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Assessing Pollution Levels in Effluents of Industries in City Zone of Faisalabad, Pakistan

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Abstract: In present study, assessment of the effluents from seven industries including ghee, Ni-Cr plating, battery, tannery: Lower Heat Unit (LHU), tannery: Higher Heat Unit (HHU), textile: Dying Unit (DU) and textile: Finishing Unit (FU) in city zone of Faisalabad, Pakistan showed that some of them were high in some water pollutants while some were high in other types of water pollutants. Environmental pollutants quantitatively analyzed include nickel, zinc, copper, iron, temperature, pH, conductivity, hardness, turbidity, salinity, sulfate, total acidity as $CaCO_3$, total alkalinity as $CaCO_3$, chloride, fluoride, Total Dissolved Solids (TDS), nitrate, nitrite, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), phosphorous, sodium, potassium, calcium and magnesium. The results of present study revealed that effluents from all industries causing severe toxic metal pollution. While analysis of physico-chemical parameters showed that although all industries causing some type of physico-chemical pollution but textile industry (FU) effluents were above permissible limits in most of physico-chemical parameters analyzed. These wastewaters are normally discharged into neighboring water bodies. The treatment of any form of waste before disposal into the environment is important and ensures safety of the populace and assessment of pollution caused by effluents is therefore necessary for appropriate selection of treatment plan.

Key words: Physico-chemical parameters, metal pollution, industrial effluents, water quality assessment

INTRODUCTION

Water is undoubtedly the most precious natural resource that exists on our planet. Although we recognize this fact, we disregard it by polluting our rivers, lakes and oceans. Subsequently, we are slowly but surely harming our planet to the point where organisms are dying at a very alarming rate. In addition to innocent organisms dying off, our drinking water has become greatly affected as is our ability to use water for recreational purposes. Discharge of toxic chemicals, over-pumping of aquifers, long-range atmospheric transport of pollutants and contamination of water bodies with substances that promote algal growth (possibly leading to eutrophication) are some of today's major causes of water quality degradation. It has been unequivocally demonstrated that water of good quality is crucial to sustainable socio-economic development[1]. Contamination of drinking water supplies from industrial waste is a result of various types of industrial processes and disposal practices. Industries which use large amounts of water in their processes (like steam production, as solvent, for washing purposes, as coolant, for rinsing, for waste disposal practices and for finishing operations etc.) include chemical manufacturers, steel plants, battery industry, metal processors, textile manufacturers, tanneries, ghee mills and Ni-Cr plating[2,3]. Much of the industrial wastewater in the Faisalabad is being used for agricultural purposes and then enters the food chain (which has man at its top). The discharge also enter river Cheenab by way of sloughs that lead directly to the river. The runoff from the industries negatively affects the water quality of the river, which affects the wildlife surrounding the river. The quality of water may be described in terms of the concentration and state (dissolved or particulate) of some or all of the organic and inorganic material present in the water, together with certain physical characteristics of the water[4]. In order to combat water pollution, we must understand the problems and become part of the solution. Industries which discharge a large quantity of untreated wastewater having diverse nature of pollutants into water bodies are main cause of water pollution in Pakistan. The effluents discharged by these industries consist of organic, inorganic chemicals and toxic metals[5]. Physico- chemical parameters cause the development of colour, bad odour, eutrophication and reduction of sunlight through water consequently affecting aesthetic quality of water. The heavy and trace metal present in polluted water enter into human body through food chain and may causes adverse affects[6]. Keeping in view adverse affects of physico-chemical and toxic metals a pressing need has emerged for comprehensive and

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accurate assessments of trends in wastewater quality, in order to raise awareness of the urgent need to address the consequences of present and future threats of contamination and to provide a basis for action at all levels. Reliable monitoring data are the indispensable basis for such assessments. This study was undertaken with objectives to quality assessment of effluents for irrigation purposes; to assess the level of physico-chemical parameters of industrial effluents and to assess the level of toxic metal ions in industrial effluents.

MATERIALS AND METHODS

Sample collection: The wastewater samples from seven industries viz., ghee, Ni-Cr plating, battery, tannery (LHU), tannery (HHU), textile (DU) and textile (FU) were selected for industrial wastewater quality assessment. The sites for sample collection were within city zone of Faisalabad, Pakistan. Each site was visited once a week and triplicate samples were collected from various parts of the system from all industries during one year period from August, 2004 to August, 2005. Samples were collected in polyethylene bottles[7] and placed in a cooler for transportation. Once all the samples were collected, they were brought back the Analytical Laboratory, located in Department of Chemistry, University of Agriculture, Faisalabad, Pakistan, where physico-chemical parameters, trace and heavy metals were analyzed in industrial effluent samples. All instruments used in this study were properly calibrated before analysis according to user manual.

Physicochemical parameters determination: Average value of three replicates was taken for each determination. Temperature (2550B), pH (4500-H^+B) and salinity (2520B) were determined using pH/conductivity meter (Innolab pH/Conductivity meter) immediately after collection of samples. Conductivity (2510B) was also determined by same meter but it was determined by cooling sample to 20°C. Hardness was determined from separate determination of Ca and Mg (2340B). Dissolved Oxygen (DO) and Biological Dissolved Oxygen (BOD) were determined by Dissolved Oxygen Meter Model Acorn DO6 using standard methods 4500-0G and 5210B, respectively. Chemical Oxygen Demand (COD) was determined using closed reflux method[9]. Turbidity was estimated by nephelometeric method using LaMotte 2020 Portable Turbidity Meter (2130B), total acidity as $CaCO_3$ and total alkalinity as $CaCO_3$ were estimated by titration standard methods 2310B and 2320B, respectively, Total Dissolved Solids (TDS) were determined by using standard method 2540C[8]. Chloride, fluoride, nitrate, nitrite, phosphorous and sulfate were determined by titration methods approved by UNEP/WHO[10]. Sodium and potassium were estimated by flame photometer (The Sherwood Model 410). Calcium and magnesium were determined using atomic absorption spectrophotometer (AAnalyst 300, Perkin Elmer)[11].

Trace and heavy metal analysis: Seven different industrial wastewater streams contaminated with various trace and heavy metals were evaluated for identification and quantification analysis of nickel, zinc, copper and iron using Flame Atomic Absorption Spectrometry (FAAS), using a Perkin-Elmer AAnalyst 300 atomic absorption spectrometer equipped with an air-acetylene burner and controlled by Intel personal computer. Average value of three replicates was taken for each determination[11].

Data evaluation: The statistical calculation was done according to the standard method. The results are given as mean±SD values[12].

RESULTS AND DISCUSSION

Physicochemical parameters: Temperature of effluents discharge by seven industries ranged from 30.67±0.01 to 54.76±0.01°C. While temperature of ghee mill (47.93±0.01°C), textile industry (DU, 43.87±0.02°C) and textile industry (FU, 54.76±0.01°C) recorded was much higher than permissible limit (<35°C) (Table 1). These industries are causing thermal pollution in water bodies. Thermal pollution can lead to decrease the dissolved oxygen level in the water while also increasing the biological demand of aquatic organisms for oxygen. Temperature of four other industries was comparable to permissible limit. pH of effluents from seven industries differed remarkably from each other which ranged from 3.06±0.01 to 12.4±0.01. Except Ni-Cr plating industry the effluent pH of all other industries are out of recommended permissible range (6.5-8.5). Most fish can tolerate pH values of about 5.0 to 9.0, but serious anglers look for waters between pH 6.5 and 8.2[13]. Conductivity of most industries was found in acceptable range. Recommended permissible limit for hardness, salinity, total acidity as $CaCO_3$, nitrite, phosphorous and potassium is yet not established, their data is presented in Table 1. Turbidity of tested industrial wastewater was found from 54±0.17 to 92±0.07 NTU which was quite above from recommended permissible limit of <5NTU. Turbidity effect fish and aquatic life by: Interference with sunlight penetration. Water plants need light for photosynthesis. If suspended particles block out light,

Table 1: Physico-chemical parameters assessment in effluents of industries in city zone of Faisalabad, Pakistan

Physico-chemical parameters	Permissible Limit (mg L^{-1})[a]	Ghee mill	Ni-Cr plating industry	Battery industry	Tannery industry (LHU)	Tannery industry (HHU)	Textile industry (DU)	Textile industry (FU)
Temperature (°C)	<35	47.93±0.01	30.67±0.01	31.67±0.02	35.81±0.01	35.97±0.01	43.87±0.02	54.76±0.01
pH	6.5-8.5	12.4±0.01	7.88±0.01	3.06±0.01	4.61±0.01	3.63±0.01	8.68±0.01	11.84±0.01
Conductivity (µS cm^{-1})	2500 (at 20°C)	2399.65±0.04	1876.34±0.03	2530.37±0.05	2265.15±0.07	3089.24±0.04	1420.63±0.05	3209.57±0.05
Hardness (mg L^{-1})	*	21.16±0.09	159.52±0.08	163.19±0.09	995.72±0.01	961.08±0.02	164.55±0.08	25.60±0.07
Turbidity (NTU)	<5	78±0.15	54±0.17	59±0.13	92±0.07	83±0.14	66±0.13	69±0.12
Salinity (ppt)	*	15.01±0.01	0.20±0.01	18.90±0.02	0.84±0.01	2.04±0.01	0.59±0.01	7.00±0.02
Sulfate (mg L^{-1})	250	275.46±0.23	906.36±0.45	843.62±0.69	545.15±0.46	689.91±0.42	834.25±0.58	943.26±0.69
Total alkalinity, mg $CaCO_3L^{-1}$	400	278.15±0.13	17.14±0.09	0.00±0.00	102.89±0.12	0.00±0.00	64.16±0.03	560.48±0.35
Total acidity as mg $CaCO_3L^{-1}$	*	2750.95±0.85	3100.98±0.69	6100.99±0.49	2850.49±0.97	5750.49±0.68	5100.49±0.93	2500.49±0.75
Chloride (mg L^{-1})	250	2380.56±1.12	860.45±0.92	140.15±0.52	60.15±0.12	80.45±0.17	1020.15±0.96	3960.48±1.95
Fluoride (mg L^{-1})	2	10.26±0.12	9.45±0.16	4.14±0.11	5.15±0.23	5.62±0.15	6.79±0.07	7.42±0.04
TDS (mg L^{-1})	500	3369.39±1.17	3226.45±1.25	3033.56±1.39	3546.48±1.25	4389.48±1.46	3050.11±1.02	5559.23±1.99
Nitrate (mg L^{-1})	45	3.26±0.01	2.73±0.01	2.03±0.01	2.45±0.02	2.43±0.02	1.09±0.01	3.56±0.02
Nitrite (mg L^{-1})	*	13.26±0.02	12.56±0.04	12.05±0.03	11.26±0.03	13.02±0.04	10.23±0.01	14.26±0.05
DO (mg L^{-1})	6-9.5	7.19±0.01	7.37±0.01	7.46±0.01	6.53±0.02	6.45±0.02	7.26±0.02	7.48±0.03
BOD (mg L^{-1})	<500	987.56±0.12	205.47±0.35	126.98±0.14	2558.46±0.96	2715.62±1.03	556.23±0.23	1412.23±0.86
COD (mg L^{-1})	<1000	2498.15±0.69	546.23±0.86	445.15±0.77	5456.78±0.96	5645.89±0.78	985.45±0.97	2365.84±0.94
Phosphorous (mg L^{-1})	*	2.13±0.01	1.98±0.01	2.36±0.01	2.98±0.01	1.05±0.01	1.14±0.01	3.04±0.01
Sodium (mg L^{-1})	20	203.95±0.23	106.53±0.14	73.61±0.09	215.11±0.13	243.76±0.17	208.65±0.59	256.68±0.34
Potassium (mg L^{-1})	*	166.28±0.06	49.09±0.01	52.92±0.01	102.12±0.01	115.31±0.02	177.32±0.02	189.69±0.02
Calcium (mg L^{-1})	*	5.68±0.01	28.51±0.01	9.29±0.01	337.70±0.02	321.80±0.06	11.05±0.01	0.34±0.01
Magnesium (mg L^{-1})	*	1.69±0.01	21.45±0.03	33.99±0.01	37.03±0.06	38.26±0.09	33.26±0.05	6.00±0.13

[a] Limits recommended for good quality domestic water. Limits suggested by U.S. Environmental Protection Agency; Drinking Water Regulations and Health Advisories, EPA 822-R-94-001, May 1994, * Limits not established, ± = SD

Table 2: Trace and heavy metal pollution assessment in effluents of industries in city zone of Faisalabad, Pakistan

Metal (mg L^{-1})	Permissible Limit (mg L^{-1})[a]	Ghee mill	Ni-Cr plating industry	Battery industry	Tannery industry (LHU)	Tannery industry (HHU)	Textile industry (DU)	Textile industry (FU)
Ni	0.10	34.89±0.01	183.56±0.01	21.19±0.01	43.29±0.02	47.26±0.06	31.38±0.01	31.09±0.01
Cu	1.30	0.02±0.01	0.89±0.01	72.26±0.01	0.05±0.01	0.04±0.01	0.155±0.01	0.60±0.02
Zn	5.00	1.89±0.04	2.09±0.03	27.55±0.05	0.89±0.07	4.69±0.04	0.29±0.05	8.13±0.05
Fe	0.30	0.93±0.01	6.32±0.02	91.11±0.06	0.76±0.01	5.23±0.01	1.43±0.1	1.90±0.01

[a] Limits recommended for good quality domestic water. Limits suggested by U.S. Environmental Protection Agency; Drinking Water Regulations and Health Advisories, EPA 822-R-94-001, May 1994, ± = SD

photosynthesis and the production of oxygen for fish and aquatic life will be reduced. If light levels get too low, photosynthesis may stop altogether and algae will die. Similarly when rate of photosynthesis decreased then O_2 concentration become lower and CO_2 concentration become higher[13].

Sulfate (545.15±0.46 to 943.26±0.69 mg L^{-1}) was above permissible limit of 250 mg L^{-1}. In industrial wastewaters containing sulphate localized corrosion of iron, steel and aluminium in plants and pipe work can occur through the action of sulphate-reducing bacteria. Alkalinity is not a pollutant. It is a total measure of the substances in water that have acid-neutralizing ability. Alkalinity is important for fish and aquatic life because it protects or buffers against pH changes (keeps the pH fairly constant) and makes water less vulnerable to acid rain. The main sources of natural alkalinity are rocks, which contain carbonate, bicarbonate and hydroxide compounds. Borates, silicates and phosphates may also contribute to alkalinity. Total alkalinity as $CaCO_3$ was found in range from 0 to 560.48±0.35 mg L^{-1} in industrial effluents tested. Only textile industry (FU) has higher value of Total alkalinity as $CaCO_3$ (560.48±0.35 mg L^{-1}) than recommended permissible limit of 400 mg L^{-1}. Recommended limit for chloride for good quality domestic water is 250 mg L^{-1} but effluents of ghee industry; Ni-Cr plating, textile industry (DU) and textile industry (FU) had more chlorides than recommended limit. Effluent of textile industry (FU) has extremely high value of chloride. Chloride becomes more toxic when they combined with other toxic substances such as cyanides, phenols and ammonia[14]. Fluoride (4.14±0.11 to 10.26±0.12 mg L^{-1}) was above permissible limits in all tested effluents. Excessive amounts of fluoride are perceptible and can cause tooth discolorations.

TDS varied industry to industry from 3033.56±1.39 to 5559.23±1.99 mg L^{-1}. While permissible TDS limit is 500 mg L^{-1}. Textile industry (FU) effluent showed maximum TDS value of 5559.23±1.99 mg L^{-1}. Nitrate were present under recommended range in all industrial effluents. DO in industrial effluents was in range from 6.45±0.02 to 7.48±0.03 mg L^{-1}. Numerous scientific studies suggest that 4-5 mg L^{-1} of DO is the minimum amount that will support a large, diverse fish population. The DO level in good fishing waters generally averages about 9.0 mg L^{-1}. The BOD is used as an approximate measure of the amount of biochemically degradable organic matter present in a sample. The permissible limit for BOD is <500 mg L^{-1}. Only wastewater from Ni-Cr plating and battery industry have BOD in recommended range. COD is a vital test for assessing the quality of effluents and waste waters prior to discharge. The COD test predicts the oxygen requirement of the effluent and is used for monitoring and control of discharges and for assessment treatment plant performance. COD value of effluents quite varied among industries with maximum showed by tannery industry (LHU). The impact of an effluent on the receiving water is predicted by its DO. This is because the removal of oxygen from the natural water reduces its ability to sustain aquatic life. The COD test is therefore performed as routine in laboratories of water utilities and industrial companies.

Trace and heavy metal: Concentration of Ni and Fe were above safe limits in all the effluents tested, while Cu and Zn varied from industry to industry. Higher values of Ni were found in the effluent of Ni-Cr plating industry (183.56±0.01 mg L^{-1}) while concentration level of Ni in the effluents of ghee mill (34.89±0.01 mg L^{-1}), battery industry (21.19±0.01 mg L^{-1}), tannery industry (LHU) (43.29±0.02 mg L^{-1}), tannery industry (HHU) (47.26±0.06 mg L^{-1}), textile industry (DU) (31.38±0.01 mg L^{-1}) and textile industry (FU) (31.09±0.01 mg L^{-1}) were low but above permissible limit of 0.10 mg L^{-1}. Nickel mainly affects the digestive tract and central nervous system. Nickel also has a cytotoxic effect. Like all metals, nickel acts as a so-called hapten[15]. Analysis showed higher concentration of Fe in battery industry, followed by medium concentration in Ni-Cr plating and tannery industry (HHU) while lower concentration in ghee mill, tannery (LHU), textile industry (DU) and textile industry (FU) but above permissible limit (Table 2) recommended by U.S. Environmental Protection Agency (1992). The effect of iron overload on some organs, such as the skin, is trivial, while hemosiderotic harm to others, such as the liver, can be fatal[16]. Only battery industry (72.26±0.01 mg L^{-1}) effluent was found to contain highly toxic concentration of copper. The effluents from other six industries had concentration of copper in recommended range. Copper in large amounts is extremely toxic to living organisms. The presence of copper (Cu) ion cause serious toxicological concerns, it is usually known to deposit in brain, skin, liver, pancreas and myocardium[17]. Zn was present above recommended permissible limit in effluents of battery (27.55±0.05 mg L^{-1}) and Textile (FU) (8.13±0.05 mg L^{-1}) industries, while effluents from all other industries were found to contain acceptable limit of zinc. High doses of zinc for long periods of time may lead to a lower concentration of plasma lipoproteins and decrease copper absorption[18]. Decreased copper status may also inhibit the transport of iron and as a result cause anemia[19]. Zinc also found to has adverse effect on the human skin as skin irritant.

Results obtained in this study revealed that concentration of toxic metals and physico-chemical parameters varied from industry to industry. In most of cases analyzed industrial effluent samples were found to be above permissible limits suggested by U.S. Environmental Protection Agency (1994). Although effluents discharged by all industries are causing serious pollution but effluent discharged by Textile industry (FU) is causing severe pollution in city zone of Faisalabad, Pakistan. In case of textile industry (FU) except nitrate and DO all other parameters which were analyzed during present study were found above recommended permissible limits. While in all other industries factors causing pollution are less as compared to textile industry (FU) but there contribution towards cause of pollution cannot be ignored because they are also causing severe pollution of some particular pollutants. The higher concentrations of these parameters are being discharged to Cheenab river and industrial wastewater is also directly used for irrigation purposes by farmers. Industrial wastewater can also be mixed up with ground water after leaching and may cause number of water born diseases. Therefore it is suggested that the treatment of industrial wastewater to remove or minimize pollution parameters before disposal into the environment is important and ensures safety of the populace.

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