Journal of Advanced Research (2016) 7, 597–610

Cairo University

Journal of Advanced Research

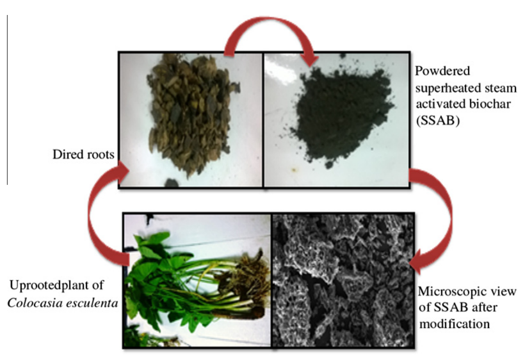
ORIGINAL ARTICLE

# Biosorptive uptake of $Fe^{2+}$, $Cu^{2+}$ and $As^{5+}$ by activated biochar derived from *Colocasia esculenta*: Isotherm, kinetics, thermodynamics, and cost estimation

**Soumya Banerjee [a], Shraboni Mukherjee [a], Augustine LaminKa-ot [b], S.R. Joshi [b], Tamal Mandal [a], Gopinath Halder [a,*]**

[a] *Department of Chemical Engg, National Institute of Technology Durgapur, West Bengal, India*
[b] *Department of Biotechnology and Bioinformatics, North-Eastern Hill University, Shillong, India*

G R A P H I C A L   A B S T R A C T




A R T I C L E   I N F O

*Article history:*
Received 24 April 2016
Received in revised form 12 June 2016

A B S T R A C T

The adsorptive capability of superheated steam activated biochar (SSAB) produced from *Colocasia esculenta* was investigated for removal of $Cu^{2+}$, $Fe^{2+}$ and $As^{5+}$ from simulated coal mine wastewater. SSAB was characterized by scanning electron microscopy, Fourier transform

* Corresponding author. Fax: +91 3432754078.
E-mail address: gopinath_haldar@yahoo.co.in (G. Halder).

Peer review under responsibility of Cairo University.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jare.2016.06.002
2090-1232 

Accepted 13 June 2016
Available online 17 June 2016

*Keywords:*
Metal removal
Activated biochar
Adsorption
Desorption
Regeneration
Cost estimation

infrared spectroscopy and Brunauer–Emmett–Teller analyser. Adsorption isotherm indicated monolayer adsorption which fitted best in Langmuir isotherm model. Thermodynamic study suggested the removal process to be exothermic, feasible and spontaneous in nature. Adsorption of $Fe^{2+}$, $Cu^{2+}$ and $As^{5+}$ on to SSAB was found to be governed by pseudo-second order kinetic model. Efficacy of SSAB in terms of metal desorption, regeneration and reusability for multiple cycles was studied. Regeneration of metal desorbed SSAB with 1 N sodium hydroxide maintained its effectiveness towards multiple metal adsorption cycles. Cost estimation of SSAB production substantiated its cost effectiveness as compared to commercially available activated carbon. Hence, SSAB could be a promising adsorbent for metal ions removal from aqueous solution.



## Introduction

Increase in metal toxicity due to advancement in industrialization and excessive exploitation of natural resources has created a major environmental concern for the past couple of decades. Natural resources such as groundwater are being contaminated due to progressive urbanization which resulted in depletion of portable water in many parts of the world [1,2]. Among various industries such as tanning, electroplating, smelting, and wood polishing, mining has been considered as one of the major sources of metal discharge into natural water systems [3]. This has been one of the oldest anthropogenic activities where coal is used as a source of energy. Due to extensive open cast and underground mining, quality of groundwater has been affected severely. Generation of leachates and dumping of coal in mining areas have also contributed towards contamination of underground water table thereby deteriorating its quality [4]. Ores containing metals are transported from earth crust onto the mine surface and from there it reaches adjoining water bodies by both anthropogenic and physical activities [5]. Hence contamination of groundwater has become a serious environmental issue since it leads to an abrupt increase in heavy metal concentration within other natural resources [6]. In human body, some of these heavy metals are required in trace amounts as daily supplements which become toxic if the amount exceeds [7]. Severe rules have been imposed by various authorities on the discharge of heavy metals in open topography and water systems [8]. Among several metal discharges into water bodies, concentrations of iron ($Fe^{2+}$), copper ($Cu^{2+}$) and arsenic ($As^{5+}$) have been increasing rapidly in groundwater [9–11]. Different organizations viz. United State Environmental Protection Agency (USEPA), World Health Organization (WHO), Indian Standard Institutions (ISI), Indian Council of Medical Research (ICMR) and Central Pollution Control Board (CPCB) which deal with environmental pollution and resources, have prescribed the permissible limits and harmful effects of these three metal ions on human health [12–15] which are tabulated in Table 1.

Several methods have already been reported on removal of $Fe^{2+}$, $Cu^{2+}$ and $As^{5+}$ from aqueous solutions, viz., ion-exchange [16], membrane filtration [17], reverse osmosis [18], chemical precipitation [19], and adsorption [20]. Among these methods, adsorption is considered to be a potential technique in removal and recovery of metal ions from aqueous solution [21]. At lower metal concentration, some of these conventional technologies have been reported to be ineffective whereas metal removal by adsorption is possible even at a lower concentration of 1 mg/L [22,23]. Since adsorption is a metabolism free process, dried biomass of plants can be effectively used as adsorbents because they remain unaffected by the toxic effect of heavy metals [24].

Various adsorbents derived from microbes and plant biomasses such as *Saccharomyces cerevisiae*, *Ceratophyllum demersum*, *Myriophyllum spicatum*, *Potamogeton lucens*, *Salvinia herzogii*, and *Eichhornia crassipes* have been used in metal removal [25–28]. The cost of using microbe-based biomass is quite high compared to plant-based biomass. Therefore, more attention is being paid by researchers on plant biomass since it can be easily processed with least production cost [29]. Leaves of *Ficus religiosa*, coffee beans, coconut shell and coir, jute stick, cereals, lemon juice derived zinc oxide nanoparticles, etc., have been used to prepare activated carbon for the removal of $Fe^{2+}$, $Cu^{2+}$ and $As^{5+}$ from water [30–32]. However, the metal uptake capability of activated biochar developed from *Colocasia esculenta* has not been reported yet.

Therefore, the present study aimed towards preparation and characterization of superheated steam activated biochar of *C. esculenta* roots for its application in $Fe^{2+}$, $Cu^{2+}$ and $As^{5+}$ removal under the influence of six process parameters viz. pH, temperature, adsorbent dose, initial metal concentra-

**Table 1** Permissible limits and health risk of $Fe^{2+}$, $Cu^{2+}$ and $As^{5+}$.

| Metal ion | USEPA (mg/L) | WHO (mg/L) | ISI (mg/L) | ICMR (mg/L) | CPCB (mg/L) | Health risk |
|---|---|---|---|---|---|---|
| $Fe^{2+}$ | – | 0.1 | 0.3 | 1.0 | 1.0 | Haemorrhagic necrosis sloughing of mucosal area in stomach haemochromatosis |
| $Cu^{2+}$ | 1.3 | 1.0 | 0.05 | 1.5 | 1.5 | Gastrointestinal disorder, irritation of nose, mouth, eyes, headache |
| $As^{5+}$ | 0.05 | 1.5 | 1.5 | 0.05 | – | Abdominal pain, vomiting, diarrhea, muscular pain, flushing of skin, skin cancer |