

## The Physico-Chemical Studies of Wastewater in Hawassa Textile Industry

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### Abstract

This paper presents a case study of the **comprehensive** physico-chemical studies of industrial wastewater of Hawassa Textile Factory of Ethiopia using chemical analytical methods which represents a heavy source of environmental pollution that entering a water reservoir. The physico-chemical parameters such as color, odor, temperature, pH, electrical conductivity (EC), total dissolved solid (TDS), total suspended solid (TSS), biochemical oxygen demand (BOD), and chemical oxygen demand (COD) in effluent and adjacent water samples were assessed. Wastewater sample in triplicates mode from Hawassa textile and receiving water bodies were analyzed for the above parameters separately using standard methods. The results were compared with standard values for wastewater set by authorized bodies. The results showed that textile effluents were blue black colored and have pungent odor. The range of temperature was 17.80-25.75°C and pH was 8.080-11.21. The experimental analytical values of EC, TDS, TSS, BOD, and COD, of textile effluent were found 31.01-46.30, 277.0-900.4, 90.50-147.0, 93.00-188.0, and 189.6-264.0mg/L respectively. Except for temperature the analyzed values of all samples exceeded the prescribed guideline limit. The COD values of all the samples were very high indicating high degree of pollution. Thus Hawassa textile effluents are one of the sources of pollution for receiving water which will affect the flora and fauna existing in the surrounding environments. This case study strongly underlines the need for treatment of textile effluent before they are discharged into the surrounding water reservoir.

**Keywords:** Physico-chemical parameters; Wastewater; Hawassa textile factory; Chemical analyses

### Introduction

Effluent generated by the industries is one of the sources of pollution. Contaminated air, soil, and water by effluents from the industries are associated with heavy disease burden [1]. Textile processing operations are considered an important part of the industrial sector in both developed and developing countries, like Ethiopia. However the textile industry is one of the most complex manufacturing industries with operations and processes as diverse as its products. Due to this diversity it is almost impossible to describe a "typical" textile effluent [2]. The technology of transforming cotton and synthetic fibers into fabrics and dyed fabrics generates various kinds of wastes. However, environmental problems of the textile industries are mainly caused by discharges of wastewater/effluents during dyeing and finishing processes [3]. Textile finishing processes involve a series of washing treatments designed to remove impurities and impart to the material desired properties of aesthetic appeal and touch [4].

Fabric dyeing involves the following major steps; scouring, bleaching, dyeing, dye fixation and fabric softening. Scouring is performed to remove impurities through the use of alkaline baths prior to further wet processing. Garment washing involves the use of detergents and softeners to remove dirt and improve the fabric texture before finished garments are sent to the market [4]. Thus wastewater generated from the textile processing industries contains high amounts of suspended solids, dissolved solids, unreacted dyestuffs (color), BOD, COD, heavy metals and other auxiliary chemicals that are used in the various stages of dyeing and other processes [5-10].

Cottons and cotton-based textiles are processed through three main stages, comprising spinning, knitting or weaving and wet processing. These textile processes and associated wastes are discussed below.

### Spinning

Spinning is the process which converts raw fiber into yarn or thread. The spinning process is entirely dry, although some yarns maybe dyed and finished as a final customer product [11].

### Knitting

Knitting is carried out by interlocking a series of yarn loops, usually

using sophisticated, high speed machinery. This process is almost completely dry, although some oils may be applied during the process for lubrication. These are removed by subsequent processing and enter the wastewater stream [12].

### Weaving

Weaving is the most common method used for producing fabrics. Prior to weaving, the warp threads are coated with a size, to increase their tensile strength and smoothness. Natural starches are the most commonly used sizes, although compounds such as Polyvinyl Alcohol (PVA), resins, alkali-soluble cellulose derivatives, and gelatin glue have been used. Other chemicals, such as lubricants and fillers, are often added to impart additional properties to a fabric. This process usually adds on about 10-15% to the woven goods.

### Sizing

Sizing is carried out before the weaving process to increase the strength and smoothness of the yarn, to reduce yarn breakages. Yarns used for the production of knitted fabric are usually treated with waxes or lubricants. Cotton is the most heavily sized fiber with loads of up to 200 g/kg applied to the warp yarn. This is because starch/starch derivatives are usually employed, for which loadings are significantly higher than for synthetic sizes. A range of additional agents are generally present in most size preparations for cotton [13].

### Singeing

Singeing is a dry process, it considered as a part of the wet

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processing. Unlike other wet processing operations, it does not call for large quantities of water, except for quenching the material after singeing. Therefore, this is environmental friendly. The most significant development that has taken place in direct flame singeing of woven fabrics is the design of burners to produce high intensity flame with uniform temperature using natural gas, butane or propane. This direct flame heights and clogged flame jets. To avoid or eliminate these problems, indirect singeing system has been developed [14].

### Desizing

Sizes have, in general, a high biological oxygen demand (BOD) and will contribute significantly to the waste load of the mill's effluent. Reports show that waste stream of the desizing operation can contribute up to 40-50% of the total pollution load of a mill's wastewater. The goal of these methods is to hydrolyze the starch. Unlike starch, synthetic starches stay intact during desizing, can be recovered and reused [15]. Gums and PVA may be removed by a simple hot wash but starch and its derivatives have to be made soluble by soaking with acids, enzymes or oxidants before being removed by a hot wash.

### Scouring

Scouring is usually the first step in the processing of knitted goods and will remove the knitting oils which were applied to the yarn prior to knitting [16]. This is usually done at high temperatures (above 100°C) with sodium hydroxide and produces strongly alkaline effluents (around pH 12.5) with high organic loads. They tend to be dark in color and have high concentrations of Total Dissolved Solids (TDS), oil and grease. Common scouring agents include detergents, soaps, alkalis, antistatic agents, wetting agents, foamers, defoamers and lubricants.

### Bleaching

Almost all fabric containing cellulose's are being bleached to remove the natural colored matter. Mainly flavonoids are responsible for the color of cotton [16,17]. It has three technologies: sodium hypochlorite bleaching; hydrogen peroxide bleaching and sodium chlorite bleaching. Hydrogen peroxide bleaching is carried out under alkaline conditions which generate effluents with a low organic content, high TDS levels and strong alkalinity (pH 9-12) and temperatures close to boiling. Furthermore, a huge amount of water is needed to remove hydrogen peroxide from fabrics, which can cause problems in dyeing. Therefore, replacement of hydrogen peroxide by an enzymatic bleaching system would not only lead to better product quality due to less fiber damage but also to substantial savings on washing water needed for the removal of hydrogen peroxide [18] reported for the first time the enhancement of the bleaching effect achieved on cotton fabrics using laccases (copper-containing oxidize enzymes found in plants) in low concentrations. More recently a combined ultrasound-laccase treatment for cotton bleaching was also reported [19].

### Mercerization

In this process overall fabric size and made it stronger and easier to dye. Baths containing very concentrated solutions of sodium hydroxide (20-30%) are used [20] to improve luster, strength and dye uptake and it also removes immature fibers. Excess sodium hydroxide is normally recovered for reuse in either the scouring or other mercerization stages. Sufficient washing is required after this step to remove any traces of caustic soda [15]. If discharge is required then the alkali is neutralized, leading to the discharge of large quantities of salt.

### Dyeing

Dyeing industry effluents are one of the most problematic

wastewaters to be treated not only for their high chemical oxygen demand, but also for high biological oxygen demand, suspended solids, turbidity, toxic constituents but also for color, which is the first contaminant discernible by the human eye (Figure 1 below shows dye mixing and its removal from the floor). Dyes are classified as follows: anionic: - direct, acid and reactive dyes; cationic: - basic dyes; non-ionic:- disperse dyes [21].

Water soluble reactive and acid dyes are problematic; as they pass through the conventional treatment system unaffected, posing problems. Hence, their removal is also of great importance [22]. Dyes most commonly applied to cotton are reactive and direct dyes. Basic dyes have high brilliance and intensity of colors and are highly visible even in very low concentration [23]. Metal complex dyes are mostly chromium based, which is carcinogenic [22,23].

### Printing

Textile printing is the process of applying color to fabric in definite patterns or designs. Textile printing is related to dyeing but, whereas in dyeing proper the whole fabric is uniformly covered with one color, in printing one or more colors are applied to it in certain parts only, and in sharply defined patterns [24].

### Finishing

In textile manufacturing, finishing refers to the processes that convert the woven or knitted cloth into a usable material and more specifically to any process performed after dyeing the yarn or fabric to improve the look, performance, or "hand" (feel) of the finished textile or clothing [25]. Some finishing techniques such as bleaching and dyeing are applied to yarn before it is woven while others are applied to the grey cloth directly after it is woven or knitted. The general process from raw cotton picked to finishing and its pollution is given below in Figure 2 below.

As it was observed above textile wastewater contains substantial pollution loads in terms of Temperature, Color, pH, COD, BOD, TDS, TSS, and EC hence characterizing textile wastewater is a prerequisite to investigate the appropriate treatment options and to evaluate the treatment plant. However, very little work has been done on the characterization of textile wastewater in Ethiopia in general and Hawassa textile (southern Ethiopia) in particular. The study assessed the physico-chemical characteristics (Color, Odor, Temperature, pH, TSS, TDS, BOD, COD and EC) of effluents in Hawassa textile industry and adjacent water bodies.

### Methods and Materials

Samples were collected from Hawassa Textile Waste, Tikur Wuha (river) and Hawassa Lake. Wastewater samples was collected in plastic containers previously cleaned by washing in non-ionic detergent,

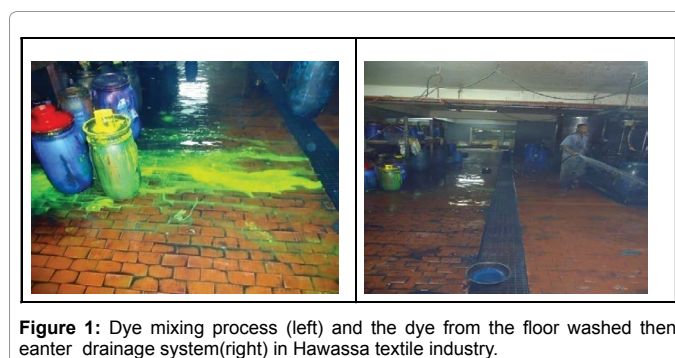
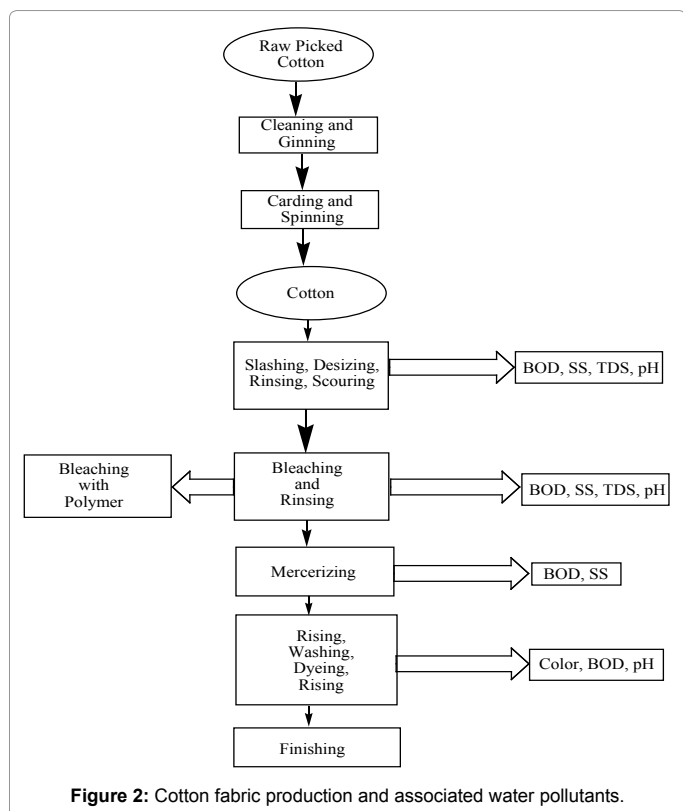


Figure 1: Dye mixing process (left) and the dye from the floor washed then enter drainage system(right) in Hawassa textile industry.



rinsed with tap water and later soaked in 10%  $\text{HNO}_3$  for 24 hours and finally rinsed with deionized water prior to usage. During sampling, sample bottles were rinsed with water which was sampled. Wastewater was collected before treatment, after treatment at lagoon, and from Tikur Wuha River and Hawassa Lake at a peak hour of production in one month interval in triplicate. All the samples collected were analyzed separately. The pH, temperature and electrical conductivity of sample were recorded during each sampling. Then the samples were stored in the refrigerator at about  $4^\circ\text{C}$  prior to analysis. Parameters such as, TDS, TSS, BOD, COD of the samples were measured using various standard methods (APHA, 1998) in water supply and environmental engineering laboratory; at Arba Minch university.

The obtained data was analyzed by descriptive statistics (Minimum conc., Maximum Conc., Mean conc. and standard deviation by using SPSS (Statistical Package for Social Sciences)). The all figures were generated by Microsoft Office Excel 2007 during the analysis of EIA process and were used directly for results interpretation. The precision of the all analyses were measured using the standard deviation techniques and calculated in mg/L for the each sample.

## Result and Discussion

Waste water was being discharged directly into drains that connect the industry to the main drainage network to the River named Tikur Wuha which flows in Lake Hawassa. A huge volume of untreated textile dye waste water is discharged into various drains adjoining textile printing units. A number of azo dyes were used in textile printing industries [26]. The results of the Physico-chemical Properties of Effluent and neighboring water bodies are given in Table 1 below.

### Color and Odor

The effluent collected from Hawassa textile was blue black colored and have pungent smell may be due to presence of organic and human

contamination. High TDS (maximum value 900.4 mg/L) and TSS (maximum value 147.0mg/L) detected (as shown in Table 1 above) could be attributed to the high color from various dyestuffs being used in the textile mills.

### Temperature

Temperature increase may become barrier to fish migration and in this way seriously affect on reproduction of species. The major sources of thermal pollution are industrial cooling systems working in a manufacturing plant or a power plant. Temperature and some other parameters of waste effluents and water bodies were measured in sample site as shown in Figure 3.1 below.

It has been reported that textile and other dye effluents are produced at relatively high temperatures [27]. Reports are also available that the bio-chemical reactions of aquatic organisms are temperature dependent [28]. Increase in temperature of water body will promote chemical reactions in the water. In the present study the temperature varies between minimum of  $15.60^\circ\text{C}$  and maximum of  $29.00^\circ\text{C}$  for the effluents collected from textile industries and neighboring water bodies which is below the guide line limit [29] as shown Figure 3a above.

### pH

The toxicity of heavy metals also gets enhanced at particular pH. Thus, pH is having primary importance in deciding the quality of waste water effluent. Waters with pH value of about 10 are exceptional and may reflect contamination by strong bases such as  $\text{NaOH}$  and  $\text{Ca}(\text{OH})_2$  [30].

The mean pH value of the sample collected ranged from 8.177 to 11.11 which lie above the permissible limit and is found to be basic (Figure 3b – 3f above). This shows Hawassa textile effluents are highly alkaline may be due to dyeing and printing process in Hawassa textile. This alkalinity has effect on the buffering capacity of the water systems and needs to be monitored in all cases. High alkalinity is a measure of wastewater strength and shows the capacity of wastewaters to neutralize acids, and is undesirable. Hence Hawassa effluents affect physical and chemical properties of water which in turn adversely affects aquatic life, plants and humans. This also changes soil permeability which results in polluting underground resources of water [31]. Effluents of other textile and dye industry showed similar pH trend, as seen in the present study, being alkaline in nature [32].

### Electrical Conductivity (EC)

Water with high EC affects the soil structure, permeability and irrigation. Conductivity is measured to establish the pollution zone around an effluent discharge [33]. Electrical conductivity of studied effluent was found to be minimum of  $31.01 \mu\text{scm}^{-1}$  and maximum of  $46.30 \mu\text{scm}^{-1}$ .

### Biological Oxygen Demand (BOD)

Biochemical oxygen demand is a measure of the quantity of oxygen used by microorganisms (e.g., aerobic bacteria) in the oxidation of organic matter. Urban runoff carries pet wastes from streets and sidewalks, nutrients from lawn fertilizers, leaves, grass clippings, and paper from residential areas, which increase oxygen demand.

BOD of effluent determined was maximum of 188.0 mg/L and minimum of 93.00 mg/L as shown in Table 1 above. The BOD of the studied waste water sample is higher than guide line limit 30 mg/L [34]. High level of BOD is an indication of the contamination and there could be low oxygen available for living organisms in the neighboring water

Industry	Parameters.	Year 2012/13								
		Site	First Round	Second Round	Third Round	Mean.	St. Dev.	Max. Value.	Min. Value.	Guide Line Limit
Hawassa	Color	BT	B. Black	B. Black	B. Black	-	-	-	-	Offensive color not acceptable [34]
		AT	B. Black	B. Black	B. Black	-	-	-	-	
		TW	L. Blue	L. Blue	L. Blue	-	-	-	-	
		HL	Colorless	Colorless	Colorless	-	-	-	-	
	Odor	BT	Pungent	Pungent	Pungent	-	-	-	-	
		AT	Pungent	Pungent	Pungent	-	-	-	-	
		TW	Odorless	Odorless	Odorless	-	-	-	-	
		HL	Odorless	Odorless	Odorless	-	-	-	-	
	Temp °C	BT	24.50	25.60	25.75	25.28	0.557	25.75	24.50	≤ 37 °C [34]
		AT	22.80	23.70	23.80	23.43	0.450	23.80	22.80	
		TW	18.90	20.30	19.30	19.50	0.589	20.30	18.90	
		HL	17.80	18.90	19.00	18.57	0.544	19.00	17.80	
	pH	BT	11.12	11.21	11.00	11.11	0.086	11.21	11.00	6.00 – 9.00[38]
		AT	10.03	10.18	10.53	10.25	0.209	10.53	10.03	
		TWW	8.080	8.350	8.550	8.327	0.193	8.550	8.080	
		HL	8.340	8.080	8.110	8.177	0.1106	8.340	8.080	
	EC(µscm <sup>-1</sup> )	BT	45.17	46.30	45.70	45.72	0.462	46.30	45.17	NA
		AT	37.19	36.40	36.24	36.61	0.415	37.19	36.24	
		TWW	31.01	33.50	36.29	33.60	2.157	36.29	31.01	
		HL	36.39	36.70	36.75	36.61	0.159	36.75	36.39	
	TDS(mg/L)	BT	891.1	900.4	899.5	897.0	4.188	900.4	891.1	≤250 mg/L[38]
		AT	483.0	499.0	506.8	496.3	9.907	506.8	483.0	
		TWW	288.0	277.0	291.0	285.3	6.018	291.0	277.0	
		HL	382.0	366.0	397.5	381.8	12.86	397.5	382.0	
	TSS(mg/L)	BT	140.0	147.0	144.0	143.7	2.867	147.0	140.0	≤ 30 mg/L[34]
		AT	138.0	133.5	139.5	137.0	2.549	139.5	133.5	
		TWW	102.0	109.0	106.8	106.0	2.918	109.0	106.8	
		HL	96.00	98.00	90.50	94.83	3.171	96.00	90.50	
BOD(mg/L)	BT	183.0	180.4	182.0	181.8	1.071	183.0	180.4	≤ 30 mg/L[34]	
	AT	149.0	188.0	181.7	172.9	17.09	188.0	149.0		
	TWW	101.3	108.7	106.5	105.5	3.102	108.7	101.3		
	HL	93.00	99.30	99.85	97.38	3.108	99.85	93.00		
COD(mg/L)	BT	328.0	327.1	329.7	328.3	1.078	329.7	327.1	≤ 160 mg/L [38]	
	AT	264.0	253.0	257.6	258.2	4.511	264.0	253.0		
	TWW	218.0	220.0	226.5	221.5	3.629	226.5	218.0		
	HL	196.0	189.6	197.5	194.4	3.426	197.5	189.6		

BT:- Before Treatment, AT:- After Treatment, TW:- Tikur Woha, HL:- Hawassa Lake

**Table 1:** Physico-chemical properties of effluent samples from hawassa textile and receiving water bodies.

bodies. Therefore consistent analysis of BOD needs to be encouraged for these textile industry effluents.

### Chemical Oxygen Demand (COD)

High COD levels imply toxic condition and the presence of biologically resistant organic substances or COD values conveyed the amount of dissolved oxidizable organic matter including non-biodegradable matter present in it.

COD value in sample effluent was found to be minimum of 189.6

mg/L and maximum of 329.7 mg/L in Hawassa and neighboring water. As shown in Table 1 above Hawassa textile Industry is having maximum COD of 329.7 mg/L and minimum COD of 189.6mg/L. It is above the guide line limit in all sample sites. High COD levels imply toxic condition and the presence of biologically resistant organic substances [32].

### Total Dissolved Solids (TDS)

In water, TDS are composed mainly of carbonates, bicarbonates,

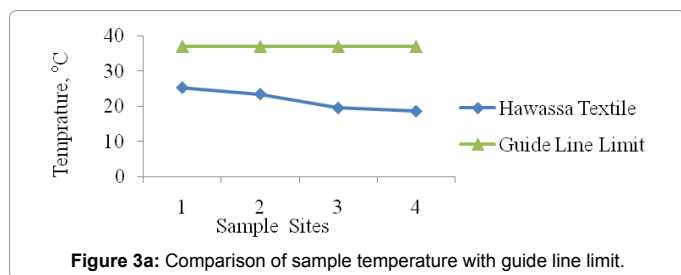


Figure 3a: Comparison of sample temperature with guide line limit.

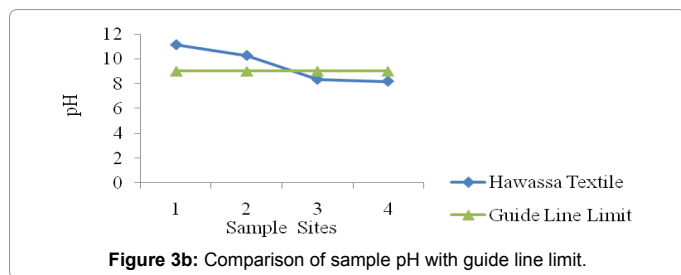


Figure 3b: Comparison of sample pH with guide line limit.

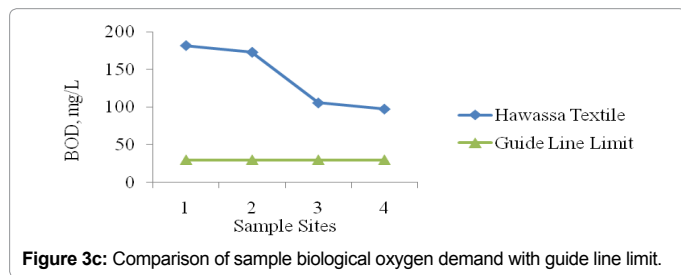


Figure 3c: Comparison of sample biological oxygen demand with guide line limit.

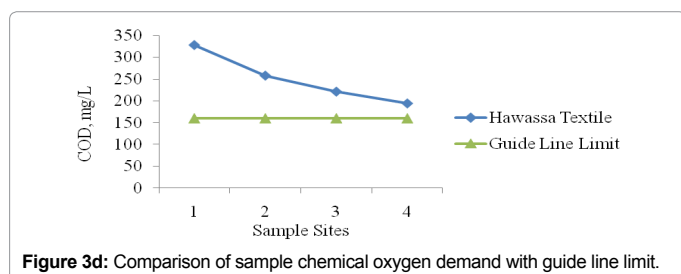


Figure 3d: Comparison of sample chemical oxygen demand with guide line limit.

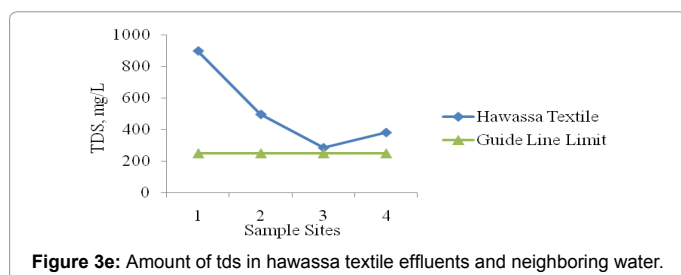


Figure 3e: Amount of tds in hawassa textile effluents and neighboring water.

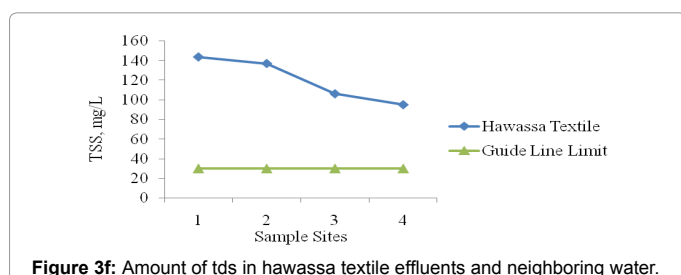


Figure 3f: Amount of tds in hawassa textile effluents and neighboring water.

chlorides, phosphates and nitrates of calcium, magnesium, potassium and manganese, organic matter salts and other particles. High TSS and TDS detected could be attributed to the high color (from the various dyestuffs being used in the textile mills) and they may be major sources of the heavy metals. Increased heavy metals concentrations in river sediments could increase suspended solids concentrations [35]. During the dry season, the occasional dust re-suspension could introduce these metals into the atmosphere along with the particulates. With this, they could constitute health problems in the form of air pollution. Some of the vapors formed above have great potential to nucleate thus becoming particulate problem to the environment. In addition to this are the products of reactions between some of the chemicals present in the effluents [36] which may be toxic to the environment.

TDS of the effluents was found to be maximum of 897.0 mg/L which exceed the guide line limit [37]. High TDS values may be associated with excessive scaling in pipes, which may cause corrosion and the settle able and suspended solids are high and this will affect the operation and sizing of treatment units. Solids concentration is another important characteristic of wastewater [38]. If the roots of a plant are placed in water with a high salt concentration the water from the plant moves into the salt water and the plant wilts. So irrigation with high TDS water will result in decrease in optimal crop production. High concentration of TDS and turbidity from suspended solids reduce water clarity and cloudy water absorbs more heat and blocks light penetrations. Therefore, increased turbidity increases water temperature and prevents photosynthesis which in turn reduces the concentration of DO as warm water hold less DO than cold water.

## Conclusions

In general, the textile industry emits a wide variety of pollutants from all stages in the processing of fibers and fabrics. These include liquid effluent, solid waste, hazardous waste, emissions to air and noise pollution. It is important to investigate all aspects of reducing wastes and emissions from the textile industry, as not only will it result in improved environmental performance, but also substantial savings for the individual companies.

Based on the above experimental evidences, the obtained values of physicochemical characteristics viz TSS, TDS, BOD, COD etc. in the wastewater of the textile factory and neighboring water bodies are above guideline permissible limit in all the sampling sites. These are the most frightening values and cause a real threat to the environment [35]. The recorded pH values in waste water of Hawassa Textile Factory before and after treatment were found above guideline permissible limit of EIA process. These could mean the factory poses series pollution load to the environment in general and the aquatic habitat in particular. Over and above, the ratio values of BOD: COD in the most of the sampling sites were found far lower which indicates the biological treatment of the effluent is not feasible and the waste water treatment plant of the Hawassa textile factory is inefficient. Therefore, the effluent control and proper treatment of factory waste water is highly needed before discharging into the environment [36]. In conclusion, the effluents of Hawassa textile industry are far from the prescribed limits under defined international scale of EIA process. The finding of the studies suggests that the effluents are toxic in nature and require serious treatment before disposal on land in favors of Eco-environments of Hawassa city.

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