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Physicochemical Characterization of Textile Effluent from A Dying Industry in Tiruppur of Tamil Nadu

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ABSTRACT

Paramount water pollution in a number of lentic systems is caused by textile and dye industries that discharge various chemical contaminants through effluents. For the present study, effluent samples were collected in situ from the outlaw of a textile dying factory in Tiruppur, that discharge effluents, claimed to be treated, into River Noyyal a tributary of Kaveri River. Effluent was collected from three stations, station I in the vicinity of the source and station II and III, located 10 and 20 meters away from the source respectively. The current work focused on the quantification of physical characteristics, chemical components, mineral and heavy metal contaminants in the dying industry effluent. Physical attributes like turbidity, electrical conductivity and TDS were above permissible limits. Chemical factors like free ammonia, DO, COD and BOD fluctuated significantly from the permissible limits. Minerals like Mg, NO_3, Na, K_1SO_4 and Cl were present in concentrations above the permissible limits. Heavy metals like Al, Cd, Cr, Fe, Fb, Co, Ag and Mg were recorded in significantly high concentrations. Addition of this effluent into the water body is injurious to human beings and to the riverine biota.

Keywords: *Textile dyes, Effluent, Physico - Chemical Parameters, water quality, heavy metals, water pollution.*

1. INTRODUCTION

Water pollution in aquatic systems can be attributed to industries that release various chemical contaminants along with their generated effluents [1]. Further environmental damage effects are caused by sludge, oil spills, leakages, and industrial discharge [2]. Toxic substances in untreated or partially treated effluents negatively impact all forms of life once discharged [3,4]. Pollutants also negatively impact ground water when their components leach into the soil [5]. Approximately 70% of industrial waste generated in developing nations is reportedly released without treatment [6].

Textile dye effluents discharged into water bodies decrease water transparency, which in turn lowers the dissolved oxygen concentration affecting aerobic [7]. High nitrogen levels in textile industry effluent can cause eutrophication in closed water bodies. Apart from highly toxic heavy metals like chromium (Cr), dye house effluents primarily contain other chemical impurities. These include inorganic salt cations such as Fe, Zn, Cu, Ca and Na as well as anions like SO_4^{2+}, NO_3^-, PO_4^{2-} . These substances negatively affect parameters like Dissolved Oxygen (DO), Total Suspended Solids (TSS), and Total Dissolved Solids (TDS) [8]. Dyes contribute to the overall toxicity at all processing stages, leading to a high level of BOD, salinity, colour, surfactants, fibers, heavy metals and turbidity. Characterization of textile wastewater is very important to develop strategies for water treatment and reuse.

In the modern world, effluent from the dyeing industry has become a difficult problem. Since dyes have numerous uses it is anticipated, that its manufacturing would increase eventually. Due to the various applications an annual growth in dye output is anticipated [9]. Each year, research identifies over 10,000 commercially available dyes [10]. These dyes are employed in the manufacturing of carpets, textiles, food, paper, pharmaceuticals, and leather. Factory wastewater is responsible for human mutation, allergic dermatitis, skin irritation and environment pollution [11] various types of dyes can be classified, including direct dyes, reactive dyes, vat dyes, disperse dyes and azo dyes [12]. A number of industries disperse dyes which are present in water bodies and most aquatic life are at heavy risk [13].

2. MATERIALS AND METHODS

For this study, effluent samples were collected from a textile dyeing factory in Tiruppur. Effluent samples were collected from three stations; station I, in the vicinity of the source and stations II and III, located 10 and 20 meters away from the source respectively. At stations II and III, the effluent became diluted. Effluents were collected in 2-liter polythene containers, carefully transported to the laboratory, and stored at 20ºC for further analysis. The effluents for BOD estimation were placed in ice pails, thus halting microbial activity. The physical and chemical characteristics of the dyeing industry effluent such as hydrogen ion concentration (pH), total alkalinity, total acidity, COD, BOD, Total dissolved solids (TDS), Total suspended solids (TSS), chlorides and sulphides were analyzed using Standard Methods [14].

Effluent samples were collected directly from the discharge point monthly for 12 months, from April 2023 till March, 2024. The collected samples were sequentially numbered and underwent specific treatments—including preservation, fixation, and careful management—before analysis to prevent any alteration of their various factors. The chemical analysis and testing of the samples were carried out in a controlled laboratory environment.

The wastewater samples were immediately analysed for pH using a pH meter and Electrical Conductivity (EC) using an EC meter. Coagulation and flocculation were used to separate suspended, colloidal and dissolved contents from the effluent. Chloride (Cl) was determined titrimetrically using standard $AgNO_3$, while phosphate (PO_4^{-3}) was analyzed, with a spectrophotometer. In addition to the above tests, BOD and COD tests analyses were performed on the collected samples in the laboratory, following standard procedures (IS-10200, 2012). All measurements are expressed in mg/L and mEq/L exception of pH and EC.

Untreated or inadequately treated textile dye effluent poses a significant risk to both aquatic and terrestrial organisms, damaging the natural ecosystem and potentially causing long-term problems. This study was designed to determine the physicochemical parameters and heavy metal concentration in effluent from a large dyeing industry located in textile city of Tiruppur, Tamil Nadu. (11.1085° N and 77.34 11°E) situated on the banks of River Noyyal.

3. RESULTS AND DISCUSSION

The physicochemical properties are *in situ* measurements of the Dyeing Industry Effluents, collected from three stations along River Noyyal, Tiruppur.

The pH of the water in the source points 8.5 which gradually reached the normal limits of 7.4 in Station III. The alkaline in the dyeing industry effluent are responsible for rise in pH in the first station [15] while temperature is more dependent on ambient conditions, turbidity fluctuation between 10 and 40 in the three stations. Turbidity is more than 25 times higher than 25 times higher than permissible limit in station I. This prevence the passage of photosynthetic light into the riverine system. Electrical conductivity depends on the charged particles found in the effluent in station I. TDS is very high (4323I 390) μ mholcm in station I and corresponding electrical conductivity also is high due to high TDS.

In station I, the total hardness, total alkanity, free ammonia, DO, COD and BOD recorded values significantly different from the permissible limits. This indicated the impure nature of the water sample in station I, which is the source point of receiving the partially treated effluent. In Station III a recovery is noticed for the various characteristics due to the dilution of the effluent and addition of substantial quantities of water.

Ionic species like calcium, magnesium, nitrates, fluoride, sulphate, phosphate and chloride (Table III) significantly increased or decreased in the first station and approached near normal values as the effluent reached station III. Exactly similar trend is noticed for heavy metals found in the dying industry.

It has been made statutory to treat textile and Dying Industry and effluents before discharging them into river Noyyal in Tiruppur. Elusive treatments are responsible for the release of certain pollutants, in concentrations significantly different from the permissible limits. This affects the riverine system and makes the water unsuitable for human use. In real time situations, water receding from the onslaught of pollutants from one factory gets again affected by effluents released from the next factory. Thus, the series of factory along the river Noyyal make the water polluted to some extent. The RO and other treatment processes available in each factory should be highly precise to prevent this type of pollutant leaching.

Heavy metals

Textile effluents are incredibly diverse in their chemical compositions due to the vast array of chemicals used in processing. Beyond dyes and their auxiliaries, over 8,000 different chemicals can be found, including various acids, surfactants, salts, metals oxidizing reducing agents [16]. Dyes are significant photo pollutants, considered undesirable even in trace amounts [17]. Untreated heavy metals accumulate in various biosystems, causing various health complications. This study, therefore, focused on identifying the heavy metals present in potentially untreated textile effluents. The value of aluminium in the three stations is 1.21 mg/l, 1.00mg/l, 0.9 mg/l respectively. In textile wastewater aluminium is often used in the form of alum or other aluminium compounds to help remove various pollutants including dyes. The value of the cadmium station I is 0.006 mg/l and station II are 0.004 and station III is 0.003. The world health organization (WHO) recommends a guideline limit

0.003 mg/l (3 μg/L) for cadmium drinking water. The United States Environmental protection Agency (USEPA) has established a maximum contamination level (MCL) of 0.005 mg/l for cadmium in drinking water. In our study, even a small increase at Station I showed that acute or chronic exposure to cadmium (Cd) can lead to high blood pressure, kidney damage, the destruction of red blood cells. The value of the Bartum is in three station water sample is (9.0574 mg/l, 9.0413mg/l, 8.012mg/l). The value of the calcium is in three station 21.1821 mg/l, 18.151 mg/l, 17.413 mg/l). Chromium was recorded at negative concentrations across three stations, with values of -3.632 mg/l, -3.6023 mg/l, -2.5421mg/l. Iron content in the effluent samples from three stations was 1.1338 mg/l, 1.013 mg/l and 1.013mg/l. Copper is recorded in those stations was 0.0117mg/l, 0.011 mg/l and 0.011 mg/l. The value of lead is 0.3802 in station I. 0.3302 mg/l is station II and 0.211mg/l in station II. WHO sets a limit of 0.01 mg/l for lead in drinking water. Cobalt is a heavy metal that can contaminate textile waste water. In our study cobalt present in the untreated water in three sites (0.0501 mg/l 0.0401 mg/l and 0.0401 mg/l) respectively. WHO guideline for cobalt in drinking water is 0.005 mg/l. Manganese in the textile waste water is due to the impurities present in chemical used in various steps. Therefore, its concentration in waste water was found to be low. It was recorded in three 0.1553 mg/l, 0.1433, 0.313 mg/l and 0.313mg/l respectively. Untreated wastewater samples from three stations contained Nickel at concentrations of 0.0509 mg/l, 0.051 mg/l and 0.0406 mg mg/l. Nickel frequently contaminates effluent streams from industries such as stainless-steel metal alloys, coinage, paint, and plating. This heavy metal can cause various health issues in humans, including eczema, allergies, lung cancer, pulmonary fibrosis, and heart and liver dysfunction. Strontium recorded in the three stations were 0.1698 mg/l, 0.1540 mg/l and 0.1421 mg/l respectively. The value of Vanddium is recorded in untreated waste water in three station 2.0231 mg/l, 2.013 mg/l and 1.0145 mg/l which is significantly higher than the permissible level of 5.1mg/l. Zinc found in the effluent is 0.0111 mg/l in station I, 0.0111 mg/l in station II and 0.0111 mg/l in station III. The value of magnesium in three station is 36.4819 mg/l, 34.4819 mg/l and 32.4819 mg/l. Sodium content was found in the textile effluent is in three station is 779.14 mg/l, 775.01 mg/l and 772.12 mg/l respectively.

Table 1 Physical Characteristics of the untreated Dyeing Industry Effluent collected in situ

S No	Characteristics	Unit	Collection points			(WHO) permissible limits
			Station I	Station II	Station III	
1	pH		8.5±0.74	7.7±0.54	7.4±0.69	6.5-8.5
2	Temperature	°C	27±3	27±2.5	28±2.4	
3	Turbidity	NTU	40±3.6	25±1.8	10±1.1	<1.5
4	Electrical Conductivity	µS/cm	6650±640	3400±298	2506±218	2250µS/cm
5	Total dissolved solids	mg/l	4323±390	2730±327	1654±148	300

Table 2 Chemical Characteristics of the Dyeing Industry Effluent collected in situ

S No	Characteristics	Unit	Collection points			WHO permissible limits
			Station I	Station II	Station III	
1	Total hardness as CaCo3	mg/l	0.80±111	7.60±64	6.30±71	200mg/l(BIS)
2	Total Alkalinity as	mg/l	492±28.6	332±21.3	356±32.8	600 mg/l (IS)
3	Free Ammonia as NH_3	mg/l	2.54±0.24	1.62±0.13	1.15±0.13	0.15 mg/l(WHO)
4	Dissolved Oxygen (DO)	mg/l	5.1±0.46	5.9±0.42	6.1±0.57	6.5-8
5	COD	mg/l	228±15.6	148±14.6	55.8±4.3	10
6	BOD	mg/l	4.5±0.32	5.8±0.41	8.8±0.66	<5
7	COD/BOD ratio	mg/l	50.66	25.52	6.34	

Table 3 Mineral content of the Dyeing Industry Effluent collected in situ

S No	Minerals	Unit	Effluent Sample			Permissible limits
			Station I	Station II	Station III	
1.	Calcium as Ca	mg/l	210±14.5	178±12.8	94±8.6	75
2.	Sodium	mg/l	779.14 ± 68.4	775.01±58.2	772.12±84.8	200
3.	Potassium	mg/l	64.0145±5.99	62.0135±6.00	60.013±5.65	12.0
4.	Magnesium as Mg	mg/l	104±9.4	82±6.8	30±0.42	150
5.	Nitrite as NO_2	mg/l	0.12±0.01	0.09±0.007	0.05±0.002	0.2mg/l
6.	Nitrate as NO_3	mg/l	17±1.1	1.5±1.3	8±0.94	10
7.	Fluoride as F	mg/l	0.06±0.04	0.5±0.06	0.4±0.05	1.0
8.	Sulphate as SO_4	mg/l	214±22.4	176±20.4	79±6.1	200
9.	Phosphate as PO_4	mg/l	0.20±0.018	0.20±0.021	0.15±0.01	1.0
10.	Chloride as Cl	mg/l	1740±154	1015±84	560±47.8	250

Table 4 Heavy metal content of the Dyeing Industry Effluent collected in situ

S No	Heavy Metals	Unit	Effluent Water Sample			Permissible Limit P.L
			Station I	Station II	Station III	
1	Aluminium as Al	mg/l	1.21±0.120	1.00±0.002	0.9±0.008	0.2 mg/l
2	Cadmium as Cd	mg/l	0.0054±0.0004	0.0045±0.002	0.003±0.004	0.003 mg/l
3	Barium as Ba	mg/l	9.057±0.8	9.04±0.09	8.012±0.07	2.0 mg/l
5	Chromium as Cr	mg/l	0.234±0.3	0.175±0.016	0.121±0.011	0.08 mg/l
6	Iron as Fe	mg/l	1.1338±0.110	1.013±0.009	1.013±0.009	0.3 mg/l
7	Copper as Cu	mg/l	0.0117±0.0009	0.011±0.009	0.004±0.003	1.3 mg/l
8	Lead as Pb	mg/l	0.3802±0.0278	0.3302±0.02	0.211±0.02	0.01 mg/l
9	Cobalt as Co	mg/l	0.0501±0.005	0.0501±0.005	0.400±0.03	0.005 mg/l
10	Manganese as Mn	mg/l	0.1553±0.014	0.143±0.012	0.121±0.010	0.3 mg/l
11	Silver as Ag	mg/l	0.4137±0.039	0.313±0.029	0.313±0.029	0.1 mg/l
12	Nickel as Ni	mg/l	0.0509±0.004	0.0506±0.003	0.0406±0.002	70 mg/l
13	Strontium as Sr	mg/l	0.1698±0.010	0.1540±0.011	0.1421±0.012	4 mg/l
15	Vanadium as V	mg/l	2.0231±0.199	2.013±1.99	1.0145±0.08	5.1 mg/l
16	Zinc as Zn	mg/l	0.0111±0.001	0.0111±0.001	0.0111±0.001	5 mg/l
17	Magnesium as Mg	mg/l	36.4819±3.248	34.4819±3.01	32.4819±2.98	10-50 mg/l

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