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THE ENVIRONMENTAL IMPACT AND THE WASTEWATER QUALITY OF THE TEXTILE WET PROCESSING IN THE SUDAN

Mutasim.A. Ahmed [1], Elfadil H. Haroon [2], Elhassan.A. Mohammed [3]

1. Department of Textile Engineering, Faculty of Textile, University of Gezira, Sudan.
2. Department of Textile Technology, Faculty of Engineering, Sudan University for Science and Technology, Sudan.
3. Department of Environmental Health, Faculty of Health, University of Gezira, Sudan.

ABSTRACT

The purpose of this study is to evaluate the environmental impacts of the textile wet processing in one Textile Mill (at Khartoum North) and to estimate the pollution load and the required degree of treatment of wastewater produced.

The study includes the important parameters affecting pollution overload associated with the wet processing stages, such as desizing, scouring, bleaching, dyeing, finishing and washing.

Different industrial wastewater samples were taken at different intervals of time, and subjected to various tests, by the different analytical methods. The instrumental methods of analysis used are UV- visible and atomic absorption spectrophotometer (AAS), digital pH meter, COD reactor, BOD incubator, etc.

The study proved that, the extensive use of chemicals, dyestuffs and water results in generation of highly polluted water differing in magnitude and quality.

Key words: Textile, Wet Processing, Pollution, Wastewater, Environmental Performance.

الخلاصة

في هذا البحث أجريت الدراســة على احد مصــانع النسـيج بالخرطوم بحري, وهدف البحث الى تقييم الوضــع البيئي والتأثيرات البيئية الناتجة عن العمليات الرطبة التي تتبع في المصـــنع, و إيجاد درجة الاجهاد البيئي وايجاد درجة المعالجة المطلوبة للتخلص من التلوث اوتقليله ليكون وفق ما هو مسموح به عالميا.

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أجريت الدراسة على أهم العوامل المرتبطة بعمليات التصنيع المختلفة التي لها دور كبير في الاجهاد البيئي وتحميله؛ كازالة النشا ، الغلية ، التبييض ، الصباغة ، التجهيز والغسيل.
أخذت عينات مختلفة من مياه الصرف الصناعي للمصنع في أوقات مختلفة, وقد أجريت عليها اختبارات عديدة وذلك بإستخدام طرق تحليلية وأجهزة مختلفة مثل: مطياف الضوء المرئي وفوق البنفسجي ومطياف الامتصاص الذري, ومطياف اللهب, العكارة ، مفاعل COD و BOD وغيرها.
أثبت النتائج والدراسة أن الإستخدام المكثف للمواد الكيميائية والأصباغ والمياه تنتج عنها كميات مقدرة من مياه الصرف الملوثة التي تتفاوت في درجة تلوثها ومحتوياتها وتركيزها مثل: الأكسجين الكيميائي المطلوب ,الأكسجين الاحيائي المطلوب ، المعادن الثقيلة ، الأنيونات ، اللون, الأس الهيدروجيني، وغيرها. وقد وجد أن مياه الصرف تحتوي على مواد سامة ومواد غير قابلة للتحلل الاحيائي و البكتيري .

INTRODUCTION

In the Sudan there are several textile factories, some are capable of producing bleached, colored, and finished products. The coloration and finishing operations involve several wet processing stages. Every single operation requires chemicals, dyestuffs, and auxiliaries. Some of these chemicals may have harmful effects to the environment, due to the production of much wastewater and effluents. Since most of the factories have no treatment plants, the wastewater is directly released to the environment, and this may lead to pollution overload.
Not so many of the chemicals used in textile production and processing are highly toxic, though some materials may have long-term toxic effects. For example, some dyestuffs based on benzidine were withdrawn on the basis of their suspected long-term toxic effects on users in the dyestuff industry [(1)] (Smith, 1994). Surfactants, widely used in industry, are often toxic to the more sensitive varieties of fish, such as rainbow trout.
Textile manufacturing is one of the largest industrial producers of wastewater on average approximately 72 kg of water is required to produce 1kg of textile fabric [(2)] (APHA,1989). The textile industry uses different fibers such as, vegetable fibers (cotton), animal fibres (wool and silk), mineral fibres (asbestos and glass), regenerated fibres (viscose rayon and acetate) and a wide range of synthetic materials, nylon, polyester, and acrylics. The stages of textile production are fiber production, fiber processing, spinning, yarn preparation, fabric production, bleaching, dyeing, printing and finishing [(4)] (Lewis,1991).
Textile production involves a number of wet processes that may use chemicals, solvents of volatile organic compounds (VOCS), dyestuffs and finishing agents [(3)] (ATMI,1989).

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Wet processing is a term used to describe a wide range of preparation, coloration and finishing techniques performed on the textile product. Within the textile manufacturing chain wet processing is clearly identified as having a potentially adverse effect on the environment.

In industrial process there are basically four types of wastewater produced, solids, semi-solids (sludge), liquids, and gases. Any one of these types can have the potential to be hazardous, e.g.: - 1- Carcinogenic. 2- Corrosive. 3- Explosive. 4- Flammable. 5- Infectious.6- Irritant.7- Mutagenic. 8- Radioactive. 9- Strong sensitizing.10- Toxic / Poisonous [(4)] (Lewis, 1991).

MATERIALS AND METHODS

1. Materials

Wastewater was segregated and collected from a textile factory at different processing operations viz. scouring, bleaching, and dyeing with different dyestuffs e.g. (vat- bemacron, reactive- bezactive) and finishing. Five different samples as in the following table were taken according to standard methods (8135) [(2)] (APHA, 1989) at different periods each sample was taken five times.

Types and specifications of samples

No.	Type of waste	Specifications
1	Washing	detergent
2	Scouring	Caustic soda, wetting agent, NaCl, detergent
3	Bleaching	H_2O_2 ,NaOH, Sodium silicate, surfactant
4	Bemacron dye (vat)	Dye, sodium hydrosulfite, NaOH, leveling agent
5	Bezactive dye (reactive)	Dye, NaCl, NaOH,

2. Instruments and Methods

UV-Spectrophotometer, atomic absorption spectrophotometer (AAS), chemical oxygen demand (COD), reactor, biological oxygen demand(BOD), air incubator.

The BOD test is used to determine the relative amount of oxygen required by bacteria to oxidize the organic matter present in the wastewater [(4)] (Lewis, 1991).

The principle of the test is that, it measures the change over five days in dissolve oxygen (DO) in stopper bottle completely filled with the wastewater or dilution of it. A special dilution water is used which is buffered to pH 7.2 and contains essential inorganic nutrients. The method used was "ISO 5815",[(3)] (ATMI,1989), using 300 ml incubator bottles, and air incubator, thermostatically controlled at 20 ^{o}C. The samples were collected from the factory according to the standard method

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(1hour before test), and the dilutions were made using air-saturated distilled water [(4)] (Lewis, 1991). The following chemicals were then added according to concentrations and volumes specified as follows: ferric chloride (2ML,0.25g/L), calcium chloride (2mL,36.4G/L), magnesium sulfate (2mL,22.5g/L), and 2Ml of phosphate buffer which was composed of the following: (8.5 g/l KH_2PO_4), (33.4g/l Na_2PO_4) and (1.7g/lNH_4Cl). The sample was placed in 1000ml graduated cylinder and diluted with aerated distilled water. The diluted samples were transferred into BOD bottles and incubated for 5 days at 20 ^oC. The initial(D1) and the final(D2) dissolved oxygen (DO) were determined by titration with sodium thiosulphate (0.25N) using starch indicator, after the addition of manganese sulfate (2ml), azide (2ml), and sulfuric acid (2ml) [(4)] (Lewis,1991). The volume which was taken from sodium thiosulphate (0.25N) is equivalent to the amount of dissolved oxygen required.

The concentration of BOD is calculated as follows: -

$$BOD_5\ (mg/L) = \frac{D1-D2}{P}$$

Where: BOD= biochemical oxygen demand (mg/L)

D1 = Initial DO of the diluted wastewater sample (mg/L)

D2 = Final DO of the diluted wastewater sample after incubation for 5 Days (mg/L).

P = Decimal fraction of the wastewater sample used

$$= \frac{\text{milliliters of waste sample}}{\text{milliliters volume of the BOD bottle or dilution water}}$$

The (COD) test is widely used to characterize and measure the amount of pollutants as organic matters or the strength of wastewater [(5)] (Clair, 2003). The test measures the amount of oxygen required for chemical oxidation of organic compounds to carbon dioxide and water regardless of the presence of a substance that undergoes a biological assimilation.

The basis of the test is that, nearly all organic compounds can be fully oxidized to carbon dioxide with a strong oxidizing agent under acidic conditions [(5)] (Clair,2003).

The amount of oxygen required for oxidizing an organic compound to carbon dioxide, ammonia and water is given by the equation: -

$$C_nH_aO_bN_c + \left(n + \frac{a}{4} - \frac{b}{2} - \frac{3}{4}c\right)O_2 \rightarrow nCO_2 + \left(\frac{a}{2} - \frac{3}{2}c\right)H_2O + cHN_3$$

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The method used was standard method (ISO 6060, 1989) [3] (ATMI,1989).
The samples to be tested were collected according to the standard method (1hour before test); the standard solutions were prepared according to specific concentrations potassium dichromate 0.25N, conc. sulfuric acid, silver sulfate, mercuric sulfate, ferrous ammonium sulfate, ferrion indicator.

A sample was tested according to the following procedure:-
0.4g mercuric sulfate was placed in the COD reactor in reflux flasks. 20 ml of each sample was pipetted and diluted with 20 ml distilled water, 10 ml of potassium dichromate was added to each flask, 4 glass beads were added, and the contents were mixed well, then 30 ml of concentrated sulfuric acid containing silver sulfate was added. The contents were refluxed for 2 hours, and cooled. The condenser was washed with distilled water, and the content was diluted to 100 ml and cooled to room temperature. The excess dichromate was titrated with standard ferrous ammonium sulfate using ferrion indicator until the change of color from (blue-green to brown-green to reddish-brown) was observed. A blank containing 20 ml distilled water was treated and refluxed in the same manner.
The reaction mechanism may be represented as follows:-

$$6Fe^{2+} + Cr_2O_7^{2-} + 14H^+ \longrightarrow 6Fe^{3+} + 2Cr^{3+} + 7H_2O$$

The chemical oxygen demand was calculated according to the following equation:

$$\text{COD (mg/L)} = \frac{(a - b)\ c \times 8000}{\text{Sample volume (ml)}}$$

Where: a = volume of ferrous ammonium sulfate used in the blank sample
b = volume of ferrous ammonium sulfate used in the original sample
c = normality of ferrous ammonium sulfate.

Metals such as chromium and copper were traced in wastewater by using AAS. Nitric acid digestion method (APHA, 3030E) [3] (ATMI, 1989) was used. After the samples were collected according to the standard method (within two hours before the test), the instrument was calibrated using standard solutions. The test was run for all the wastewater samples from (washing, scouring, bleaching, vat dyeing and reactive dyeing).
A standard method (Sulfa Ver4 method 8051) [2] (APHA, 1989) was used for measuring the concentration of sulfates, using UV-Spectrometer. The method used a power pillow which was, adapted from standard methods for examination of water and wastewater procedure, which is equivalent to US EPA method [7] (EPA, 1992).
The instrument used for measuring chloride ions was UV-Spectrometer. The method used was mercuric thiocyanate, Hach program 1400 for water and

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wastewater adapted from (Zall, etal, 1956). The samples were tested for COD, BOD, anions (sulfate - chloride), cations (copper - chromium), color and pH.)[8] (UNEP, 1996).

RESULTS AND DISCUSSION

The results of all the tested samples for COD, BOD, anions (sulfates- chlorides), cations (copper - chromium), color and pH, were tabulated in table (1).

Table (1) Results of physical and chemical parameters of wastewater samples

No.	Type of waste	COD mg/L	BOD mg/L	Sulfate mg/L	Chloride mg/L	Copper mg/L	Chromium mg/L	Color Pt-Co	pH
1	Washing	1121	457	45.6	95.7	0.00	0.00	157.4	8.5
2	Scouring	1470	426	68.5	342.4	0.00	0.00	96.74	9.8
3	Bleaching	1149	354	76.3	250.8	0.00	0.00	140.6	12.9
4	Dyeing, (vat)	2124	562	224.9	385.4	0.43	1.23	2421	12.6
5	Dyeing, (reactive)	1850	518	758.7	496.2	0.38	0.39	3112	12.5

From table (1) and fig.(1) the highest value of COD was obtained from sample No.4 which was a wastewater from vat dyeing(2124mg/L), whereas the lowest value was detected for sample No.1 which was a wastewater from washing,(1121mg/L).The highest BOD was reported for sample No.4 (vat dyeing,562 mg/L) and the lowest value was for sample No.3 (bleaching,1149mg/L). Generally, the readings for COD and BOD are relatively high for wastewater from dye bath due to the use of jigger machines where high dosages of dyes and auxiliaries are required to achieve the desired shade, in addition to the low exhaustion% of the dyestuff used, and the higher percentage of the hydrolyzed reactive dye during dyeing. Consequently, significant amount of dyes is released into the wastewater contributing to the higher values of these parameters [1] (Smith, 1994). The values of COD and BOD for wastewater from fabric preparation were also high enough compared to the standard limit values obtained from literature (NEQS limits 80-150 mg/L) [1] (Smith, 1994); this can be attributed to the fact that, most of the fabric contaminations, such as dust, coloring matters, waxes, fats, sizing materials, etc., were removed here, producing effluent contained spent chemicals and fabric contamination. The high values of these parameters indicated potential depletion of dissolved oxygen in the water body, which could cause adverse effect on biological activity in water environment [9] (Lomas, 1993). The highest concentration of anions (sulfate, and chloride) was

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reported for sample No.5 (reactive dyes) and No.4(vat dyes), as in table (1) and fig (1); this could be attributed to the addition of salts during the dye manufacture such as (salting out), or during dye application as electrolytes for improvement of the dye exhaustion and leveling[1] (Smith,1994). The lowest concentration (45.6mg/l) was recorded for sample No.1 (washing 95.7mg/L). The sulfate ion concentration of sample No.5 was the only one that exceeded the NEQS limit which was (600mg/L) [3] (ATMI, 1989). All the samples were proved to be alkaline (pH 8.5-12.6), which exceeded the upper limits of pH suitable for most of the aquatic life. The range of the standard for most countries is (6-9), the highest pH was reported for sample No.4 (12.6), which was from vat dyeing. [10] (Glover, 1993). For cations (copper, chromium) the highest concentration was given by wastewater from dyeing. For wastewater from fabric preparation the concentration for each metal is zero. When comparing chromium results with the NEQS limits, it was found that, sample No.4 (1.23mg/L) exceeded the limit, whereas sample No.5 (0.39 mg/L) was below the limit. When the results of chromium and copper for sample No. (4 and 5) were compared to that of the U.S, EPA performance guidelines (chromium = 0.10mg/L), (copper = 0.25mg/L) they exceeded the limits [7] (EPA, 1992). These will necessitate the treatment of the wastewater to meet the levels specified in the performance guidelines.

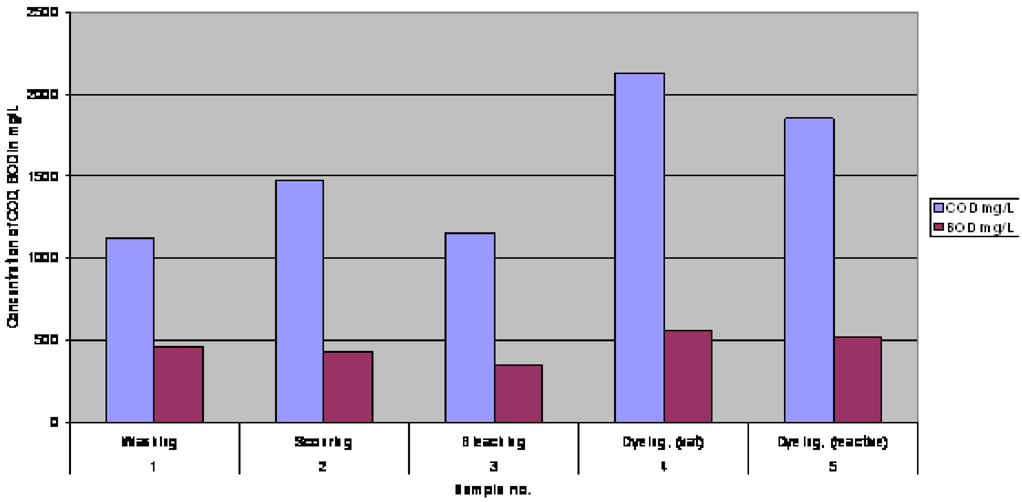

Fig.1 Results of concentration of COD and BOD

Chromium is toxic to aquatic animals, and harmful to humans above the limits specified. The toxicity is a function of temperature, pH, degree of water hardness, and different chromium species. The negative health effect may be lung cancer,

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kidney damage, headaches. Usually chromium has cumulative effect, which tends to accumulate in the food chain of living organisms [6] (Smith, 1986).

Wastewater from reactive and vat dyeing showed the highest apparent color value expressed as Pt-Co,(3112, 2421 respectively), (where 1 color unit is equivalent to 1mg/L platinum as chloroplatinate ion), as table (1) and fig (2) showed, whilst the lowest concentration was reported for sample No.2 (scouring 96.74 pt-Co). All the reported cases exceeded the guidelines for the U.S. EPA (150mg/L) except the samples No. (2 and 3). The relatively higher color concentrations for samples No. (4 and 5) might be attributed to the high liquor to good ratios used in jigger machines, the low dye exhaustion, hydrolyzed dye (reactive), electrolytes, alkalis, and other auxiliaries. As a result, the effluent contained high concentration of dye which would increase the pollution overload. To bring the concentration within the allowable limits [7] (EPA, 1992), either one must reduce the source of pollution by changing the methods of dyeing, or increasing the exhaustion percentage. Another technique is to reuse the dye liquor for medium or light shades or to renovate the dye bath. Otherwise it would be quite important to treat the wastewater by either precipitation with (metal salts and carbon adsorption), decolorization with hydrogen peroxide, ozone, treatment with ultra-violet light, or any other biological, physical, and chemical methods[6] (Smith,1986).

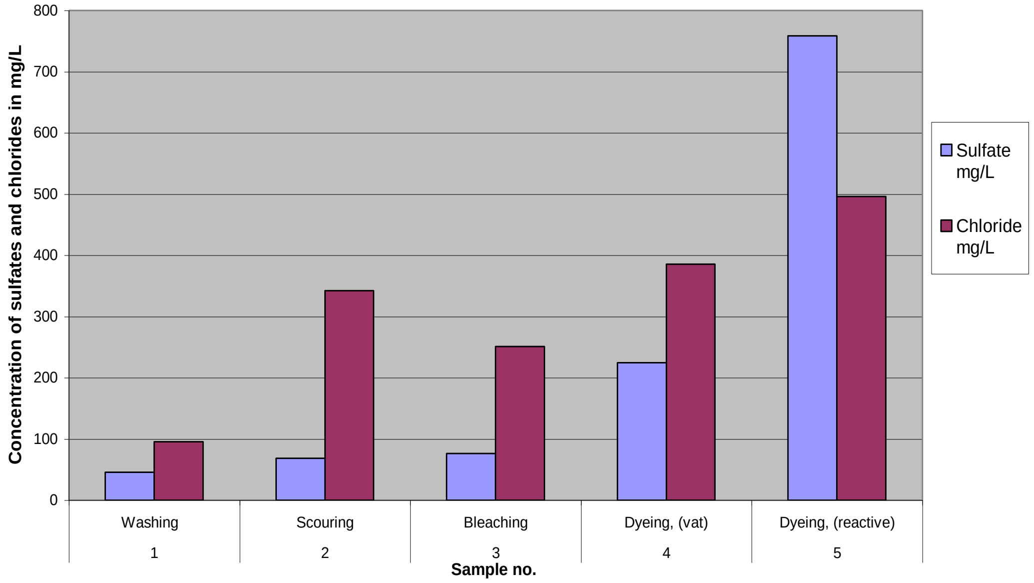

Fig.2 Results of sulfates and chlorides for the samples

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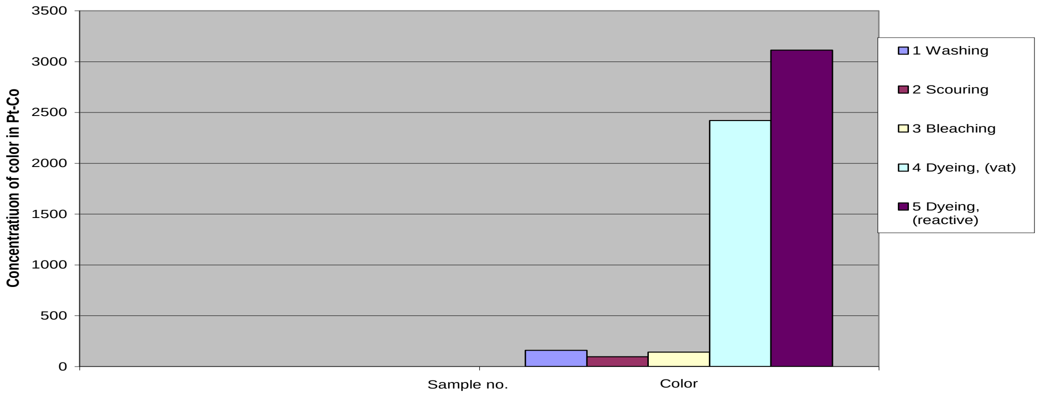

Fig.3 Results of concentration of color

The data in table (2) indicated higher values of both limits of NEQS, BOD=80mg/L, and COD = 150mg/L.

The values also exceeded the guidelines for industrial wastewater of textile mills for U.S. COD and BOD compared to the standard EPA (BOD=30mg/L, COD= 200mg/L). The high values of both COD and BOD indicated high organic pollution levels and a great deal of degradable materials entered the water [(6)] (Smith, 1986), due to that microorganisms were required to degrade and break down the organic substances [(10)] (Glover, 1993), consequently the microorganisms consumed large quantities of oxygen in the process. This essentially caused suffocation of aquatic organisms that required oxygen to survive.

From literature it is known that, the ratio of BOD- to-COD for textile wastewater, generally, ranges from 0.4 to 0.5 which is comparable to that of domestic water; this range shows that, the wastewater may respond to biological treatment [(5)] (Clair,2003).

Table (2): Ratio of BOD to COD for the tested samples

No.	Type of waste	COD (mg/L)	BOD(mg/L)	Ratio BOD/COD
1	Washing	1121	457	0.41
2	Scouring	1470	426	0.29
3	Bleaching	1149	354	0.31
4	Dyeing, (vat)	2124	562	0.26
5	Dyeing, (reactive)	1850	518	0.28

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Table (2) showed that only washing water has this range. All the other samples showed ratios of BOD/COD below 0.4 which would indicate the presence of toxic, materials, nonbiodegradable or less readily biodegradable materials. The lowest ratio of BOD/COD which is reported for vat dyeing water, indicated its high pollution load and high toxicity, although, the highest values of both COD and BOD were reported for it as in table (2).

Table (3): Estimated wastewater strength and pollution load

Pollution parameters	**Pollution load (g/kg)**			
	Washing	Scouring	Bleaching	Dyeing
Chemical oxygen demand	224	293	231	402
Biological oxygen demand	91	85	71	108
Sulfates	9	19	15	98
Chlorides	18	68	49	87
Chromium	0	0	0	0.24

From table (3) it can be said that the highest pollution load was indicated for dyeing followed by scouring. This was due to the higher concentrations of COD, BOD, sulfate, chloride, and chromium in the wastewater from the dyeing process.

Table (4): Estimated required degree (%) of wastewater treatment

parameters	**Mean values**	**Required degree of treatment (%)**
pH	11	22
BOD(mg/L)	463	478
COD(mg/L)	1542	671
Sulfates(mg/L)	235	0
Chlorides(mg/L)	314	0
Chromium(mg/L)	0.32	70
Copper (mg/L)	0.16	0
Color (Pt-Co)(mg/L)	1366	810

From table (4) the highest required degree of treatment of wastewater is for color (810%), next for COD (671%), BOD (478%), chromium (70%) and pH (22%) respectively. Sulfate and chlorides do not require any treatment.

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CONCLUSION

In the textile mill the wet processing employs much water used either as a carrier for transporting chemicals and dyestuffs to fabrics, or for washing purposes. The volume of water used for each 1kg of fabric was found to be 180 liters. The environmental impacts of wet processing resulted from the impacts associated with the various fabric processing stages including desizing, scouring, bleaching, dyeing, finishing, and the various washing stages after every single wet processing operation.

From the samples tested and reported, the following points can be concluded:

1. The highest pH is reported for samples from dyeing, where as the lowest pH value is for samples from washing; both values are not within the range of the standards.
2. The highest concentrations of color are reported for samples from dyeing (vat, and reactive) which exceed the standard limits.
3. The highest COD and BOD values are determined for samples from vat and reactive dyeings, both exceed the standard limits, the lowest values are reported for wastewater from bleaching which also exceed the standard limits.
4. The highest concentration of sulfate is determined for samples from reactive dyes, the lowest is for samples from washing, and both are well within the standard limits.
5. The higher concentration of chlorides is reported for samples from reactive dyes, and the lower is for wastewater from washing, most of the reported cases are within the allowable standard limits.
6. Higher values of heavy metals (copper, chromium) are determined for wastewater from vat and reactive dyes which exceeded the US, EPA standard limits, where as the wastewater from scouring, bleaching and washing contained no chromium or copper ions.
7. The ratio of BOD to COD in most of the reported cases are not within the acceptable standard limits, except the sample from washing which is well within the standard range, this can indicate that, most of the reported samples contained toxic non-biodegradable substances especially those from vat and reactive dyes.
8. The highest pollution load is reported for samples from dyeing.
9. The parameters which require the highest degree of treatment are color, COD, and, BOD.

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REFERENCES

1. Smith B, (1994).Best Pollution Prevention Management Practices for the Textile Mills, in Press, US EPA.
2. APHA-AWWA.WPCF, 1989, Standard Methods for Examination of Water and Wastewater, (17th Edition), Washington, 1989.
3. ISO 6060: Water Quality Determination of Chemical Oxygen, Detail ATMI's E3 Program**:** Encouraging Environmental Excellence Report 1995- Cases Studies of Pollution Prevention – American. Textile Industries, USA.
4. Lewis J, Schurk J, (1991). Incorporating Pollution Prevention Concepts into Higher Education, University of Washington, Department of Ecology.(2005)
5. Clair N. Sawyer, Perry L. McCarty, (2003). Chemistry of Environmental Engineering and Science, 5th Edition, New York: McGraw-hill. ISBN 0072480661.
6. Smith B**, (**1986). Polymer and Text. Chemistry Program, NCSU, College of Textiles, Raleigh, NC.
7. EPA-600/4-79-020, 1983; Standard Methods, 1992, p.3-61 Standard Method, 1992, p.3-61
8. United Nations Environmental Program (UNEP**),** (1996). Cleaner Production in Textile Wet Processing, Work Book Trainer, Paris, 1996.
9. Lomas, M**, (**1993**).** Textile Wet Processing and the Environment, *Journal of the Society of Dyers and Colorists*, 109: p 10-12.
10. Glover, Brain; Pierce, H Jeffery, (1993). A Return to Nature, *Journal of the Society of Dyers and Colorists*, 109: P 5-9.