Eco. Env. & Cons. 28 (1) : 2022; pp. (165-171)

ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2022.v28i01.021

A Study on the modification of bio-sand filter with Ashes

Neelu Das[1], Shashikant Singh[2], Dipankar Sutradhar[3], Alok Saikia[3] and Hemanta Brahma[3]

[1]Department of Civil Engineering, Central Institute of Technology Kokrajhar. Kokrajhar 783 370, Assam, India
[2]Department of Civil Engineering, NERIST, Nirjuli 791 109, Arunachal Pradesh, India
[3]Department of Instrumentation Engineering, Central Institute of Technology Kokrajhar, Kokrajhar 783 370 , Assam, India

(Received 14 November, 2020; Accepted 10 May, 2021)

ABSTRACT

This study investigates the viable applications of two different waste materials namely areca nut husk and water hyacinth stem in the form of ash which were used as adsorbent material to modify the bio-sand filter focusing on sustainable development. The effectiveness of the filter was determined by testing for total dissolved solids, pH, the presence of heavy metals (As, Cd and Pb) and microbiological analysis in the raw and purified water. As was reduced to 69% and 76%, Cd to 51.5% and 69% and Pb to 45.9% and 57.8% in ANA and WHA purified water respectively. The microbiological analysis reveals that the filters greatly improved the bacteriological quality of water by recording a removal efficiency of 69.5% and 89.5% in purified water samples. Obtained results shows that the wastes which were considered as a curse to the ecosystem can be turned out to be wealth for Civil Engineering applications.

Key words: *Areca nut husk ash (ANA), Water hyacinth stem ash (WHA), Microbiological analysis, Bio-sand water purifier.*

Introduction

Water is the basic necessity of a human being along with food and air so, it can be termed as the 'Elixir of life' (Rajankar *et al*., 2009). As we know 71% of the Earth is covered with water but only 1% of that is consumable. So, drinking water has great influences on people's everyday life. In developing countries like India, resources of safe drinking water are inadequate. Surface water is generally used for drinking purpose and hence contamination is hard to elude. Perilous drinking water leads to diarrheal diseases and statistics of the World Health Organization reveals that ninety percent of the deaths in children of developing countries, where the resistance capacity of the children to infections are low only because of the unsafe drinking water (WHO, 2000). The bio-sand filter is a simple and low-cost household water treatment device, which has been used for the treatment of water for hundreds of years. These filters are built with a bed of fine sand as the filtration media, and gravel to support the sand. A complex biological layer, 'Schmutzdecke', which contains bacteria culture, is grown on the slow sand filter surface (Wotton and Hirabayashi, 1999). As water passes through the 'Schmutzdecke' layer, particles of dissolved organic material are absorbed and metabolized. Slow sand filters are capable of filtering water up to a certain turbidity level since water with high turbidity clogs up the filter bed rapidly. Slow sand

([1]Assistant Prof., [2]Prof.)

filters are very operational at removing heavy metals, and it is often combined with activated carbon to eliminate organic material as well as to improve odor and taste. Carbon is known as a popular adsorbent of impurities. Activated carbon is processed carbon which is more attractive to chemicals and impurities. Currently, there is a great concern in finding inexpensive and effective alternatives to the prevailing commercial activated carbon. Exploring cost-effective and new adsorbing material will help in maintaining environmental sustainability and future commercial applications. The cost of adsorbent prepared from biological material or waste is very little matched to the cost of commercially available products.

India ranks first in the areca nut (betel nut, *Areca catechu*) production in the world having around 4 hundred thousand hectares area with 4.78 hundred thousand tons production (Indian Horticulture Database, 2011). The husk of the areca nut is removed before it is sold (in dry form) and consumed, which leads to a large quantity of this bio-waste unutilized. The quantity of areca nut husk obtained from an areca nut garden is approximately 5.5 - 6 metric tons per hectares per year, and this creates a major problem in the disposal. Water hyacinth (*Eichhornia crassipes*) is a very antagonistic invader that can form thick mats on the water surface. It is known as the nastiest among all aquatic plants in the world and characterized by quick growth rates, wide scattering capabilities, large and vigorous reproductive output, known to double their population in two weeks. A high rate of water loss through the leaves of water hyacinth is observed by evapotranspiration and in India, 26% of the water loss was observed through water hyacinth cover. This water loss is 7.76 ± 1.36 times higher in different seasons and it is several times higher than the evaporation from a free water surface (Verma, *et al.*, 2003). Because of its overwhelming effects on aquatic ecology and man, it is known as "Blue devil" or "Bengal terror" in India (Ghosh, 2010).

The various agricultural waste which is readily available, practically everywhere in the world such as olive waste, rice husk, maize, corn cob,bagasse, coir pith is explored as low-cost adsorbent. Periasamy *et al*. (1996) investigated the potential of peanut hull (PHC)as activated carbon for adsorbing Cu(II) from a solution which contains 20 mg/L Cu(II) by using 0.9g PHC per liter in the pH range of 4 to 10, which is 18 times greater than that of granular activated carbon. Khalid *et al.* (1998) has studied the adsorption potential of rice husk for arsenic ions from aqueous solution and reported maximum adsorption of ricehusk which was treated with 0.01 mol/L of HNO_3, HCl, H_2SO_4 or $HClO_4$ using 1g of this adsorbent for 5.97 X 10^{-3} mol/L of arsenic in 5 mins. Ahluwalia *et al.* (2005) have studied the potential of waste tea leaves in the removal of lead, iron, zinc, and nickel from water. The order of adsorption of metals as lead, iron, zinc and then nickel from 5 to 100 mg/L of metal solution. Parab, *et al*. (2006) used coir pith for adsorption of Co(II), Cr(III) and Ni(II) from single-ion solutions as well as from amixture of them. Batch adsorption technique was used by the authors for determining the efficiency of the adsorbent and from the obtained results they recommended coir pith as an efficient adsorbent material for the removal of Co(II), Cr(III) and Ni(II) from water and nuclear power plant coolant water. Kumar *et al*. (2007) found out the effectiveness of the areca nut peels activated carbon for removing dyes from dye wastewater. They reported that a dose of 0.5 g/l is optimum for removing 91.8% of the dye at pH 10 for a contact time of 35 mins for a dye concentration of 5 mg/l and concluded that powdered areca nut peels activated carbons was an attractive candidate for removing dyes from dye wastewater. Wang *et al*. (2008) studied the potential of rice hull ash (RHA) as adsorption of lead (II) ion from aqueous solution. They reported that the rate of removal of lead (II) was increased by increasing the initial lead concentration, pH, stroke speed, or adsorption temperature. Uddin *et al.* (2009) investigated the potential of tea waste for the removal of methylene blue from aqueous solution. FTIR technique was used to examine the interaction between adsorbent and methylene blue. The adsorption capacity of tea waste was found to be 85.16 mg/g. Uddin *et al.* (2014) carried out a study to determine the adsorption of methylene blue dye from an aqueous solution of HCl acid-treated water hyacinth. Water hyacinth was soaked in 0.1 M HCl for 20 min and again washed with distilled water. It was then dried in an oven, at a temperature range of 90^0 -100 ^{0} C for 8 hours. The dried WH was ground, and the powder was used as an adsorbent. Najem, (2015) investigated the adsorption capacity of water hyacinth roots in removing the heavy metals namely lead, cadmium, chromium, and copper from their aqueous solutions and test results revealed excellent biosorption capacity of water hyacinth root, removal of Pb was found to be the highest and Cr was lowest.

Joshi, (2017) studied the possibility of Fe_2O_3 /areca nut activated carbon composite, prepared by chemical activation with phosphoric acid at 400 °C under nitrogen atmosphere for removal of fluoride from water. They reported that the percentage removal of fluoride by the adsorbent was ~75 % at a contact time of 180 minutes and the maximum adsorption was observed at pH2 with an adsorbent dose of 20 gm/l.

There are limited studies on the utilization of areca nut husk and water hyacinth, the two entirely free sources of bio-masses to date and this has motivated to explore the utility of these brown wastes as adsorbent material to modify the bio-sand filter for safe drinkable water. Such a study would help in understanding the possibility of seeing something that was once just waste, become a new resource.

Materials and Methods

Areca nut husk ash and water hyacinth stem ash as an adsorbent

The areca nut husk ash (ANA) and water hyacinth stem ash (WHA) was used to remove contaminants and impurities, using chemical adsorption in a traditional bio-sand filter in this study. Commercially used activated carbon are commonlyavailable in 8 x 30 mesh or 0.60 mm to 2.36 mm (largest), 12 x 40 mesh or 0.42 mm to 1.72 mm (most common), and 20 x 50 mesh or 0.29 mm to 0.84 mm (finest), finer the mesh, better is the contact and removal. The burned ash without grinding in ball mill was screened through a 300µ sieve and the retained ash on the sieve was used as adsorbent (Fig. 1).

Fig. 1. ANA (a) and WHA (b) retained on 300µ sieve.

Fig. 2 shows the spectrum of ANA and WHA which was analyzed by an X-ray diffraction test. ANA has a highly crystalline structure and the major constituents are silica and potassium oxide with a comparatively lesser amount of calcite (Das and Singh, 2015). While in WHA, calcite and potassium oxide is present as a major constituent with silica is present as a minor constituent and can be attributed to the original inorganic elements present in water hyacinth stem ash. The most distinguished crystalline materials were potassium oxide, calcite, and quartz (Das and Singh, 2016).

Sand and gravel

Locally available river sand (Beki river, Barpeta, India) conforming to grading zone III as per IS: 383-1970 (BIS (1970) was used and was sieved thoroughly and the portion passing through 4.75 mm - 1.18 mm (coarse sand) and 1.18 mm – 150 micron(fine sand) was used as filter media in the present study. Gravels passing through 12 mm sieve and retained on 4.75 mm was used.

Water

It was collected from an open well near the C.I.T. Kokrajhar campus.

Filter installation

The sand and gravels were washed several times using tap water until the wash water became clear. The filtering medium is placed in layers as shown in **Fig. 3**.

1st layer- ash obtained from burning of locally available brown waste is placed on the top 25 mm layer,
2nd layer- is filled with 50 mm of fine sand,
3rd layer- additional 75 mm layer of coarse sand is poured, and

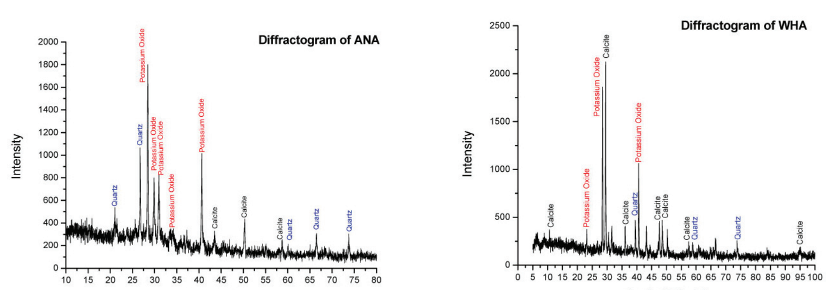

Fig. 2. X-ray diffractogram of ANA and WHA.

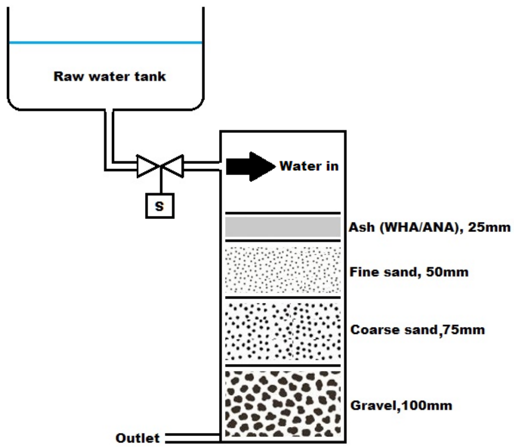

Fig. 3. Line diagram of carbon and sand filter used in the study.

4th layer- 100 mm layer of gravel is placed at the bottom.

Microbiological Test

The presence of bacteria and other microorganisms in drinking water is a matter of great concern while quality and safety are considered. In the present study to test the presence of microorganisms like bacteria and viruses in the carbon-sand purified water, the plate count technique using nutrient agar is used. For this 1ml sample volume of the purified water (ANA-purified and WHA-purified) was derived from a series of dilution and then dispensed the sample using a serological pipette into the middle of the empty Petri disc. The preparation of serial dilutions of the samples is necessary for ensuring the appropriate number of generation of colonies, where the statistically significant range of these colonies are 30 to 300 cfu. If there are more than 300 cfu on a plate, then the colonies will be crowded and overlapping. Then 18 ml of melted (pre-sterilized in an autoclave) nutrient agar medium (at 48 ^{0}C) is carefully poured on the Petri disc. For the cultivation of bacteria and to enumerate the microorganism in water and other materials this method is best suited. If the nutrient agar is too hot or too cold, the bacteria present in the sample will die and the medium may be uneven when it gets solidified respectively. The Petri disc was incubated aerobically at 35 ^{0}C for 18-24 hours or longer when necessary.

Heavy Metal Test

In recent years the contamination of water with heavy metal is becoming a prime importance to ascertain the potential health risk by its concentration. This test is carried out for the detection of arsenic, cadmium and lead in the raw as well as in the purified water samples. All the filtered and raw water samples are analysed by Metalyser® Portable HM1000 (manufactured by Trace$_2$o). This instrument works on the principle of Anodic Stripping Voltammetry (ASV) equipped with a sonde and a buffer delivery system. World Health Organization (WHO) standardized some guidelines for the presence of heavy metals in drinking water (Rehman *et al*., 2018). The values of standardization are mentioned in Table 1.

Table 1. WHO's drinking water standards for heavy metals.

Parameter	WHO guideline value (ppb)
Arsenic (As)	<10
Cadmium (Cd)	<3
Lead (Pb)	<10
Mercury (Hg)	<6
Copper (Cu)	<2000.0
Zinc (Zn)	<4000.0

TDS Test

TDS (total dissolved solids) denote to any mineral deposits, metals, salts, anions and cations liquefied in water. This includes all present in water other than the pure water (H_2O) molecule and suspended solids. In this study, the spectrophotometric method was used for the estimation of TDS by reading the absorbance over a wide range of wavelength ranging from 200-1100 nm using LAMBDA - 45 Ultra-Violet/ Visible spectrum Spectrophotometer, manufactured by PerkinElmer. First, absorbance was set to zero (0) with distilled (deionized) water, and then the absorbance of raw, ANA purified and WHA purified water samples were measured. This method of measuring absorbance over the wide range of wavelength is suitable for uncontaminated natural waters and potable water supplies that have low organic content.

pH Test

The pH of water is the hydrogen ion (H+) concentration in the fluid. According to the Bureau of Indian Standard (BIS), the pH of drinking water should be between 6.5 - 8.5 (IS 10500:2012) (BIS, 2012) and the test was done for tested water samples using the instrument pH Testr 30.

Results and Discussion

Microbiological Test

The results obtained from the microbiological test are reported in Table 2 and the photographs of the appearance of colonies on the Petri discs for the tested samples are shown in **Fig. 4**. Low levels of translucent colonies (bacteria/microorganism) in the finished purified water (ANA/WHA purified) are an indicator that the modified bio-sand treatment system is functioning properly to producing safe drinking water. The advantage of using the plate count method is that the appeared translucent colonies are generally small and compact and hence easier to count, but have few morphological characteristics that could assist in the identification of microorganisms. The genera of bacteria indicated in this plate count methods, and their concentrations, normally vary depending on some factors including the cultivation conditions, type of medium, incubation temperature and incubation time.

Table 2. Microbiological test results.

Tested water sample	Counts of translucent colonies (no's)	
	Concentrated sample	Diluted sample
Raw water	Infinite	Infinite
ANA purified water	23	7
WHA purified water	19	2

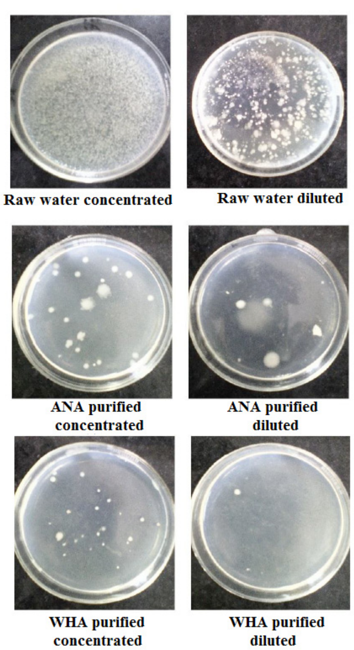

Fig. 4. Photographs of the appearance of colonies on the Petri discs for the tested samples.

Heavy Metal Test

The test results obtained with raw water samples, ANA and WHA purified water samples are presented in Table 3 and the plot of current vs potential for the metals tested (Ar, Cd, and Pb) are shown in **Fig 5** and **6**. Arsenic is reduced by 76% that of the raw water by using water hyacinth stem ash and 69% when areca nut ash is used. The cadmium is reduced by 17% and 69% with areca nut husk ash, and water hyacinth stem ash respectively. Lead can be reduced up to 57% as well.This shows that ANA and WHA modified filters are more efficient in removing As from water.

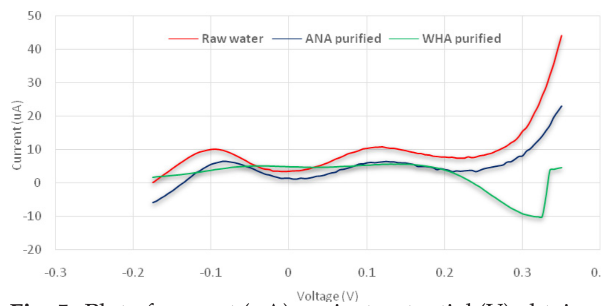

Fig. 5. Plot of current (µA) against potential (V) obtained in Arsenic (As) determination.

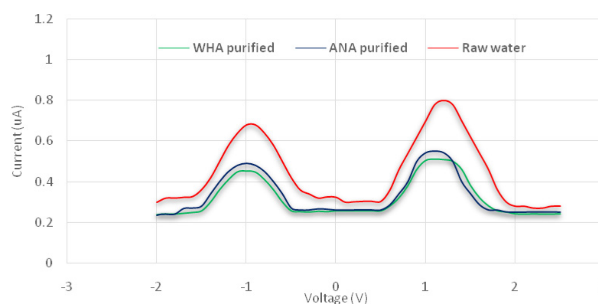

Fig. 6. Plot of current (µA) against potential (V) obtained in Cadmium (Cd) and Lead (Pb) determination.

TDS Test

There was no detectable change observed in the absorbance over the wavelengths in the near UV region (200 - 380 nm) and visible region (380 - 780 nm) in the tested water samples. But in the near-infrared region, particularly in 1090 - 1100 nm range, noticeable changes in the absorbance of raw vs purified water samples were detected and the wavelength of maximum absorbance (ë$_{max}$) was 1098nm. From the graph shown in Fig. 7, it is clear that the near-infrared absorbing compound present in the raw water sample

Table 3. Test results obtained by Metalyser.

Presence of Parameters (ppb)	Tested water samples		
	Raw water	ANA purified water	WHA purified water
Arsenic (As)	11.20	3.250	2.679
Cadmium (Cd)	2.78	1.348	0.857
Lead (Pb)	6.72	3.635	2.834

is vague in the ANA purified and WHA purified water samples. Previous researchers have proved that organic solids and polymers can absorb in the near-infrared (NIR) region (1000 – 2000 nm) and most of these NIR-absorbing materials are also electrochemically active (Wang *et al.*, 2004).

pH Test

The results (Table 4) show that the addition of ANA and WHA layer in the modified bio-sand filter maintains the pH level comparable to the normal portable water.

Conclusion

The major findings from the experiments conducted in this investigation can be summarized as below:

- Microbiological analysis of the purified water yields a very satisfactory result. The designed filters were found to be capable of controlling the count of microorganisms found in the raw water.
- ANA and WHA modified filters will work wonders in high Arsenic content water.
- The water collected from the modified filters showed a very little absorption of light compared to the raw enforces that the filters are effective in removing a significant amount of dissolved solids.
- pH test results have portrayed almost the same pH value for the two purified samples and raw water which is between 6.5-8.5.

The ANA and WHA perform well in removing microorganisms, heavy metals like arsenic, cadmium, lead and dissolve solids and can be adopted and widely used as an adsorbent for treating water

Table 4. pH test results

Characteristics	Raw water	ANA purified water	WHA purified water
pH	7.68	7.46	7.42

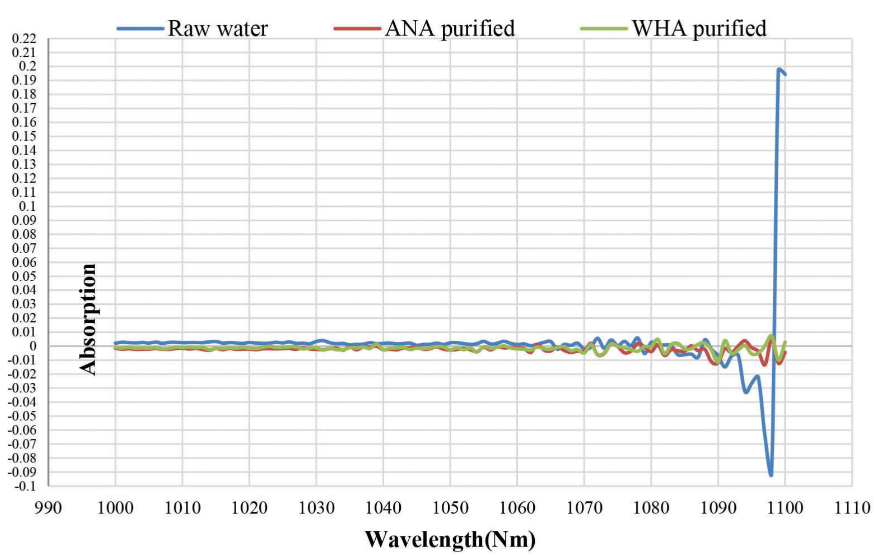

Fig. 7. Graph of TDS analysis using a spectrophotometer.

not only to minimize cost inefficiency but also improve profitability.

References

Ahluwalia, S. S. and Goyal, D. 2005. Removal of heavy metals by waste tea leaves from aqueous solution. *Engineering in life Sciences*. 5 (2) : 158-162.

BIS, I. 1970. 383 1970. Specification for Coarse and Fine Aggregates from Natural Sources for Concrete. *Bureau of Indian Standards, New Delhi, India*.

BIS, I. 2012. 10500: 2012. *Indian standard drinking water-specification (second revision), Bureau of Indian Standards, New Delhi*.

Das, N. and Singh, S. 2015. Potential of Arecanut Husk Ash as Supplimentary Cementitious Material. *Concrete Research Letters*. 6 (3) : 126-135.

Das, N. and Singh, S. 2016. Evaluation of water hyacinth stem ash as pozzolanic material for use in blended cement. *Journal of Civil Engineering, Science and Technology*. 7 (1) : 1-8.

Ghosh, D. 2010. "Blue devil" or "Bengal terror" in India.

Indian Horticulture Database 2011: p.202-203; http://nhb.gov.in/area-pro/database-2011.pdf.

Joshi, S. 2017. Comparative Study on the Adsorption Capacity of Activated Carbon Prepared from Lapsi Seed Stone and Betel nut using Phosphoric Acid. *Journal of the Institute of Engineering*. 13 (1) : 153-159.

Khalid, N., Ahmad, S., Toheed, A. and Ahmed, J. 1998. Immobilization of arsenic on rice husk. *Adsorption Science & Technology*. 16 (8) : 655-666.

Kumar, K.A. and Prakash, S.M. 2007. Color Removal Using Arecanut Peels as an Adsorbent. *Journal of Environmental ResearhAnd Development*. 2 (2) : 173-179.

Periasamy, K. and Namasivayam, C. 1996. Removal of copper (II) by adsorption onto peanut hull carbon from water and copper plating industry wastewater. *Chemosphere*. 32 (4) : 769-789.

Rajankar, P.N., Gulhane, S.R., Tambekar, D.H., Ramteke, D.S. and Wate, S.R. 2009. Water quality assessment of groundwater resources in Nagpur Region (India) based on WQI. *Journal of Chemistry*. 6 (3) : 905-908.

Verma, R., Singh, S.P. and Raj, K.G. 2003. Assessment of changes in water-hyacinth coverage of water bodies in northern part of Bangalore city using temporal remote sensing data. *Current Science*. 795-804.

World Health Organization, 2000. WHO world water day report. *WHO, Geneva, Switzerland*.

Wotton, R.S. and Hirabayashi, K. 1999. Midge larvae (Diptera: Chironomidae) as engineers in slow sand filter beds. *Water Research*. 33 (6) : 1509-1515.

Parab, H., Joshi, S., Shenoy, N., Lali, A., Sarma, U.S. and Sudersanan, M. 2006. Determination of kinetic and equilibrium parameters of the batch adsorption of Co (II), Cr (III) and Ni (II) onto coir pith. *Process Biochemistry*. 41 (3) : 609-615.

Wang, L.H. and Lin, C.I. 2008. Adsorption of lead (II) ion from aqueous solution using rice hull ash. *Industrial & Engineering Chemistry Research*. 47 (14) : 4891-4897.

Uddin, M. T., Islam, M. A., Mahmud, S. and Rukanuzzaman, M. 2009. Adsorptive removal of methylene blue by tea waste. *Journal of Hazardous Materials*. 164 (1) : 53-60.

Uddin, M.D., Islam, M. and Das, S. 2014. A novel biosorbent, water-hyacinth, uptaking methylene bue from aqueous solution: kinetics and equilibrium studies. *International Journal of Chemical Engineering*. 2014.

Najem, A.M. 2015. Evaluation the Biosorption Capacity of Water Hyacinth (*Eichhornia crassipes*) Root for Some Heavy Metals. *Iraqi Journal of Science*. 56 (4A) : 2846-2852.

Rehman, K., Fatima, F., Waheed, I. and Akash, M.S.H. 2018. Prevalence of exposure of heavy metals and their impact on health consequences. *Journal of Cellular Biochemistry*. 119 (1) : 157-184.

Wang, Z. Y., Zhang, J., Wu, X., Birau, M., Yu, G., Yu, H. and Todd, E. 2004. Near-infrared absorbing organic materials. *Pure and Applied Chemistry*. 76 (7-8) : 1435-1443.