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Original article

Evaluation of the Arsenic Removal Efficiency of Oyster Mushroom *(Pleurotus ostreatus)*

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Abstract

Arsenic (As) contamination in ground water has become a serious health hazard. Present study explored the efficiency of modified mushroom biomass in mitigating drinking water arsenic contamination. Usage of iron oxide coated powder of the oyster mushroom *(Pleurotus ostreatus)* had been found efficient in removing arsenic from drinking water. At 1 g/L concentration, the modified mushroom powder could reduce up to 70% of the arsenite [As(III)] in the current experimental set up. However, effect of pH, temperature, concentration of biomass and arsenite [As(III)] in the media as well as exposure time greatly affect the adsorption process. Thus, mitigation of arsenic in the drinking water using the mushroom *P. ostreatus* seems promising.

Keywords: ***Arsenic contamination, adsorption, modified fungal biomass, mushroom, mycology.***

Introduction

Arsenic (As), a heavy metal, has become a public health nuisance as it poses grave physiological concern to the human and living organisms [1]. Though As constitutes 1.5 parts per million of the earth's crust and is an indispensable part of the metamorphic and igneous rocks, the inorganic form of arsenic is hazardous to the cardiac, respiratory, skin and nervous system [2]. Cancer, diabetes and teratogenic effect of arsenic is also alarming [2]. World health organization (WHO) has pointed to the ground water contamination of the geo-genic arsenic as the main culprit to the human, organismal and environmental hazard [3]. WHO has limited the level of arsenic in drinking water as 10 µg/L [3]. Unfortunately, arsenic level in the ground water of about 110 countries had been found beyond the WHO recommended level and over 300 million people around the world are at risk of arsenic poisoning [3]. Among the 110 countries suffering from arsenic poisoning, Bangladesh stands at the peak along with some parts of India, the west Bengal. About 120 million people of Bangladesh and India have been suffering from arsenicosis directly and/or indirectly [4-10]. Though arsenic poisoning does not manifest at once, chronic exposure to arsenic contaminated water especially drinking result in physical and mental deterioration [4-10]. In addition to the natural suppliance through weathering of rocks and volcanic eruption, regular exploitation of ores, mines, petroleum, fossil fuel, herbicides and pesticides, the level of arsenic in soil and ground water is soaring [4-10]. Thus, for the sake of the humanity, minimizing the level of arsenic in the drinking water has reached momentum. Though multiple measures have been taken round the globe to mitigate this havoc, there is still crisis for easy, handy, cheap, natural source-oriented as well as side effect free approach to thwart arsenic contamination. Thus, the present study has been aimed at introducing a natural resource based arsenic mitigating strategy in drinking water so that people of both underdeveloped and developed countries could be benefitted and arsenic poisoning could be lessened.

In nature, especially in the ground water and soil, arsenic (As) remains either in the form of arsenite, As(III) or as arsenate, As(V) [11]. Factors affecting the existence of either form include pH and the redox potential of the water milieu [12]. At reducing condition, the predominant form is As (III) while the As(V) exists in the oxidizing state of the aqueous environment [12]. Between the two forms, As(III) is much toxic to the humans and other living organisms [12]. However, at natural pH and redox potential of the most of the water bodies, As(III) remains electrically neutral and is not easily adsorbed on mineral surfaces [12]. Thus, metal coated biomass of various types had been suggested as arsenic removal agents. Among others, iron, more specifically iron oxide coating of the biomass seems apt in formulating arsenic removal agent. Surface modification of fungal biomass through cation incorporation could aid in arsenic removal potentiality of the edible macro fungi or mushroom [13]. Thus, the present study has been designed to modify the fungal biomass i.e. the *Pleurotus ostreatus* powder through coating them with iron oxide [$Fe(NO_3)_3 \cdot 9H_2O$] in the experimental media. Reason for choosing iron oxide is their biocompatibility, reduced price, easy availability and less toxicity.

Materials and methods

Mushroom fruiting body preparation

Fresh fruiting bodies of *P. ostreatus* had been purchased from Bangladesh national mushroom development institute. Fruiting bodies had been cleaned, sun dried and ground into powder. Mushroom powder had been utilized for arsenic adsorption.

Arsenic sample preparation

1mg/L of arsenic (III) solution had been prepared using (NaAsO2) (w/v). The pH of the solution had been adjusted with NaOH and/or nitric acid.

1g of mushroom powder had been applied for each 100 mL of the prepared 1mg/L As (III) solution. The mixture had been vortexed for 5 minutes, kept at room temperature for different period (1hr - 24 hr). Performing centrifugation at 2500 rpm for 5 minutes, the supernatant had been collected and tested for determination of as (III) concentration using atomic absorption spectrophotometer.

For preparing iron oxide-coated mushroom samples, 2 molar solution of Fe(NO3)3·9H2O had been prepared, mixed with every 20 g of mushroom powder in porcelain pot, pH adjusted with NaOH and homogenized. The mixture had been kept at oven at 80∘C for 24 h. Using mortar and pestle and filter paper (Whatman no. 1), the coated biomass had been separated. All the experiments had been performed at triplicate and results have been performed on percentage scale.

Results and discussion

Figure 1 depicts the comparative arsenic removal rate of *P. ostreatus* powder alone and iron-oxide treated *P. ostreatus* powder at different pH. Between these two categories, the latter showed higher removal effect. Compared to acidic, at alkaline pH, the As(III) removal rate was higher. The highest removal of As(III) had been observed at pH 8.0 (65% for iron-oxide treated and 8% for the mushroom powder alone). At pH 8, As(III) is better adsorbed with iron oxide coated biomass because it becomes ionized partially into $H_2AsO_3^-$ form. As the alkalinity of the medium increases, increased OH^- ions in the solution compete much intensively with the arsenate ions resulting in lowered adsorption of As(III). Observed As(III) removal effect of iron oxide coated mushroom could be in line with those observed for iron oxide coated sand, iron activated carbon or metal oxide treated chitin and chitosan beads.

Effect of incubation timing on biosorption of As(III) by iron oxide coated *P. ostreatus* powder had been shown in figure 2. As (III) biosorption rate parallelly increases with incubation time up to 48 hours. Then, there occurs a standstill condition in As(III) biosorption. This might be due to attainment of adsorption saturation by the *P. ostreatus* powder.

However, temperature had not so much viable effect on As(III) adsorption by the iron coated *P. ostreatus* powder (figure 3). At 25 °C, adsorption rate was 50% and increased up to 55% at 30 °C. Afterwards, increment of temperature up to 75 °C had no detectable change in absorption rate of As(III). This might be due to that the biochemical reactions and relevant microcosm most pertinent for AS(III) removal are at their best feat within the temperature range of 25 – 30 °C. Our findings are in compatible with some previous findings.

In order to evaluate the As(III) adsorption potentiality of the *P. ostreatus*, we exposed the iron oxide coated form of this mushroom to different concentration (1-10 mg/L) of As(III) at the experimental milieu (figure 4). *P. ostreatus* iron oxide coated powder showed As(III) adsorption potential at the As(III) concentration range of 1-5 g/L (figure 4). Beyond this concentration, *P. ostreatus* iron oxide coated form showed lowered adsorption rate (figure 4). Also, the adsorption rate in the As(III) concentration range of 1-5 g/L remained the same (figure 4). May be the iron coated *P. ostreatus* form adsorbed As(III) until their saturation limit and once the saturation limit has crossed (here, 5 g/L As conc.), *P. ostreatus* could no longer adsorb As(III).

Finally, we checked the effect of the amount of mushroom biomass on As(III) adsorption (figure 5). The rate of As(III) adsorption paralleled the amount of iron coated *P. ostreatus* powder (figure 5). This might be due to the added biomass governed extra adsorption capacity of the *P. ostreatus* powder.

Ours is the first study employing the edible mushroom *P. ostreatus* against arsenic contamination in the drinking water. Thus, direct compare and contrast with other studies could not be performed. However, some published data indicate the usage of other types of mushrooms, spent mushroom substances in arsenic removal efforts. Of them, the utilization of *P. cornucoupiae* in biosorption of Cu and Cd had been reported [14]. Those data are in line with that of ours. *Agaricus bisporus,* another edible mushroom, could efficiently remove Fe, Ni and Co from the contaminated drinking water [15]. In addition to these metalloids, the medicinal mushroom, *Ganoderma lucidum*, had been found biosorption effect on Zr and Zn at the aqueous medium [16-17]. Beyond mushroom, the pomegranate peel had almost similar effect in removing Cu and Pb from drinking water [18].

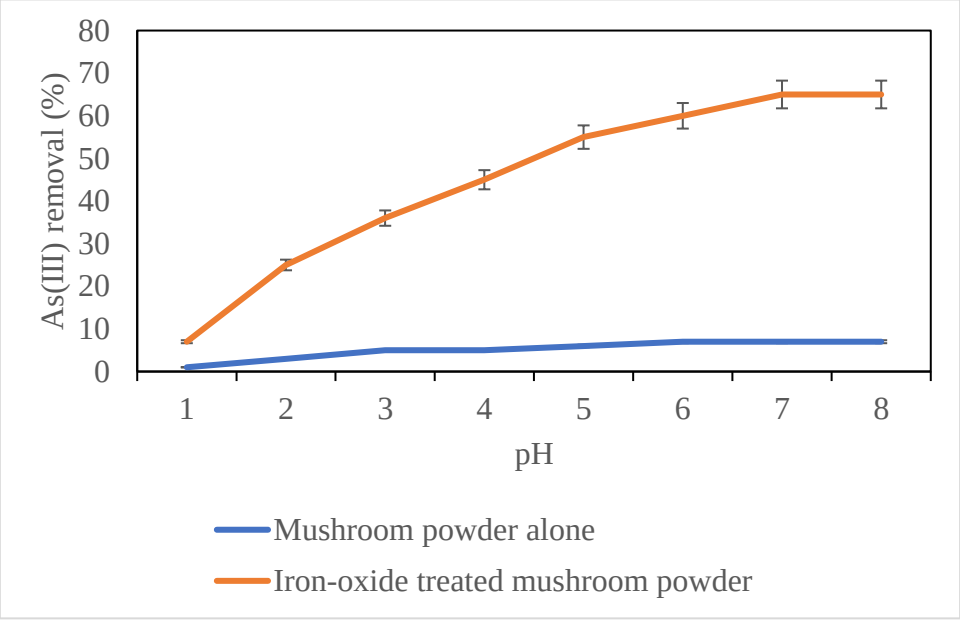

Figure 1. Effect of pH on As (III) removal by *P. ostreatus*.

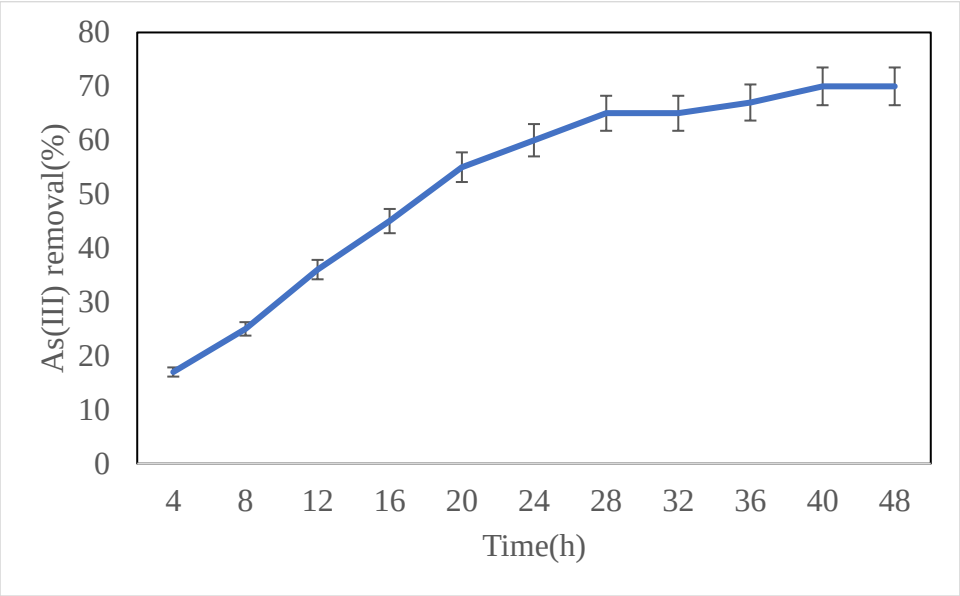

Figure 2. Effect of incubation time on As(III) removal by *P. ostreatus*

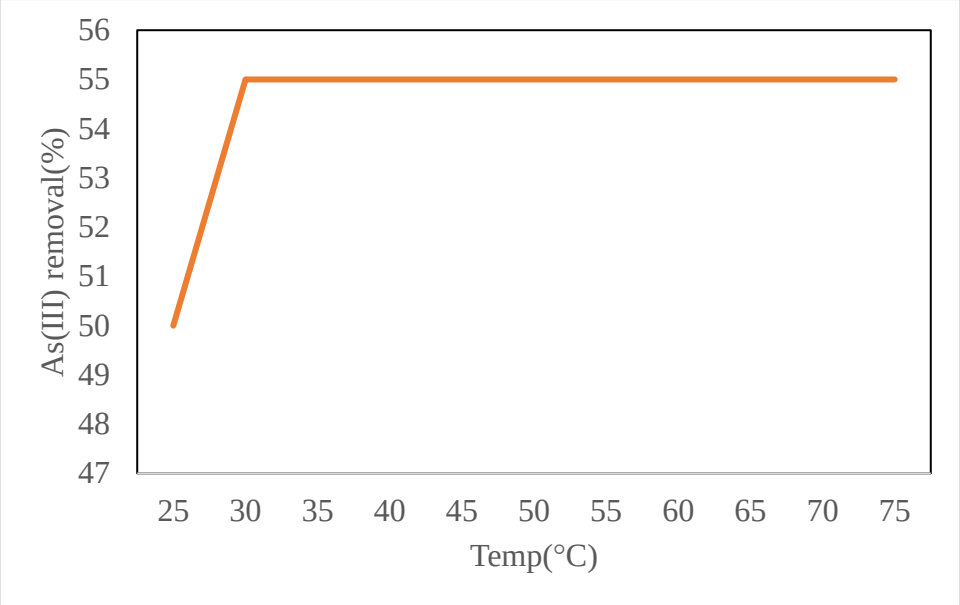

Figure 3. Effect of temperature on As(III) removal by *P. ostreatus*.

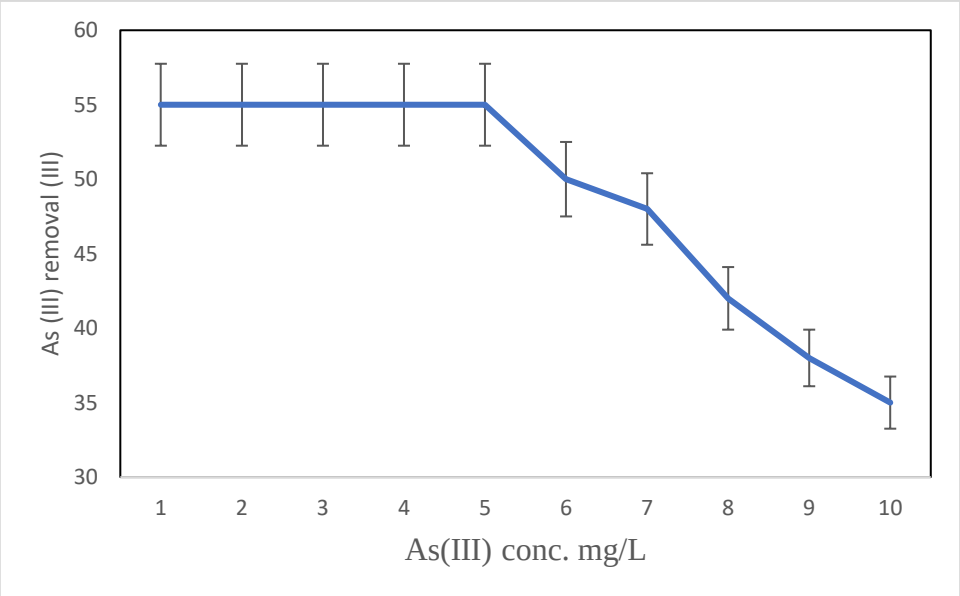

Figure 4. Effect of initial concentration of As(III) on its removal by *P. ostreatus*.

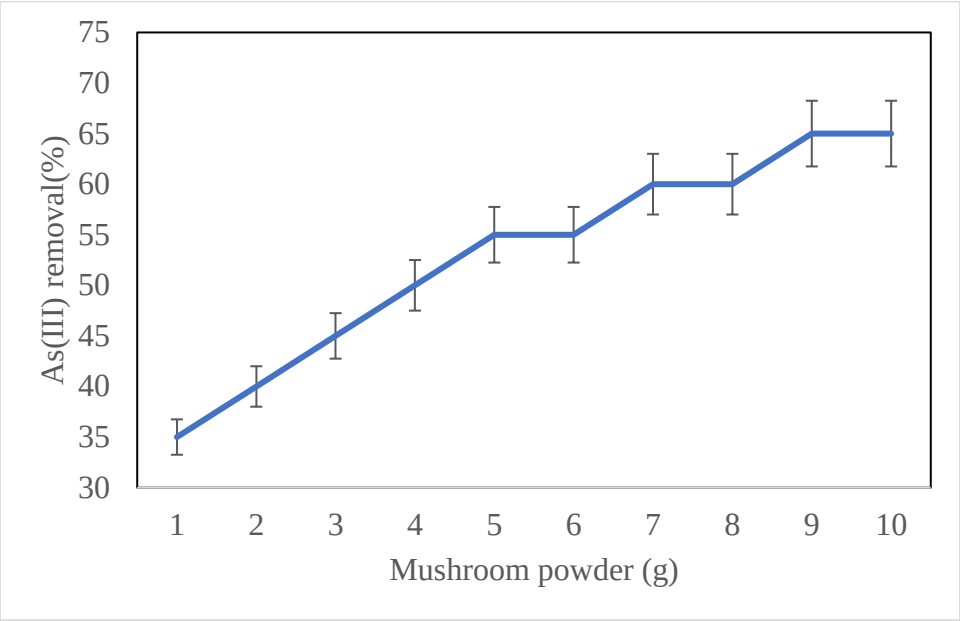

Figure 5. Effect of *P. ostreatus* biomass concentration on As(III) removal.

Conclusion

Arsenic poisoning through water contamination has been taking heavy toll globally. Modified fungal biomass, specifically, iron oxide coated powder of the edible mushroom *P. ostreatus* had been found efficient in removing arsenite [As(III)] from drinking water. Natural, cost-effective, easy to use approach described through this study would aid greatly in mitigating arsenic contamination in drinking water. People from both developing and developed countries will be benefitted highly through the outcome of the present study. However, our future study incorporating human subjects would aid make the current study much applied for the wellbeing of the humanity globally.

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Conflict of interest

Authors declare no conflict of interest.

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