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SYSTEM PERFORMANCE USING RECIRCULATING SAND FILTER: PROPOSAL ON SEWAGE TREATMENT

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ABSTRACT
With growing concerns over freshwater availability, concept of treating and recycling waste water is progressively getting more pertinent. However, Wastewater to be recycled need to be treated first for ensuring its quality sufficiently fit for designated uses, such as irrigation, industrial processes, toilet flushing, ground water recharge etc. Wastewater treatment can be specifically tailored to meet the water quality requirements of a planned reuse, as some would need only moderate treatment while others may require higher degree purification. Although there are many techniques to overcome the sewage connected septic problems, selecting the appropriate system type, size and location at the site depends on the wastewater flow and composition information. Design conditions include wastewater characteristics, system owner preference for siting, operation and maintenance, and cost, regulatory requirements prescribed by the permitting agency's rule, and the receiver's site capacity to treat. Each of these must be evaluated in light of the others before an appropriate design concept can be developed. As the design and implementation of the treatment techniques must comply with the rules and regulations of the permitting entity, the current proposal focuses only on the general guidance for the evaluation of the site's design boundaries and requirements and selection of suitable designs to meet the performance requirements.

KEYWORDS:
Nitrification, Organic loading rate, Septic tank, Sewage

INTRODUCTION

Sewage is an important contemplation for every part of the world as the effects of sewage on the environment are largely with the negative impacts [1, 5, 6]. It needs to be appropriately treated before it can be disposed of usually into the water bodies. Sewage consists of 99.9% of solids and only 0.1% of liquid. Of 99.9% of solids, there are settleable solids and non-settleable solids, as well as the organic and in-organic solids. Depending upon the source from which the sewage is generating, it may be strong or medium or weak in their characteristics and composition. Especially, the waste water generating from the industrials or the mixture of commercial and domestic sewage, sometimes are very strong in their physical characteristics. In general, the amount of organic matters present in sewage indicates the strength of sewage. The high level of organic matters in sewage leads to high level of BOD (Bio-chemical oxygen demand) and high level of COD (Chemical oxygen demand). When the pollution level is discharged into the stream, the DO content of the stream goes depleting. This depletion is known as Deoxygenation. The rate of deoxygenation (k) is directly proportional to the amount of organic matters present in sewage. The depletion of DO (Dissolved oxygen) in the water bodies is another major issue in the environment as the BOD or COD level increases with the increase in BOD or COD of sewage when it is mixing with the river streams, ponds, lakes and the other water bodies [7]. The depletion of oxygen in the water

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bodies also highly affect the aquatic life systems as it is noted that the minimum of 2ppm of dissolved oxygen is required for the flourish and survival of fishes in the water bodies. The organic matter present in sewage may belong to two groups: Carbonaceous matter and Nitrogenous matter. The depletion of dissolved oxygen in the water bodies leads to the pre-aging, technically called "Eutrophication".

The artificial process of changing or removing the objectionable constituents present in sewage to make it less dangerous and offensive is called sewage treatment. The main objectives of sewage treatment include:

i) to reduce the strength of sewage so that it may not pollute the receiving water
ii) to reduce its volume in general
iii) to destroy the pathogens
iv) to enable the safe and satisfactory disposal
v) to recycle and reuse waste water for the reuse in irrigation, thereby preserving the water resources, which is scarce in arid and semiarid regions of the world [2].

Analyzing the characteristics of sewage can also detect the markers of oxidative stress in collective samples. It can help the researchers to determine the effects of environmental pollution on particular communities.

Domestic sewage pollution is the severe threat for the community, caused to the earth by domestic use. The domestic sewage originating primarily from the kitchen, bathroom, and laundry sources, food preparation, dishwashing, garbage, toilets, baths, showers, and sinks. Sewage is the term used for wastewater that often contains fasces, urine and laundry waste. Sewage disposal is a major problem in developing countries as many people in these areas don't have access to sanitary conditions and clean water. Untreated sewage water in areas without access to sanitary conditions can contaminate the ground water, which can lead to various diseases. Untreated sewage may contain water; nutrients (nitrogen and phosphorus); solids (including organic matter); pathogens (including bacteria, viruses and protozoa); helminthes (intestinal worms and worm-like parasites) ; oils and greases; runoff from streets, parking lots and roofs; heavy metals (including mercury, cadmium, lead, chromium, copper) and many toxic chemicals including PCBs, PAHs, dioxins, furans, pesticides, phenols and chlorinated organic. Additionally, sewage is the liquid waste produced by households and industries.

Sewage can be subdivided into black water and grey water (Figure. 1). Black water sewage is the stuff that comes out of toilets. Its contents may include fasces, urine, paper, condoms, tampons and water and any other material that people find convenient to flush down toilets. Grey water, on the other hand, consists of the out flow from wash basins, baths, kitchen, washing machines and sinks. The contents of gray water may include food remains, oil, detergents, dirt and water. All of the disposal sewage directly or indirectly gives the negative impacts to the environment.

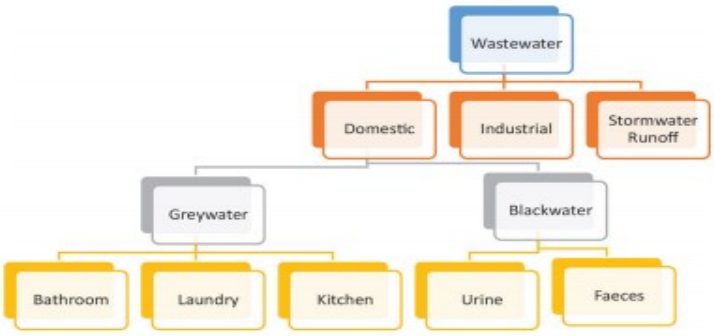

Fig. 1: *Different types of waste water*

The toxic substances enter into the water bodies, dissolved, suspended in water or get deposited on the bed of the water body. The resulting water pollution causes the quality of the water to deteriorate and affects the aquatic ecosystems. Domestic sewage contains a wide variety of dissolved and suspended impurities. It amounts to a very small fraction of the sewage by weight, but it is large by volume and contains impurities such as organic materials and plant nutrients that tend to rot. The main organic materials are food and vegetable wastes. Plant nutrients come from chemical soaps, washing powders and others. Domestic sewage is also very likely to

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contain disease-causing microbes. The various substances that we use for keeping our houses clean add to water pollution because they contain harmful chemicals.

Most detergents and washing powders contain phosphates which are used to soften the water, among other things. These and other chemicals contained in washing powders affect the health of all forms of life in the water. So, when sewage enters a lake or stream, microorganisms begin to decompose the organic materials. Oxygen is consumed as micro-organisms use it in their metabolism.

The nitrates, phosphates, and organic matter found in human waste serve as a food for algae and bacteria. This causes these organisms to overpopulate to the point where they use up most of the dissolved oxygen that is naturally found in water, making it difficult for other organisms in this aquatic environment to live. The bacteria in sewage are chiefly strangling the other organisms. Some of the over-populated organisms are the disease-causing microorganisms. Phosphates are also found in soaps and detergents, but there are other household products that we use every day that can be toxic to many animals and humans if they are dumped directly into a water body. Sewage also contains high levels of nutrients such as phosphate and nitrates which can lead to the "deaths "of rivers lakes and seas through Eutrophication. High levels of phosphate and nitrates promote the rapid growth of algae. When these algae "bloom", die and decompose they remove dissolved oxygen from the water.

The unavailability of oxygen then leads to the death of fish and other animals that need oxygen from the water. Excess nutrients are discharged to the marine environment through sewage, fertilizers from agriculture and by nitrogen oxides from burning fossil fuels. Increased nutrients may lead to Eutrophication which is an excessive growth of marine plant life and decay. Plants such as algae often experience a population increase (called an algal bloom) which limit the sunlight available and cause lack of oxygen in water. When oxygen levels decline, marine animals, coral reefs, sea grass beds and other vital habitats in the Wider Caribbean Region suffer and may die. Some algal blooms are toxic and may harm or even kill whales, dolphins and other marine mammals – and cause hundreds of millions of dollars worth of damage to commercial fisheries.

Health Risks

Domestic sewage pollution is mainly due to the common pathogens (Table.1), affects the health of human [3] especially to the swimmer or bathers who are directly have a contact with the polluted water. Bathers are at increased risk of contracting illness (eye infections) due to bacteria and viruses present in sewage effluent.

Economic Loss

As a result of polluted water, our beach and other water source attraction of tourism become polluted and dirt. The high income loss results due to the closing of beach and commercial shellfish beds upon the sewage contamination, which in turn, affects the economy.

The improper disposal of sewage poses high risks to the community both in developed countries and underdeveloped countries. If the sewage is not properly treated, it can lead to a wide variety of illnesses include meningitis, typhoid, ear infections, conjunctivitis, pneumonia, septicemia, skin rashes and diarrhea, gastroenteritis, hepatitis, salmonella infections, cholera, bacillary dysentery [8].

RATIONALE OF THE PROJECT

According to Dr. Subash Thanappan (2019), the execution of the proposed sewage treatment unit rely upon the interest of the surrounding community [4]. Keeping this in mind, a group investigation (Figure-2) was made at-site in Awaro Condominium (Figure-3) opposite to Golf- ground in Ambo, Ethiopia and has proved that human-being is both a creator and a moulder of his environment. Figure 2 shows the overflow of sewage from the existing septic tanks responsible for the environmental degradation poses threat to the society [9] in the study area. It has been observed in some of the houses that the sewage in the toilet, the liquid waste from other fixtures flows away very slowly. Wet areas are seen at the top of the existing septic tanks and there is a strong unpleasant smell near the septic tank. It is mainly due to the improper maintenance of the septic tanks by which the scum blanket may become too thick and block the inlet pipe, the inlet and outlet pipes may be blocked by solid matter, the sludge may have accumulated so that it fills the tank and the tank's bottom, sides may have been cracked.

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Table 1. *Common pathogens in Untreated Domestic Sewage*

Agent	Species	Disease
Bacteria	Campylobacter jejune	Gastroenteritis (possibly long-term sequelae e.g., arthritis)
	Escherichia coli	Gastroenteritis
	E. coli O157:H7	Bloody diarrhea, hemolytic uremic syndrome
	Helicobacter pylori	Abdominal pain, peptic ulcers, gastric cancer
	Salmonella *spp.*	Salmonellosis, gastroenteritis, diarrhea (possibly long-term sequelae e.g., arthritis)
	Salmonella typhi	Typhoid fever
	Shigella *spp*	Dysentery (possibly long-term sequelae e.g., arthritis)
	Vibrio cholera	Cholera
Viruses	Adenovirus	Respiratory disease, eye infections
	Astrovirus	Gastroenteritis
	Calicivirus	Gastroenteritis
	Coronavirus	Gastroenteritis
	Enteroviruses	Gastroenteritis
	Echovirus	Fever, rash, respiratory and heart disease, aseptic meningitis
	Poliovirus	Paralysis, aseptic meningitis
	Hepatitis A and E	Infectious hepatitis
	Parvovirus	Gastroenteritis
	Norovirus	Gastroenteritis
	Rotavirus	Gastroenteritis

Source: WHO, 2006 ; Simon Toze, 1997 [8, 10]

Figure -1.1 On-site Group Investigation	Figure-1.2 Awaro Condominium in Ambo Town	Figure-1.3 Plant growth near the pipe lines

Fig. 2. *On-site Investigation*

Some septic system overflow happens because of improper design. According to Purdue University, drainage pipes need a slope of 1 percent to 2 percent for waste to drain effectively. If the slope is too shallow, materials will not flow as intended, and the pipe will need to be replaced. The plant roots (Figure-3) grow near the pipes shows that the walls of the pipe could collapse and prevent proper drainage.

RELEVANCE OF THE PROJECT

General Objectives

The primary objective of the current proposal is to introduce 'Recirculating Sand Filter System' to overcome the septic conditions in the study area which could directly empower the integrated waste water management, and sustainable development.

In order to achieve the primary objective of the proposed study, the following specific objectives are planned and organized to perform in the following linear path:

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- Site selection for the execution of the proposed work
- Construction of the recirculating sand filters comprising a septic tank, recirculation chamber and the final disposal chamber.

Feasibility of the Project

The study area 'Awaro Condominium; is located in Ambo, the West Shewa zone of the Oromia Region, west of the capital city, Addis Ababa. The town has latitude of 8°59′N and longitude of 37°51′E and an elevation of 2101 meters. The Awaro condominium is surrounded by the residential colonies and agricultural field. Awaro condominium has different patterns of houses with different dwelling units and currently occupied by both the locals and expatriates.

Fig. 3. *Location of Study Area*

RSFs produce a high quality effluent with approximately 85 to 95% BOD and TSS removal. In addition, almost complete nitrification is achieved. Denitrification has been shown to occur in RSFs. Depending on modifications in design and operation, 50% or more of applied nitrogen can be removed. The performance of an RSF depends on the type and biodegradability of the wastewater, the environmental conditions within the filter, and the design characteristics of the filter. Temperature affects the rate of microbial growth, chemical reactions, and other factors that affect the stabilization of wastewater within the RSF. Although physical and chemical processes play an important role in the removal of many particles, the biological processes play the most important role since bacteria are the primary workers in sand filters.

Other parameters that affect the performance and design of RSFs are the degree of wastewater pretreatment, the media size, media depth, hydraulic loading rate, organic loading rate, and dosing techniques and frequency. The effectiveness of a granular material as filter media is dependent on the size and uniformity of the grains. The size of the granular media affects how much wastewater is filtered, the rate of filtration, the penetration depth of particulate matter, and the quality of the filter effluent. High hydraulic loading rates are typically used for filters that receive higher quality wastewater. The accumulation of organic material in the filter bed is another factor that affects the performance of RSF's. As with hydraulic loading, an increase in the organic loading rate results in shorter filter life.

PROJECT DESIGN

The Open sand Filter with under-drains is waste water management system designed to maximize the removal of pollutants from the waste water. The RSF (Figure-3) is an "open sand filter" and a sand media (The sand shall have an effective size D_{10} of not less than 1.5 millimeter or more than 2.5 millimeter and a uniformity coefficient (Cu) of 1.5 to 2.5 to a depth of 2 feet) . A layer of graded gravel (about 12 inches) is provided under the sand for support to the media and to surround the under-drain system. The population of this community is around 350, mostly residential with some commercial establishments. The wastewater generates from the stores, restaurants, and about 50 residences to be first pretreated and allowed for the settlement in the plain sedimentation tank. Thus, the partially clarified effluent is to be then collected and conveyed to an RSF and finally pumped to a drain field for the final disposal [5].

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The filtrate from the sand filter is collected by under-drains that are located at the bottom of the bed. The filter discharge line passing through the recirculation tank is located near the top of the tank. The typical sand filter (Figure-4) is a PVC-lined or concrete box filled with a specific sand material. A network of small diameter pipes is placed in a gravel-filled bed on top of the sand. The septic tank effluent is pumped under low pressure through the pipes in controlled doses to insure uniform distribution. A Recirculating Sand Filter (RSF) System is a modified version of the old-fashioned, single-pass open sand filter. It was designed to alleviate the odor problems. RSF is suitable for the apartments because they require 'less land area' and do not require highly trained operators; RSFs are often used to treat wastewater collected from clustered residences / apartments / condominium and small communities [1]. The cost of RSFs depends on the labor, materials, site, capacity of the system, and characteristics of the wastewater. The recirculating sand filter purifies septic tank effluent sufficiently that it can be disposed subsurface in most soils, or, where allowed, disinfected and disposed into surface waters [5, 6].

As the wastewater moves downward through the filter media, it absorbs oxygen in the pore spaces between the media particles. This oxygen eliminates the odor associated with the wastewater. The treated wastewater is collected in under-drains at the bottom of the sand filter, and then a portion is discharged for further treatment or disposal, while another portion is recycled back into the recirculation tank [3].

PROJECT MANAGEMENT AND IMPLEMENTATION

a. Although it is very challenging to manage the proposed project, with the available man power, the ingredients such as sand, gravel, broken bricks, broken glasses etc will be collected from the source.
b. The concerned government organization could be approached for getting the sanction of the required land to execute the proposed work at site.
c. With the help of minimum masons & labors, the construction work could be executed and implemented successfully.

MONITORING AND EVALUATION

RSFs require routine maintenance, although the complexity of maintenance is generally minimal. Primary O&M tasks include monitoring the influent and effluent, inspecting the dosing equipment, maintaining the filter surface, checking the discharge head on the orifices, and flushing the distribution manifold annually. The surface of the sand bed should be kept weed free. In addition, the septic tank should be checked for sludge and scum buildup and pumped as needed. The recirculation tank should also be inspected and maintained as necessary.

RISK FACTORS

a. Tiresome travel to work
b. Long hours of work
c. Weekly maintenance is required for the media, pumps, and controls capacity

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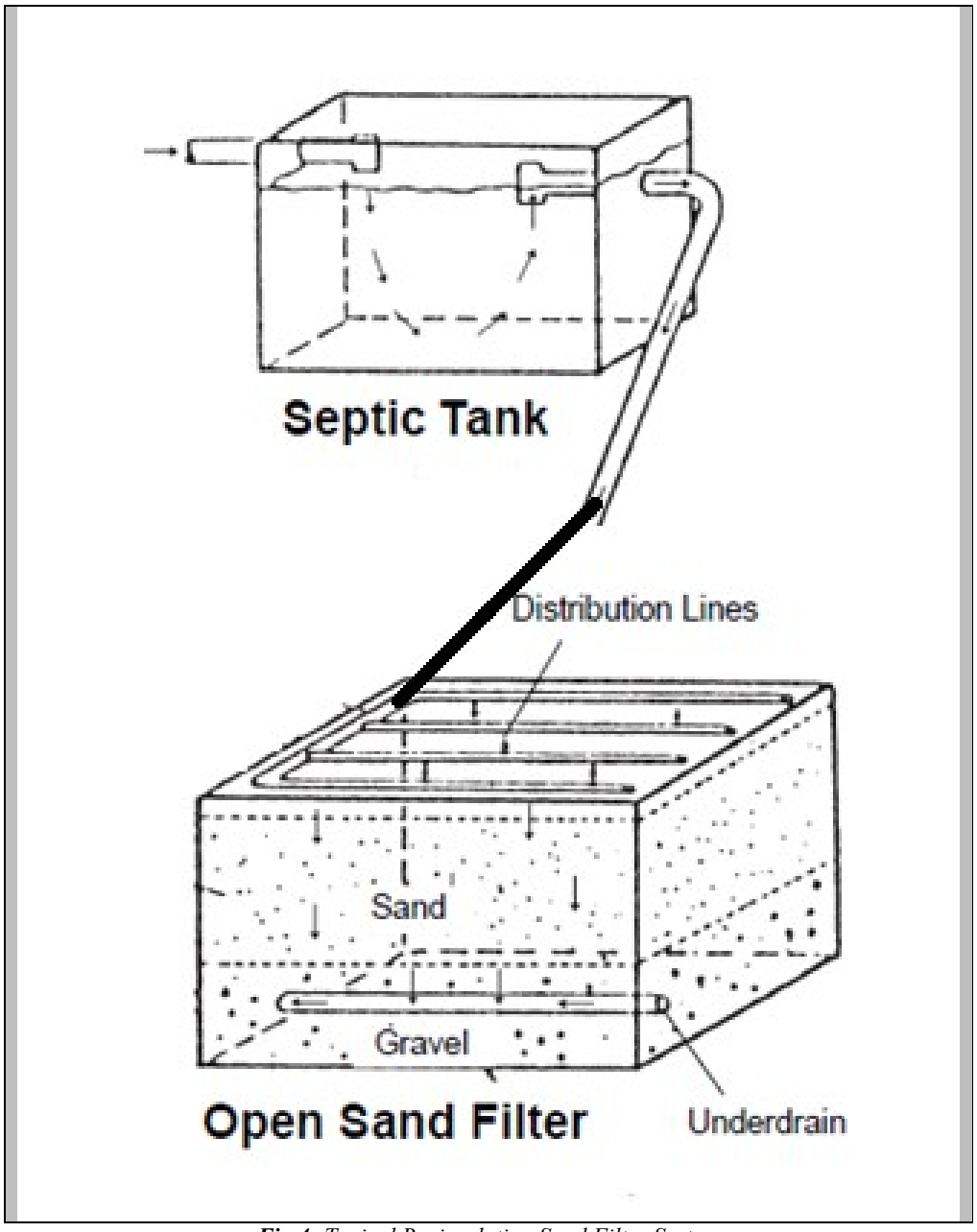

Fig.4: *Typical Recirculating Sand Filter System*

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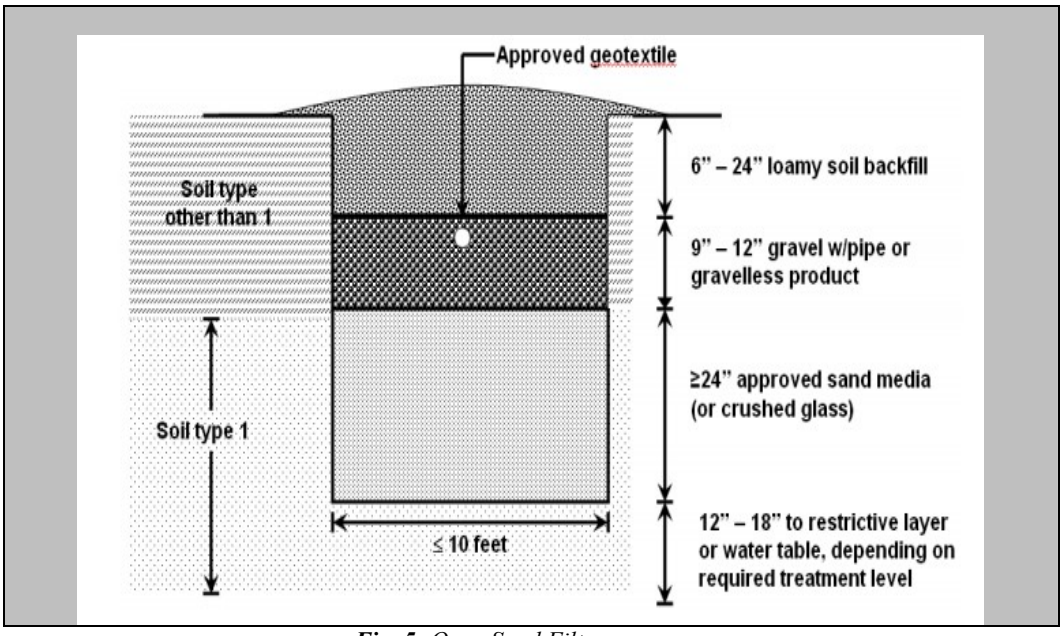

Fig. 5: *Open Sand Filter*

CONCLUSION

1. Wastewater effluents must be treated effectively so as not to pose any health related negative impacts to the users of surface water resources like river streams, ponds, lakes etc.
2. The major cause for the failing state of wastewater treatment facilities is mainly due to the inadequate coverage of wastewater treatment facilities in both urban and rural areas, poor operational state of wastewater infrastructure, design weaknesses, expertise, insufficient funds allocated for wastewater treatment, overloaded capacities of existing facilities, improper maintenance of septic tanks, and inefficient monitoring for compliance with recommended guidelines.
3. As the surface water is the major source for the water supply to satisfy the demand of the whole community, enforcement of water and environmental laws must be in place to protect the environment and the health.
4. A well designed recirculating sand filter system could definitely help the community to overcome all the negative impacts of domestic sewage in the targeted area.

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Thanks to Ambo University – Institute of Technology, Ambo, Ethiopia, for set us an opportunity to bring into being a proposal for the community service on the sewage treatment system to triumph over the sewage related issues in the affected area.

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