Journal of Quality and Technology Management
Volume V, Issue I1, Dec, 2009, pg. 27-40

Quality Characterization and Magnitude of Pollution Implication in Textile Mills Effluents

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Abstract

Effluents from textile industries contain different types of dyes, which because of high molecular weight and complex chemical structures, show low level of biodegradability. Hence, direct deposition of these effluents into sewage networks, produce disturbances in treatment processes and exert pollution load on water bodies. Effluents from nine major textile industries in Karachi industrial areas (Sindh Industrial Trading Estate, Korangi Industrial Area, Landhi Industrial Trading Estate, Federal B. Industrial Area and North Karachi Industrial Trading Estate) were characterized for proposed effluent characterization. Seven of the measured parameters exceeded the limit set by the Pakistan Environmental Protection Agency. pH concentration exceeded in all the samples excepted Textile 9, while temperature was as well higher than the recommended limit, while biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total dissolve solids (TDS), and sulfide (S^{2-}) were higher by about 2-5 folds respectively. Oil and Grease detected in Textile 1, 2, 5 and Textile 7 samples higher than the limits, while in Textile 3, 6, 7 and 8 are within the limits. Ammonia (NH_3) was detected in all the samples within the limit, exceeded only in Textile 4 & 7. Color intensity is higher in all the samples (Textile 1- 9) by about 350 folds on the average. Chromium (Cr_{total}) and Iron (Fe_{total}) were detected in 20% samples were exceeded the limits. Manganese (Mn) and Zinc (Zn) was detected in 88 % samples were within the limits. Mercury (Hg) was detected in 100 % sample within the limits; Cupper (Cu) was detected in 55 % samples higher than the limits, exceeded 3 folds on the average. The present study is focused on the pollution implications of effluents from textile industries in the city because of the risk of human exposure and environmental degradation by this massive discharge effluent.

***Key Words**: Textile Effluent, BOD, COD, sulfide, TDS, pollution implication*

Introduction

The textiles mill actually represents a range of industries with operations and processes as diverse as its products (Nosheen et al, 2002). Industrial pollution is one of the problems presently facing Pakistan and several efforts are being vigorously pursued to control it in various industries spanning length and breadth of the country to see that people live in a disease free environment. Effluent generated by the textile industries is one of the important sources of pollution Increasingly stringent effluent discharge permit limitations have been put into effect The textile industry generally has difficulty in meeting wastewater discharge limits, particularly with regard to dissolved solids, pH, BOD, COD, sometimes, heavy metals and color of effluent (Chen et al, 2005)

Effluents from textile industries contain different types of dyes, which because of high molecular weight and complex chemical structures, show low level of biodegradability. Hence, direct deposition of these effluents into sewage networks, produce disturbances in biological treatment processes. These types of effluents produce high concentrations of inorganic salts, acidsand bases in biological reactors leading to the increase of treatment costs (Gholami et al, 2001).

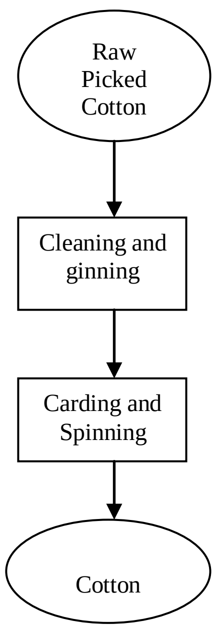
Industrial emission and waste effluent generated from factories are associated with heavy disease burden (WHO, 2000 and 2002) and this could be part of the reasons for the current shorter life expectancy, 61.4 years both for male and female in the country (WHO, 2003) when compared to the developed nations. Some heavy metals contained in these effluents (either in free form in the effluents or adsorbed in the suspended solids) from the industries have been found to be carcinogenic (Tamburlaine et al, 2002) while other chemicals equally present are poisonous depending on the dose and exposure duration (Lawrence and McCabe, 2002). These chemicals are not only poisonous to humans but also found toxic to aquatic life (WHO, 2000 and 2002) and potential sources of food contamination (Novick, 1999).

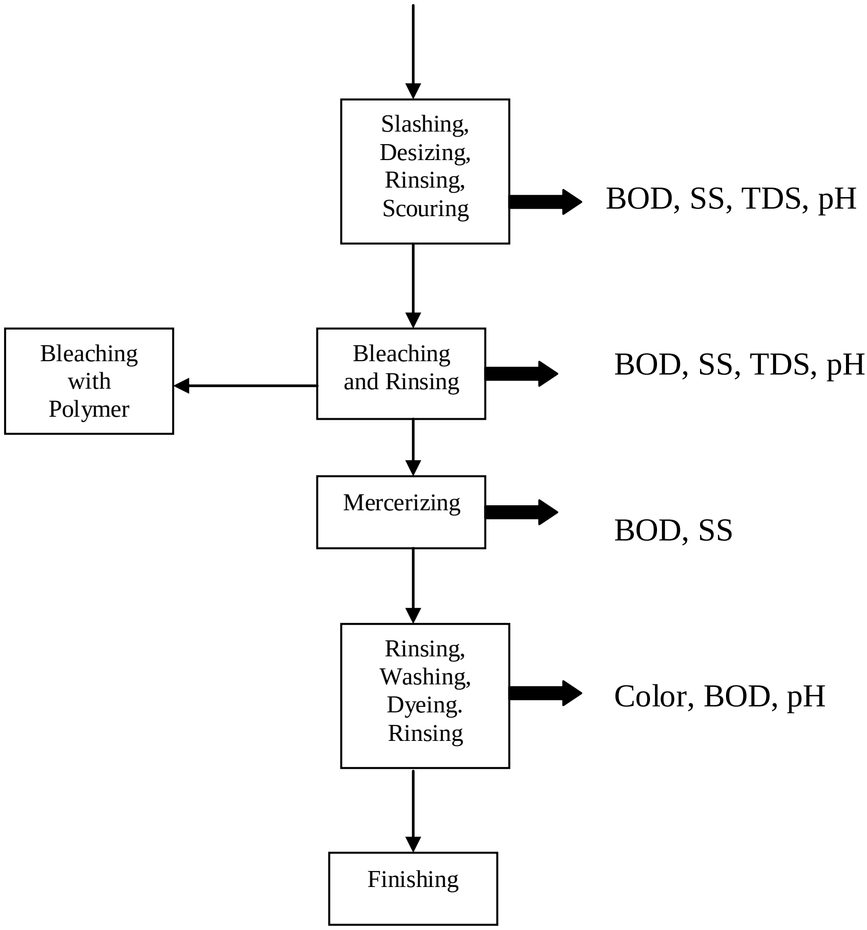
Ammonia is harmful to fish or other aquatic organisms at free (un-ionized) concentration of 10- 50 μg/L or higher pH and the sulphide in the effluent are of environmental concern (WHO, 2000 and 2002) because they can lead to poor air quality of an area if not properly taken care of thus becoming threat to human**s**, vegetation, and materials. The same is applicable to pH that has been identified to raise health issue**s** if water available for human use is not of the required pH level (WHO 1993). Textile industries are major sources of these effluents (Ghoreishi and Haghighi 2003) due to the nature of their operations which requires high volume of water that eventually results in high wastewater generation. They are one of the largest water users and polluters (Babu et al 2007). Karachi (Lat. 24.86 °N, Long 67.01 °E) located in Sindh Province occupies southern portion of Pakistan on the Arabian Sea northwest of the mouth of the Indus River (Nergis et al, 2000). As at 1998 (the last official censuses date in Pakistan) it had a population of 9,339,023 but currently projected to be home to about 12,315,843 people (TWG, 2008).

Industrially, it is one of the most developed cities in Pakistan and textile industries are some of its dominating industry. It is on record that the first industry in Pakistan was established in this city and this could be one of the reasons for its high population density (TWG, 2008). Malir and Lyari are major rivers in the city receiving effluents from these industries and draining in to Arabian Sea (Nergis et al, 2000). Both the rivers run across the entire city length carrying pollutants and dumping in to Arabian Sea. The City is characterized with high evaporation during the dry season. This could result in volatilization of chemicals in the effluents and release of heavy metals as particulates due to their adsorption on the effluents' solids. Thus, air quality around the banks of these Rivers and the entire city could be negatively affected. This calls for a proper treatment of effluents from the industries to be sure that environmental indicators do not exceed the set limit at any point in time. The textile industry is distinguished by raw material used and this determines the volume of water required for production as well as wastewater generated.

Production may be from raw cotton, raw wool, and synthetic materials shown in Figure 1. The nine major industries studied are raw cotton-based. In this type of production, slashing, bleaching, mercerizing, and dyeing are the major water consumption activities as well as wastewater generation shown in Figure 1.

Figure 1: Cotton Fabric Production and Associated Water Pollutants





The nature of the processing exerts a strong influence on the potential impacts associated with textile manufacturing operations due to the different characteristics associated with these effluents given in Table 1. Specific water use varies from 60-400 L/kg of fabric, depending on the type of fabric (Bruggen et al, 2001 and EPA, 1998). Every process and operation within a textile dyeing and finishing plant has an environmental aspect that should be considered and for which environmental pollution control strategies need to be developed. This is in addition to the input of a wide range of chemicals, which, if not contained in the final product, become waste treatment and disposal problems.

Table 1: Textile Industry Processes and Effluent Characteristics

Process	Effluent Composition	Pollutant Nature
Sizing	Starch, waxes, Carboxymethyl Cellulose (CMC), Polyvinyl Alcohol (PVA), wetting agents.	High in BOD, COD
Desizing	Starch, CMC, PVA, fats, waxes, pectins	High in BOD, COD, SS, dissolved solids (DS)
Bleaching	Sodium Hypochlorite, Cl_2, NaOH, H_2O_2, acids, Surfactants, $NaSiO_3$, Sodium Phosphate, short cotton fiber.	High alkalinity, high SS
Mercerizing	Sodium Hydroxide, cotton wax	High pH, low BOD, high DS
Dyeing	Dyestuffs Urea, reducing agents, oxidizing agents, Acetic acid, detergents, wetting agents.	strongly colored, high BOD, DS, low SS, heavy metals
Printing	Pastes, urea, starches, gums, oils, binders, acids, Thickeners, cross-linkers, reducing agents, alkali	highly colored, high BOD Oily appearance, SS slightly alkaline

Source: (Bruggen et al, 2001 and EPA, 1998)

Key environmental issues associated with textile manufacture are water use, treatment and disposal of liquid effluent shown in Table 3. The risk factors are primarily associated with the wet processes desizing, scouring, bleaching, mercerizing, dyeing and finishing. Desizing, scouring and bleaching processes produce large quantities of wastewater. Treatment for color removal can increase the risk of pollution. For instance, treating azo-dyes results in production of amines which could be a greater environmental risk than the dye itself. It is reported that textile effluents is **very low** in terms of LC50 and exhibit very high toxicity with acute toxicity unit (ATU) levels between 22 and 960 (Navarro et al, 2001). Dyes contributed to overall toxicity at all process stages. Also, dye baths could have high level of BOD, COD, color, toxicity, surfactants, fibers and turbidity, and contain heavy metals (EPA, 1998). They generally constitute a small fraction of total liquid effluent, but may contribute a high proportion of total contaminants. Note that textile effluents are highly colored and saline, contain non-biodegradable compounds, and are high in Biochemical and Chemical Oxygen Demand (BOD, COD) given in Table 3. It is reported that the presence of metals and other dye compounds inhibit microbial activity and some cases may cause failure of biological treatment system (Wynne et al, 2001). USEPA reported that the pollution parameters in textile effluents are suspended solids, BOD, COD, nitrogen, phosphate, temperature, toxic chemicals (phenol), chromium and heavy metals, pH, alkalinity-acidity, oils and grease, Sulphide, and Coliform bacteria (EPA, 1974). Pakistan Environmental Protection Agency also supported these and demands for their proper monitoring in the textile effluents in the country (PEPA, 2000). Textile effluents are high in BOD due to fiber residues and suspended solids (EPA, 1998). They can contaminate water with Oils & Grease, and waxes, while some may contain heavy metals such as chromium, copper, zinc and mercury (PEPA, 2000) Dyeing process usually contributes chromium, lead, zinc and copper to wastewater (Benavides, 1992) Copper is toxic to aquatic plants at concentrations below 1.0 mg/l while concentrations near this level can be toxic to some fishes (Sawyer and McCarty, 1978 and Nergis et al, 2005).

Methodology

All field meters and equipment shown in Table 2 were checked and calibrated according to the manufacturers specifications. The pH meter was calibrated using buffers of pH 4.0, 7.0 and 10.0; TDS/conductivity/salinity meter was calibrated using the potassium chloride solution provided by the manufacturer; the spectrophotometers were checked for malfunctioning by passing standard solutions of all the parameters to be measured; Blank samples (deionized water) were passed between every three measurements of effluent samples so as to check for any eventual contamination or abnormal response of the equipment. Reproducibility of results was regularly checked by carrying out periodic analysis of aliquots collected from one sample.

Table 2. Analytical Equipment and Materials Used in this Study

Sr. #	Apparatus/Equipment Description	Model	Manufacturer
1	Visible Spectrophotometer	DR 2800	HACH
2.	BOD Track	26197-01	HACH
3	COD Digestion Reactor	DRB280	HACH
4	Conductivity Meter	SensIon196	HACH
5	pH Meter	SensIon196	HACH
6	Dissolved Oxygen Meter	SensIon196	HACH
7	Electronic Balance	AB204-S	Metler Toledo
8	Digital Titrator	062	HACH
9	Incubator	205-2	HACH
10	Desiccators	-	Pyrex
11	Water De-ionizer	W400	Barloworld
12	Atomic Absorption Spectrometer	AA3100	Perkin Elmer

Fieldwork involved taking samples; points at which effluents discharge into drains for laboratory analyses. Two liters of each sample was taken in plastic containers and one liter per sample was taken in glass containers for BOD, Oil and Grease determination. The samples were taken during the period of heaviest activity corresponding to the highest volume discharge and hence the worst situation. There was a need for sample preservation and for all the parameters; recommended methods were used (APHA. 1998 and HACH, 1997). In-situ measurements for some of the parameters, pH and temperature were carried out using portable conductivity meter. Determination of other parameters {total dissolved solids (TDS), total suspended solids (TSS), color, ammonia, and Sulphide} was carried out in the laboratory using the spectrophotometers. Heavy metal (Cr, Cu, Fe, Mn, Zn) determination was carried out using Atomic Absorption Spectrometer (AAS), while Mercury was determined by mercury hydride (vapor generation) system. Oil & Grease concentration determination, gravimetrical method was used after solvent extraction with n-hexane. Chemical oxygen demand (COD) was determined by the dichromate digestion method while biochemical oxygen demand (BOD) was determined by the respirometric method (APHA, 1998).

Appraisal of Results

Generally the effluents characteristics need to be properly monitored for better environmental protection. All the textile mills had their effluents had temperatures between 34.7 and 47.8 ^{o}C given in Table 3 which are higher than the set limit by the National Environmental Quality Standards (PEPA, 2000), the pH range 7.75-11.61, calls for more attention. These effluents were basic in nature. The colors of all the effluents were very high in concentration. They ranged from 612-4637 Pt-Co with effluents from Textile 1, 3 and 4 having values above 100 PtCo. With the exception of wastewater from Tex 5 & 9 that has a TDS concentration of 3040 and 1056 mg/L the other effluents had TDS levels higher than the acceptable limit of 3500 mg/L. Though the total suspended solids levels in the effluent from Textile 2 and Textile 9 could be acceptable, the effluents from the other Tex had TSS levels more than 2 folds of the acceptable limit. Both measured BOD and COD levels also exceeded the set limits by about 2 and 10 folds respectively. Apart from Textile 2 and 9, the sulphide levels in the effluents were high (1.58-3.14 mg/L) as against the standard limit of 1 mg/L. Except Tex. 7, Ammonia levels were within limits in Textile 1-6 & 8-9, effluents 6.82-34.8 mg/L. Oil and grease was detected in the effluents from Textile 3,4,6,8-9 were below the 10.0 mg/L NEQS limit while in Textile 1,2,5&7 has higher than the limit. Heavy metals concentrations were higher than the set limits in the effluents shown in Table 4. Effluents samples had copper levels range between 0.07-5.14 mg/L as against lower set (less than 1.0) limit. While chromium was range between 0.5 to 1.57 mg/L, Text 1 and 4 has high concentration of 1.57 and 1.07, set limit is 1.0 mg/L, in nine of the textile effluents. Similarly Mn, Fe, and Zn concentration are within the limits except Text 1 and 2. Mercury was not detected in all the samples tested.

Table 3: Textile Mills Effluents Physico-chemical Characteristics

Analytes *N=45*	NEQS Limit	Tex. 1	Tex. 2	Tex. 3	Tex. 4	Tex. 5	Tex. 6	Tex. 7	Tex. 8	Tex. 9
Flow rate (M^3/day)	-	510.37±1.34	1,886.0±2.7	2,478.0±3.58	1,280.0±2.4	1,073±1.9	963±0.86	873±0.95	736±0.67	64.0±1.55
Temperature (°C)	40	47.8±4.8	41.7±3.66	43.5±5.2	45.7±7.9	44.6±2.7	42.8±1.64	46.3±3.4	41.9±2.8	34.7±2.2
pH Value (SU)	6-10	11.61±0.73	11.23±0.52	11.04±1.04	11.53±0.95	11.44±1.04	12.28±1.76	**12.76±0.83**	11.04±0.6	7.75±0.28
BOD_5	80	580±12	407±9.6	786±14.6	659±6.4	594±4.8	618±5.6	731±12.7	672±8.3	117±4.9
COD	150	2120±18.6 1	650±13.7	2430±24.6	2190±17.09	1586±12.0	1764±23.0	2184±9.7	1792±27	238±8.26
TSS	150	245±3.7	135±2.5	471±4.8	462±2.9	283±5.2	347±9.6	409±4.2	389±1.8	49±1.64
TDS	3500	7130±20.6	4200±13.41	1480±8.96	3848±12.68	3040±7.6	3970±11	2764±4.6	3926±16	1056±14.8
Oil & Grease	10	26.0±1.2	28.3±0.97	8.9±0.4	7.7±0.84	14.27±2.8	8.03±0.26	17.6±0.5	9.2±1.4	4.6±0.63
Ammonia	40	12.72±0.24	20.01±1.5	12.8±0.6	41.96±0.8	18.26±0.4	21.93±1.7	53.2±2.4	34.8±1.6	6.82±0.43
Sulphide	1.0	1.64±0.04	0.17±0.02	1.58±0.14	1.09±0.06	2.48±0.36	1.83±0.4	2.36±0.28	3.14±0.24	0.1±0.03
Chlorine (Residual & Total)	1.0	0.05±0.003	0.01±0.002	1.14±0.04	1.06±0.05	2.63±0.16	1.84±0.7	3.87±0.62	1.06±0.2	0.76±0.03
Color (Pt-Co)	-	2275±32.6	612±12.9	3537±23.8 4	637±31.7	4673±26	1164±13.8	1690±8	2014±18.6	103±4.6
Dissolved Oxygen	-	2.5±1.24	2.9±1.03	3.08±1.14	1.2±0.8	2.64±0.8	1.3±0.24	1.5±0.1	2.4±0.2	7.0±1.6

Tex.: Textile Mills 1 to 9, Units in mg/l unless otherwise stated.

Table 4: Heavy Metal Concentrations in Textile Mills' Effluents

Analytes *N=* 45	NEQS Limit	Tex. 1	Tex. 2	Tex. 3	Tex. 4	Tex. 5	Tex. 6	Tex. 7	Tex. 8	Tex. 9
hromium	**1.0**	1.57±0.24	0.97±0.11	0.18±0.03	1.07±0.17	0.725±0.02	0.863±0.046	0.493±0.04	0.962±0.02 8	0.5±0.06
opper	**1.0**	0.96±0.03	2.04±0.28	1.16±0.17	5.14±0.53	0.83±0.016	1.67±0.08	0.724±0.02	1.19±0.04	0.07±0.004
langanese	**1.5**	0.95±0.11	1.65±0.24	1.18±0.16	0.37±0.04	0.946±0.02	1.374±0.16	0.849±0.11	0.768±0.05	0.86±0.02
on	**2.0**	2.14±0.18	1.45±0.06	2.09±0.13	1.75±0.06	1.39±0.43	1.82±0.27	1.896±0.25	1.627±0.18	1.97±0.11
inc	**5.0**	6.48±0.85	4.33±0.69	2.36±0.17	3.08±0.24	4.39±0.37	2.84±0.18	3.972±0.44	4.754±0.36	2.19±0.08
lercury	**0.001**	ND	ND	ND	ND	ND	ND	ND	ND	ND

Tex.: Textile Mills 1 to 9, ND: Not detected in ppm, Units in mg/l unless otherwise stated.

Results and Discussion

The most important measure of water quality is the dissolved oxygen (DO) (Peirce et al, 1997). The low level of DO recorded could result in the non maintenance of conditions favorable to the aerobic organisms. This could lead to anaerobic organisms taking over with the resultant creation of conditions making the water body uninhabitable to gill-breathing aquatic organisms. Hydrogen Sulphide is formed under conditions of deficient oxygen in the presence of organic materials and Sulphate (WHO, 2000). This could be a possible reason for the high Sulphide measured in the effluents analyzed. The high levels of BOD are indications of the pollution strength of the wastewaters. They also indicate that there could be low oxygen available for living organisms in the wastewater when utilizing the organic matter present. High COD levels imply toxic condition and the presence of biologically resistant organic substances (Sawyer and McCarty 1978). The settleable and suspended solids are high and this will affect the operation and sizing of treatment units. Solids concentration is another important characteristic of wastewater (Lee and Lin, 1999). High alkalinity increases with wastewater strength. It shows the capacity of wastewaters to neutralize acids, and is undesirable. Heavy metals in the wastewaters could be of negative impact to the environment, trace heavy metal contamination of an area to industrial effluent (Sekhar et al, 2003). The negative impacts from textile mills effluents could be felt as far as all the regions covered by the River basin, the main receptor of these effluents. High heavy metal concentration has found in these rivers attributed this to industries. The textile industries which are some of the most active in the city could be one of the sources and this confirms the potential dangers associated with high copper levels detected in the effluents analyzed (Nergis, 2000).

In Pakistan, climate is determined primarily by the distance from the ocean to the secondary elevation hills and as such, the temperature is always warm and precipitation decreases from the coast (TWG, 2006) While high temperature increases evaporation rate of wastewaters thus polluting the air of an area, washout effect associated with rainfall (Jauregui and Luando, 1999) which is characterized by high precipitation, reduces air pollution. The two climatic conditions of Pakistan under which Karachi city falls is an indication that adequate efforts should be made to prevent air pollution. The natural cleansing of air pollution in the area could be low due to low precipitation and associated high wind speed while the reverse is the case for its air pollution inducing potential.

Detected effluents' parameters could be form gaseous emission and particulates the potential threat they pose to the environment especially around Lyari and Malir River basins calls for stringent control measure. Of the five world air pollution episodes, three of them 1930, 1948, and 1952, happened around riverbanks (EPA, 2008) supported by temperature inversions. Oil and grease, ammonia, sulphide, and color, are potential air pollution sources from these effluents. Meteorological conditions which include wind speed and annual average temperature (USEPA, 2002) are important factors. At any temperature, liquids can evaporate due to higher kinetic energy of some molecules. These molecules with higher kinetic energy will be able to escape the intermolecular attractive forces in the liquids and enter the gas phase. Evaporation increases as the liquid temperature increases due to the increased number of molecules with the necessary kinetic energy level to escape. This confirms that high temperature of city especially during the long dry season could increase the potential of the discharged effluents from the textile mills to pollute air in the environment. High color associated with these effluents should be adequately treated before discharge. The impacts of temperature on diffusivities both in the air and water (USEPA, 2001) could influence emissions of both ammonia and sulphide detected in the effluents while volatilization of oil and grease that could be induced by the same high temperature could introduce organic compounds into the environment thus polluting the air. When the effluents are discharged into the river, heavy metals present can be adsorbed on the river's soil and sediments and during the dry season, water evaporation could expose them to the environment. High TSS and TDS detected could be attributed to the high color (from the various dyestuffs being used in the textile mills) and they may be major sources of the heavy metals. Increased heavy metals concentrations in river sediments could increase suspended solids concentrations. During the dry season, the occasional dust re-suspension could introduce these metals into the atmosphere along with the particulates. With this, they could constitute health problems in form of air pollution. Some of the vapors formed above have great potential to nucleate thus becoming particulate problem to the environment. In addition to these are the products of reactions between some of the chemicals present in the effluents (Soldan, 2003) which may be toxic to the environment. Removal of the pollutants from these effluents is the only sure way of safer environment and this can be achieved by treatment to required level.

Conclusion and Recommendations

The qualities of effluents studied were grossly below the set limits by the Pakistan Environmental Protection Agency and some world bodies like the World Health Organization in all textile mills. The effluents are not uniform in characteristics and this may make it extremely difficult to use a central effluent treatment plant. Lower levels of some of these parameters in Text. 9 (with effluent treatment plant) when compared to the other four Text (with no effluent treatment plant) indicate that a uniform characteristics is attainable for or all the effluents if a measure of treatment is introduced at textile mills level. Lower levels of parameters could make the proposed central treatment plant cheaper to maintain even at greater efficiency. The results also show that air quality of the area covered by the entire city could be negatively affected by both the gaseous emissions and particulates which could be released from the effluents. Meteorological conditions of the area are strong influencing factors. Rainfall appears in city around July-August and retreats in September. The associated relatively high wind speed and low temperature during this period could lower air pollution problems but the situation may not be the same for the longer dry season. Incorporation of appropriate heavy metal recovery in the proposed central effluent treatment as proposed could be of great advantage for environmental protection especially around the river banks where animals do concentrate (Gaballah and Kilbertus, 1998). The impacts around these banks could be much (since it is the final receiving point of the effluents) if adequate measures are not taken before the final discharge.

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