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Physicochemical Characterization and Heavy Metal Concentration in Effluent of Textile Industry

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Abstract:

Water pollution caused by the textile industry is mainly by the release of waste streams coming out from wet processing operations like scouring bleaching, dyeing and printing etc. Due to this chemical pollution, the normal functioning of cell is disturbed and this in turn may cause alteration in physiology and biochemical mechanisms of animals resulting in impairment of important functions like respiration, osmoregulation, reproduction and even mortality.In the present investigation, the concentration of selected heavy metals and physicochemical characteristics of the effluent samples were evaluated to ascertain the efficiency of industry's waste water treatment process. Conventional methods were employed for determination of physicochemical parameters while, heavy metals in the effluent samples were analyzed using an atomic absorption spectrophotometer. The results obtained from the physicochemical analysis of all the samples of effluent indicated high temperatures, alkaline pH, and foul smell and were highly colored. The TSS values in all the samples and TDS values in some samples were also very high. All the samples except one sample have high microbial load which reflects in their high BOD values. The COD values of all the samples were very high indicating high degree of pollution. The results also showed elevated levels of inorganic metals. The concentration of heavy metals also has great variability. Thus textile effluent was a major source of water pollution which will affect the flora and fauna existing in such environments. This study anchors on the need for treatment textile effluent before they are discharged into the environment.

Keywords: Heavy metal, Pollution, Textile Industry Effluent, Physicochemical Parameter

1.0 Introduction:

With escalating demand for textile products, the textile mills and its waste water have been increasing proportionally, making a major problem of pollution in India. Nature has an amazing ability to cope up with small amount of water wastes and pollution, but it would be hazardous or harmful if billions of gallons of waste water produced everyday are not treated before releasing them back to the environment. The quantities and characteristics of discharged effluent vary from industry to industry depending on the water consumption and average daily product. Untreated or incompletely treated textile effluent is notoriously known to contain i) large amount of total suspended solids which increases the turbidity in water and prevents the light from reaching aquatic plants and animals, ii) large amount of total dissolved solids limiting the industrial and agricultural use of water, iii) high levels of chemical oxygen demand (indicating high degree of pollution) and biological oxygen demand (leads to lowering of the level of dissolved oxygen thereby inhibiting aquatic habitats) and iv) elevated temperatures which lower the rate of dissolution of atmospheric oxygen in the water and affects the sustainability of the aquatic habitats due to reduction in the level of the dissolved oxygen.[1] It also causes problems of foaming and color persistence, having a highly fluctuating pH affecting the solubility and chemical forms of most substances in water. Most of the heavy metals are essential for growth of organisms but are only required in low concentrations.[2] The increasing concentration of heavy metals leads to bioaccumulation of metals in fauna and flora if the rate of uptake of heavy metals by the organisms is more than the excretion phase. Heavy metals are not biodegradable so they accumulate in primary organs in the body and over time begin to fester, leading to various symptoms of diseases.[3] Thus, untreated or incompletely treated textile effluent can be harmful to both aquatic and terrestrial life by adversely affecting on the natural ecosystem and long term health effects. The aim of this study was to examine the physicochemical properties and heavy metal levels of effluent discharged by Sumukh textile mill, Vapi, Gujarat, India. The study

was also carried out to determine the efficiency of industry's treatment process.

2.0 Materials and Methods:

2.1 Collection of Effluent Samples:

The sampling was carried out in September, 2011. The sampling site in the present paper is a local textile mill (STM) located in Vapi. Samples were collected from the different sites of the selected area in a wide mouth polyethylene bottle. Reference water sample was taken from a pond, 3 km away from the mill area. One portion of each effluent sample was immediately preserved with concentrated nitric acid for heavy metal analysis. After acidification the samples were stored at 4^{o} C in refrigerator to prevent change in volume due to evaporation.

2.2 Chemicals:

All the chemicals used in the study were of analytical grade and were procured from Merck (Mumbai, India).

2.3 Sample Analysis:

Temperature, pH, colour and smell of the samples were recorded on the spot from where the samples were collected. Temperature was measured using mercury thermometer graduated from 0^{o} to 100^{o} C. pH was determined using portable pH meter. COD and BOD were determined instantly after bringing the samples to laboratory. COD was measured using COD instrument directly. The Wrinkler method was adopted for measurement of BOD values of the collected effluent samples.[4] Electrical conductivity was measured with a Philips PW 9526 digital conductivity meter. TSS and TDS were evaluated using filtration and evaporation (at 105^{o} C) extraction process respectively with hot air oven.[5] Analysis of different metal ions in the effluent samples was determined by Atomic Absorption Spectrophotometer as per the standard methods.

2.4 Statistical Analysis:

The data are represented as mean ± standard deviation. All the data were analyzed statistically applying student't' test, for all the studied parameters.

3.0 Results and Discussion:

Effluent samples were analyzed for different physiochemical parameters, including metal ions discharged into waste water as shown in Table 1, 2 and 3. Temperature of all effluent samples showed significant ($p < 0.05$) variations. Samples from site 2 and 4 had temperatures above the permissible limits (40^{0} C) for industrial effluent discharged. It havebeen reported that textile and other dye effluents are produced at relatively high temperatures.[6] Reports are also available that the bio-chemical reactions of aquatic organisms are temperature dependent.[3] Increase in temperature of water body will promote chemical reactions in the water.

pH of all the samples was slight to moderate basic in naturewith not significant differences among various sites. pH of sample 1, 2, 3 and 4, were not within the range of recommended pH standard limits (6.0 to 10.0). Effluents of other textile and dye industry showed similar pH trend, as seen in the present study, being alkaline in nature.[7,8] One of the author corroborated the fact that metabolic activities of aquatic organisms are also dependent on the pH values.[9] However, EC values of all samples were significantly different ($p < 0.05$), except for samples from site 3 and 5. Conductivity is measured to establish the pollution zone around an effluent discharge.[10] TSS in effluent samples was high among all the samples, as compared to the reference water sample, as well as the standard limits (150.0 mg/L). TDS of some samples in the study under discussion were exceeding the standard limits. The colors of the effluent samples were several times higher than the allowable limit with high COD and BOD. COD of all samples was also very high indicating high degree of pollution. Similar findings, regarding high COD of effluent discharge from a cluster of small scale cotton textile units were observed.[11] Student's t-test revealed significant ($p < 0.05$) differences in the BOD of all the samples. BOD of all the samples, except sample from site 2, was exceeding the permissible standard limits. These results are in line with the work of other author on textile effluent in India, with BOD ranging from 400-1000 mg/l.[8] High BOD reflects high concentrations of substances that can be biologically degraded, thereby consuming oxygen and potentially resulting in dissolved oxygen.

Table 1: Physicochemical characterization of effluent samples from various sites (mean of 3 analysis). Means sharing common letter do not differ significantly, others differ significantly ($p < 0.05$).

Site	Temperature °C	pH	EC mS/cm	TSS* (mg/L)	TDS* (mg/L)	COD (mg/L)	BOD (mg/L)	Colour	Odour
11	33.69 ±0.19 a	12.22 ±0.05 a	3.42 ±0.12 a	419.87 ±0.07 a	2458.66 ±0.20 a	1726.52 ±0.20 a	563.78 ±0.08 a	Brown	Fishy
22	50.67 ±0.05 b	12.53 ±0.05b	6.55 ±0.15 b	760.41 ±0.14 b	4975.20 ±0.07 b	449.50 ±0.15 b	71.75 ±0.12 b	Brown	Fishy
33	31.53 ±0.11 c	12.36 ±0.09 ac	2.59 ±0.09 c	527.61 ±0.13 c	4934.70 ±0.08 bc	2078.55 ±0.18 c	852.63 ±0.19 c	Dark mauve	Pungent
44	43.43 ±0.08 d	12.7 ±0.09 bd	5.55 ±0.03 d	527.61 ±0.13 cd	3850.23 ±0.03 d	1692.41 ±0.03 d	373.61 ±0.06 d	Brown	Pungent
55	30.50 ±0.04 e	9.17 ±0.06 e	2.15 ±0.04 ce	1545.68 ±0.13e	1279.33 ±0.07 e	1088.62 ±0.13 e	243.54 ±0.14 e	Dark grey	Fishy
76	32.76 ±0.05 f	9.29 ±0.04 ef	1.34 ±0.03 f	1549.49 ±0.09 f	1235.58 ±0.17 f	1036.76 ±0.13 f	233.61 ±0.13 f	Black	Fishy
R*	28.04 ±0.05 g	7.92 ±0.02 g	0.59 ±0.02 g	40.59 ±0.25 g	201.45 ±0.23 g	31.49 ±0.24 g	22.06 ±0.17 g	Clear	None

*TSS = Total Suspended Solids, TDS= Total Dissolved Solids, R= Reference water sample (pond)

Table 2: Inorganic elements present in effluent at various sites (mean of 3 analysis). Means sharing common letter do not differ significantly, others differ significantly ($p < 0.05$).

Site	Sodium (Na)	Potassium (K)	Phosphorus (P)
1	155.56 ± 0.15 a	54.83 ± 0.37 a	0.17 ± 0.01 a
2	259.06 ± 0.45 b	113.64 ± 0.19 b	0.41 ± 0.15 b
3	183.46 ± 0.18 c	93.7 ± 0.02 c	0.44 ± 0.10 c
4	151.44 ± 0.20 d	40.50 ± 0.22 d	0.65 ± 0.04 d
5	86.32 ± 0.07 e	64.61 ± 0.17 e	2.35 ± 0.02 e
6	87.67 ± 0.14 f	63.42 ± 0.15 f	1.27 ± 0.02 f
R	43.77 ± 0.02 g	24.71 ± 0.11 g	0.05 ± 0.02 g

Na concentrations in the effluent samples were high in the present investigation which is one of the consequences of textile processing.[12] Effluent samples also contained high concentrations of K and P, as compared to the reference water. It was studied that the effect of effluent used to irrigate an orchid, which was high in P and K levels.[13] When samples were assessed for metal ion concentrations, the heavy metals Cu, Mn, Cd, Ni, Zn and Fe were all above the recommended standard permissible range in the two samples of the reservoir (samples from site 5 and 6). All the samples collected exhibited elevated levels of Cr. The levels Pb in all the samples were below the standard limits. It have been reported that the major problem associated with textile processing effluents is presence of heavy metal ions, which arise from material used in the dyeing process or in a considerably high amount, from metal containing dye.[14]

Table 3: Metal ions (mg/L) present in effluent at various sites (mean of 3 analysis). Means sharing common letter do not differ significantly, others differ significantly ($p < 0.05$)

Site	Zn	Cu	Fe	Mn	Ni	Cd	Cr	Pb
1	0.48 ±0.08 a	0.51 ± 0.07 a	0.41 ± 0.03 a	0.36 ± 0.02 a	0.62 ± 0.03 a	0.06 ± 0.00 a	1.16 ± 0.00 a	0.16 ± 0.00 a
2	0.88 ±0.05 b	0.39 ± 0.08 b	0.71 ± 0.04 b	0.38 ± 0.01 ab	0.18 ± 0.00 b	0.02 ± 0.00 b	1.16 ± 0.02 ab	0.35 ± 0.01 b
3	1.21 ±0.06 c	0.17 ± 0.00 c	0.30 ± 0.03 c	0.33 ± 0.07 c	0.06 ± 0.00 c	0.06 ± 0.00 ac	1.49 ± 0.02 c	0.35 ± 0.01 bc
4	0.60 ±0.06 d	0.17 ± 0.00 cd	0.38 ± 0.05 d	0.07 ± 0.00 d	0.06 ± 0.01 cd	0.06 ± 0.01 acd	1.31 ± 0.03 d	0.16 ± 0.01 d
5	6.55 ±0.02 e	9.26 ± 0.04 e	111.38 ± 0.12 e	7.74 ± 0.08 e	1.15 ± 0.01 e	0.72 ± 0.01 e	2.20 ± 0.03 e	0.24 ± 0.00 e
6	7.32 ± 0.1 f	7.51 ± 0.07 f	110.64 ± 0.24 f	7.53 ± 0.02 ef	1.16 ± 0.00 ef	0.74 ± 0.02 f	2.19 ± 0.02 f	0.23 ± 0.01 f
R	0.15 ±0.02 g	0.15 ± 0.01 g	0.17 ± 0.01 bg	0.43 ± 0.02 g	0.02 ± 0.00 g	0.00 ±0.00 bg	0.01 ±0.00 g	0.00 ±0.00 g

4.0 Conclusion:

This study has shown that Sumukh textile mill discharges effluent with high degree of alkalinity, metal ion concentrations, high COD and BOD values which are not in compliance with standards. This questions the functionality of the treatment plants in the company. This study reveals that effluent from Sumukh textile mill was highly polluted; there is urgent need to follow adequate effluent treatment methods before their discharge to surface water for reducing their potential environmental hazards. Strict environmental laws become imperative so as to curb this stress.

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