Remediation of Arsenic in Tube-Well Water by Using Various Adsorbents

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Abstract

The present research deals with the remediation of one of the heavy toxic metals as arsenic (As) in the tube-well water by using various adsorbents such as sand, marble, the product of rice husk and different biosorbents. The aim of the study was to contribute some information to reduce As content by using various adsorbents which are available in nature. In Myanmar, many researchers have been done by various modern techniques to analyse the drinking water. They have been pointed that especially ground water in Ayeyarwady region was found to be remarkably high content of As that can be hazardous to human health of local peoples. In fact, a localized problem was related to public health. Therefore, the present research designated to examine the remediation of As from the tube-well water until to reach acceptable level of drinking quality by using reliable methods. The results noted that the present method was very familiar to apply for the public because it is cost effective and very easy to use in home without chemicals. At first, the tube-well water samples were collected from Hinthada and Kyonpyaw Township and measured the As content by using Atomic Absorption Spectrophotometer (AAS) at Department of Chemistry, Hinthada University. Then the samples were selected as the high content of As in water to remediate that contents of heavy metal with the various adsorbents by column type method, consecutively. After the As remediating water samples were measured again to know how much reducing content of As were left before the remediation process. According to the results, it was found that the content of As could be remediated from 9.1920 to 2.8074 ppb for the sample of Hinthada whereas from 8.9430 to 7.0185 ppb for the sample of Kyonpyaw Township.

Keywords: tube-well water, remediation, arsenic, various adsorbents, AAS

Introduction

The water cycle involves evaporation, transpiration, cloud formation, and precipitation. Only a minor amount of water remains in circulation between the atmosphere and water bodies on the earth's surface, living organisms, underground water bodies and oceans. Our body uses water in all its cells, organs and tissues to help regulate its temperature and maintain other bodily functions. Because our body loses water through breathing, sweating, and digestion, it's important to rehydrate by drinking fluids and eating foods that contain water (Valecha and Bhatnagar, 1988). There are three major global resources of water, (a) precipitation over the earth's surface in the form of rain, dew and snow; (b) surface water; as rivers and lakes and; (c) underground water (Wong and Dixon, 1995). Groundwater is the water found underground in the cracks and spaces in soil, sand and rock. It is stored and moves slowly through geologic formations of soil, sand and rocks called aquifers. A tube well is a type of groundwater well in which stainless steel tube or pipe is bored into an underground aquifer.

In Ayeyarwady Region, private wells supply drinking water and the most of local peoples rely on it. Consequently, Environmental Protection Agency (EPA) recommends that private well owners should test their water periodically to ensure that it is safe for drinking.

Heavy Metals and Aspect of Arsenic

Heavy metals are naturally occurring elements that have a high atomic weight and a density at least 5 times greater than that of water. Their multiple industrial, domestic, agricultural, medical and technological applications have led to their wide distribution in the environment and caused badly effects on human health. Their toxicity depends on several

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factors including the dose, route of exposure, and chemical species, as well as the age, gender, genetics, and nutritional status (Wang and Zhang, 1999).

Arsenic is one of the heavy toxic metals that occurs naturally in rocks and soil and is used for a variety of purposes within industry and agriculture. Arsenic can enter the water supply from natural deposits in the earth or from industrial and agricultural pollution. Arsenic is removed from the air by rain, snow, and gradual settling. Once on the ground or in surface water, arsenic can slowly enter groundwater. High arsenic levels in private wells may come from certain arsenic containing fertilizers used in the past or industrial waste (Prater, 1975).

Heating or boiling water will not remove arsenic. Because some of the water evaporates during the boiling process, the arsenic concentrations can actually increase slightly as the water is boiled. There are many modernized water treatment methods such as reverse osmosis, ultra-filtration, distillation or ion exchange (Anderson and Kim, 2003). Arsenic can pose a serious risk to our health (Fig. 1). It can cause skin changes, cancer, stomach-related symptoms such as vomiting and nervous system damage, reduction in blood cell production, liver enlargement, loss of sensation in the limbs and brain damage. The most significant among them has been for high blood pressure, heart attacks and other similar conditions related to the circulatory system. Arsenic exposure can be fatal in high doses and the cause of major, long-term health risks in lower dosed (WHO, 2010). Arsenic in drinking water is absorbed by the body when it was swallowed and distributed by the bloodstream. It does not enter the body through the skin or by inhalation during bathing or showering. The highest levels of arsenic are found in nails and hair, which accumulate arsenic over time. Inorganic arsenic is a confirmed carcinogen and is the most significant chemical contaminant in drinking-water globally. Arsenic can also occur in an organic form such as those found in seafood are less harmful to health (WHO, 2010).

*(Anderson and Kim, 2003)
Figure (1). Health effect associated with arsenic exposure by drinking contaminated water

Adsorption and Biosorption

Adsorption involves the accumulation or contraction of substances at a surface. The process can occur at an interface between any two phases such as liquid-liquid, gas-solid, liquid-solid interfaces. The material being concentrated or adsorbed is the adsorbate and the adsorbing phase is termed the adsorbent (Bhatt and Jha, 1999).The most important factor affecting adsorption; surface area of adsorbent, particle size of adsorbent, contact time or residence time, solubility of solute (adsorbate) in liquid (waste water or contaminated water), size of the molecule with respect to size of the pores, degree of the ionization of the adsorbate molecule and pH. Biosorption can be defined as the ability of biological materials to accumulate heavy metals from wastewater through metabolically mediated or physico-chemical pathways of uptake. Various adsorbents available in nature such as sands, marbles, by-product of rice husk as well as pseudostem of *Musa* sp. (Ngapyaw Ou) and sponge gourd *Luffa* sp. (Thabut Ou) were used as biosorbents in remediation process of the present study.

Sand (Fig. 2.a) is a granular material composed of finely divided rock and mineral particles. Sand consists of the elements: aluminium, silicon, magnesium and oxygen and also the chemical compound silicon dioxide (SiO_2), also known as silica (Website-1). Marble (Figure 2 a) is one of the most luxurious flooring for use in the home (Website-2).There are three different types of marble: calcite marble, dolomite marble and magnesium marble. Rice husk (Fig. 2.b) is one of the major by-products derived in the milling of paddy rice. Although crude protein and fats are low, carbon and oxygen constitutes 40 % and 36 % respectively with about 5 % hydrogen. Rice husk power is usually used as heating system in cooking, boiler, etc. and obtained by-product from the heating system is applied as adsorbent to remove impurities in many purposes (Website-3). *Musa* is one of two or three genera in the family Musaceae that includes banana and plantains. In pseudostem of *Musa* sp. (Ngapyaw Ou) shown in figure (3) and the properties contain as follow; cellulose 31-35 %, hemicellulose 14-17 %, lignin 15-16 %, acid soluble lignin 5.05 %, fiber length 2.21 %, fiber width 22.2 % (Wong, *et.al.*, 2002). *Luffa* is a genus of tropical and subtropical vines in the cucumber family. *Luffa*-derived sponges (Fig. 4) are tough on dirt but non-abrasive and perfect for washing our face, body, dishes, floor, or car. It includes ash 0.7 %, lignin 15.2 % and cellulose 83 % (Website-4).

(a) Sand Marble (b) Rice husk Cooker By-product

Figure (2). (a) Sands and Marbles, (b) By-product of rice husk used as biosorbent

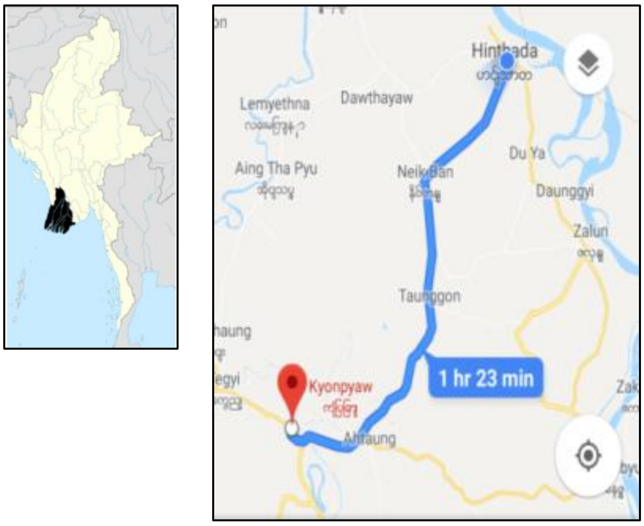
Figure (3). Pseudostem of *Musa* sp. (Ngapyaw Ou) used as biosorbent

Figure (4). Sponge gourd *Luffa* sp. (Thabut Ou) used as adsorbent

Materials and Methods

Sampling: In Ayeyarwady Region, private wells supply domestic besides drinking water and the most of local peoples rely on it. Many water researchers have been studied by various point of view, it was found that one of the heavy toxic metals, arsenic content highly contained in groundwater of Ayeyarwady Region. So private tube-well water should be tested periodically to ensure that it is safe for drinking. And also Department of Chemistry and the local health departments should collaborate and mutually help in water treatment with yearly testing for heavy toxic metals, bacteria and nitrates. Therefore, the present research designated to examine the remediation of As in the tube-well water until to reach acceptable level of drinking quality with the reliable methods by using various adsorbents which are readily available in nature. Out of the twenty-six Townships of Ayeyarwady Region, Hinthada and Kyonpyaw shown in figures (5.a) and (5.b) were chosen for the sampling sites where are located on the Ayeyarwady River. The two sampling sites are far about 60 km and it takes for 1 hr and 23 mins by car. The tube-well water samples were collected in June, 2018 from Ouyintaung Quarter, Padamyar Quarter and Awyine-kyaung-su Village in Hinthada and Thaunggyi Village in Kyonpyaw Township. The water samples were collected by means of a water sampler.

Instrument: Atomic Absorption Spectrophotometer, (AAS) (Shimadzu-AA-7000) at Department of Chemistry, Hinthada University



*(Website-5)

Figure (5). (a) Map of Ayeyarwady locator in Myanmar and (b) Location map of Hinthada Kyonpyaw Township

Determination of Arsenic (As) in Collected Tube-Well Water Samples byAAS

The collected private tube-well water samples were examined to record initial arsenic content by AAS as shown in figure (6). It is high-sensitivity analysis, flexible system configuration and can definitely record the results until parts per billion (ppb) value.

Figure (6). Atomic absorption spectrophotometer

Preparation of Various Adsorbents

To remediate arsenic content in water samples, the various adsorbents used in this experiment were sand, marble, by-product of rice husk, and different biosorbents: pseudostem of *Musa* sp. (Ngapyaw Ou) and sponge gourd *Luffa* sp. (Thabut Ou). These were prepared as the following procedures.

Preparation of sand

Sands were collected from shore of Ayeyarwady river and cleaned with distilled water. Then these were dried on the sun to prevent other watery effect. The sun-dried sands were placed in container to use as an adsorbent.

Preparation of marble

Marbles were collected from the bank of the Ayeyarwady river and cleaned with distilled water. Marbles were prepared the same as procedure of sands and placed in container to apply in the experiment.

Preparation of by-product of rice husk

Rice husk was collected from Mi-ba-myittar rice mill at Puzontaung Village in Hinthada. It was used as fuel for cooking in domestic and then collected as the by-product of rice husk. That was boiled and cleaned with distilled water. After drying in sun, by- product of rice husk was placed in container to use as one of the adsorbents.

Preparation of different biosorbents

(a) Pseudostem of *Musa* sp. (Ngapyaw Ou)

Pseudostem of *Musa* sp. (Ngapyaw Ou) was collected from Yone-tha-linn Village in Hinthada. It was sliced and boiled with distilled water to remove colour and some impurities. After cooling, extract of Ngapyaw Ou was tested with pH paper to view on pH changes. The boiling process was continued until not to change in pH paper anymore. Then, the slice of Ngapyaw Ou was taken and dried in sun to use as a biosorbent.

(b) Sponge gourd *Luffa* sp. (Thabut Ou)

Sponge gourd *Luffa* sp. (Thabut Ou) was collected from Nga-khone-su Village in Hinthada. It was cut as pieces and boiled with distilled water to remove colour and some impurities. Sponge gourd *Luffa* sp. (Thabut Ou) was prepared as the procedure of (Ngapyaw Ou) and also used as the next biosorbent.

Removal of Arsenic Content in Selected Tube-Well Water Samples by Using Various Adsorbents

Out of the water samples recorded by AAS, the highest arsenic content was selected as the tested samples to remediate the content of arsenic in the tube-well water. Remediation of arsenic content in selected tube-well water samples was done by column type method. The prepared adsorbents: sand (100 g), marble (150 g), by-product of rice husk (10 g), each (5 g) of biosorbents such as pseudostem of *Musa* sp. (Ngapyaw Ou) and sponge gourd *Luffa* sp. (Thabut Ou) were separately placed in each of plastic bottle as shown in figure (7). In the procedure, one of the collected water samples was taken to slowly flow and consecutively passed through onto the prepared various adsorbents step by step. Similarly, the next collected water sample was also processed as the same way. After that the flowed water samples were received and stored in room temperature for measuring AAS again.

Figure (7). Remediation of arsenic in tube-well water with the various adsorbents by column type method

Determination of Remediated Arsenic (As) in Tested Tube-Well Water Samples by AAS

After removing arsenic in tube-well water samples, it was checked again by AAS to know how much remediation of arsenic content in the tested samples. The resultant data were reported and explained as follow.

Results and Discussion

Initial Detection of Arsenic Content in Tube-Well Water from Hinthada and Kyonpyaw Township

Atomic absorption spectrophotometry is commonly used in many analytical laboratories for determination of trace elements in water sample. The assessment of metal pollution is an important aspect of most water quality assessment programmes. The Global Environment Monitoring System (GEMS) Programm GEMS/WATER includes ten metals: As, Al, Cd, Cr, Cu, Fe, Hg, Ni, Pb, and Mn. The United States Environmental Protection Agency (USEPA) considers eight trace element as high priority: As, Cd, Cu, Cr, Pb, Hg, Ni and Zn (WHO, 2010).

In the present work, arsenic content in tube-well water was determined by atomic absorption spectrophotometric method and results of arsenic were analysed in private tube-well water supply at Ouyintaung Quarter, Padamyar Quarter and Awyine-kyaung-su Village in Hinthada and Thaunggyi Village in Kyonpyaw Township are presented in table (1) and figure (8). It was observed that initial arsenic content contained 2.6716 ppb in Ouyintaung Quarter, 9.1920 ppb in Padamyar Quarter, not detected in Awyine-kyaung-su Village respectively and also 8.9430 ppb in Thaunggyi village, Kyonpyaw Township. Out of the results, it was obvious that arsenic contents found in the samples of Padamyar Quarter, Hinthada and Thaunggyi Village, Kyonpyaw were higher than that of other detected water samples. Nevertheless, arsenic content in a private tube-well of Awyine-kyaung-su Village, Hinthada Township was not detected in the present study as the AAS record. In fact, arsenic content in ground water could be variable seasonally or periodically. The prior knowledge of contamination in ground water have pointed out that arsenic content in water could differ in rainy season and the other drying season because arsenic is removed from the air by rain, snow, and gradual settling. It is believed that naturally occurring arsenic content becomes higher when ground water levels drop significantly. Because some of the water evaporates during the drying process, the arsenic concentrations can actually increase slightly as the water is evaporated. Whatever it was recommended that water contamination including arsenic content should be inquired before using as drinking water. After drilling tube-well in home, factory or anywhere, it should be noted that to test until to reach acceptable level of drinking quality and related to take a help of local health centers or laboratory even Department of Chemistry, Hinthada University. In the study, although the results revealed that the heavy toxic metal, As levels in every collected water samples were below the WHO permissible level (10 ppb), as the matter of fact in the project plan it was needed to reduce the highest As content in detected samples. Therefore, the highest As content samples were led to remediate as possible as with the use of various adsorbents available from natural sources.

Remediation of Arsenic Content in Selected Tube-Well Water Samples by Using Various Adsorbents

As the project plan, arsenic content in contaminated private tube-well water was remediated by using various adsorbents available in nature. This present study intended to transfer knowledge from this research work to the public that private tube-well should not be used without any testing for drinking quality. And also the methods used in the present study were very easy to apply for local needs. Sand, marble, by-product of rice husk, and different biosorbents such as pseudostem of *Musa* sp. (Ngapyaw Ou) and sponge gourd *Luffa* sp. (Thabut Ou) were available in nature and cost effective as using them in home. From the experiment, it was evidenced that adsorbents could contract and accumulate the impurities because of their own distinct ion exchange power, cleaning action and physico-chemical properties such as cellulose, fiber, etc. After being initial test, the water samples in the highest content of arsenic might be chosen for the project plan. As it was, although all tested water samples were below WHO permissible level, the prominent contents in water samples: Padamyar Quarter, Hinthada (9.1920 ppb) and Thaunggyi Village, Kyonpyaw Township (8.9430 ppb) were selected to follow the remediation of As content by using various adsorbents including different biosorbents available from natural sources.

Determination of Remediated Arsenic (As) in Tested Tube-Well Water Samples by AAS

By measuring with Atomic Absorption Spectrophotometer (AAS), arsenic content was observed again to know how much remediation of As content from originated tube-well water sample with the use of various adsorbents in this study. The obtained results showed that the content of As could be remediated from 9.1920 to 2.8074 ppb for the sample of Hinthada whereas from 8.9430 to 7.0185 ppb for the sample of Kyonpyaw Township. The remediated percentages of arsenic were calculated and it was denoted that the private tube-well water sample from Hinthada could be remediated until to reach 69.4582 % nevertheless 21.5196 % was reduced in the sample collected from Kyonpyaw Township (Table 2 and Fig. 9). From the observation, it couldn't be observed the fact why remediation percent were quite different from each other although the same way and adsorbents were used in the project work. At that point, there were many considerable factors upon the research work. So it might be suggested that the further studies need to solve this problem and should be changed in stages of the process. Other effects of physico-chemicals will need to other examine. For example, each result in every remediating steps should be adjusted and compared which adsorbent was more reliable to reduce the contaminated As in water instead of only measuring the final result of As content. The next, as for the heavy metals contamination, the collected water sample should be examined the comparable data before and after preparing sedimentation process. That could be a point of view in which more reliable suggestions would be informed to the local peoples. Moreover the local peoples should be helped and informed about Atomic Absorption Spectrophotometer (AAS) running in Department of Chemistry, Hinthada University. According to National Water Policy in Myanmar goal, the whole nations should cooperate in the two broad areas such as water resources management and water resources use to become a water efficient nation in year 2020.

Table (1). Initial Detected Content of Arsenic in Private Tube-Well Water from Hinthada and Kyonpyaw Township by AAS

Sr.	**Sampling Site**	**Observed Value (ppb)**	**Drinking Standard WHO/(ppb)**	**Effluent Standard *(ppb)**	**Remarks**
1.	Ouyintaung Quarter, Hinthada	2.6716	10	≤ 50	Normal
2.	Padamyar Quarter, Hinthada	9.1920	10	≤ 50	Near to the level of WHO standard (Selected to remediate As content)
3.	Awyine-kyaung-su Village in Hinthada	ND	10	≤ 50	Normal
4.	Thaunggyi Village in Kyonpyaw Township	8.9430	10	≤ 50	Near to the level of WHO standard (Selected to remediate As content)

ND = not detected

*(Occupational and Environmental Health Division, Department of Public Health, 2018)

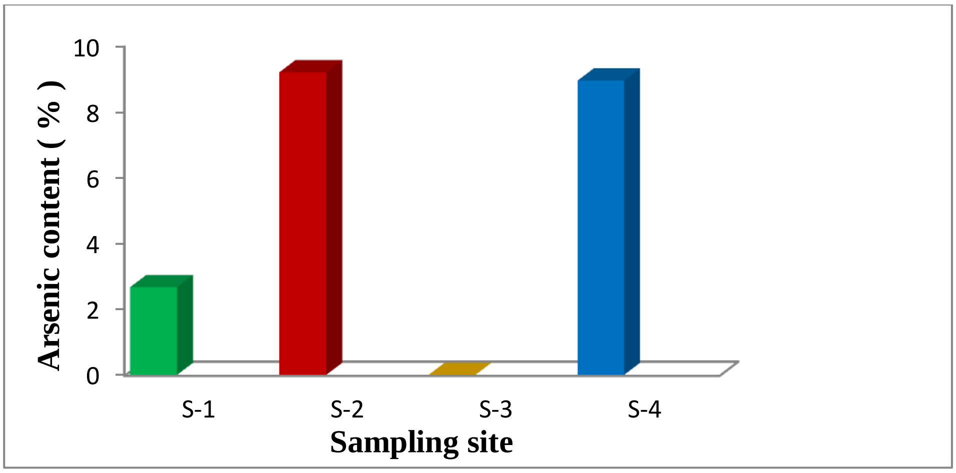


Figure (8). Histogram of initial detected content of arsenic in private tube-well water from Hinthada and Kyonpyaw Township by AAS (
S-1 = Ouyintaung Quarter, Hinthada,
S-2 = Padamyar Quarter, Hinthada,
S-3 = Awyine-kyaung-su Village, Hinthada,
S-4 = Thaunggyi Village, Kyonpyaw

Table (2). Determination of Remediated Arsenic (As) Content in Selected Tube-Well Water Samples by AAS

Sr.	Selected Sample Site (The highest Content of As)	Initial Value (ppb)	Remaining value (ppb)	Remediated percent of As (%)	Remarks
1.	Padamyar Quarter, Hinthada	9.1920	2.8074	69.4582	Pronounced remediation of As content
2.	Thaunggyi Village in Kyonpyaw	8.9430	7.0185	21.5196	Just relieved As content

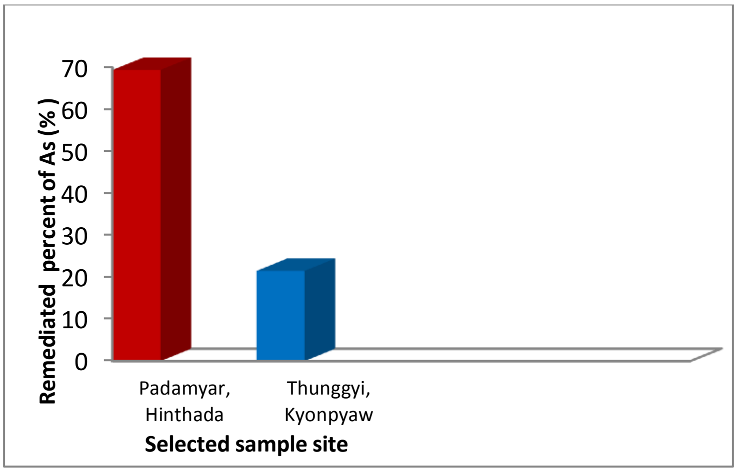


Figure (9). Histogram of remediated arsenic (As) content in selected tube-well water samples by AAS

Conclusion

The present study is to assess one of the heavy toxic metals, arsenic contamination in tube-well water with a view and to point out the remediation of arsenic content in private tube-well water from some locals of Ayeyarwady Region by using various adsorbents and different biosorbents available in nature.

Arsenic contaminated water could be directly detrimental to the health of human by using as a drinking water. In the present work, the physico-chemical characteristics of various adsorbents, and arsenic contents during the study period could be observed and concluded as follows .

Arsenic content of tube-well water samples were found to be 2.6716 ppb in Ouyintaung quarter, 9.1920 ppb in Padamyar Quarter, not detected in Awyine-kyaung-su Village and also 8.9430 ppb in Thaunggyi Village, Kyonpyaw Township by AAS. It could be assigned that these values were below WHO permissible level designated drinking standard.

Furthermore, As concentration in all of the collected tube-well water samples could be assigned to coincide with the value of effluent standard of water.

Nevertheless, the project have been planned for the remediation of As in tube-well water by using natural adsorbents without chemicals. Therefore, a prominent amount of As (9.1920 ppb) in Padamyar Quarter, Hinthada was selected to continue the remediation process and followed by the second highest (8.9430 ppb), As content found in the water sample of Thaunggyi Village, Kyonpyaw Township was also targeted to reduce as possible as.

Eliminated levels of As from the two selected locals were also detected by AAS and these were found to be 2.8074 ppb in water sample of Hinthada and 7.0185 ppb in the sample of Kyonpyaw Township. Of the two samples, tube-well water in Hinthada was remarkably remediated about 69.4582 % whereas 21.5196 % of the water sample in Kyonpyaw Township. Whatever it is, due to drinking standard (WHO) and effluent standard, these are reliable normal conditions.

From the research work, it can be advocated that various adsorbents available in nature may be substituted in modern methods such as reverse osmosis (RO), ultra filtration (UF) water purifier as one of the purification processes.

As the conclusion, the present study of the project was not completed yet. It needs to continue to test the bioremediation of arsenic for each step of process. Also this study would like to recommend for the future study to examine the other available biosorbents on that of other toxic heavy metals.

Moreover, there is a need to properly manage wastes in the city and then control and monitor human activities in order to ensure that such activities have minimal negative effects on the city stream.

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