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Physico-Chemical Assessment and Analysis of Hazardous Organic Substances from Textile Industrial Effluents from Sachin and Kadodara, GIDC, Surat, India

Shrivastava VH* **and Shinde SG**

Department of Nanochemistry, Kavayitri Bahinabai Chaudhari North Maharashtra University, Delhi, India

***Corresponding author:** Shrivastava VH, Department of Nanochemistry, Kavayitri Bahinabai Chaudhari North Maharashtra University, Delhi, India,
E-mail: drvinodshrivastava1962@gmail.com

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Abstract

Surat GIDC, Gujarat is one of the largest producer in textile industry in India. The ever growing demand is fulfilled by very fast supplying process, this leads to bad practices during textiles operations which causes water pollution in this region. Since Surat is closer to the Arabian Sea, the polluted water is passed in to the sea through various water channels therefore, it is necessary to identify and characterize hazardous substances from these effluents. For this study samples were collected from two important textile industry clusters viz. Sachin and Kadodara, GIDC, Surat and stored by following standard sampling procedures. Physico-chemical parameters such as pH, Chloride, Sulphate, Electrical Conductance, Total Dissolve Solid, COD and BOD were determined. Solvent extraction method was employed to prepare samples for the detection of organic substances by FTIR and GC/MS techniques. FTIR confirmed the presence of various functionalities related to organic origin and GC/MS technique revealed the presence of linear, cyclic and polycyclic aliphatic and aromatic organic compounds in the collected samples with high toxicity. Physico-chemical parameters were used for the statistical analysis of water samples and standard statistical methods such as mean, errors, standard deviation, regression coefficient analysis and correlation were used which were helpful for the determination of water quality index and the results obtain were compared to assign the water quality standards authenticated by WHO, USPH and BIS. The prime focus was to detect organic pollutants and the assessment proved the presence of hazardous organic substances in the collected textile effluent samples.

Keywords: Physico-chemical; BOD; COD; Carcinogenic; Mutagenic; GC/MS; FTIR

Introduction

Hydrosphere is one of the most important segment of environment. Water plays an important role in various life processes of living organisms, supporting the life process by virtue of its unique properties. The overall development of human being revolves around water, therefore water is an essential component in every aspect of human existence. Quality and quantity of water is the most important factor in determining well- being of human society. However, with the other essential components of environment like air and soil, water is also facing the effects of human activities, now a day's water pollution is continuously increasing because of rapid growth in industrialization and the most important contributors in water pollution are organic pollutants, since they are highly stable in water bodies, resistant to biodegradation and carcinogenic. Different types of industries like textile, plastics, pharmaceutical, paper etc. release large amount of effluents which contain enormous amount of organic moieties and when these discharge released in water bodies without or little prior treatment they can cause serious effects and show carcinogenic, mutagenic and other harmful effects towards aquatic life and eventually towards human being [1].

India is one of the largest textile producer in the world and textile industries are the largest contributor of organic pollutants. Dyes, organic chemicals and its residue released during textile processing, dyeing and printing processes introduce organic pollutants in waste water. Currently, more than100,000 different types of dyes are commercially available and more than 1.6 million tons of dyes are produced annually, and 10-15% of this volume is discharged in water bodies. Even at very less concentration (ppm), colored organic pollutants can be visible and can cause serious problems to water bodies and its residents. Most of the dyes are of coal tar origin and hence possess aromatic organic framework and can undergo anaerobic decomposition to form potential carcinogens which may enter in to human body through food chain. Apart from that, they may trap essential sunlight which is important for photosynthesis and affect oxygen dissolution, increase biochemical oxygen demand (BOD) and chemical oxygen demand (COD) which is not an ideal situation for the existence of any aquatic living species.

Oceans are the largest sinks of various types of pollutants, since most of the organic matter in the form of industrial effluent without or little prior treatment is first release in to the smaller and larger rivers and eventually enters in to the seas (**Figure 1**) therefore, oceans are now a days known as the dumping ground of all types of pollutants. Large number of the textile industrial clusters are situated either near rivers or seas and hence release all types of waste water in these water reservoirs. Most of them ignore pre-treatment processes like biodegradation, coagulation–flocculation, adsorption, ozone treatment, electrochemical processes, reverse osmosis, nanofiltration, advance oxidation process (AOP's) etc. before discharging waste water in to the water bodies and hence continue to add large amount of organic pollutants in to the nearer water reservoirs [2].

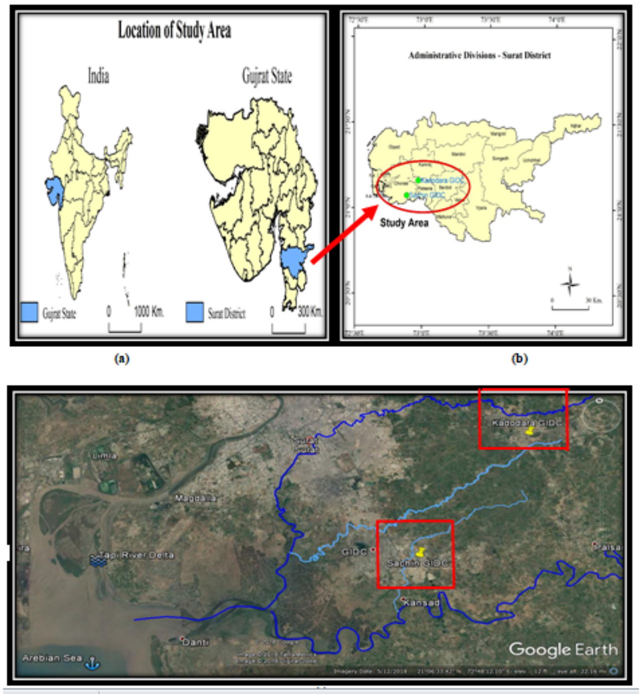

Figure 1: Map information of Sachin and Kadodara, GIDC, Surat.

The selected zone Gujarat Industrial Development co-operation (GIDC), Surat, Gujarat, India for this study exist in the immediate vicinity of the Arabian Sea. The textile industries employ different types of chemical processes during textile processing, dyeing and printing and release enormous amount of chemicals like acetic acid, formic acid, oxalic acid, ammonium sulphate, bleaches, caustic soda, organic solvent, wetting agent, softeners, hydrosulphites with variety of organic dyes like disperse, vat, reactive, azo dyes and many more. Therefore, it is very essential to analyze and characterize the effluents which are released by these industries which will eventually enters in to the nearby reservoir through different channels, which in this case is Arabian Sea [3].

The present work is dedicated to identify various organic substances from these textile waste water effluent and to identify potential hazard for the living organism and ultimately human being. GC/MS and FTIR techniques were helpful to identify organic moieties in selected samples from each cluster and as anticipated reveled large number of linear, cyclic and polycyclic aliphatic as well as aromatic organic substances. Since, effluent from these industries were chemically complex in nature, physico-chemical studies were very informative and proved to be an important tool to analyze the quality of the waste water effluent. Statistical analysis was helpful for the comparison of theses effluent samples with standard water quality parameters and calculation of water quality index was helpful to compare quality of collected samples with ideal values given by various national and international agencies [4].

Collection of Water Samples and Sample Preparation

Three samples from three different places of Sachin and Kadodara, (GIDC), Surat (**Figure 2**) were collected. pH and TDS of the samples were recorded immediately after withdrawal. The collect samples were stored in pre-cleaned (Acetone and 1% (v/v) Nitric Acid, Fisher Sci. India), dried and tightly sealed 500 ml dark amber colored glass bottles and stored in thermocol ice box and finally stored in refrigerator for further analysis. Out of six samples, two samples were chosen for GC/MS and FTIR analysis and all used for the physicochemical studies. The labelling of the collected samples is given in **Table 1.**

Sr.No.	Sample Name	Place of Sample	Source of effluent
1	S1	Sachin, GIDC	West side, from industry outlet.
2	S2	Sachin, GIDC	North side, from industry outlet.
3	S3	Sachin, GIDC	East side, from waste water channel.
4	K1	Kadodara, GIDC	Middle, from industry outlet.
5	K2	Kadodara, GIDC	North side, from water channel.
6	K3	Kadodara, GIDC	South side, from industry outlet near channel.

Table 1: Location of samples with graphical representation.

Figure 2: Sample sites at Sachin, GIDC, Surat.

Solvent extraction process by using pure AR grade Diethyl ether (Sigma Aldrich, India) and separating funnel was employed for the preparation of two collected effluent samples each from both industrial clusters. 25 ml of collected effluent sample out of 100 ml was extracted with 100 ml of Diethyl ether, then aqueous layer was removed and again 25 ml of remaining sample was added in to the organic layer and extracted, this process was again repeated for remaining sample to increase the extraction efficiency [5].

Analysis of Sample by FTIR and GC/MS

The water sample S1 and K3 were used for the preparation of samples for the FTIR and GC/MS studies by solvent extraction method with the help of Diethyl ether as an organic solvent. The organic moieties found in these samples are discussed with the help of FTIR frequencies of functionalities in **Table 2** and GC/MS information with the help of molecular weight and probable structure.

Sample- S1			Sample- K3		
S.N.	Frequency (cm-1)	Probable Functional Group	S.N	Frequency (cm-1)	Probable Functional Group
1	3429.52	O-H (broad) hydrogen bonded	1	3438.15	O-H (broad) hydrogen bonded
2	2924.65	Alkane sp3 C-H stretching	2	2924.53	Alkane sp3 C-H stretching
3	2856.01	Alkane sp3 C-H stretching, C-H aldehyde	3	1736.88	C=O stretching in aldehydes and Esters
4	1740.02	C=O stretching in aldehydes	4	1382.83	N-O stretching
3	1634.63	N-H bending	3	1464.44	C-H bending in –CH3 and –CH2
4	1461.34	sp3 C-H bending in –CH3 and –CH2	4	1288.45	C-O stretching in esters and ethers
5	1298.95	C=C aromatic	5	1265.08	C-O-C starching in ethers
6	1255.09	C-O-C starching in ethers	6	1122.57	C-N starching in amines
7	1106.23	C-O Stretching in alcohols and phenols	7	1096.86	C-O stretching
8	951.03	Aromatic C=C-H stretching	8	929.69	Aromatic C=C-H stretching
9	804.42	Multi(mono, di, tri) substituted benzene	9	863.36	Tri substituted benzene
10	573.15	C-X stretching	10	722.2	Substituted benzene

Table 2 : Detected organic functionalities from collected effluent sample S1 and K3.

Toxic effects of some organic substances found in sample S1 and K3

It is difficult to relate found organic substances exactly with the toxicity mentioned in the various articles. The essential criteria here is the functional groups and structural similarities. With the help of information of functionalities found in organics in the samples, it is relatively easy to compare these substances with the toxicity of similar substances with identical functional groups towards aquatic organisms and humans reported in literature. The toxicity of few organics from S1 and K3 samples is discussed [6].

Physicochemical Parameters Status of Effluent Samples

pH: pH is a logarithmic scale used to specify the acidity or basicity of an aqueous solution. pH is an essential criteria for water analysis and plays an important role in all vital processes of living organisms. Change in pH value may cause serious problems to aquatic life such as increase in heart rate, curve spine, malformation of head, metabolism and even mortality. The pH values obtain at the sites are within the range of permeable limits of various national and international agencies. Sample S1 and S3 shows slightly basic pH than rest of the collected samples.

Electrical conducvity EC: Electrical conductivity is a measure of cations as well as anions in water. Increases in EC generally indicates increase in these inorganic species. Change in cationic and anionic concentration is very lethal for the aquatic life and human beings. Liver, kidney, digestive system and nervous systems are highly affected by these cations and anions.The collected samples show very much higher EC values, may be because of various unit operation in textile industry.

Total dissolve solid (TDS): TDS is a measurement of inorganic salts, organic matter and other dissolved materials in water. The important contributors for the TDS values are presence of Na+, Ca^{2+}, Mg^{2+}, CO_3^{2-} , SO_4^{2-} , Cl^- etc. in water. Change in concentration of these ionic species in water alter the population of different types of species like microorganisms, algae and fishesh. TDS values obtain in the collected samples are dangerously higher than the standard values of water quality, this is a clear indication of presence of various organic as well as inorganic substances in textile water effluent [7].

Sulphates (SO_4^{2-}): Sulphate anaerobic metabolism produces phosphates in water bodies through decomposition of organic matter and phosphates are an essential nutrients for plant, hence excess growth of vegetation which is also known as eutrophication is a common problem throughout the Presence of sulphates in water samples is very less when compared to the standard values given by various agencies.

Chloride (Cl^-): Many textile production process are the main contributor of chlorides in water Excess of Cl^- can cause serious problems to habitats of aquatic organisms and show harmful effects to human being through its corrosive action. Chloride level in collected samples is at higher site and it is expected because of excess use of chlorinated substances in textile processing.

BOD and COD: Oxygen related environmental parameters like DO, BOD and COD are interrelated with each other. Increase in BOD and COD values are attributed to low dissolve oxygen and higher pollution. Samples from both the industrial area show very high BOD and COD value and therefore indicate the presence of organic carbon. This is a cause of concern since high organic carbon decrease the dissolve oxygen level and seriously affects aquatic life [8].

Pearson Correlation Coefficient (R) Data of Various Parameters

The calculated correlation coefficient (R) for various parameters. The correlation coefficient (R) denotes the relationship between two variables. The TDS and pH show strong correlation which is an indication of high salt content in water which is confirmed by Cl^- and EC correlation value, TDS and COD are correlated due to the high concentration of organics in to the collected water samples. BOD and sulphate correlate due to the participation of sulphates in decomposition of organic matter eventually effect BOD.

Water Quality Index (WQI)

Water quality index (WQI) for various water types is acceptable within the 100 point range, for instance 90-100 range is unsuitable for potable purpose, 70-90 very poor water quality, 50-70 poor water quality, 25-50 good quality water, 0-25 excellent quality. The tasted water parameters such as pH, EC, TDS, sulphate and chloride are essential factors in deciding water quality. The calculate water quality index was found to be at very higher site than ideal WQI values especially from Sachin, GIDC region. Water quality in this region is so poor that it is not even fit for portable purpose. The calculated water quality index is depicted [9,10].

Conclusion

The core aim of this study was to assess the overall impacts of textile effluents in the industrial zone near Arabian Sea. The successful application of GC/MS techniques leads to the identification of vast number of linear, cyclic, polycyclic, aliphatic as well as aromatic organic contaminants which are released in the form of effluent from these textile industries. The organic moieties which found are either intermediates or byproducts of various textile industry processes. FTIR analysis also confirmed various functionalities such as long chain hydrocarbons, halogenated hydrocarbons, substituted benzene and phenols which are highly hazardous to the biosphere. It is found that the identified organic compounds are highly mutagenic, carcinogenic and alter various life process of aquatic residents and human beings.

Physico-chemical parameters were studied and statistical analysis provided important information which was helpful for the comparison of the collected water samples with standard water quality parameter. It is found that apart from pH most of the found parameters are well above the dangerous level and calculated water quality index values are very much higher than expected values. The most important parameters were BOD and COD which are directly related to the amount of dissolve oxygen in water. BOD and COD values in the range of 700 to 1900 mg/L of O2 is very much higher than standard values and is the striking indication of severe pollution. Therefore, it is highly recommended not to ignore necessary pre-treatment process like biodegradation, adsorption, reverse osmosis, coagulation–flocculation, nanofiltration, ozone treatment, advance oxidation process (AOP's) etc. before discharging these waste water effluents in to the hydrosphere. Furthermore, high TDS and Chloride levels should be regulate to protect smaller aquatic species. This small initiative from the authorities is important to develop sustainable environment for the aquatic as well as human life.

Conflicts of interest

There are no conflicts to declare.

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