux method, Back titration
TSS	Gravimetric method
TDS	Evaporation method
Metals	Emission Spectroscopy, ICP-OES

3 Results and Discussion

3.1 Physical characteristics of wastewater

Physical characteristics of wastewater collected from different sampling sites are shown in Table 3.

Concentration of solids indicates an important characteristic of wastewater. Physical characteristics of wastewater were determined based on solid concentration including total suspended solid (TSS) and total dissolve solids (TDS). TSS and TDS contents of the analyzed effluents at all sampling stations ranged between 14-612 mg/l, 777-6700 mg/l respectively. The highest TSS concentration was recorded in the effluents generated by Pency Mills while lowest concentration was recorded in effluent of Comfort Knitwear. However TSS concentration in effluent of all industries was found within permissible limit of PEQS except Pency Garment industry which is exceeding PEQS limit (Fig. 3). Higher concentration of TDS in wastewaters is due to the presence of dissolved inorganic and organic contaminants. Das et al. (2010) have also described analogous results of increase in TDS.

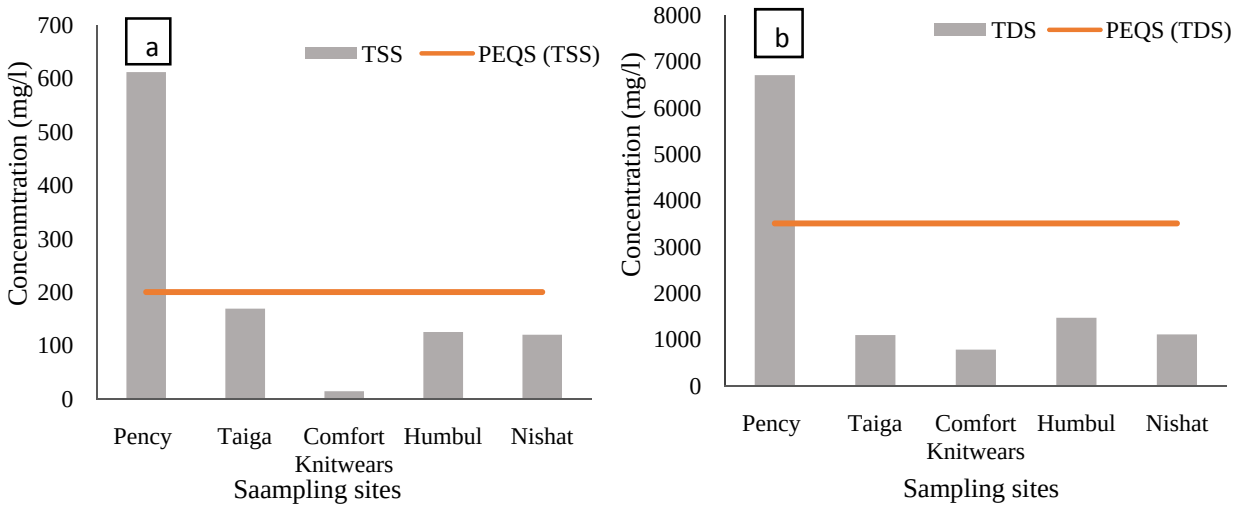


Fig. 3 Concentration of total (a) suspended solids and (b) dissolved solids, in wastewater samples collected from five industries in Lahore.

3.2 Chemical characteristics of wastewater

Table 3 illustrates the results of chemical analysis of wastewater samples collected from five industries in Lahore.

3.2.1 PH

pH represents important characteristic of water and small changes in its level can disturb quality of water making it unsuitable for use. pH value of analyzed effluents at all monitored sites was found to be alkaline in nature. The pH varied from 6.8 to 8.6 in effluents of all industries. Lowest value of pH observed at Humbul Mill while its highest value observed at Taiga Mill. However pH value at all monitoring sites are within permissible limit of Punjab Environmental Quality Standard (PEQS) (Fig. 4). The alkaline nature of the tannery effluent is due to the presence of carbonates and bicarbonate. Similar results were described by Navaraj and Yasmin (2012).

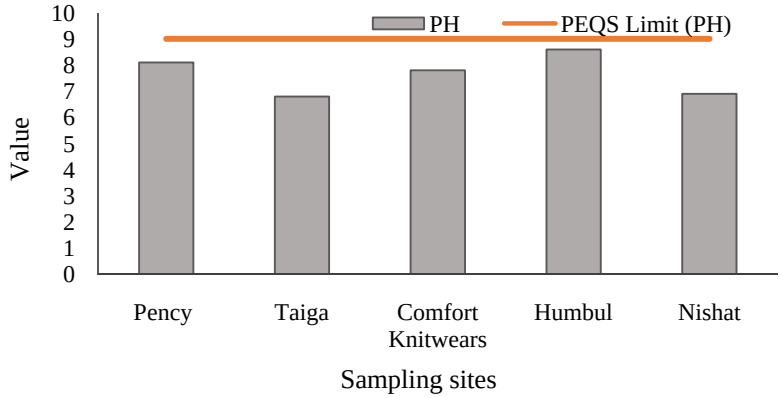


Fig. 4 pH value in effluent of different industries.

3.2.2 Biological and Chemical Oxygen Demand (BOD)

Fig. 5 illustrates the level of biological and chemical oxygen demand in wastewater effluents by different industries in Lahore. Maximum value of BOD observed 520 mg/l in effluent of Pency Mills and its lowest value observed 54 mg/l in effluent of Comfort Knitwear. BOD values monitoring at all sites are higher than permissible limit of PEQS except Comfort Knitwear whose effluent exceeded PEQS limit. High value of BOD indicates the presence of massive amount of organic substances present in waste water. Larger concentration of organic constituents utilizes large quantity of O_2 and enhances the level of BOD. COD values of analyzed effluents varied from 118-957 mg/l in all five water samples collected from different industries. COD level at all sampling stations was also higher than permissible limit of PEQS except Comfort Knitwear. Maximum value of COD was observed957 mg/l in effluent discharged by Pency Mills and its lowest value observed 118 mg/l in effluent of Comfort Knitwear. COD level commonly indicates the concentration of organic matter in wastewater which is not decomposed by microorganisms(Islam, 2014).

3.2.3 Metals content

Fig. 6 illustrates the concentration of different metals in wastewater effluents by five industries in Lahore. Chromium is considered as important constituent releasing from leather and dying industries (Otten et al., 2006). Chromium (Cr) concentration measured at all sampling sites varied from 0.004-0.08 mg/l and found within permissible limit except Comfort Knitwear which is releasing 2.96 mg/l chromium concentration in wastewater. Mercury concentration in effluents of Pency Mill found very near to permissible limit of PEQS while its level in effluents of other industries are below the permissible limit. The permissible limit for Barium (Ba) of 1.5 mg/l was exceeded by Taiga Mill which is releasing high 2.35 mg/l of Ba concentration in

wastewater. However values of Barium in effluents of other industries were found within permissible limit. Effluent discharged by dying, printing and garments industries is a major source of chromium, barium and mercury. Effluents of Comfort Mill contains high amount of iron concentration than other industries however iron concentration in effluents of all industries was found within permissible limit of PEQS. Effluents releasing from Comfort Mill contains 0.96 mg/l of iron contents. Higher concentration of iron in effluent of Pency and Comfort Knitwear is due to its chemical nature. Mostly units working in these industries are dying and printing which release high concentration of metals like iron. iron is an important constituent of effluent released from chemicals and steel industries(Environment, 2004). Concentration of Manganese (Mn) and Boron (B) of analyzed effluents at all sampling sites varied from 0.01–0.94 mg/l, 0.02-0.8 mg/l respectively. Highest concentration of Manganese (Mn) and Boron (B) was found in effluent of Comfort Knitwear Mill. Chloride (Cl^-) concentration monitoring at all sites was found within permissible limit of PEQS except Pency Mills which is releasing wastewater having chloride concentration 2690 mg/l.

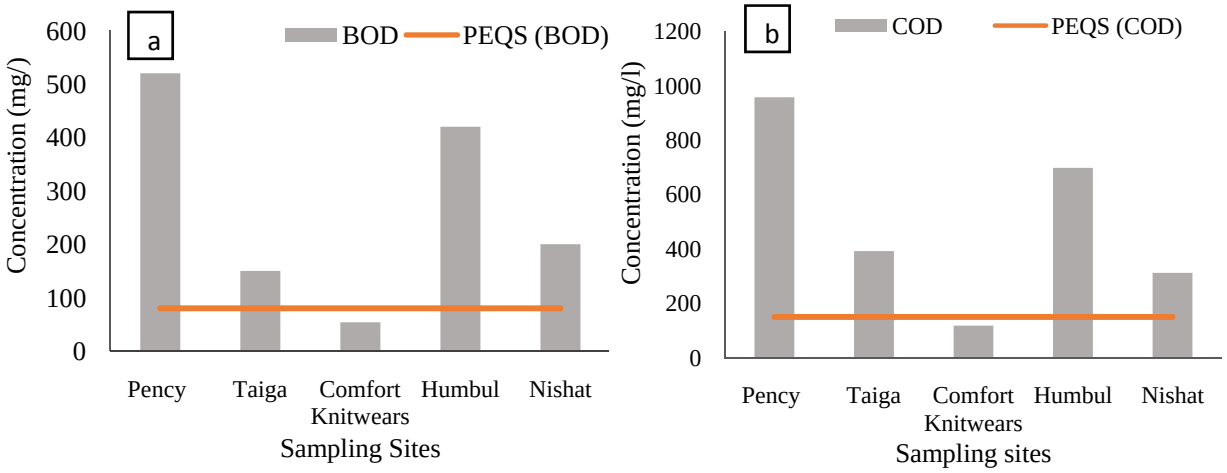
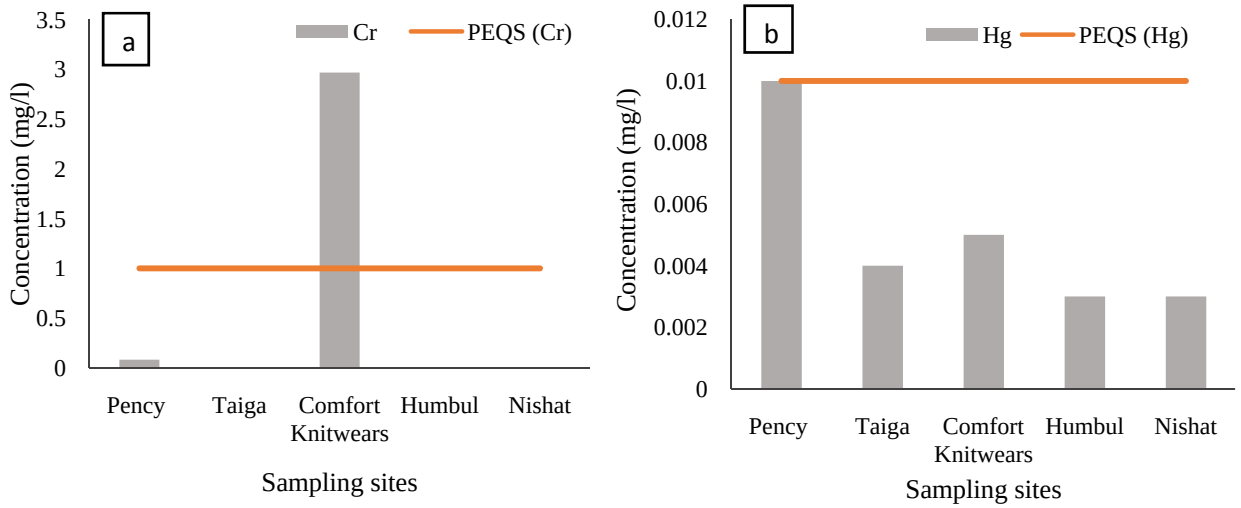


Fig. 5 Biological and chemical oxygen demand of wastewater effluents by five industries in Lahore.



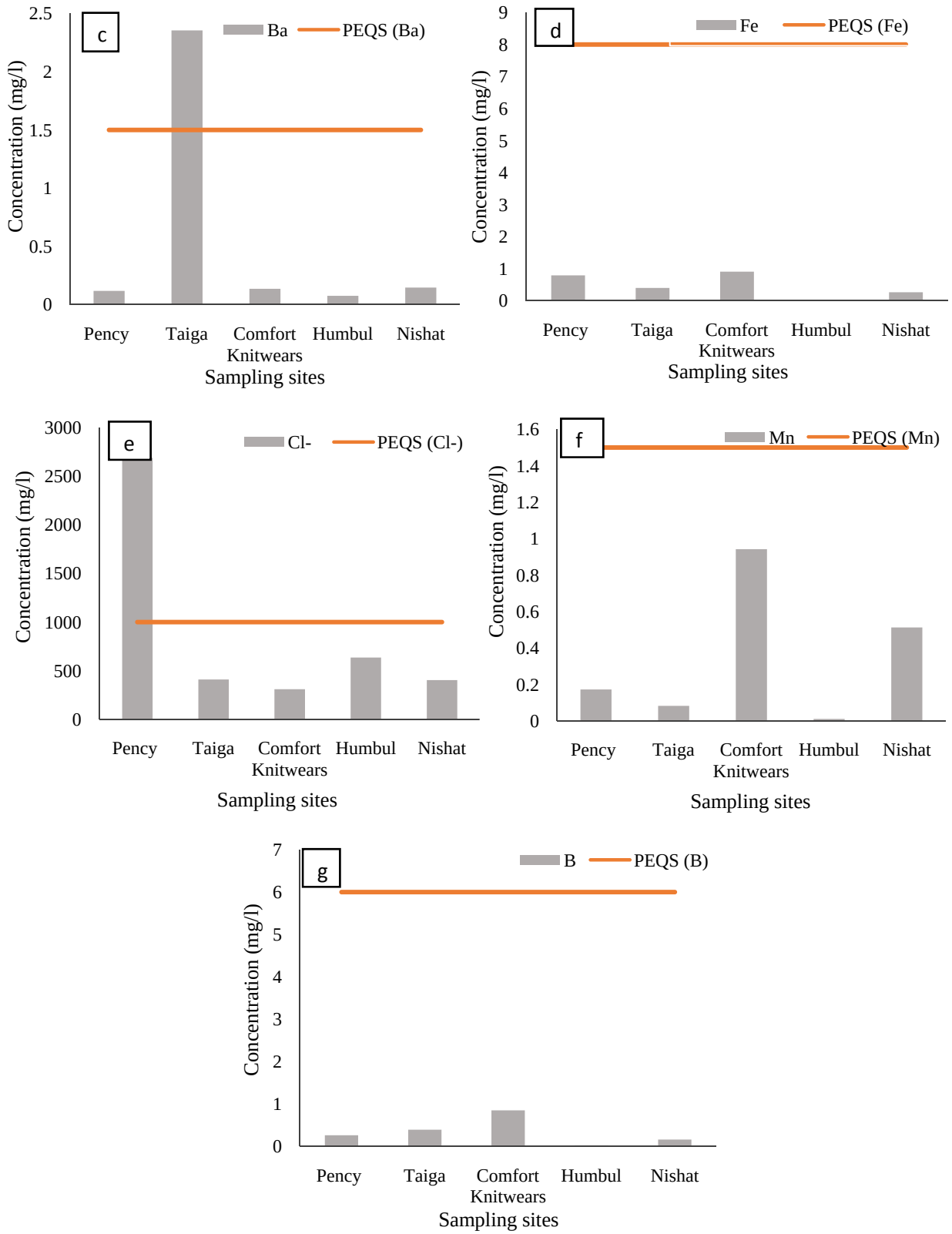


Fig. 6 Concentration of metals in wastewater effluents by five industries.

Table 3 Physico- chemical characteristics of industrial wastewater.

		Sampling Sites					
Parameters	Unit	Pensy Garments	Taiga Apparel	Comfort Knitwear	Humbul Textile	Nishat Mill	PEQS Limits
pH value (H+)		8.1	6.8	7.8	8.6	6.9	6_9
BOD	mg/l	520	150	54	420	200	80 mg/l
COD	mg/l	957	392	118	698	312	150 mg/l
TSS	mg/l	612	169	14	125	120	200 mg/l
TDS	mg/l	6700	1092	777	1465	1104	3500 mg/l
Chloride (as Cl-)	mg/l	2690	410	310	636	403	1000 mg/l
Chromium	mg/l	0.084	0.008	2.969	0.004	0.004	1 mg/l
Mercury	mg/l	0.01	0.004	0.005	0.003	0.003	0.01 mg/l
Barium (Ba)	mg/l	0.118	2.354	0.136	0.075	0.146	1.5 mg/l
Iron (Fe)	mg/l	0.789	0.398	0.906	0.026	0.261	8 mg/l
Manganese (Mn)	mg/l	0.172	0.082	0.942	0.01	0.512	1.5 mg/l
Boron (B) (T)	mg/l	0.258	0.389	0.848	0.021	0.156	6 mg/l

3.3 Pollution loading

For better judgment of the organic and heavy metals pollution loading in environment, determination of COD/BOD5 ratio and overall metals concentration are of great importance. These parameters give a good way to capture the degree of pollution created by industries.

3.3.1 COD/BOD ratio

The COD/BOD5 ratio characterizes the biodegradability of the considered effluent. It is considered that if wastewater discharged directly into receiving waters without treatment its COD/BOD5 ratio should between 0.3-0.8. High level of this ratio represents an increase of non-biodegradable organic matter in wastewater (Rodier, 2005). Highest values of COD/BOD5 were found for Taiga and Comfort Mill showing high biodegradability than other points however COD/BOD ratio for all industries exceeded the standard COD/BOD ratio (Fig. 7).

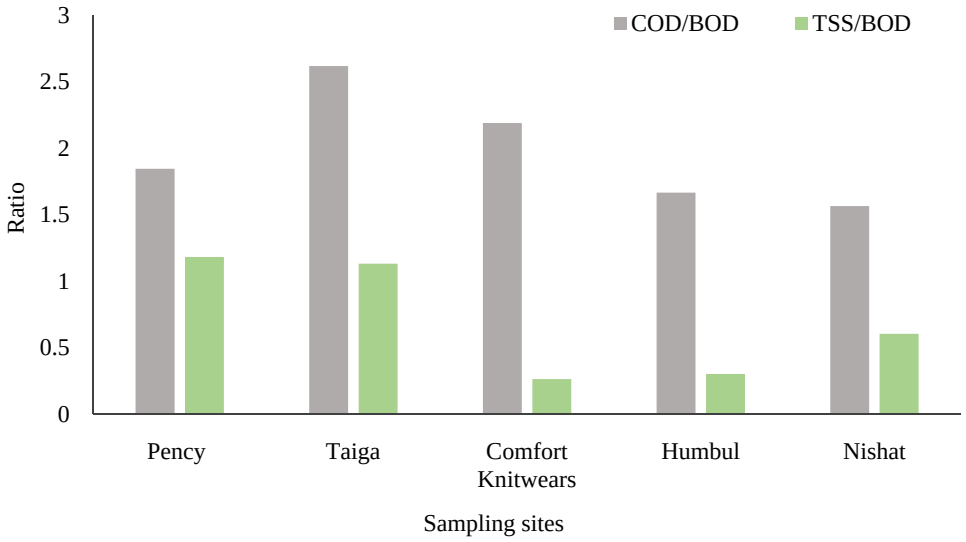


Fig. 7 Organic pollution loading of five industries.

3.3.2 Overall concentration of heavy metals

Pollution loading of heavy metals from effluent of doddering industries was assessed through overall concentration of metals released by each industry. Fig. 8 illustrates overall metals content in effluent of each industry and number of parameters exceeding permissible limit of PEQS. Maximum value of overall metal concentration observed 2691 mg/l in effluent discharged by Pency Mill and its lowest value observed 315 mg/l in effluent of Comfort Knitwear. High value of overall metal concentration in effluent of Pency indicates that it is releasing more quantity of metals in wastewater. It was also found that number of parameters exceeded PEQS limit are more in Pency Garments as compared to other industries.

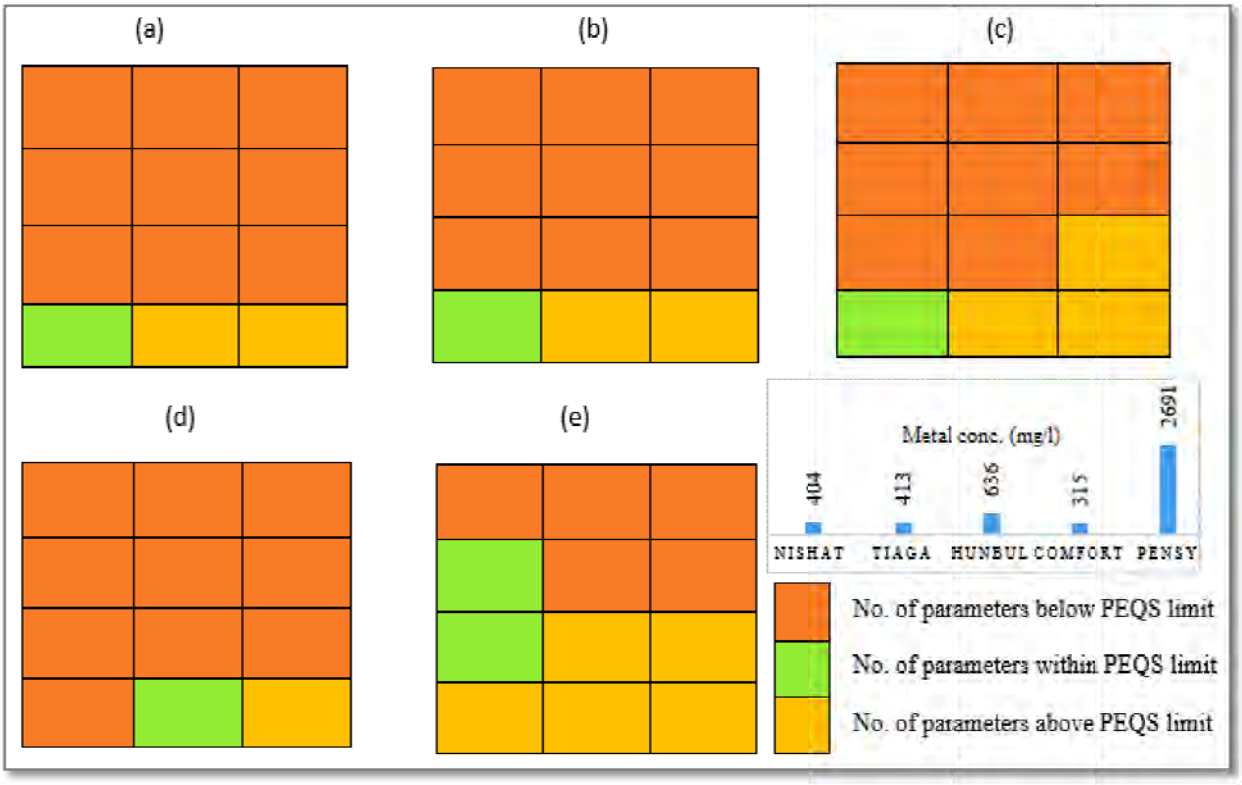


Fig. 8 Overall metals conc. in effluents of (a) Nishat Mills (b) Taiga Apparel (c) Hunbul Text. Pvt. Limited (d) Comfort Knitwear (e) Pensy Garments.

3.4 Possible relationships of physico-chemical parameters

Analyzed results of experiment show that some parameters might be correlated and their behavior significantly depends on each other. Pearson correlation coefficients were calculated between all parameters at all five selected sites (Table 4). Mostly parameters seem to be associated with each other. Based on conclusion, high positive correlations were found between the following parameters.

1. COD and TSS, TDS, Cl at all five sampling stations.
2. TSS and TDS, Cl, Hg at all five sampling stations.
3. TDS and Cl, Hg at all five sampling stations.
4. Cl and Hg at all five sampling stations.
5. Cr and Fe, Mn, Ba at all five sampling stations.
6. Hg and Fe at all five sampling stations.
7. Fe and Mn, Ba at all five sampling stations.
8. Mn and B at all five sampling stations.
9. PH and BOD, COD at all five sampling stations.

10. BOD and TDS, TSS, COD, Cl-, Hg at all five sampling stations.

Table 4 Pearson Correlation matrix for physico-chemical parameters at all sampling sites.

	pH	BOD	COD	TSS	TDS	Cl	Cr	Hg	Ba	Fe	Mn	B
pH	1											
BOD	.62**	1										
COD	.55**	.97**	1									
TSS	.23	.78**	.85**	1								
TDS	.36	.78**	.83**	.98**	1							
Cl	.39	.80**	.84**	.98**	.99**	1						
Cr	.12	-.60**	-.61**	-.44	-.29	-.29	1					
Hg	.29	.53**	.61**	.88**	.93**	.92**	.02	1				
Ba	-62**	-.36	-.19	-.09	-.25	-.26	-.24	-.18	1			
Fe	.00	-.20	-.13	.30	.39	.38	.67**	.69**	-.10	1		
Mn	-.17	-.68**	-.74**	-.45	-.33	-.33	.86**	-.05	-.36	.59**	1	
B	-.17	-.69**	-.63**	-.31	-.22	-.22	.90**	.14	.11	.80**	.77**	1

**. Correlation is significant at the 0.01 level (2-tailed).

4 Conclusions

In present study several parameters of wastewater were analyzed to judge the physico-chemical characteristics of wastewater which is being discharged from five industries in Lahore. Results obtained for different parameters were varied site to site depending on the type of units working in industries and the nature of wastewater being generated. Most of physico-chemical parameters were found above permissible limit of Punjab Environmental Quality Standard (PEQS). The disposal of such type of waste water into freshwater bodies may deteriorate the quality of water. Especially metals contents released from chemical industries change the chemical composition water, can create harmful effects to aquatic life and the people living around industrial zone. This type of study should be conducted before installing any treatment plant in industry. This study recommends that wastewater generating from industries should be treated before throwing it into water channels.

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