Textile Effluents and Their Contribution Towards Aquatic Pollution in the Kabul River (Pakistan)

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Summary: Textile effluent is one of the major sources of pollution in the Kabul River at the North-West Frontier Province of Pakistan. Effluent samples from individual processes of a textile mill at Nowshera were chemically evaluated for organic strength, total solids, trace toxic metals and other common pollutants. The results have shown different parameters to be in the range; temperature 32-130°C, pH 8.05-11.38, electrical conductivity 400-16160 μ mhos/cm. Total solids, which were measured at 105°C, 180°C and 550°C were respectively in the range of 460-18080 mg/l, 250-1613 mg/l and 240-14460 mg/l. Total dissolved solids at 105°C, 180°C and 550°C were found in the range of 360-1506 mg/l, 220-13430 mg/l and 210-12740 mg/l respectively. Whereas, total suspended solids at these temperatures were found to be in the range of 100-3020 mg/l, 30-1670 mg/l and 30-1030 mg/l respectively. Chemical oxygen demand was in the range of 1500-4160 mg O_2/l. Total hardness was 70-290 mg/l, calcium 0-60 mg/l, magnesium 50-230 mg/l, sodium 40-3286 mg/l, potassium 12-236 mg/l, chloride 29-1018 mg/l, sulphate 529-2991 mg/l and sulphide 608-1832 mg/l. Trace toxic metals were found in the ranges; copper 0.04-0.17 mg/l, cadmium 0-0.16 mg/l, chromium 0.5-0.8 mg/l, nickel 0-0.04 mg/l, lead 0.07-0.14 and manganese 0.01-0.11 mg/l.

It was concluded that the textile industry under study discharges various pollutants in concentrations that are above the permissible limits laid down by the national and international standards. The textile effluents contain toxic metals, high oxygen demanding wastes and appreciable amount of sulphide. This study also indicates the presence and the deleterious effects of industrial pollutants in general and sulphide in particular, as alarmingly high concentration of sulphide (608 times higher than the permissible limit) being discharged into Kabul River. This could logically be linked with the substantial decrease in fish crop specifically at and down-stream of the discharging point, and overall reduction in fish population in the Kabul River.

Introduction

Kabul River is an easy mean of disposal of industrial effluents from a large number of industrial units situated along the river [1]. It has been reported [2] in a survey covering hazardous industrial units in North-West Frontier Province that there are 348 industries, which are within the Kabul River watershed. These include; 4 sugar mills, 2 distilleries, 3 ghee/oil factories, 5 textile mills, 2 woolen mills, 12 tanneries, 3 paper and board mills, 10 chemical and pharmaceutical factories, 4 match factories, 10 soap industries and numerous other industries with virtually no facilities of effluent treatment [2]. The industrial effluents from these installations have already contributed significantly in deteriorating the quality of not only the Kabul River water [1, 3-4] but the sub-surface water of the area as well. Probably, due to the similar reasons Pakistan was blamed by the United Nations [5] to be a "Polluters paradise."

The use of polluted waters has been reported to have adverse effects on the livestock and vegetation [6] and on soil and vegetation [7]. The implications of heavily polluted waters can be gauged with the fact that 40% of deaths in Pakistan are related to water borne diseases such as typhoid, diarrhoea, infective hepatitis etc. [8]. Although, Kabul River water is mainly used for irrigation, watering livestock, fishing, recreation, transportation, washing, bathing etc., the river is blamed for causing skin diseases in humans, maladies in livestock and periodic fish kills [2]. It has been reported [9] that Kabul River is no longer fit for drinking, its major

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tasks today are as a carrier of domestic and industrial wastes, and to provide water for irrigation. Previously, Karns [4], Khan *et al.* [10] and Akif and Khattak [11] have studied the impacts of industrial pollution on the receiving water bodies of different rivers including Kabul River. It has also been reported [1,3] that industries at Amangarh (Nowshera) come second after the Khazana Sugar Mills at Peshawar that pollute the receiving water of Kabul River due to discharge of high oxygen demanding wastes.

Although, paper/paper board mills are regarded as the main polluting industries of the Kabul River at Amangarh, very little work has been reported on the contribution of textile mills effluents with respect to their pollutional load and their impacts on the surface water bodies. This paper examines the adverse effects of the textile effluents at Amangarh (Nowshera) and their contribution on the aquatic pollution of the Kabul River.

Results and Discussion

Flow diagram (Figure 1) shows different processes involved in the manufacture of textile products. Before dyeing, two main chemical processes namely, scouring and bleaching are employed to remove impurities and colour from fabric materials so that appropriate surface could be prepared for subsequent dyeing and printing. The major chemicals that are used during these processes are soap, sodium silicate, caustic soda, hydrogen peroxide, oil and stabilisers whereas those commonly used in dyeing are different classes of dyes, formic acid, chenrite, glacial acetic acid, magnesium chloride, calsoline oil, starch, soda ash etc. Due to presence of these chemicals, effluents of a very complex nature can be expected from each process. The main drain, which collects the effluents of all processes, also receives wastewater from toilets before being discharged into the Kabul River.

All the effluents (Table 1) except that from bleaching had a higher temperature, ranging from 32 to 130°C, the temperature of the mixed effluent in the main drain was 50°C. The bleaching process was producing effluent of 32°C, which was within the permissible limit (40°C) of National Environmental Quality Standards (NEQS). Continuous discharge of hot effluents in appreciable quantity (0.12 million gallons/day) can result in decreasing the dissolved oxygen level in water bodies, which is regarded as very damaging to aquatic life and can destroy flora

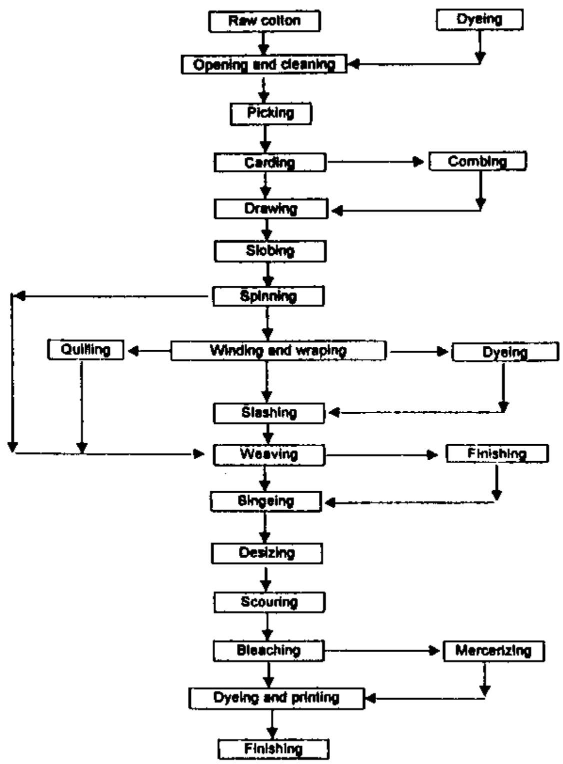

Fig. 1: Flow diagram of cotton textile

and fauna. The individual effluents from bleaching and cotton dyeing processes (Table 1) had pH of 10.18 and 11.38, respectively. These are also above the NEQS, however the combined effluent (pH 8.26) was within the permissible limit as NEQS range for pH is 6-10 (Table 2). Electrical conductivity of all the samples was in the range of 400-16160 μ mhos/cm. The permissible limit (for potable water) is 400 μ mhos/cm, however the threshold limit of this parameter for wastewater is not suggested in the NEQS. Effluent produced during the cotton dyeing had a very high conductivity (16160 μ mhos/cm) which was over 40 times higher than the permissible limit of potable water. This clearly indicates the use of different inorganic salts during the cotton dyeing process. The mixed effluent (Table 1) had lower conductivity (750 μ mhos/cm) compared to bleaching (2600 μ mhos/cm), the cloth dyeing (1730 μ mhos/cm) and the cotton dyeing (16160 μ mhos/cm).

Oxygen demanding wastes in all the processes (Table 1) were found quite high including the mixed effluent, the NEQS limit for the same is 150 mg O_2/l. Comparing COD values with the permissible limits

Table-1:Physico-chemical characteristics of the textile effluents

Parameters	Effluents				
	Scour wash	Bleaching	Cloth dyeing	Cotton dyeing	Mixed
Temperature (°C)	85.0	32.0	130.0	63.0	50.0
pH	8.05	10.18	9.5	11.3	8.26
Elect. conductivity (μ mhos/cm)	400	2600	1730	16160	750
Chemical oxygen demand COD (mg O_2/l)	1500	4300	2480	3320	4160
Hydroxide alkalinity as $CaCO_3$ (mg/l)	Nil	264.0	Nil	748.0	Nil
Carbonate alkalinity as $CaCO_3$ (mg/l)	Nil	Nil	4620.0	924.0	Nil
Bicarbonate alkalinity as $CaCO_3$ (mg/l)	924	Nil	1518.0	Nil	770.0
Total hardness as $CaCO_3$ (mg/l)	70.0	80.0	90.0	140.0	290.0
Calcium as $CaCO_3$ (mg/l)	20.0	Nil	Nil	Nil	60.0
Magnesium as $CaCO_3$ (mg/l)	50.0	80.0	90.0	140.0	230.0
Sodium as Na^+ (mg/l)	466.71	920.0	3286.7	4800.0	100.0
Potassium as K^+ (mg/l)	12.0	11.7	21.7	236.3	20.7
Chloride as Cl^- (mg/l)	29.1	48.5	630.5	1018.0	38.8
Sulphate as SO_4^{--} (mg/l)	926.0	1251.6	2951.0	2991.7	529.0
Sulphide as S^{--} (mg/l)	Nil	872.0	1088.0	1832.0	608.0

Table-2:National Environmental Quality Standards (NEQS) for municipal and liquid industrial effluents of Pakistan [14]

Parameter	Standards*
Temperature	40 °C
pH	6-10
5-days biochemical oxygen demand (BOD) at 20°C	80 mg O_2/l
Chemical oxygen demand (COD)	150 mg O_2/l
Total suspended solids (TSS)	150 mg/l
Total dissolved solids (TDS)	3500 mg/l
Chloride as Cl^-	1000 mg/l
Suphate as SO_4^{-}	600 mg/l
Sulphide as S^{-}	1.0 mg/l
Copper as Cu^{++}	1.0 mg/l
Cadmium as Cd^{++}	0.1 mg/l
Chromium (trivalent and hexavalent)	1.0 mg/l
Lead as Pb^{++}	0.5 mg/l
Nickel as Ni^{++}	1.0 mg/l
Manganese as Mn^{++}	1.5 mg/l

*Relevant to the existing studies

(Table 2); scour wash generated 10 times higher oxygen demanding wastes and bleaching 29 times. Inspite of dilution in the combined drain, which was caused by the wastewaters from individual processes, the COD of the mixed effluent (4160 mg O_2/l) did not decrease and it remained almost 28 times higher than the permissible level. The reason of this increase can partly be attributed to the presence of wastewater from toilets and partly the higher flow rate of bleaching effluent.

Mainly bicarbonate, carbonate and hydroxide ions cause alkalinities, although other ions can also contribute partially. pH and alkalinities are interrelated [12]. When pH is less than 8.3, presence of phenolphthalein alkalinity (commonly known as p-alkalinity) is unlikely. As such, both hydroxide and carbonate alkalinities [12] are minimal. In such a case, total alkalinity of a solution is solely due to bicarbonate ions. This effect is predominant in effluents from scour wash and mixed effluent. In both the cases, pH was below 8.3 and therefore the alkalinities were mainly caused by bicarbonate ions. Absence of hydroxide and carbonate alkalinities in the mixed effluent might be due to the possible precipitation of Ca as $CaCO_3$ that had previously occurred in effluents from individual processes. This effect is also apparent from the calcium concentration (Table 1) in effluents from bleaching, cloth dyeing and cotton dyeing processes where pH was also more than 8.3. The calcium concentration in the effluents of bleaching, cloth dyeing and cotton dyeing processes was therefore zero. This precipitation was facilitated by higher pH as well. On the other hand, the effluents from the scour wash and mixed effluent had 20 mg/l and 60 mg/l calcium as $CaCO_3$ respectively where pH in both the samples was less than 8.3. This argument is also supported by the fact that the overall hardness of effluents was quite low (Table 1) which substantiates the occurrence of precipitation, the values being in the range of 70-290 mg/l. All these values are however, within the NEQS (Table 2). The calcium concentration in the mixed effluent is higher than the sum of calcium concentrations in all processes. This could be due to the flow of wastewater from toilets, which result in increasing the calcium level. Magnesium in all the effluents was in the range of 50-230 mg/l (Table 1). Although, these values are within the limits, the combined effect of magnesium and sulphate can not be overlooked due to their synergistic effect, which imparts laxativity to water for human beings [13]. The sulphate concentration of individual processes remained very high, NEQS being 600 mg/l [14]. Keeping in view the synergistic effect of these ions, its long-term consequences on the water body of Kabul River would raise concern. This effect has previously been discussed by Khan *et al.* [13, 15]. It has been reported previously [3] that Kabul River water was more saline than the Indus River in terms of magnesium and sulphate, where their ranges were 55-225 mg/l and 57-226 mg/l respectively [3]. It is therefore very important to look at the existing pollution load of magnesium and sulphate, as these ions will further deteriorate the quality of Kabul River water. Sodium concentration in scour wash was 466.7 mg/l, bleaching 1920 mg/l and cloth dyeing 3286.7 mg/l. This was due to the usage of sodium salts including caustic soda. Potassium concentration was in the range of 11.7-236.3 mg/l. NEQS do not suggest any guidelines for Na^+ and K^+, therefore no comments can be made.

Sulphides are believed to have gills damaging effects which dies away after infection, therefore higher concentration of sulphide is detrimental to fish population [12]. All the individual textile effluents except the scour wash (Table 1) had a very high sulphide concentration (608-1832 mg/l), the permissible limit being 1.0 mg/l (Table 2). It can be concluded that these effluents can be regarded as the only detrimental source of pollution, which can eradicate fish population from a quite longer stretch of River Kabul.

Table 3 shows concentration of the total suspended and dissolved solids. At 105°C and 180°C, moisture and only highly volatile organics are respectively removed whereas, the solids determined at 550°C gives a collective concentration of both fixed and volatile solids [12]. Volatile solids may be mainly organic matters, although partially it may also be the weight lost due to decomposition or volatilisation of some mineral salts [12]. Total dissolved solids (Table 3) are higher than the NEQS permissible limit in the effluent discharged from bleaching and cotton dyeing processes. The NEQS allow up to 3500 mg/l for TDS (Table 2). Cotton dyeing process produced around four times higher dissolved solids than the permissible limit. Effluents from scour wash and cloth dyeing and the mixed effluents were found to have solids within the limits. The mixed effluent had a quite low concentration of dissolved solids. This indicates a removal of not only inorganic but some organics as well, by processes like adsorption or coagulation/precipitation that could occur in the drain carrying mixed effluent. As a result, organics in TDS was reduced from 825 mg/l to 295 mg/l (Table 3). The biodegradability of these organics in the mixed drain seems unlikely; as COD (4160 mg O2/l) of the mixed effluent did not reduce. A similar trend can also be seen in the TSS. TSS (Table 3) in the effluents from bleaching and cotton dyeing processes were 9 to 20 times higher than the NEQS permissible limits of 150 mg/l. These concentrations were however reduced significantly to 495 mg/l when all the effluents reached in the main drain. This clearly substantiates the process of coagulation/precipitation. Re-examining Table 1, it is apparent that bleaching and cotton dyeing effluents had higher pH (10.18 and 11.38, respectively) and pH > 8.5 favours coagulation [16].

Heavy metals are toxic by nature due to their bioaccumulation and slow excretion [17, 18]. Table 4 shows the concentrations of different heavy metals in the textile effluents. All the values were found within the limits excepts cadmium (0.16 mg/l) in the scour wash. The concentration of cadmium was however below detection limit in the mixed effluent. The NEQS allows only 0.1 mg/l as total of the heavy metals concentrations in effluents. As indicated in Table 5, cadmium is not only toxic to aquatic biota but it can impair kidney and testicular tissue and may damage red blood cells [17, 18]. Heavy metals especially cadmium is extremely toxic to aquatic biota at very low concentrations. The acute toxicity of cadmium as 96 hours lethal concentration (LC_{50}) for some of the test species like, *Daphnia magna* and Rainbow trout was 0.29 (g/l and 0.04 (g/l [19] respectively. This is in fact a very low concentration,

Table-3: Solids concentration in textile mills effluents

Parameters	Temp.(°C)	Effluent: Scour wash	Bleaching	Cloth dyeing	Cotton dyeing	Mixed
	105	460	7510	1710	18080	1320
Total solids (mg/l)	180	250	7190	1520	16130	850
	550	240	6090	940	14460	550
	105	360	6200	1550	15060	825
Total dissolved solids (mg/l)	180	220	6161	1400	14910	428
	550	210	5080	840	14170	295
	105	100	1310	220	3020	495
Total suspended solids (mg/l)	180	30	1030	120	1670	422
	550	30	1010	100	1030	255

Table-4: Concentration of heavy metals in textile mills effluents

Metal ion	Effluent samples			
	Scour wash	Bleaching	Cotton dying	Mixed effluent
Cu^{++}	0.17	0.17	0.04	0.07
Cd^{++}	0.16	BDL	BDL	BDL
Cr^{++}	0.62	0.70	0.80	0.50
Pb^{++}	0.14	0.14	0.07	0.07
Ni^{++}	0.04	0.01	Nil	0.01
Mn^{++}	0.11	0.12	0.05	0.01

BDL: Below detection limit

Table 5. Toxic elements in natural waters, their sources and significance

Elements	Sources	Effects and significance
Copper [18]	Metal plating, industrial and domestic waste, mining, mineral leaching	Essential trace element, not very toxic to animals, toxic to plants and algae at moderate level
Cadmium [18]	Industrial discharge, mining waste, metal plating, water pipes	Replaces zinc biologically, cause high blood pressure kidney damage, destruction of testicular tissue and red blood cells, toxicity to aquatic biota
Chromium [19]	Industrial discharge, tannery, chromium plating, steel alloy industries	Helps in fat and carbohydrates metabolism in most organisms, chromate cause irritation in eyes, noise and throat, and may damage liver and kidney on chronic exposure, causes perforation in nasal septum and chromosome abnormalities in humans.
Lead [18]	Industry, mining, plumbing Coal, gasoline	Toxic (anaemia, Kidney diseases, nervous disorder), wild life destroyer.
Nickel [19]	Nickel plating industries, effluents from ghee industries and Ceramic industry.	Dermatitis and respiratory disorders in animals, causes enzyme inhibition.
Manganese [19]	Steel industry	Biologically an essential microneutrient for most organism. Causes cramp, tremors, hallucinations, manganic pneumonia and renal degeneration.

therefore any mismanagement with regard to Cd^{++} discharge can be lethal to the ecosystem of Kabul River water. This risk will remain as long as the cadmium containing effluents are discharged without any prior treatment therefore persistence of this risk can not be over looked.

Table 6 shows a comparison of the pollutional load in effluents of the textile mills in Pakistan (personal communication). The data indicate that the textile mills at Nowshera discharge a warmer effluent (50°C) than most of the mills indicated (Table 6). COD (4160 mg O_2/l) were also found several folds higher than most of the mills except Adamjee Mills Karachi where it was 5530 mg O_2/l. Comparing the data of Table 6 in the light of NEQS it is apparent that the effluents of the textile mills under study had a higher temperature, suspended solids and very high COD.

Experimental

All the reagents were of analytical grade and were used without further purification. Standard methods [12] were employed for all the analyses. Samples were collected in plastic bottles, which were washed with hot water, followed by distilled water and finally with the sample. Samples for heavy metals were collected in separate one liter capacity plastic bottles and 5 ml of conc. HNO_3 was added to avoid any possible adsorption on the internal walls of the container. Samples for sulphide were separately collected and their sulphide was fixed with 1-1.5 ml zinc acetate solution on spot.

The temperature, pH and electrical conductivity of the samples were measured on spot, using a centigrade thermometer, a stick type pH meter (Gallenkamp, England) and a conductivity meter (HI 8033, Hanna Instruments, Italy) respectively. A flame photometer (PFP 7 Jenway, London) was used for the measurement of sodium and potassium. Open reflux method was used for the determination of COD. Polarized Zeeman Atomic Absorption Spectrophotometer (Z-8000, Hatachi, Japan) was used for the estimation of heavy metals. Oven (210, Memmert, Germany,) and furnace (Thermolyne 1500) were respectively used for drying and ignition of samples. Whatman 42 ashless filter papers were used throughout the studies.

Table 6. Comparison of effluents pollution load among different textile mills in Pakistan

Textile mills	Discharge (million gallons/day)	Temp. (°C)	pH	TSS (mg/l)	COD (mg O_2/l)	Organic loading rate (lb. BOD/day)
Adamjee Mills Karachi	0.45	45	10.3	1390	5530	750
Colony Textile Mills Multan	3.45	51	8.0	608	231	6650
Crescent Textile Mills Faisalabad	0.47	42	7.9	275	514	2000
Govt. Weaving and Finishing Centre Shahdara, Lahore	0.08	31	7.8	1724	453	305
Textile Mills Amangarh, Nowshera (This study)	0.12	50	8.26	495	4160	-

Conclusions

These studies conclude that the effluents of the textile mills at Nowshera had a higher temperature, suspended solids, dissolved solids, oxygen demanding wastes and over 600 times more sulphide concentration than the NEQS. All these parameters collectively contribute towards reduction in the fish population in the Kabul River. As a result, the natural spawning process of fish and their migration can be disturbed. The presence of very high oxygen demanding wastes can reduce the DO level and higher TSS can cause turbidity in the receiving water causing a localized pollution especially at the vicinity and down stream of discharge and can detract the aesthetic look of the river. Proper on-site treatment of industrial wastewater is vital to be installed. Furthermore, implementation of NEQS with full force is highly inevitable.

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