Use of Solar Still in Heavy Metals Removal from Kitchen Wastewater

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***Abstract* — Indiscriminate discharge of wastewater into the environment can lead to environmental pollution. Heavy metals present in wastewater can infiltrate into the ground to cause groundwater contamination. In this study, a solar still was employed in the removal of heavy metals from domestic wastewater. Five wastewater samples with high heavy metal contents were kept in a solar still and subjected to heat from the sun. The solar still was constructed using locally available materials. The concentration of Iron (Fe), Zinc (Zn), Manganese (Mn), Chromium (Cr) and Cadmium (Cd) in the untreated and treated wastewater samples were determined. The study revealed a drastic reduction in the heavy metal content of the treated wastewater, however, the heavy metal content of most of the treated wastewater samples did not fall within World Health Organization (WHO) limit for potable water. Remarkably, The Zn content of four out of the five treated wastewater samples fell within WHO limit for potable water except for sample 2 which witnessed a drastic reduction from 13.9 to 3.28 mg/L but still did not meet up with WHO limit of 3 mg/L. The treated wastewater can be safely discharged into the environment; however, further treatment is required to make the water safe for human consumption.**

***Key words* — Heavy metals, solar still, treatment, wastewater, treatment.**

I. INTRODUCTION

More than one billion people worldwide do not have accesses to safe drinking water and, about 2.5 billion people lack access to adequate sanitation services [1]. The shortage of water resulting from population growth is considered one of the worst sources of distress for man and often regarded as a constraint to sustainable development [2]. The high consumption of fresh water and generation of huge volume of noxious wastewater is a significant environmental concern [3]. People who use contaminated water are susceptible to waterborne diseases [4]. About 4 billion cases of diarrhoea are reported annually, with 88 % of them being linked to the use of unclean water, and insufficient sanitation and hygiene [5]. There are very limited options to confront the challenges of freshwater shortage problem; these options include desalination, recycling and re-use [6]-[8]. New and evenhanded ways of using, saving, and recycling the limited water resources have become inevitable [9].

Simply put, domestic wastewater refers to flows discharged principally from residential sources generated by such activities as food preparation, laundry, cleaning and personal hygiene. Domestic wastewater is broadly classified into black wastewater and gray wastewater. Black water includes toilet wastewater while gray wastewater includes kitchen wastewater. Kitchen wastewater is a good example of domestic wastewater that can be treated and re-used. Kitchen wastewater is a type of gray wastewater that has gained substantial attention because of its high content of organic pollutants as well as oil and grease. If not properly managed, this wastewater may seep into the ground and reach a source of water to contaminate it [10], [11]. In Nigeria, the use of ground water through shallow wells and boreholes has become conventional in order to meet the ever-increasing water demand [12].

Heavy metal pollution is a major water problem in many developing countries as a result of unplanned urbanization [13]. Heavy metals are a group of trace elements which include Cadmium, Chromium, Copper, Iron, Lead, Manganese and Zinc. They have relatively high density of over 4×10^6 mg/L [14]. Heavy metals are highly toxic, carcinogenic and non-degradable [15]. They easily gather and persevere in water and soils in the environment from where they are easily transmitted to humans through the food chain [16]. Gathering of heavy metals within the body can lead to a deterioration in the mental, intellectual, and physical health of the individual [17]. Worldwide environmental changes have dramatically increased the overall 'load' of heavy metals in the environment [18]. Heavy metals are poisonous and are capable of contaminating water systems even in very low concentrations [14].

Numerous techniques have been employed to remove heavy metals from contaminated water. They include reverse osmosis, ion exchange, membrane filtration, solvent extraction, chemical precipitation, adsorption, and electrochemical treatment [19]-[28]. [29] utilized limestone to reduce the heavy metal content of wastewater, this method successfully reduced the heavy metal content of the contaminated water to safe levels. Many of these methods were effective in the removal of heavy metals, however, they are capital intensive with high operational costs.

Solar distillation, through the use of solar still, does not only purify water sources, but also effectively desalinates them [30]. A solar still is a mechanism that purifies water of different sources; saline and contaminated. There are two types of solar stills - passive and active solar stills, both have basically the same working principle. The principle of solar water treatment involves trapping of water vapour in a containment such that after saturation, it condenses and distills without escaping to the atmosphere. Solar still uses

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heat from the sun in water purification. The sun is a priceless resource needed for maintaining life on earth. The amount of energy in one hour of sunlight is enough to sustain the energy needs of all people on earth for one year [31]. The act of distilling water is an effective method of reducing pollutants in water simply by boiling it and collecting the steam that is generated via evaporation and condensation [32]. According to [33], the most basic form of solar distillation which involves the use of heat energy from the sun in wastewater treatment is the solar still. Solar stills could be single-slope or double-slope and are usually made with materials that have low thermal transfer coefficient [34]. The yield of a solar still depends on factors such collector area, interior temperature, solar radiation, interior and exterior material, inclination angle and wind speed [35]. Studies have shown that even the purest rainwater may not be as clean as the treated wastewater obtained from solar stills [36]. This paper is aimed at assessing the efficiency of solar still in the removal of heavy metals from kitchen wastewater.

II. Methodology

A. Experimental Set-up

The experimental set-up is shown in Fig. 1. The solar still used in this study was constructed using locally available materials. The solar still consist of a base made of aluminum embedded in a box of wood. The box has a length of 0.8 m, breadth of 0.8 m and height of 0.6m at the rear and 0.15 m at the front. The tilt angle of the glass is 300 o. Embedded in the solar still is a box of thermocol (Styrofoam) located between the aluminum base and the wooden box. The thermocol (Styrofoam) serves as an insulator. The inlet for the wastewater is placed at the back of the still. The distillate trough is fixed such that the water slipping on the surface of the glass flows under gravity into the outlet for the distilled which is located at left bottom of the solar still. The experimental set-up was placed at the back of the Water Resources and Environmental Engineering laboratory of the Federal University of Technology, Akure.

Fig. 1. Experimental set-up.

B. Water Samples

Five (5) domestic wastewater samples used for this study were collected from residential buildings in Akure metropolis, Ondo State, South western Nigeria. Kitchen wastewater were indiscriminately channeled into the environment from these residential buildings. The untreated wastewater samples were collected in 20 litres containers. After the distillation process, the treated wastewater samples were collected in 1 litre containers. The water samples (before and after solar treatment) were taken to the laboratory within 4 hours of collection in order to preserve the quality of the samples.

C. Laboratory Analysis

The laboratory analysis was carried out in the Central laboratory of FUTA using Atomic Absorption Spectrometry (AAS) as described in [37]. The concentration of the following metals in the raw and treated wastewater samples were determined: Iron (Fe), Zinc (Zn), Manganese (Mn), Chromium (Cr), and Cadmium. The results obtained were compared with WHO standard for potable water.

III. Results and Discussion

The results of the water quality analysis are presented in Fig. 2 to 6. The Fe content of the untreated wastewater reduced drastically in all the wastewater samples subjected to solar distillation as shown in Fig. 2. However, the Fe content of the treated wastewater still exceeded the WHO standard for potable water. The Zn content of the wastewater samples reduced greatly after treatment with solar still as shown in Fig. 3. The Zn content of four out of the five treated wastewater samples fell within WHO limit for potable water except for sample 2 which witnessed a drastic reduction from 13.9 to 3.28 mg/L but still did not meet up with WHO limit of 3 mg/L. Zn is an essential trace element found in virtually in all food and potable water in the form of salts. High levels of Zn in the untreated water could be as a result of dissolution of Zn from pipes conveying the wastewater. Fig. 4 shows the Mn content of the untreated and treated wastewater samples. There was a significant reduction in the Mn content of the wastewater samples analyzed, however the Mn content of all the treated wastewater samples did not meet up with WHO standard for potable water. Fig. 5 and 6 shows the Cr and Cd contents of both the untreated and treated wastewater samples. A substantial reduction was observed in the concentrations of these heavy metals after solar distillation, however the concentration of none of the treated wastewater samples fell within WHO standard for potable water. High levels of Cr and Cd in potable water is known to cause hypertension in humans [38]. The Fe, Mn, Cr and Cd contents in all treated water samples were higher than maximum permissible level according to [39] standard. The presence of these heavy metals in very large quantities even after treatment by solar distillation is a serious health risk and should be looked upon by concerned authorities [40].

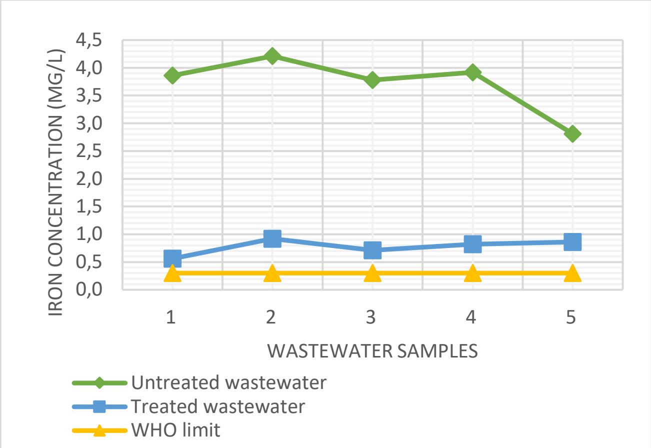

Fig. 2. Iron Content of untreated and treated wastewater samples.

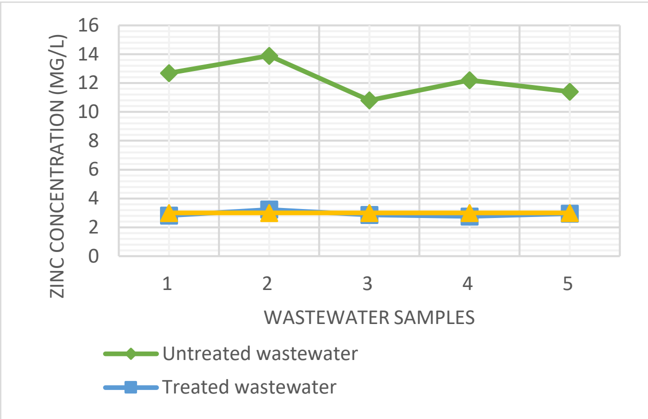

Fig. 3. Zinc Content of untreated and treated wastewater samples.

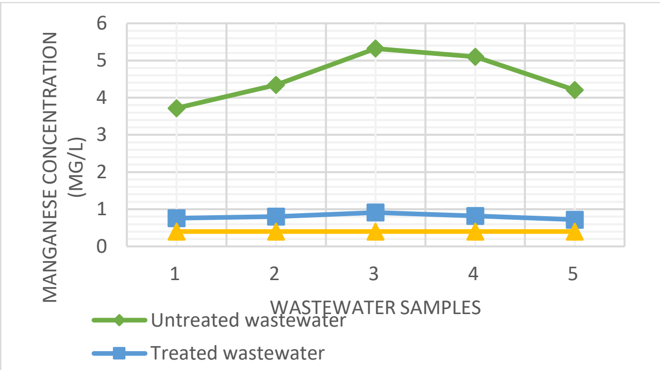

Fig. 4. Manganese Content of untreated and treated wastewater samples.

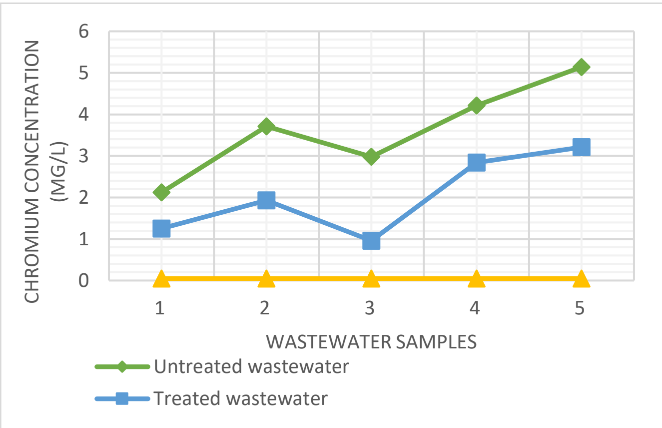

Fig. 5. Chromium Content of untreated and treated wastewater samples.

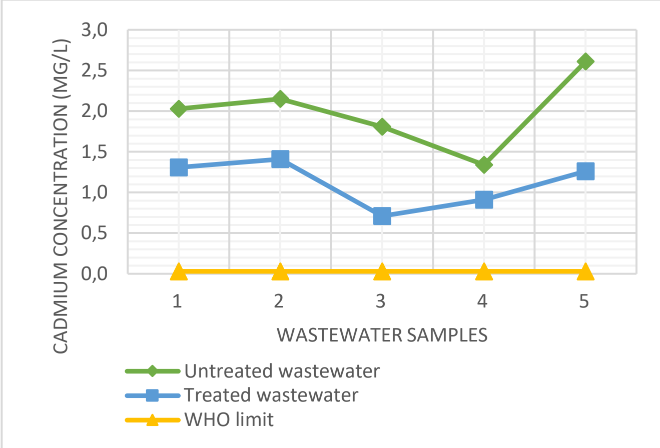

Fig. 6. Cadmium Content of untreated and treated wastewater samples.

IV. Conclusion

In this study, solar distillation was used to reduce the heavy metal content of domestic wastewater samples indiscriminately dumped into the environment. Wastewater samples with high heavy metals content were kept in a solar still and subjected to heat from the sun. The study revealed a drastic reduction in the heavy metal content of the treated wastewater, however, the heavy metal contents of most of the treated wastewater samples did not fall within WHO limit for potable water. It is noteworthy that the Zn content of four out of the five treated wastewater samples fell within WHO limit for potable water. This method is affordable and easy to operate, the solar still is reusable. This treatment method has successfully reduced the heavy metal content of the wastewater samples so that discharge into the environment can be acceptable, however, further treatment is needed to make the water safe for human consumption.

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Conflict of Interest

The author declares that there is no conflict of interest.

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