Reclamation of wastewater with contemporary and economical techniques in developing countries: A case study of Ethiopia, East Africa.

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Abstract : Sub-Saharan countries are growing at rapid speed in respect of population and industrialization, among them Ethiopia can be a model. Thisstudy has astounding weighing up all consideration of the different types of wastewatercomplicationssuch as domestic wastewater of major cities of Ethiopia, Universities, textile, coffee processing and irrigational wastewater. Ethiopia is at budding stage in management ofwastewater treatment process. The major cities cumulative wastewater generation is 6,19,912 m^3/day, out of which less than 10% is treated. Few new conventional treatment systems were implemented in seven Universities by federal government of Ethiopia but more work as to be done. Agriculture, Textileand coffee industries are the backbone of Ethiopian economy but they also add huge amount pollutants like synthetic organic chemicals, dyes, and organic which is a great challenge to be managed by developing economies.
This paper has focussed on various economical techniques to reuse and recover wastewater, so that can be utilized in other purposes. Total organic carbon was reduced by 84% and 49 % using 10% loaded TiO_2-Zeolite Y and pristine TiO_2 in textile effluent and using bioremediation media have also shown promising results. Avocado peel carbon (APC) reduced COD and BOD by 98.20% and 99.18%, respectively in coffee effluent. When coagulation-flocculationand UV/H_2O_2/O_3 oxidation process was used to treat coffee effluent, COD was reduced by 67% and 87%, respectively. Pesticides are absorbed through anthropogenic microspheres; sediments into water can be treated activated bio-char. These low-cost treatments can improve the life of people.

Index Terms: Textile wastewater, coffee processed wastewater, zeolite, bioremediation, APC and AOP, microspheres, low-cost treatment and activated char.

I. INTRODUCTION

Water demand in low income countries has alleviate due to population growth, high migration rate to unplanned urban area and low structured management in water sector (Haddis, de Geyter, Smets, & Van der Bruggen, 2014). Reusing the wastewater for different purposes for community other than drinking can be the economical promising option for lack of water, globally. Report says that more than 80% of the wastewater generated by different sources is directly disposed into surface and ground water bodies; which generates water borne diseases, decreases the quality of life, and undermines the attractiveness of cities to foreign investors, and the competitiveness of tourism, water intensive industries, fisheries and agriculture(Minstry of Water Irrigation and Energy, 2015).

Ethiopia is popularly known as "the Horn of Africa" in among African countries with population is about 84,320,987 (2012 census). Ethiopia extends from 3º - 15º north of the equator, and 33º – 48º east of the Greenwich Meridian. Regardless of its deprivation, largely rural population, and a historic legacy of low investment in infrastructure, Ethiopia has been making substantial progress in increasing water supply coverage and reclamation of wastewater (The Federal democratic republic of Ethiopia, 2017). The Ethiopian government constituted Environmental ProtectionAuthority (EPA, 1997) as an environmental regulatory and monitoring body (proclamation number 295/2002) and set laws for environmental pollution control (proclamation number 300/2002) (Haddis et al., 2014). Ethiopia has vision, to reach the UAP and GTP II targets and ensure the highest quality of life embracing a beautiful and healthy natural environment free from the harmful effects of water in the urban areas By 2025 (Minstry of Water Irrigation and Energy, 2015).

II. QUANTITY OF DOMESTIC WASTEWATER IN ETHIOPIA

2.1 City wise estimation of wastewaterin Ethiopia

Table 1 illustrates the average wastewater discharge from major city of Ethiopia and their treatment capacity in percentage, which shows that this country need to miles to achieve goal towards managed disposal of wastewater. Somehow capital city of Ethiopia i.e. Addis Ababa has the highest percentage of treated wastewater disposal system among all nine cities of Ethiopia.

Table 1: Estimate Wastewater generation, 2014 (Minstry of Water Irrigation and Energy, 2015) (The Federal democratic republic of Ethiopia, 2017)

Sl No	Major City Name	Estimated Current Population	Estimated Wastewater generated (m^3/day)	Discharged after Municipal Wastewater treatment (in %)
1	Addis Ababa	6,500,000	398,985	7.5
2	Mekelle	300,000	34717	0.35
3	Bahirdar	221,991	25,538	0.22
4	Adama	350,000	33,527	0.041
5	Hawassa	240,000	26483	Less than 0.22
6	Jimma	2,486,155	19,607	0.029
7	Dire dawa	341,834	32,387	Less than 0.05
8	Gondar	180,000	32,411	0.07
9	Harar	110457	More than 16257	0.1

III. WASTE WATER TREATMENT STRATEGIES IN ETHIOPIA

3.1 University level wastewater treatment

system in Ethiopia has been reportedwhich is based on a conventional activated sludge system followed by a field infiltration system as per fig.1, this has been planned by the Federal Ministry of Education for seven University like Hawassa University (HU), Adama University (AU), Mekele University (MU), University of Gondar (UoG), Jimma University (JU), AddisAbaba University (AAU) and Kotebe College of Teacher Education (KTC) (Haddis et al., 2014).

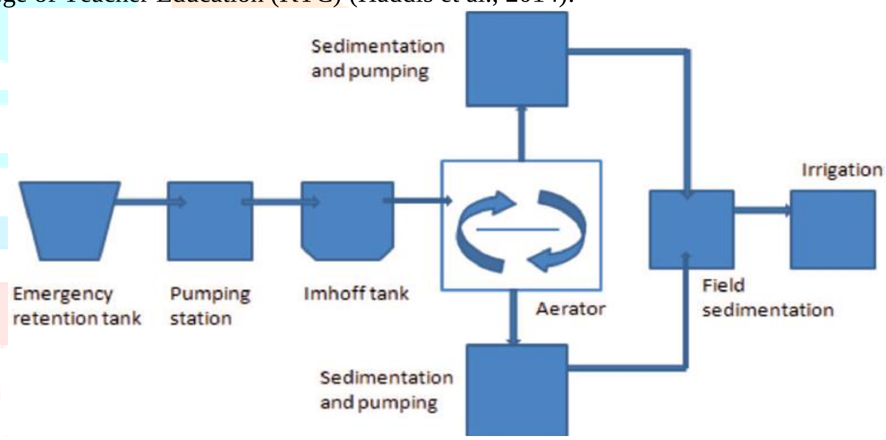

Figure 1: a schematic diagram for conventional wastewater treatment system (Haddis et al., 2014)

The author demonstrates the typical arrangement of unit process for universities which had promising result of removal of about 95% of BOD and 84% of COD, respectively. Total suspended solid and total Nitrogen has been removed upto 97% and 40% respectively. While wastewater treatment plant of AU, AAU and KTCinstitute do not working properly due to failure of activated sludge system and sedimentation tank and finally their result differ from the above mentioned data (Haddis et al., 2014).

3.2 Textile wastewater treatment

According to Ethiopian Textile Industry Development Institute(ETIDI), Ethiopian textile processing units consumed about 14,250,406 Kg of various types ofdyes and chemicals in 2011(Guesh, Mayoral, Márquez-Álvarez, Chebude, & Díaz, 2016)

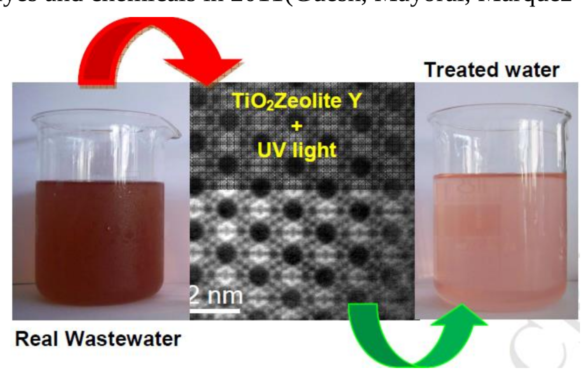

Figure 2 use of different zeolite and UV light for textile wastewater treatment (Guesh et al., 2016)

Fig.2 shows the promising result of integrated wastewater management with zeolite and UV light especially to remove the methyl orange (MO) and TOC. Guesh et al., reported 10% loaded TiO_2-Zeolite Y yielded up to 20 times higher mass normalized turnover rate (TOR) than pristine TiO_2. The reusability of this photocatalyst was tested andonly 5% decline in methyl orange (MO) contamination was observed after three cycles (Guesh et al., 2016). While Zeolite Y with SiO_2/Al_2O_3ratio of 60 (Zeolyst code CBV760, called ZY60 here) loaded with 10 and 40% TiO_2 gave the highest TOR in the degradation of the model pollutant (MO) (Díaz, 2017). Furthermore, the photocatalytic activity was tested for removal of total organic carbon (TOC) in textile wastewater of Ethiopia whichresultedin 84% and 49 % removal using 10% loaded TiO_2-Zeolite Y and pristine TiO_2, respectively (Guesh et al., 2016) and also degradation from 34.2 mg/L to 5.6 mg/L of TOC was observed by 10TZY60-zeolite (Díaz, 2017). COD is reduced to about 260 mg/L. The enhanced photocatalytic activity of the hybrid system was attributed to the dual role of the zeolite surface and to the electronic modification of the TiO_2 photocatalyst (Guesh et al., 2016).

Bioremediation is also promising tools to treat some of the pollutant of textile wastewater as for example *Lysinibacillussphaericus* SK13 and *Aeromonashydrophila* SK16 demonstrated significant potential for decolorization of Remazol Red RR, Reactive Red FB and Reactive Yellow FR Joyfix Red RBdyes (Kumar et al., 2016).

Another studies revealed that *Geobactermetallireducens* can reduce metals such as Iron, lead, chromium, uranium, fluoride and mercury.

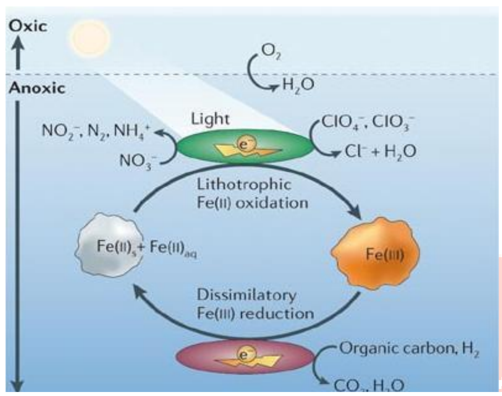

Figure 3 Iron ion transformation by *Geobacter* (Lovley & Phillips, 1988).

Fig.3 displays the transformation of iron ion by *Geobacter metallireducens* combination of light. They are able to metabolize mixture of chemicals that neither could process alone (Suraj Bhagat and Tiyasha, 2013).

3.3 Coffee processing wastewater treatment

Ethiopia is the origin of highland coffee (*Coffeaarabica Linnaeus*), with annual production about 500,000-700,000 tones.Thishas traditionally been tended and harvested as a wild tree in the highland forests of southwestern Ethiopia (Schmitt, 2006). According to data from the Ethiopian coffee and tea development and marketing authority for 2016/17, the total number of coffee processing plants in Ethiopia has now surged to 2156 (ECTA, 2017), and Almost all wet coffee processing plants in Ethiopia are located close to water bodies and have an adverse effect to water bodies because of untreated of processing wastewater disposal. The study has been reported from Jimma zone, oromia region, Ethiopia (fig.4); where, pH is found up to 5, in all cases pH is below then 7.This low pH shows that there was fermentation of sugars in the mucilage ferment (Calvert, 2002) in the presence of yeasts and CO_2 produced and the acidic characteristics of the water organic load (BOD_5 and COD), nutrients (nitrate and phosphate) and suspended solids.

Figure 4 disposal site of processed coffee wastewater at Jimma zone (Dadi et al., 2017)

Minimum values of BOD_5 and COD in effluents are found 87 mg/L and 142 mg/L, respectively (Dadi et al., 2017). Comparisons between upstream and downstream sites demonstrated deterioration in river water quality, as it is not under either US-EPA or Ethiopian EPA guidelines (Berhanu, 2017).

The high amounts of COD and BOD were reduced by 98.20% and 99.18%, respectively; using avocado peel carbon (APC) which size of APC particle taken was from 0.75 mm to 0.25 mm, surface area of 750 m^2/kg, bulk density 165 kg/m^3, porosity 75%, moisture content 8.5% and carbon content 88% (Devi, Singh, & Kumar, 2008). Authored suggest that treated wastewater touched the permissible limit for irrigation practices and disposal to stream. Since avocado peel is waste and available in plenty at Ethiopia, so it is an economical alternative. In another study of natural organic matter present in coffee processing wastewater was removed using chemical coagulation-flocculation and advanced oxidation processes (AOP). The results showed reduction of COD by 67% when coagulation-flocculation was used. UV/H2O2/O3 oxidation process removed COD by 87% as well as colour and turbidity (Zayas, Gunther, & Fernando, 2007).

3.4 Irrigation wastewater treatment

Agriculture is one of the largest occupations in Ethiopia. About 85% of the population is engaged in agricultural sector producing products like cereals, coffee, oilseed, cotton, sugarcane, vegetables, khat, cut flowers, hides, cattle, sheep, goats, fish (Ethiopian Economy, 2015). During a study it was found that Organophosphates were the most intensively used class of pesticides about 24%, out of which 8% in Large-scale closed greenhouses (LSGH), 30% large-scale open farms (LSOF), and 27% small-scale irrigated farms (SSIF) in Ethiopia. Organochloride pesticides such as dichlorodiphenyltrichloroethane (DDT) and endosulfan are used in small-scale irrigated farms in Ethiopia(Younes & Galal-Gorchev, 2000). A study revealed that Fe_3O_4@$nSiO_2$@$mSiO_2$ and Fe_3O_4@$nSiO_2$@- $mSiO_2$–5% Fe materials have promising efficiency to remove the DDTs (Tian, Liu, & He, 2014).Photo-induced degradation of DDT by TiO_2 30 mg/Lshowed great potential (Khuzwayo & Chirwa, 2017). Negatuet. al., reported that 27% farm worker follow the pesticide label, 16% kept their pesticides leftovers in storage, 75% throw the container and 16% bury it around the farm land (Negatu, Kromhout, Mekonnen, & Vermeulen, 2016). The improper utilization, handling and disposal can be hazardous for environment. Organochlorines have been found to be persistent in the environment and are likely to be found in drinking water. Organophosphorus pesticides readily hydrolysed in water, adsorbed on sediments, or readily degraded in soil, therefore found in drinking-water and get absorbed in ground water too. Several pesticides are suspected to be carcinogenic, reproductive toxin and neurological agent (Younes & Galal-Gorchev, 2000).

According to a study of low cost treatment, char filter absorbers have been used. Bamboo, eucalyptus, logan and pine logs where used as feedstock. The result showed 60% removal of 2,4-D pesticide. Multi-barrier treatment was used which included gravel filter, bio-sand filter and sorption char filter as shown in fig.5. This setup was successful to remove dissolved organic matter, biodegradables and synthetic organic compound (SOCs) like pesticides, pharmaceuticals and hydrocarbons (Kearns, Knappe, & Summers, 2014).

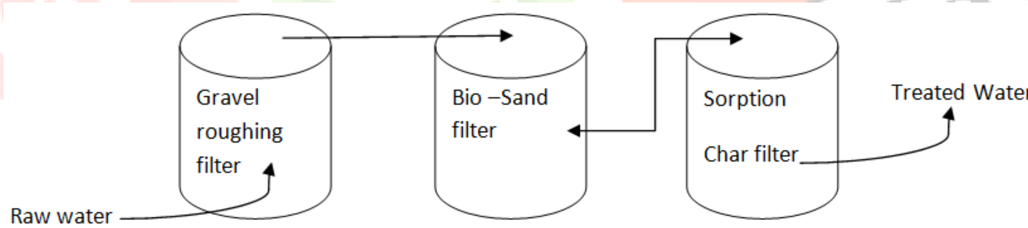

Figure 5 Multi-barrier treatment systems

IV. CONCLUSION

These economical treatment techniques for reclamation of waste water from houses, Universities, agricultural sector, textile and coffee processing industries can be a novel way to improve the life of people. Heavy metal poisoning due to natural and anthropogenic reason is common in Ethiopia. Bio-remediation using microbes like *Geobacter metallireducens*, which can reduce metals such as Iron, lead, chromium, uranium, fluoride and mercury can be a useful tool. Similarly Coffee is the life line of Ethiopian people. It is served as buna and macchiato between common people which gives high energy to them. There are many coffee processing units whose wastewater can be reused for irrigational purpose after treating with Avocado peel carbon. Avocado is one of the famous fruits of Ethiopia which gives an advantage of getting the fruit easily and huge amount in free. This will reduce transportation cost leading to a cheap treatment technique. The last area of interest is agricultural sector because 85% of population of the country is engaged in it. Farmer have use of pesticides can be reduced but cannot be eliminated so fast in a developing country so using bio-char made of local wood will be a good option. The typical Ethiopian household uses charcoal for cooking due to which charcoal making is common art for them which intern give us more motive to use bio-char based wastewater treatment which can remove not just dissolved organic matter, biodegradables as well as synthetic organic compound (SOCs) like pesticides, pharmaceuticals and hydrocarbons which cannot be removed by other low cost techniques.

This paper's motive is to highlight the need and possibility of low-cost treatment techniques which can easily make the wastewater reusable for various purposes rather than drinking. This will help to save the portable for future and increase its sustainability.

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