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Toxic Levels in Industrial Effluents and Domestic Wastewater of Mirpur, Pakistan

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The physico-chemical and bacteriological parameters in Mirpur city, Pakistan were studied to ascertain the quality of wastewater. Total 14 parameters were analyzed and results were compared with those of NEQS and WHO guidelines for wastewater. Forty five samples (6 industrial, 34 domestic and 5 fresh water) were collected from the targeted area and were analyzed for electrical conductivity (EC), TDS, pH, total hardness (TH), alkalinity, salinity, sulphates, chlorides, nitrate nitrogen, orthophosphate, sodium, potassium, total coli form and fecal coli form. Sample S₁₁ (Sangot Kho Colony) and sample S₂₄ (Akson Pharmaceutical Industry) showed maximum value of TDS and EC. Total dissolved solids and electrical conductivity are linearly correlated and around 75 % samples exceeded the maximum permissible limit of WHO. Nitrate nitrogen and pH in all samples were within range of standard desirable limits. Only 3 samples showed strong hardness. Alkalinity in 17 samples of study area surpassed the maximum permissible limit. Concentration of chloride and sulphate was comparable with each other and sulphate in 12 samples and chloride in 7 samples crossed the maximum permissible values. Major metal cations in both industrial and domestic wastewater followed the order Na > K. Concentration of sodium was investigated higher in 7 samples and similarly potassium concentration was also observed higher in 5 samples than permissible limits. All wastewater samples (industrial and domestic) indicated higher values of total coliform and fecal coliform ranging between 200-520 and 180-320 MPN/100 mL, respectively. Drinking water samples also showed the microbial contamination which exposed the underground mixing of water supply system with sewage. All samples exceeded the WHO guideline value for bacteriological contamination which is Nil/100 mL.

Keywords: Industrial effluents, Domestic wastewater, Toxic levels, Mirpur, Total coliform, Fecal coliform.

INTRODUCTION

Water is the first and foremost need of humans and is used by everyone and all living beings depend on ground water to a great extent. About 71 % earth consists of water, out of which 97 % water is found in oceans; 2 % in the form of glaciers and polar ice cap. About 1 % is available as fresh water and 0.001 % as vapours in the air, clouds and precipitation. Sea water has a great quantity of dissolved salts. Sodium chloride is found in sea water as 3-4 % along with other salts due to which the taste of sea water is saltish. Groundwater is the most important source of water and is found in grave peril. Groundwater is basically a hidden supply that seeps beneath the surface of ground, combines in natural underground reservoirs known as aquifers and is the source of water in springs and wells. However, it is endangered by water pollution, water mismanagement and exploding endangered. These are the elements which are the serious problems for underground water [1]. The reservoirs of ground water are being drained, the nature can replenish them or they are contaminated by humans, leaking sewage systems, gasoline stations, septic tanks, industrial pollutants,

agricultural wastes and leachate from waste disposal sites [2-8]. Once the deep water contaminates then it spoils the whole well and water of related areas. The slow penetration of pollutants has been called "Chemical Time Bomb" which threatened mankind. All of these problems and dangers need to be addressed and dealt with. Although groundwater is invisible but it can be measured [9]. Improved monitoring of water and industrial and waste disposal sites and in areas where fertilizers, pesticides and herbicides are used in an emergency requirement can minimize the potential disaster. Kaur *et al.* [10] indicates that the industrial effluents which are entering the water bodies not only damage the drinking water quality but also has dangerous effect on the soil microorganism and aquatic ecosystem. They investigated the effluents of sugar mills and textile industries. Their results shown that the values of parameters such as pH, TSS, TDS, BOD and COD exceed the NEQS and FMENV standard values. Rajpa and Manjappa [11] monitored the water quality of 25 ground water samples collected from different sites of Hariharataluk (India). They did analysis of the physico-chemical parameters such as pH, hardness, alkalinity, TDS, *etc.* and compared the results with the standard values

laid by Indian Council of Medical Research (ICMR) and WHO. They observed that some water samples are not suitable for human being due to high concentration of some parameters. Bolawa and Gbnela [12] examines the water quality of river Majidunn, Molatori and Ibeshe in Nigeria to high lights the effects of effluent discharge on water quality. To evaluate the effluent discharge on the rivers they use physico-chemical parameters and concentration of trace metals also determined. There results attribute the pollution tendencies of the rivers due to high levels of lead, chromium and cadmium. Jin *et al.* [13] reviewed the topics concerning to environment and public health hazards allied with wastewater disposal, treatment and reuse. In this work they discussed the following issues: water and wastewater management, microbial hazards, chemical hazards, wastewater reuse, wastewater treatment plants, wastewater disposal and sludge and biosolids. Khattak [14] worked on waste effluents of industries in Quetta and examined the heavy metals (Cu, Cd, Zn, Ni and Pb) levels and then examine the connection between industrial and environmental policies in Pakistan in light of the results of the present research work. The samples were collected from various industries in the suburb of Quetta. In analyzed water samples the concentration of metals were observed in order $Zn > Pb > Ni > Cu > Ni$. Moreover, pH, suspended solids (SS) and biological oxygen demand (BOD) were determined which were found in violation of WHO standards. Rafiquel *et al.* [15] inspected the uncleanness level of wastewater in the Kushtia industrial areas of Bangladesh. Some parameters of wastewater were analyzed like pH, electrical conductance, total dissolved solids (TDS), hardness, biochemical oxygen demand (BOD), chemical oxygen demand (COD) and concentration of heavy metals (Pb, Cd, Cr, Cu and Mn) were investigated and matched with standards of drinking water. This work points out the health hazard status of wastewater for inhabitants and aquatic living being, an ultimate concern for their existence in the area.

Mirpur is a modern city which is situated on the bank of Mangla lake. The district of Mirpur has a population of 371,000 and covers an area of 1,010 km² (390 sq miles). The Mirpur division lies between longitude 73°-75° and latitude 33°-36°. The average annual rainfall is of 1300 mm [16,17]. The district is mainly mountainous with some plains. It's hot, dry climate and other geographical conditions closely resemble those of Jhelum and Gujarat, the adjoining districts of Pakistan. Mangla Dam covers an area of 100 square mile, which generates one thousand megawatt electricity annually. Water of Jhelum and Poonch rivers is collected by this lake. Mangla dam generates 35 % of the total electricity of Pakistan. Near about 30 lac acre land is irrigated by this lake. A variety of fish is also available here in this lake [18].

Mirpur division has a similar climate to the neighbouring areas of Punjab, Pakistan. Climate is hot and humid during summer and cold during winters. June and July are the hottest months when maximum temperature reaches above 40 °C. The temperature during winter may drop to 4 °C. The average annual rainfall is 1300 mm in its catchments areas. Major share of rains is received in monsoon period. There is often a prolonged dry period from October to early January followed by winter rains from mid-January to March. Main crops are wheat

and maize. Among vegetables, potato, turnip, garlic, cauliflower, peas and onion are commonly cultivated whereas mangoes and guava are main fruits in this area. Industrial and municipal waste, agricultural runoff and atmospheric deposition are the major threats to ecological integrity and deterioration of its surface water quality [18]. Among these, the untreated discharges of municipal and industrial effluents are of importance.

EXPERIMENTAL

Sampling: During collection, preservation, handling, transportation and testing of the samples followed all the procedure and methods in accordance with the standard methods for the examination of water and wastewater [19]. To eliminate the chances of any external contaminant which could change the test results, sampling was done very carefully. Cleaned plastic polyethylene bottles rinsed with distilled water sterilized at 121 °C for 15 min were used for sampling. For bacteriological and physico-chemical analysis, polyethylene plastic bottles of 0.5 and 1.5 L, respectively were used for sampling. For maintaining record specific sampling numbers were marked on all the sampling bottles with permanent board marker. After taking samples bottles were immediately closed and sealed to avoid any external contamination. After the collection of samples, the collected samples were brought to the laboratory of Mirpur University of Science and Technology Mirpur within the recommended time to analyze for physical, chemical and bacteriological parameters. The parameters were examined and tested by following the procedures of standard methods for the examination of water and wastewater [19].

Total dissolved solids, EC and salinity were evaluated with Orion 115 conductivity meter and pH using Orion 420 A pH meter [20]. Titrimetric method was used to determine the chloride, hardness and alkalinity using standard silver nitrate, EDTA and hydrochloric acid solutions, respectively. Nitrates, sulphates and orthophosphate were estimated by spectrophotometry. Orthophosphate was determined by reducing phosphomolybdic acid formed with ascorbic acid to molybdenum blue. Nitrate was determined after derivatization with brucine sulphate [14]. The sulphate was determined as BaSO₄ using Hitachi 220 spectrophotometer by turbidimetric method. Na and K were determined by using 410 Sherwood flame photometer. The bacteriological contamination (total and fecal coliform) were calculated by most probable number (PMN) method.

RESULTS AND DISCUSSION

Forty wastewater samples (6 industrial and 34 domestic) and 5 fresh water samples (2 from main source and 3 from consumer's end) were collected from the targeted area and analyzed for EC, TDS, pH, TH, alkalinity, salinity, sulphates, chlorides, nitrate nitrogen, orthophosphate, Na, K, total coli form and fecal coli form. Sample number 17, 18, 24, 29, 34 and 39 represent industrial wastewater and sample number 41, 42, 43, 44 and 45 represent fresh water while remaining indicate domestic sewage.

pH: The pH of the industrial and domestic wastewater lies within the 6.79 to 7.07 and 6.28 to 7.7, respectively. The maximum pH value was observed at sampling stations S₃₉

(Steel industry) and S₇ (Rthoa Mohammad Ali), may be due to alkaline nature of the industrial processes and anthropogenic activities in the densely populated City of Mirpur. The pH values of all the samples were within the NEQs and WHO permissible limits (6.5-8.5).

Total dissolved solids: Dissolved materials result from the solvent action of water on liquids, solids and gases. Total dissolved solids were observed within the range 531-1792 mg/L in industrial effluents while TDS values ranged from 125-1963 mg/L in domestic wastewater. Maximum values recorded at sampling stations S₂₄ (Akson Pharmaceutical Industry) and S₁₁ (Sangot Kho Colony) were 1792 mg/L and 1963 mg/L, respectively. Thirteen samples exceeded the maximum permissible limit of WHO which is 1000 mg/L (Fig. 1).

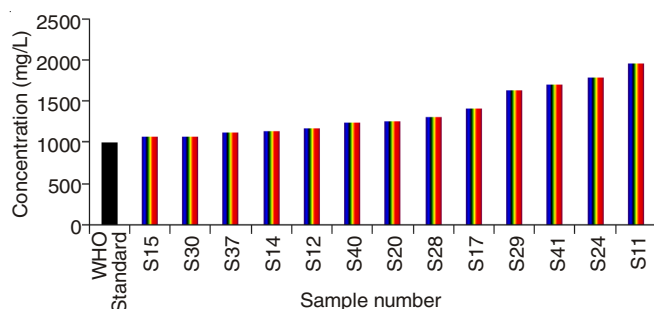


Fig. 1. Column chart showing the total dissolved solids which exceed the WHO standard value in wastewater samples

Alkalinity: Carbonates, bicarbonates and hydroxides of elements such as Mg, Ca, Na, K or NH₃ are the sources of alkalinity in wastewater. Among these the most common are the Ca and Mg carbonates, silicates, borates and phosphates. Change in pH in wastewater caused by the addition of acids is resisted by the alkalinity. The values of alkalinity in industrial wastewater samples ranged from 320-1790 mg/L and in domestic wastewater samples from 100-1200 mg/L. The alkalinity was recorded above 500 mg/L in 75 % samples. The maximum permissible value of WHO for alkalinity are 600 mg/L and 17 samples from study area exceeded this limit (Fig. 2).

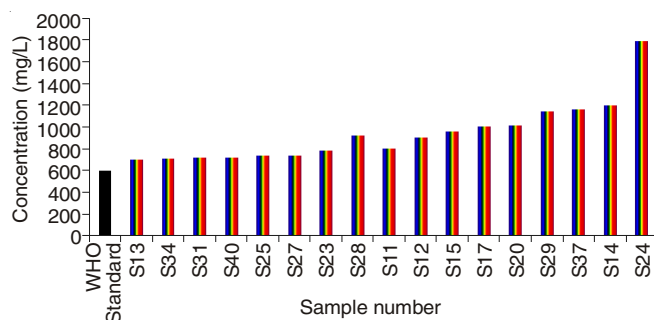


Fig. 2. Column chart showing the alkalinity values which exceed the WHO standard limit in wastewater samples

Total hardness: Water hardness is indicated by the sum of polyvalent cations soluble in water. Calcium and magnesium are the most common cations, although Mn, Fe and Sr may also contribute [21,22]. Equivalent quantity of CaCO₃ is generally reported as hardness and water is usually classified according to degree of hardness as < 75 as soft water, 75-150

as moderately hard, 150-300 as hard and > 300 mg/L as very hard [23]. The estimated total hardness values in industrial wastewater samples ranged from 72-216 mg/L and in domestic wastewater sample from 12-384 mg/L. The effect of hardness is that it may clog pipes, deposits carbonates and can coat the inside area of water tanks. Eight samples of study area were in the category of hard water, 3 samples very hard and remaining samples were moderately hard (Fig. 3).

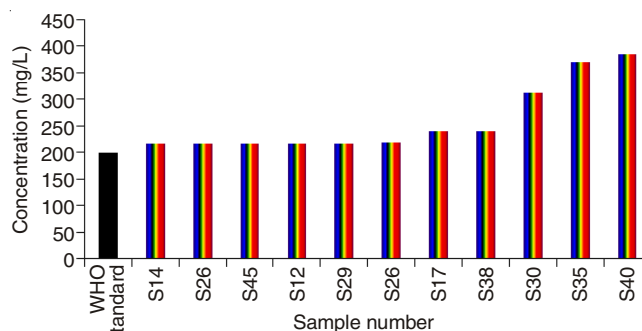


Fig. 3. Column chart showing the total hardness exceeding the WHO standard value in wastewater samples

Chlorides: Leaching of chlorides containing soils and rocks which are in contact with water are major cause of higher levels of chlorides in natural water sources. Another source of chlorides is discharge of agricultural, domestic and industrial wastewater to surface water [24]. The estimated values of chlorides from industrial wastewater were in the range of 141-354 mg/L and from residential wastewater samples in the range of 2.3-790 mg/L. Only seven samples exceeded the guide line value of WHO which is 250 mg/L (Fig. 4).

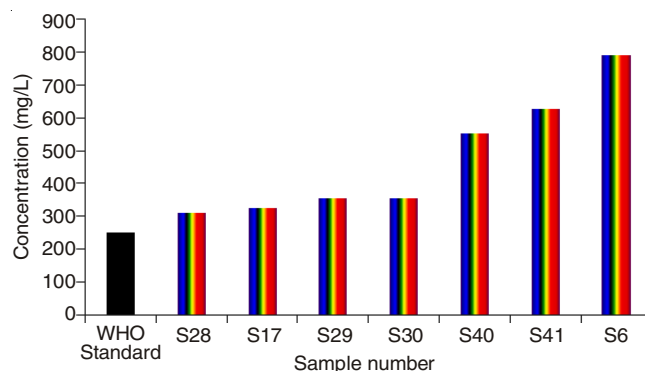


Fig. 4. Column chart showing the chloride which exceeds the WHO standard value in wastewater samples

Sulphates: Sulphates indicated higher range than the chlorides in industrial wastewater samples but the values of sulphates and chlorides in residential wastewater samples were comparable. Industrial wastewater sampling stations indicated sulphates between the range 153-663 mg/L while in residential wastewater 95-711 mg/L. Maximum values estimated at sampling sites S₂₄ (Akson pharmaceutical industry) and S₃₅ (Sector F-2 near city hospital) were 663 mg/L and 711 mg/L, respectively, may be due to the nature of chemicals used in industrial processes and type of anthropogenic activities in the relevant areas. Twelve samples showed higher values than WHO maximum permissible limit of 500 mg/L (Fig. 5).

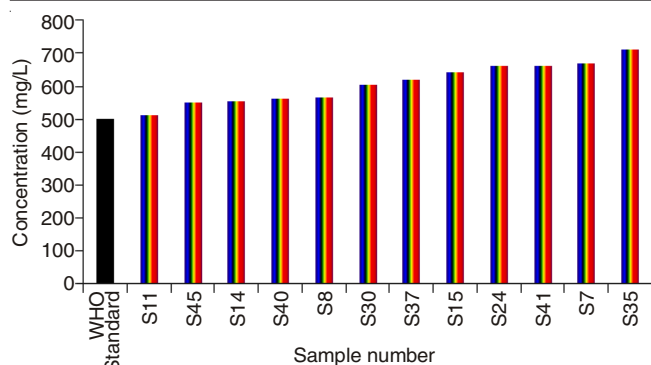


Fig. 5. Column chart showing the sulphate contents which exceed the WHO standard value in wastewater samples

Salinity: Salinity of industrial and domestic wastewater was measured within the range 0.2-1.4 g/L and 0.1-0.3 g/L, respectively. Nineteen samples exceeded the maximum permissible limit of WHO which is 0.5 g/L (Fig. 6).

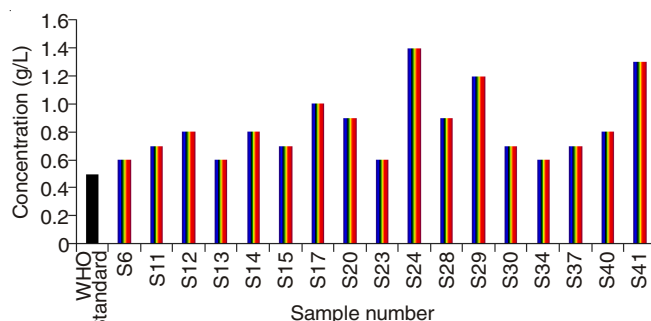


Fig. 6. Column chart showing the salinity which exceeds the WHO standard value in wastewater samples

Nitrate-nitrogen: Nitrogen is one of the necessary primary nutrients. As far as the quality of wastewater and freshwater is concerned, we are always interested in nitrite nitrogen, nitrate nitrogen, ammonia nitrogen and organic nitrogen. All these types of nitrogen are involved in establishing nitrogen cycle and are also bio-chemically interrelated. Oxidation of nitrite nitrogen generates nitrate nitrogen. Nitrate-nitrogen determined from sampling stations of wastewater were between 2.3 to 7.5 mg/L and in domestic wastewater samples indicated nitrate nitrogen between 2.1 to 7.7 mg/L. All samples of the study area were within range of standard desirable limit of WHO which is 10 mg/L.

Orthophosphate phosphorous: An essential element which plays a vital role in the normal growth of plants is phosphorous. Phosphorous is found in aqueous solution in the form of organic phosphate, orthophosphate and poly phosphate. For use in soils phosphorous is not readily available. It is only soluble under reduced conditions in acidic solutions. It is vigorously immobilized as Fe or Ca phosphate [25-27]. Industrial effluents, soaps, detergents, fertilizers and domestic sewage are the main sources of different forms of phosphate in water, but in aquatic eco-system dynamic role is played by inorganic phosphate. Orthophosphate was observed in industrial effluents in range of 1.92-8.67 mg/L and in domestic wastewaters its range was 1.69-11.64 mg/L. Maximum values evaluated at sampling sites S₁₇ (Mehran Foam industry) and S₂₈ (Sector B-1 Nangi) were 8.7 mg/L and 11.64 mg/L, respectively.

Electrical conductivity (EC): Electrical conductivity has linear relation with TDS and express the load of dissolved solids in the water. Electrical conductivity was calculated in industrial wastewater within the range 831-2800 $\mu\text{S}/\text{cm}$ with minimum at sampling site S₁₈ (New fine flour and rice mills) and maximum at S₂₄ (Akson Pharmaceutical industry). Domestic wastewater showed range between 196-2610 $\mu\text{S}/\text{cm}$ with minimum at sampling station S₅ (Dairy chaudrian town) and maximum at sampling station S₄₁ (Sector C-1 near Nadeem Marriage Hall). However, samples S₁₂, S₁₄, S₁₇, S₂₈, S₂₉, S₄₁ and S₂₄ exceeded maximum permissible limit of WHO which is 800 $\mu\text{S}/\text{cm}$ (Fig. 7).

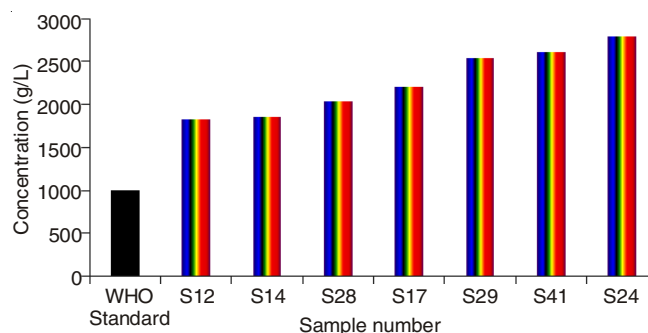


Fig. 7. Column chart showing the electrical conductivity values which exceed the WHO standard value in wastewater samples

Major metal ions (Na and K): Sodium and potassium are found in water in ionic forms. House hold activities such as washing, cooking, bathing and industrial activities are the major cause of these ions in domestic wastewater. Concentrations of sodium and potassium in the industrial samples were found within the range 90-200 mg/L and 1.4-184 mg/L, respectively. The highest metal contents of Na and K are at sampling stations S₂₄ (Akson Pharmaceutical industry) and S₁₇ (Mehran Foam Industry), respectively. Sodium and potassium content observed in domestic wastewater samples were between 16-450 mg/L and 0.1-200 mg/L, respectively. The maximum value of Na and K at sampling station S₂₃ (Sector B-2 near relax cinema) was 450 mg/L and at S₄₁ (Sector C-1 near Nadeem Marriage Hall) was 200 mg/L, respectively. For potassium five samples and Na seven samples from the study area exceeded the desirable limit of 20 mg/L and 200 mg/L, respectively (Figs. 8 and 9).

Total coliform and fecal coliform: The coliform bacterial group contains several genera of bacteria belonging to the family enteterebacteriaceae. F. coli bacteria belongs to this

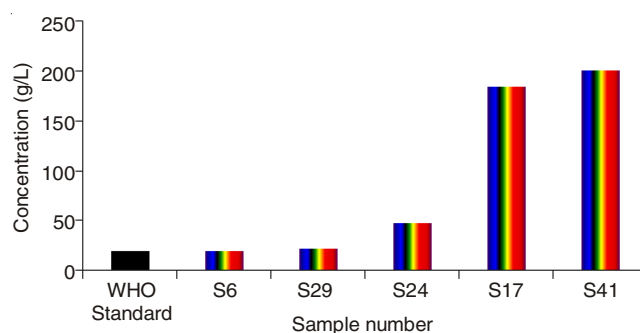


Fig. 8. Column chart showing the concentration of potassium which exceed the WHO standard value in waste water samples

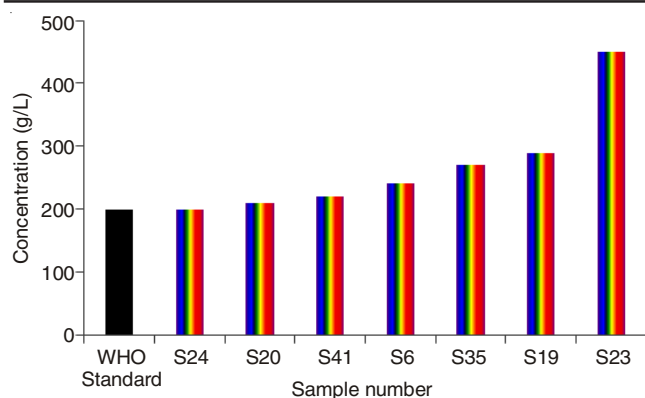


Fig. 9. Column chart showing the concentration of sodium which exceeds the WHO standard value in wastewater samples

group, are present in large numbers in the feces and intestinal tracts of human and other warm-blooded animals and can enter water bodies from human and animal waste. Except from pathogen strains of *Escherichia coli* (*E. coli*) which cause internal bleeding, *F. coli* generally do not pose a danger to animals or people but they indicate the presence of other disease causing bacteria such as those which cause typhoid, dysentery, hepatitis A and cholera. *E. coli* is the principle component of *F. coli* group. Fecal coli are subset of total coliform that come from the intestines of warm blooded animals. Since, they do not include soil organisms; they are preferred to total coliform. Infections are generally contradicted by drinking contaminated water, recreational exposure to contaminated water and the consumption of contaminated raw food exposed to polluted water. Water borne diseases of prime importance are those caused by enteric pathogens transmitted by the fecal route. According to WHO guidelines total and fecal coliform for drinking water is Nil/100 mL and for irrigation less than 1000 MPN/100 mL [28]. Total and fecal coliforms observed in industrial effluents were in the range of 300-460 MPN/100 mL and 180-300 MPN/100 mL, respectively and in domestic sewage were present between 200-520 MPN/100 mL and 180-320 MPN/mL, respectively (Fig. 10).

Drinking water samples were also analyzed for bacteriological activities and they indicated bacterial contamination. The results showed that the drinking water samples collected

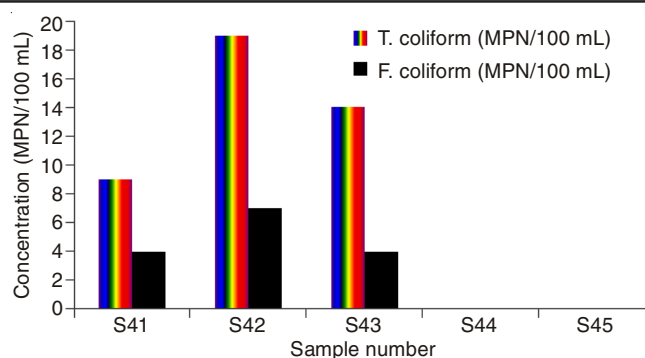


Fig. 10. Column chart showing the T. coliform and F. coliform which exceed the WHO standard value in freshwater samples

from the main source were free from total and fecal coliforms but at the consumers end samples surprisingly indicated the presence of total and fecal coliforms which were in the range of 09-19 MPN/100 mL and 04-07 MPN/100 mL, respectively. So, it was concluded that the presence of total and fecal coliform at consumers end samples may possibly be due to underground mixing of drinking water with sewage water.

Statistical analysis: The analytical data obtained was processed for detailed statistical analysis. The basic statistical parameters included minimum, maximum, mean, median and standard deviation (SD) (Table-1). Correlation coefficients and multivariate cluster analysis were also carried out to evaluate the relationships among different variables.

Correlation coefficient matrix: Correlation matrix of 14 mean variables was prepared. EC and TDS linearly correlated with salinity, Cl^- , SO_4^{2-} , alkalinity and Na. EC-TDS, EC-salinity, EC- Cl^- , EC- SO_4^{2-} and EC-Na were also strongly correlated pairs. Similarly an equally strong correlation was established between pairs; $\text{SO}_4\text{-Cl}^-$, Na- Cl^- , O- $\text{PO}_4\text{-NO}_3\text{-N}$, O- $\text{PO}_4\text{-SO}_4$ and Na-K. Most of the variables are negatively correlated with pH and $\text{NO}_3\text{-N}$. The base value of every cell content represents the Pearson coefficient which shows the significance of correlation. If the value of Pearson's coefficient is less than 0.05 then correlation is considered significant and if greater than 0.05 then correlation is considered non-significant (Table-2).

TABLE-1
STATISTICAL ANALYSIS OF PHYSICO-CHEMICAL AND BACTERIOLOGICAL
PARAMETERS IN THE WASTEWATER SAMPLES OF MIRPUR CITY

Parameters	Min	Max	Mean	Median	Mode	Standard deviation
pH (25 °C)	6.28	7.7	7.02	7.01	7.11	0.25
EC (µS/cm)	196.81	2800	1243.09	1367	-	566.05
Salinity (g/L)	0.2	1.4	0.5	0.5	0.4	0.32
TDS (mg/L)	125	1963	711.70	874.88	-	362.88
TH (mg/L)	12	384	127.54	144	168	78.85
Alkalinity (mg/L)	100	1790	623.19	670	700	296.07
Cl^- (mg/L)	2.30	790	143.43	170.16	178.6	118.60
O- PO_4 (mg/L)	2.98	11.6	5.042	3.20	-	4.51
SO_4 (mg/L)	95	711	382.28	424.40	378.4	156.16
$\text{NO}_3\text{-N}$ (mg/L)	2.10	7.7	5.042	5.72	3.9	1.40
K (mg/L)	0.1	200	5.766	9	10	41.28
Na (mg/L)	16	450	106.72	94	86	81.03
Total coliform (MPN/100 mL)	09	520	309.87	360	300	64.60
Fecal coliform (MPN/100 mL)	04	460	231.43	220	300	47.86

TABLE-2
CORRELATION COEFFICIENT MATRIX OF DIFFERENT PARAMETERS IN WASTEWATER SAMPLES

	EC	Salinity	TDS	pH	Alkalinity	Cl	TH	NO ₃ -N	Na	K	SO ₄	O-PO ₄	T. coli	F. coli
EC	1.000													
Salinity	0.996	1.000												
TDS	1.000	0.996	1.000											
pH	-0.403	-0.394	-0.402	1.000										
Alkalinity	0.788	0.772	0.788	-0.303	1.000									
Cl	0.670	0.671	0.668	-0.379	0.214	1.000								
TH	0.297	0.301	0.298	-0.347	0.422	0.098	1.000							
NO ₃ -N	-0.548	-0.562	-0.550	-0.180	-0.427	-0.030	-0.042	1.000						
Na	0.191	0.198	0.190	-0.230	-0.147	0.183	-0.294	-0.327	1.000					
K	-0.132	-0.132	-0.132	0.124	-0.190	0.006	-0.054	0.011	0.106	1.000				
SO ₄	0.033	0.009	0.032	-0.220	-0.278	0.274	-0.493	-0.065	0.612	0.398	1.000			
O-PO ₄	-0.419	-0.460	-0.420	-0.217	-0.405	-0.090	0.125	0.538	0.047	0.383	0.428	1.000		
T. coli	0.607	0.614	0.607	-0.553	0.553	0.318	0.152	-0.054	0.153	-0.205	-0.005	-0.322	1.000	
F. coli	0.598	0.602	0.599	-0.522	0.576	0.238	0.223	-0.077	0.116	-0.180	-0.087	-0.296	0.977	1.000

Multivariate cluster analysis: The multivariate cluster analysis (CA) of the selected parameters in wastewater of Mirpur based on Centroid method was carried out. A very strong cluster was observed between EC and salinity, another prominent cluster consisted of TDS-alkalinity and T. coli-F. coli. Four clusters had correlation coefficient between 0.551-0.996. The multivariate cluster analysis (CA) of the selected parameters in wastewater showed marked disproportion, manifesting the imbalance of these parameters in the wastewater. These parameters shared their clusters with one another showed mutual and exclusive relationship (Fig. 11).

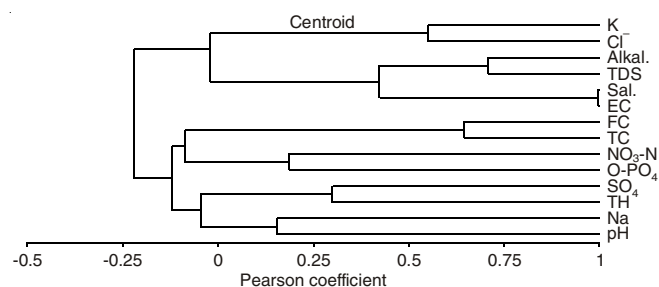


Fig. 11. Cluster analysis of the selected parameters in wastewater samples

Conclusion

In this study results of the analyzed parameters were compared with those of NEQS and WHO guidelines for wastewater. Sample S₁₁ (Sangot Kho Colony) and sample S₂₄ (Akson Pharmaceutical Industry) showed maximum value of TDS and EC. Total dissolved solids and EC were linearly correlated and about 75 % samples exceeded the maximum permissible limit of WHO. pH and nitrate-nitrogen in all samples of study area were within the range of standard desirable limits. Only 3 samples showed strong hardness. Alkalinity in 17 samples of study area exceeded the max permissible limit. Concentration of chloride and sulphates were comparable with each other and 12 samples of sulphate and 7 samples of chloride from study area exceeded the max permissible values. Major metal cations in both industrial and domestic wastewater followed the order Na > K. Concentration of sodium was investigated higher in 7 samples whereas potassium concentration was higher in 5 samples than permissible limits. All wastewater samples (industrial and domestic) indicated higher values of total coliform and fecal coliform within the ranges 200-520

and 180-320 MPN/100 mL, respectively. Drinking water samples also demonstrated the microbial contamination which was an indicator of the underground mixing of water supply system with sewage. All samples exceeded the WHO guideline value for bacteriological contamination which is Nil/100 mL. Presence of microbial contamination in drinking water at the consumer's and use of untreated industrial effluents and domestic wastewater for irrigation pose a serious threat to human health. A regular monitoring of drinking water and pre-treatment of the wastewater to be used for irrigation is recommended to minimize the health risk in the studied area.

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