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Wastewater Treatment Plant and its Design for Textile Industry

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Abstract

Wastewater treatment (WWT) system in textile industry is used to treat the effluent discharged from sizing and different wet processing of textiles in Ethiopia. Textile industry uses a large quantity of chemicals and huge amount of water for sizing of warp yarn, pretreatment of textiles and coloration processes. Wastewater Treatment Plant is important because it reduces the adverse environmental impact of the effluent discharged to the surrounding. In this study, an attempt has made to design an efficient and cost-effective Wastewater Treatment Plant based on the identified effluent characteristics from three different textile industries. To keep the confidentiality of the data from the industries the three identified industries were Represented by F1, F2 and F3. The effluent collected was incubated for 5 days at 20oC. The BOD content of the wastewater before and after incubation was calculated. DO content before incubation was 26 mg/l after incubation it is diminished to 21.4 mg/l. The wastewater treatment system studied requires less energy and maintenance cost.

Introduction

Wastewater treatment (WWT) is a broad term that applies to any process, operation or combination of processes and operations that can reduce the objectionable property of water that carried waste and render it less dangerous and repulsive to man [1]. The WW is treated before its ultimate disposal in order to Reduce the spread of communicable diseases caused by the pathogenic organisms in the sewage and Prevent the pollution of surface and ground water [2,3]. Industrial wastewater is an industrial site drainage which contains silt sand, alkali, oil, chemical, and industrial cooling wastes, which contain biocides, heat, slimes, silt. It varies from industry to industry and varies from process to process even for the same industry. For example, Textile industry effluents from scouring, carbonizing, bleaching, dyeing and finishing operations vary from each other and have different effects on the receiving environment [4,5]. The Textile industry uses a large quantity of chemicals and huge quantities of water. Detergents and caustics are used to remove dirt, grit, oils, and waxes. Bleach is used to improve whiteness and brightness. Dyes, fixing agents, and many in-organics are used to provide the brilliant array of colors the market demands. Sizing agents are added to improve weaving. Oils are added to improve spinning and knitting. Latex and glues are used as binders. A wide variety of specialty chemicals are used such as softeners, stain Release agents, and wetting agents. Many of these chemicals become part of the final product whereas the rest are removed from the fabric and are purged in the effluent stream.

The local authorities (in developed and some of developing countries) have begun to target the Textile industry to clean up the wastewater that is being discharged. Regulators are looking for toxicity due to high salt content, Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), heavy metals, and color of the effluent. Wastewater from Textile Fabric pre-treatment, Dyeing and Printing [6]. processing contains bath residues Sizing Since the mill is water and chemical intensive industry, it discharges effluent that needs attention because the effluent has various contaminants that have adverse environmental impact. Due to this reason, wastewater from Textile processing must be treated before discharge and reused to reduce the cost and to make it eco-friendly. This project is carried out because only few Textile industries have wastewater treatment plant and some of the plants are not working at all in developing countries. Therefore, this project attempts to suggest a Wastewater Treatment method including wetland treatment system.

Methods

Literature r eview

Extensive literature review has been carried out on WW, industrial WW (constituents, characteristics, and origin), WW constituent of the Textile industry and different WW treatment systems. Relevant books and internet sources have been referred. The benefits of implementing WWT system in industrial context is given due emphasis [7].

Data Collection, Industrial Visits and Observation

Using interviews and recorded documents from the identified industries, data was collected. Finally, the collected data from the industries are analyzed. Three Textile factories have been visited and data investigated. Cleaner production (CP) center of Ethiopia is also visited. Therefore, the data that will be discussed later in this project is based on these three factories and the standard obtained from CP center.

Materials

Equipment used are:

a. Glass stoppered bottle

b. Calibrated vessel

c. Different type and sizes of bottle

d. Calibrated syringe

Chemicals used are:

a. Manganous sulphate solution

b. Alkali-Azide reagent

c. Sulphuric Acid solution

d. Starch indicator

e. H13810-0 Reagent titrant solution

Procedure

Rinse the glass bottles 3 times with water sample and fill to overflow. And insert stopper and ensure that a small part of the sample spills over. Remove the stopper and add 5 drops of each manganous sulphate solution and Alkali-azide reagent. Add some more sample to fill the bottle completely. Carefully stopper the bottle again and ensure that a part of the sample spills over. This is to make sure that no air bubble has been trapped inside, which would corrupt the reading. Invert the bottle several times. The sample becomes orange yellow and flocculent precipitate forms, because oxygen is present. Stand the sample and flocculent precipitate will start to settle. After approximately 2 minutes, when the upper half of the bottle becomes limpid, add 10 drops of sulphuric acid solution. Again stopper the bottle and invert it until all particulate material is dissolved. Now the sample is ready for measurement when it is yellow and completely limpid.

Remove the cap from plastic vessel and rinse the plastic vessel with the solution in the bottle, after that fill it to the 5ml mark and replace the cap. Add one drop of starch indicator through the cap port and mix by carefully swirling the vessel in tight circles. The solution will turn to violet to blue color. Push and twist pipet tip onto tapered end of syringe ensuring an airtight-fit. Take the titration syringe and push the plunger completely in to the syringe and insert tip in to H13810-0 reagent titrant solution and pull the plunger out until the lower edge of the plunger seal is on the 0ml mark of the syringe [8].

Place the syringe tip into the cap port of the plastic vessel and slowly add the titration solution drop wise, swirling to mix after each drop. And continue adding titration solution until the solution in the plastic vessel changes from the blue to colorless. Read off the milliliters of titration solution from the syringe scale and multiply by 10 to obtain mg/l oxygen. Incubate the sample at 20°c for the five days in the incubator. After five days incubation at 20°c; the DO_f content of the effluent measured by following the above procedures effectively. Finally calculate the BOD5 of the effluent based on the DO_i content and the measured DO_f content of the effluent.

Result

The laboratory result of the BOD test can be expressed as follows (Table 1)

Table 1: The Laboratory result for BOD Test.

Test No.	DO content before Incubation mg/l	DO content after 5 days of Incubation mg/l
1	16	11
2	29	24
3	37	33
4	41	35
5	23	19
6	28	23
Average	26	21.4

Discussion

Based on the above procedure, the BOD content of the wastewater before and after incubation, taking the average of the test, are calculated. The incubation period is usually 5 days at 20°C. So, the BOD of wastewater sample is calculated as:

Where $$BOD = \frac{(DO_I - DO_F)}{P} \quad ......1$$

DO_i = Initial dissolved oxygen concentration (mg) = 26

DO_f =Final dissolved oxygen concentration (mg)=21.4

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P = Decimal fraction of the sample in the 300ml bottle = 10

Therefore, BOD5 = (26-21.4)/10 = 0.46 mg/l

Data Analysis

To suggest WWT method that is suitable for Textile processing industry, data was collected from the three factories and Ethiopia cleaner production center by using the above methodologies. The collected data are given below for each factory and CP. Data from the first Textile factory (F1) is given in the following (Table 2). Data from CP (it formulates standard discharge effluent values to the environment for Ethiopia Textile industries). The 2nd Textile factory (F2) has no WWT plant so data is collected by simply observing the WW discharged from each section and taking the WW sample for laboratory analysis. The test result is given in the above (Table 3). The third Textile mill (F3) has WWT plant, but we cannot get any relevant information from them because their treatment system is not working properly; the operation and installations of their WWT system is observed in order to know the general overview of their treatment system. During our observation, both F3 and F1 have used conventional treatment system for their effluent discharges. To see the efficiency of conventional WWT system, the data from F1 used as a reference. The comparison between conventional wastewater treatment and wetland wastewater treatment system based on the standard given by Ethiopia Cleaner Production Center, is given below in the (Table 4). To compare conventional wastewater treatment system with wetland based on their treatment efficiency, only few parameters such as BOD and TSS are taken due to lack of information. The comparison is given in the (Table 5) below.

Table 2: Effluent Discharge Data of the first Textile Factory (F1).

Parameters	Discharge values for F1 in mg/l
pH	7.9
COD	184
BOD	23
Ammonia as NH3	62
Total nitrogen suspended solids (TSS)	32
Phosphorus as PO4	0.18
Total nitrogen	6.4
Temperature	22°C
Total alkalinity as CaCO3	86

Table 3: Critical parameters and their Limiting Discharge values after treatment for Ethiopia Textile Industry.

Constituent group of Parameters	Discharge values (in mg/l) after treatment of the effluent
pH	9-Jun
COD	150
BOD	50
Ammonia as NH3	20
Total suspended solids (TSS)	30
Phosphorus as PO4	10
Total nitrogen	40
Temperature	40°C
Total alkalinity as CaCO3	86

Table 4: Comparison between conventional and wetland treatment based on data from CP standard, F1 and literature.

Parameters (based on)	Conventional wastewater treatment system mg/l	Wetland wastewater treatment system mg/l	The standards given by CP mg/l
pH	7.9	8-Jul	9-Jun
COD	184mg/l	45	150
BOD	23	8.1	50
Temperature	22OC	20oC	40oC
TSS	32	13	30
Cost	HIGH	LOW	

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Table 5: Efficiency comparison between conventional and wetland Treatment.

Parameter	Conventional Treatment System	Wetland Treatment system
BOD	85%	92.50%
TSS	85%	89.60%

According to (Table 5), the comparisons between conventional and wetland treatment system based on CP standards, wetland treatment method fulfills the requirements of CP for each parameter better than conventional treatment system as follow.

i. Wetland treatment system discharges low alkaline WW (low alkaline PH value than conventional treatment method).

ii. It highly removes COD than conventional treatment method to decrease the effluent load in large amount.

iii. It has high ability to remove BOD than conventional treatment method(this is one of the attractive features of wetland treatment it highly reduces the BOD content to 8.1 in mg/L than 23 mg/L in conventional treatment method.

iv. Wetland treatment method discharges the treated WW with slightly lower temperature than conventional treatment method.

According to (Table 6), wetland treatment system has more treatment efficiency in BOD and TSS than conventional treatment method (the efficiency calculation is expressed in appendix 2). This laboratory result used to know how much effluent load in BOD content that it has. This will used to determine the feasibility of the suggested treatment system (i.e. to increase its viability).

Table 6: Cost estimation for suggested Treatment.

Flow chart	Cost in Ethiopian Birr
Equalization tank	15000
Neutralization tank	15000
Coagulation tank	2000
Settling tank	15000
Pumps	4000
Wetland	35000
Total capital cost (sum)	86,000

Suggested Treatments

Based on the data given in the data analysis and laboratory result above a new treatment system for Ethiopian Textile industry can be suggested to reduce the environmental impact. The suggested treatment method is called wetland treatment system. Because wetland treatment systems have the following advantages over conventional treatment system:

a. High removal efficiency in BOD,COD,TSS and it regulates pH.

b. Low or no energy requirement.

c. Have high design flexibility.

d. Effective option for on-site wastewater treatment when properly designed, installed, and maintained.

e. These systems are potentially good, with low cost and appropriate technology treatment for industrial wastewater.

Process flow of wetland treatment: The process flow of wetland treatment system is shown in the figure below.

Process flow (Figure 1).

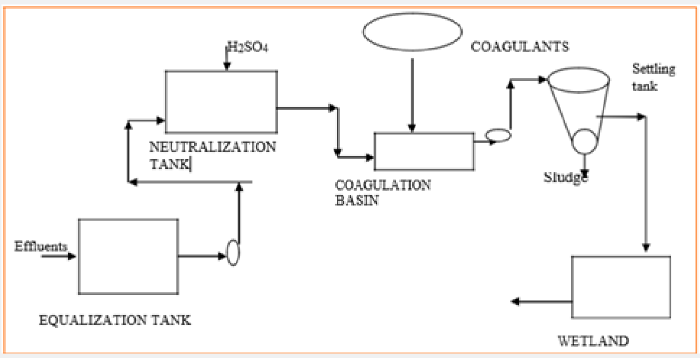

Figure 1: Flow diagram of suggested Treatment System.

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Process Description: The suggested Wetland treatment systems have the following process sequences that are:

Flow equalization: Equalization tank is the tank used to collect the effluents discharged from sizing, desizing, scouring, mercerizing, bleaching, dyeing and printing departments. The wastewater flow rates from waste generating sites vary according to

a. The type and size of the facility

b. The degree of water reuse

c. The on-site wastewater treatment methods.

Therefore, flow equalization is the process used to give equal flow rate and uniform waste load for next operations.

Neutralization: Wastewater of Textile industry has high alkaline content and contains other polluting chemicals. The alkalinity of the wastewater is neutralized (treated) at neutralization tank before entering to other treatment steps. The chemical used in neutralization process are H2SO4 or HCl.

Coagulation: It is the process whereby chemicals are added to a wastewater resulting in a reduction of the force tending to keep suspended particles apart. Chemical coagulants used for this purpose are various such as alum, iron salt, ferrous sulfate, ferric chloride and ferric sulfate. These chemicals are most effective when wastewater is slightly alkaline, and wastewaters of Textile industry are alkaline in nature [9].

Coagulant feeding: The chemical coagulant may be fed into the wastewater either in a powder form or in solution. The former is known as dry feeding, and the latter is known as wet feeding. Wet feeding equipment are generally costlier than the dry feeding equipment's, but they have advantage that they can be easily controlled and adjusted. The choice between these two types of equipment depend on the following factors. The characteristics of the coagulant and the convenience with which it can be applied: Chemicals which clog, or which are not uniform in imposition cannot be fed by a dry feeding. For example, alum being fine and uniform in size can be dry fed easily. The amount of coagulant to be used: The amount of coagulant to be used is an important factor in choosing the type of feeding arrangement. For example, if the dose of coagulant is very small, then for reasons of accuracy it must be fed in solution form. The cost of the coagulant and the size of the plant: In a plant which uses great deal of coagulants, the chemical should be purchased in its cheapest form and the plant should be equipped to use the chemicals in that form. The cost of the feeding machine is less important as compared to the cost of the coagulants in a large plant. Whereas, if the plant is small, the cost of the feeding equipment may become the governing factor, and in the case, the chemicals may be purchased in the dry form, because dry fed machines are cheaper. (Aunmia , Arun and Ashok ,2005).

Settling tank:

Settling tank is first filled with incoming wastewater from coagulation tank and can rest for a certain detention time. During this detention period, the suspended solids settle down at the bottom of the tank, at the end of the period the effluent is drown off through the outlet line.

Wetland

Wetland is a system used to treat the effluent, which comes from settling tank to remove the remaining waste by using different physical, biological and chemical activities. It has an inlet and outlet parts for the influent and effluent and it works with principle of gravity.

Mass Balance and Sample Design of the Plant for the Textile Industry

Mass balance

Neutralization tank: The original influent enters to the neutralization tank and the dosage of sulphuric acid added to the tank in order to neutralize the wastewater is assumed based on the effluent discharged by F1.

$$Q_1 = \xrightarrow{564m^3/day} Q_2 = \xrightarrow[\;]{\overset{H_2SO_4}{\downarrow}\ 6.52m^3/day} Q_3$$

$Q_3 = Q_1 + Q_2 = 564m^3/day + 6.52m^3/day = 570.52\ m^3/day.$

This is the flow rate entering to the coagulation tank

Coagulation Tank:

$$Q_1 = \xrightarrow{570.52m^3/day} Q_4 = \xrightarrow{Coagulant\ added\ 0.34m^3/day} Q_5$$

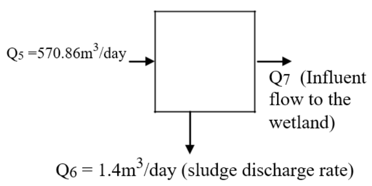
$Q_5 = Q_3 + Q_4$

$= 570.52m^3/day + 0.34m^3/day$

$= 570.86m^3/day.$

This is the flow rate entering the settling tank.

Settling tank:



$Q_5 = Q_7 + Q_6$

$Q_7 = Q_5 - Q_6$

$= 570.86m^3/day - 1.4m^3/day$

$= 569.46m^3/day$

Design of the Plant

Design of equalization tank

I. Given parameters

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Flow rate of influent to equalization tank Q = 564 m^3/day

Taking depth of the tank, H = 2.5m Detention time, t = 3hr

So, Volume of the tank required, V = Q*t

$$= 564m^3/day*3hr*(1/24)\ day/hr = 70.5m^3$$

The cross-sectional area of the tank, A = Volume of tank/ Depth of tank = V/ H =70.5m^3/2.5m = 28.2m^2 Selecting square type equalization tank of side B,

V= B2*H 70.5m^3=B2*2.5

B2= 70.5m^3/2.5m

B = 5.3m

Taking B=5m and the height 3m with additional overloading with 25% excess, the volume will be:

V= 1.25*52*3m^2

= 93.75m^3

Design of neutralization tank

Volume of the neutralization tank is the same as the volume of the equalization tank since the volume of the neutralizer, i.e. H_2SO_4, very small.

Volume of the tank = 70.5m^3

The dimension of the neutralization tank is:

L=5m

H=2.5m

W=5m

Design of coagulation tank

i. Design parameters

a. Capacity of the tank

b. Power required

c. Paddle area required

d. Amount of $Al_2(SO_4)_3.18H_2O$

The total volume of wastewater to be treated per day = 564m^3. Assume a detention period of 25min in the basin (i.e. somewhere between 10 to 30 minutes).

Therefore, Capacity of the tank = the volume of wastewater required to be treated in 25 min

$$=564m^3/24hr*(1hr/60min)*25min = 10m^3$$

According to Pnumia, et al. (Punmia, Arun and Ashok, 2005), assume G (velocity gradient) value of 50/sec (i.e. somewhere between 20 to 80/sec).

Paddle tip velocity (v) of 0.75 m/sec (i.e. somewhere between 0.6 to 0.9 m/sec) and the relative velocity of paddle (vp) of 0.5 m/sec (i.e. somewhere between 0.6 to 0.75times v). Therefore, the power required for agitating 10m^3 of wastewater with its velocity assumed at 15^{0}C can be evaluated using equation:

P=G2*μ*V

= 502*1.139*10-3*10

= 28.475Watt

The coefficient of drag CD for rectangular paddle = 1.8 Hence, the areas of paddles required can be computed using equation:

A = 2P/(CD p Vp3)

Where P = Power, CD = Coefficient of drag, p= Density, and Vp = Relative velocity of paddle

From table (In Punmia, Arun and Ashok, 2005) the value of P at 15^{0}C = 999.1 Kg/m^3

A= 2*28.47m^2/(1.8*999.1*0.513)

= 0.06m^2

1. Dosage of alum required

a. Data adopted

Flow rate (Q) = 564m^3/day

Average normal dose of alum = 11 mg/1t Amount of alum required per day can be evaluated

M = 564m^3*11mg/1t*10-3

M = 6.024Kg/day

Design of settling tank

a. Given parameter

Influent flow rate to the tank=570.86m^3/day

Detention time=2hr

High=2m

Volume of the tank are (V) = Q*t =570.86m^3/day*2/24day

=47.57m^3

Area of the tank is =volume of the tank/ high =V/H

=47.57m^3/2m =23.78m^2

Design of wetland

a. Assumption

The wastewater flow rate must be uniformly distrusted over the entire surface Wetland wastewater temperature are 20^{0}C (approaches to the average air temperature)

a. Design parameters

Influent flow rate to wetland = Q

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$Q = 567.86 m^3/day$

Depth of the wetland = H = 1m

Detention time = t = 3 day

Volume of the required wetland = V

$V = Q*t$

$V = 567.86 m^3/day*3day$

$V = 1703.58 m^3$

The cross-sectional area of the wetland = A

$A = V/H$

$A = 1703.58 m^3/1m$

$= 1703.58 m^2$

Cost estimation

The cost estimation for the flow chart of wetland wastewater treatment system is given below [5,10].

The elements used during implementation of wetland are listed below:

a. Land cost

b. Site investigation cost

c. Site clearing cost

d. Plants and Planting cost

e. Inlets/outlets cost

f. Engineering materials cost

Conclusion and Recommendations

Conclusion

Textile mill is a water and chemical intensive industry. They discharge effluents, which have an adverse impact on the environment. To reduce their impacts, it is necessary to treat the effluent. Therefore, a wastewater treatment plant suggested based on the available data and other conditions (such as climatic conditions) is called the wetland treatment system. Wetland treatment is one of the biological treatment methods. It has good treatment efficiency than the conventional WWT system; and has lower initial and operating costs because it requires less energy and maintenance cost. A factory, which would implement this design, can reduce its environmental impact due to the discharged effluent with low and reasonable cost for a long period of time because the life of wetland is around 25 years. This life can be prolonged by continual maintenance. The effluent discharged after treatment fulfils the standard characteristics stated by Ethiopia Cleaner Production Center [11].

Recommendations

In Ethiopia, some Textile factories do not have WWT system and some of them have conventional treatment plants. Such types of industry discharge the effluents released without treatment or by removing suspended particles only to the receiving bodies. Untreated effluents cause and will continue to cause not only environmental problems but have a consequence on their competitiveness to the international market. Industries with low environmental impact usually obtain ISO certification that may increase the demand of their product. Textile industry having high effluent load is recommended to apply the low-cost wetland treatment system to minimize adverse environmental impact and to thrive in a competitive global market.

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