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Assay of Physicochemical and Statistical Analysis of Textile Dyeing Effluent Generated from Different Fabrics

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ABSTRACT

Textile Industries play a significant and central role globally for the economic prosperity of numerous countries. Due to varied methods of dyeing processes involving enormous amount of water the textile processing units are blamable for major environmental pollution issues worldwide as this wastewater is released without appropriate treatment in nearby water channels. This research is aimed to conduct the physicochemical and statistical analysis of the effluent generated from dying of different fabrics. The parameters such as Power of Hydrogen Ion Concentration (pH), Conductivity, Total Dissolve solid (TDS), Total Suspended Solid (TSS), Total Hardness (TH), Biological Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Chloride (Cl^{-1}), Sulphate ($SO4^{-2}$), Sodium Ion (Na^{+1}), Magnesium Ion (Mg^{+2}) and Calcium Ion (Ca^{+2}) were analyzed. The outcomes of the analysis were correlated with the National Environmental Quality Standard (NEQS) of Pakistan and World Health Organization (WHO). It was found that all the parameters were within permissible limits except pH, TH and Ca^{+2}. The superfluous concentration of the pollutants indicates that the effluent is polluted with respect to about mentioned parameters. Such practices are creating hazardous effects on the ecology of terrestrial and aquatic life and pose a threat to the local environment.

Key Words: Textile fabrics; Textile dye effluents; Physicochemical parameters; Correlation; Statistical techniques.

1. INTRODUCTION

Textile industries contribute in the economic development around the world [1]. This segment is a vivacious asset for the emerging economies of South Asia [2]. The dyeing process is an important stage in textile manufacturing specially in wet processing. Dyes are added to the fabrics in addition, to diverse chemicals to enhance the adsorption phenomena between color and fabrics [3]. The final product is ready as textile fabric after the finishing process. However, some of these dyes and chemicals are not fully absorbed and leads to industrial effluent discharges which is itself is a hazard to the environment [4], [5]. These dyes and chemicals are also a source of contamination to the soil, sediment and surface water which results major ecological pollution challenge.

Currently there are more than 8,000 chemical products used in the dyeing process and more than one hundred thousand commercially existing dyes with an annual production of over 735 metric tons of dyestuff [6], out of which 70% are Azo Dyes, that stay impervious to microbial and chemical attacks and remains unchanged during drying and washing process [7]. The textile processing comprises of numerous operations such as spinning, weaving, desizing, scouring, bleaching, dyeing, printing, finishing, and clothing where water plays a fundamental role. The textile sector uses huge amount of water (200 m3/ton of product) which unfortunately ends up approximately 90% as wastewater [8].

Cloth manufacturing units are the largest source of environmental pollution as their production is high accordingly huge effluent is released [9], [10]. Textile wastewater has colorant which ends up as castoff sewage which causes severe environmental damages disturbing the marine ecosystem [11], [12].

The contamination levels of textile industry effluent are solely dependent on textile unit [13]. However, it is also dependent on the process and the equipment used in the factory, type of fabric produced, weight of the fabric, season [14], and the trends in fashion [15]. It is estimated that during the dyeing process around 10-25% of textile dyes are lost and about 2-20% are released as aqueous effluent causing serious environmental concerns. The textile discharges are toxic, due to high quantities of hazardous materials such as benzidine, naphthalene and other aromatic compounds [16]. The other foremost impurities in textile effluents include dissolved solids, suspended objects, biological oxygen demand, chemical oxygen demand, heat, colour, acidity, chloride, sulphur, metal ions and many other soluble substances [17]. Hence, it is impractical to illustrate a "typical" textile effluent because of its diversity in the process and the constituents used.

The importance of water on human health cannot be over stressed. Therefore, this study assessed the quality of wastewater stemming from various textile dying units, specially generated from coloring different fabrics and its possible impact on the environment, soil and water ecology. Different statistical techniques are applied to elaborate the characteristics of wastewater. Based on these characteristics, it is found during this study that the effluent is not suitable for discharge directly into aqueous bodies without proper treatment.

2. MATERIALS AND METHODS

The effluent samples were collected from a textile dyeing unit located in the Korangi Industrial Area, Karachi. This unit deals in dyeing of different fabric e.g., cotton weave, cotton knitwear, polyamide hosiery, polyester hosiery, and woolen fabric. Grab sampling technique was used for our research work. The samples were collected in proximity of the processing unit. These effluent samples were analyzed in Archroma Pakistan Ltd., labs, Karachi. The tools involved in generating Statistical Package for Social Sciences were used.

2.1 Effluent Sampling

The Textile dye effluent of different fabrics sample was collected in cleaned plastic container and all the samples were instantly shifted to the analytical Laboratory for analysis various physico-chemical parameters according to international standard methods by American Public Health Association (APHA) [18]

2.2 Data Analysis

The present study assessed twelve (12) physicochemical parameters of textile dyeing effluent generated from different fabrics. The parameters of pH, Conductivity, TDS, TSS, TH, BOD, COD, Cl-1, SO4-2, Na+1, Mg+2 and Ca+2 were analyzed and compared with NEQS. Comprehensive data of textile dye effluent of different fabrics quality parameters are shown in Table 1.

2.3 Analytical Instrument

The pH, EC and TDS reading were taken with the help of multiparameter ion analyzer (HANNA Instrument). Na^{+1} Ca^{+2}, Mg^{+2}, Cl^{-1} and $SO4^{-2}$ were measured by Metrohm 930 Compact IC Flex, BOD5 and COD parameters analyzed by HACC spectrophotometer.

2.4 Descriptive Statistics

Descriptive statistics of Textile dye effluent of different fabrics were performed using MS-Excel and Statistical Package for social Scientist (SPSS) version 20. Table 2 presents minimum, maximum, mean and standard deviation of 12 Physico-chemical parameters under observation. TSS, Conductivity, TDS and Cl^{-1} are the prevailing structures with high mean concentration of 78750.0 mg/l, 31697.5 mg/l, 17732.5 mg/l and 10098.7 mg/l respectively. This showed that, these parameters play significant role in contamination. The mean value of pH is 8.15, signifying that the effluent samples are more or less sub-alkaline in nature.

3. CORRELATION ANALYSIS

Correlation analysis is useful for interpreting wastewater quality data and relating them. This analysis reveals similarities or differences in the behavior of not conveniently identify groups of ions that behave similarly. The Pearson Correlation analysis indicated in Table 3 of twelve (12) physico-chemical parameters of textile dye effluent of different fabrics, showed moderate to very strong positive correlation between pH - TSS (r = 0.641), Conductivity - TDS (r = 1), Conductivity – TH (r = 0.567), TDS - TH (r = 0.569), TSS – BOD_5 (r = 0.558), TH – Mg^{+2} (r = 0.611), TH – Ca^{+2} (r = 0.711); BOD_5 – COD (r = 0.998), BOD_5 – Cl^{-1} (r = 0.730), BOD_5 – Na^+ (r = 0.959), Cl^{-1} – SO_4^{-2} (r = 0.808), Cl^{-1} – Na^{+1} (r = 0.831), SO_4^{-2} – Mg^{+2} (r = 0.855); SO_4^{-2} – Ca^{+2} (r = 0.772), Mg^{+2}- Ca^{+2} (r = 0.990). These robust associations are an indication of communal source. Correlation analysis of physico-chemical parameters of textile dye effluent of different fabrics, showed moderate to very strong negative correlation between pH - Conductivity (r = -0.547), pH – TDS (r = -0.534), pH - Cl (r = -0.752), pH – SO_4 (r = -0.989), pH – Mg^{+2} (r = -0.856), pH – Ca^{+2} (r = -0.777); TSS – TH (r= -0.752), TSS – SO_4 (r = -0.653), TSS – Mg^{+2} (r= -0.946), TSS – Ca^{+2} (r = -0.977), TH – BOD_5 (r = -0.893), TH – COD (r= -0.915); TH - Na (r = -0.875).

3.1 Principal Component Analysis (PCA)

The Textile Fabrics effluent is highly contaminated due to the textile process which includes various operations such as spinning, weaving, resizing, scouring, bleaching, dyeing, printing, finishing and clothing. The dyeing process in textile industries involves many chemical products that include sulfides, salts, formaldehydes, metals and surfactants. Apart from dyes, additives such as solvents, whitening agents, antifoaming chemicals, pH conditioners and finishing agents are used in the different operations as substrates or as aqueous systems with bulk volumes of water and about the same amount is discarded in the environment.

Techniques of Multivariate Statistical are extensively used in ecological information reduction and elucidation of multi component chemical and physical measurements. These methods promise a swift answer for effluence teething troubles. PCA is one such method which reduces the varied aspects of a data containing a high number of correlated variables, at the same time holding optimum variability present in the data set. The PCA is meant to reduce the input of less dominant changeable and to make simpler structure impending from PCA. It also permits evaluation between variables and chemicals in several influential features. The relationship with each other is measured by association and PCA gives evidence on the most relevant parameters. This helps to define the entire data set which results in affording reduction with very little forfeiture of the original material.

Table 1: Physico-Chemical Data of Effluent in Different Fabrics of Textile.

Parameters	Wool	Polyamide	Cotton Weave	Cotton Knitwear	NEQS Limits	WHO Limits	Units
pH	6.97	8.21	8.70	8.75	6 – 9	6.5-9	
Conductivity	32150	31420	32080	31140	N/A	-	mg/l
TDS	17990	17570	17960	17410	3500	2000	mg/l
TSS	45000	108000	92000	70000	200	100	mg/l
TH	190	70	180	160	N/A	500	mg/l
BOD_5	1580	3050	1170	10407	80	100	mg/l
COD	3300	7180	2350	2240	400	250	mg/l
Cl^{-1}	10209	10214	9946	10026	1000	250	mg/l
SO_4^{-2}	1098	1021	974	990	600	400	mg/l
Na^{+1}	7235	7334	7168	7205	N/A	200	mg/l
Mg^{+2}	60	13	17	27	N/A	5	mg/l
Ca^{+2}	142	27	51	74	N/A	200	mg/l

Table 2: Descriptive Statistics.

Parameters	Minimum	Maximum	Mean	Std. Deviation
pH	6.97	8.75	8.1575	.82831
Conductivity	31140.00	32150.00	31697.5000	496.27781
TDS	17410.00	17990.00	17732.5000	287.79333
TSS	45000.00	108000.00	78750.0000	27366.34186
TH	70.00	190.00	150.0000	54.77226
BOD_5	1040.00	3050.00	1710.0000	922.49661
COD	2240.00	7180.00	3767.5000	2324.24002
Cl^{-1}	9946.00	10214.00	10098.7500	134.24201
SO_4^{-2}	974.00	1098.00	1020.7500	55.07192
Na^{+1}	7168.00	7334.00	7235.5000	71.15476
Mg^{+2}	13.00	60.00	29.2500	21.32878
Ca^{+2}	27.00	142.00	73.5000	49.53450

Table 3: Correlation Analysis.

	pH	COND	TDS	TSS	TH	BOD_5	COD	Cl	SO_4	Na	Mg	Ca
pH	1											
Conductivity	-.547	1										
TDS	-.534	1.000	1									
TSS	.641	-.330	-.322	1								
TH	-.217	.567	.569	-.752	1							
BOD_5	-.203	-.192	-.198	.558	-.893	1						
COD	-.163	-.245	-.252	.577	-.915	.998	1					
Cl^{-1}	-.752	.000	-.014	-.158	-.459	.730	.715	1				
$SO4^{-2}$	-.989	.416	.402	-.653	.150	.237	.203	.808	1			
Na^{+1}	-.277	-.343	-.352	.389	-.875	.959	.965	.831	.347	1		
Mg^{+2}	-.856	.472	.461	-.946	.611	-.299	-.330	.414	.855	-.158	1	
Ca^{+2}	-.777	.475	.466	-.977	.711	-.433	-.462	.280	.772	-.294	.990	1

The PCA results comprising of the loadings are shown in Table 4 and Figure 2 (Scree Plot). It signifies the percentage of variance and the proportions of cumulative variance. Any factor loading values greater than 0.75 and ranging between 0.75-0.5 and 0.5-0.3 are considered as Strong. PC1 accounts for 50.46% of the over-all variance and is controlled by the resilient factor loading for TH (0.904), Mg^{+2} , (0.878),Ca^{+2} (0.926). PC2 takes care of 37.4% of the variance and is dominated by Cl^{-1}, SO_4^{-2} and Na^{+1}.

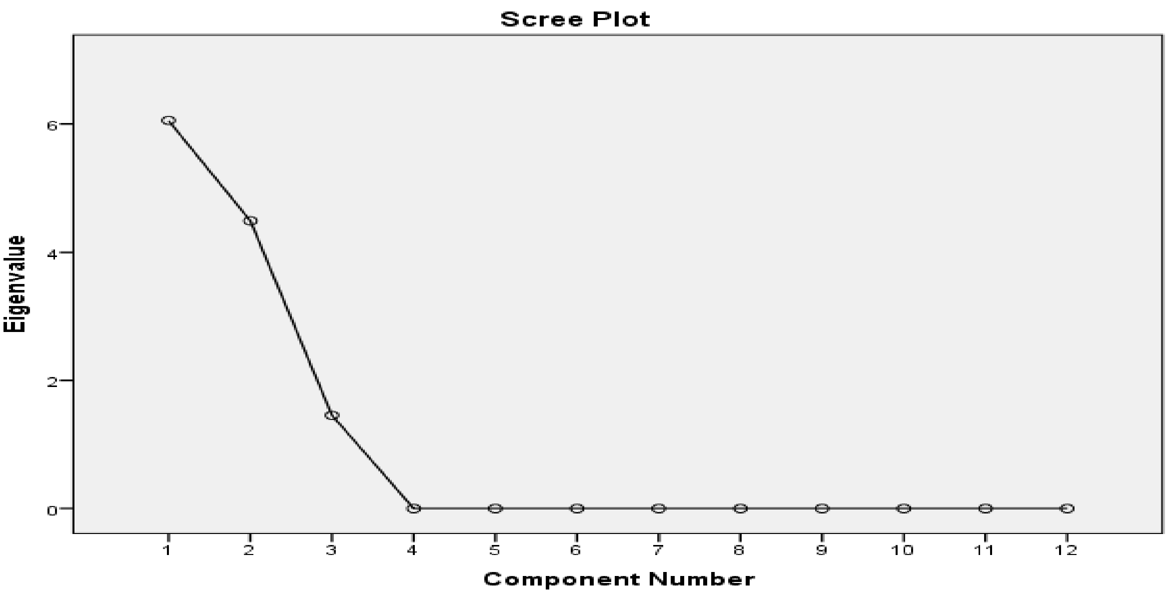

Figure 1: Scree Plot

This is worthy arrangement with the results in correlation analysis and PCA. Figure 1 above summarizes the scree plot of physico-chemical parameters. Component plot can be seen in Figure 2.

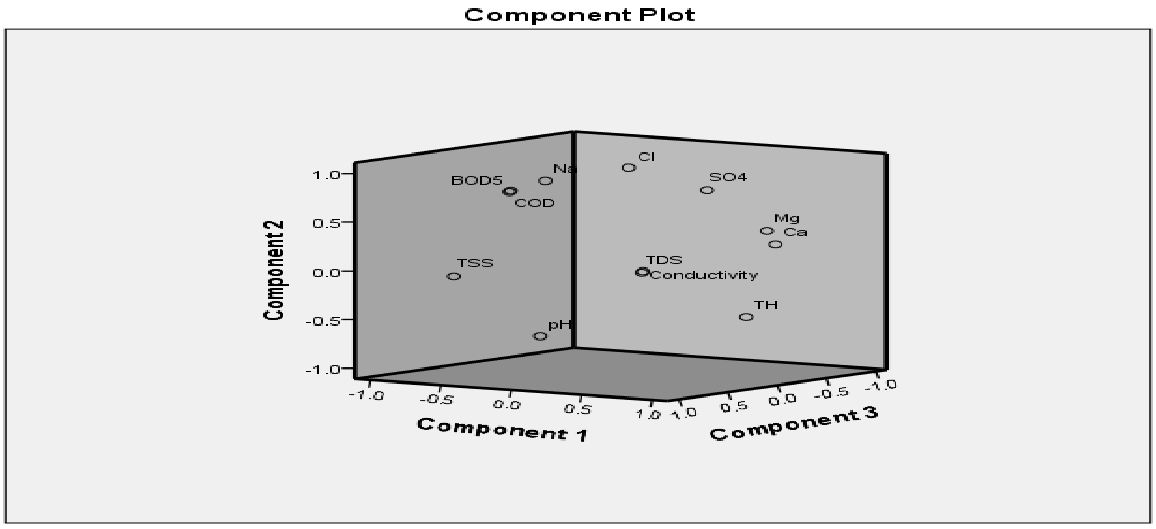

Figure 2: Component Plot of Physico-chemical parameters.

Table 4: Factor Analysis of Physico-Chemical Parameters.

	Component		
	1	2	3
pH	-.612	-.789	-.056
Conductivity	.670	.122	.732
TDS	.666	.108	.738
TSS	-.905	-.139	.401
TH	.904	-.428	.018
BOD_5	-.641	.740	.202
COD	-.676	.719	.164
Cl^{-1}	-.036	.991	-.131
SO_4^{-2}	.558	.826	-.079
Na^{+1}	-.584	.809	-.069
Mg^{+2}	.878	.419	-.229
Ca^{+2}	.926	.284	-.247
%Var	50.466	37.415	12.119
%Cum	50.466	87.881	100.000

This has robust influence loading of 0.991, 0.826 and 0.809. For PC1, TH, Mg^{+2} and Ca^{+2} have the highest factor loading value and they are the most persuasive variable for primary constituent. It also echoes that overfilling of TH, Mg^{+2} and Ca^{+2} are liable for the substantial pollution differences. For PC2, Cl^{-1}, SO_4^{-2} and Na^{+1} have the highest factor loading value, suggesting Cl^{-1}, SO_4^{-2} and Na^{+1} are also major environmental problem.

4. CONCLUSIONS

During the present study, the exorbitant pollutants values of textile dyeing effluent were studied which is discharge without appropriate treatment and creating concern with respect to pollutant load. On one hand the synthetic colorants make our life flamboyant, on other hand abundant effluent arising out of textile wet processing industry is responsible for adulterating our water bodies. Principle component analysis (PCA) and factor analysis (FA) were developed to assess the consequence of the parameters. The present study clearly enlightens the physicochemical parameter of textile effluent which is highly useful to analyze the nature and type of pollutants concentration present in the effluent. Based on the above experimental evidences it is concluded that majority of physicochemical parameters namely: pH, TDS, TSS, TH, Conductivity, BOD5, COD, Ca+2, Mg+2, Cl-1 , Na+1 and SO4-2 show modest to robust correlation amongst themselves. These robust progressive relationships advocate a common source.

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