

Removal Efficiency OF Arsenic (III) by Coconut Shell Char and Rice Husk Ash Adsorbent

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Abstract: The objective of this study was to investigate the removal efficiency of arsenic (III) by using the coconut shell char (CSC) and rice husk ash (RHA) adsorbent in the laboratory. The pH of synthetic arsenic solution, weight of adsorbent, contact time and initial arsenic concentration were tested for the optimum conditions of arsenic treatment. The result demonstrated that the optimum condition for arsenic removal by CSC was at pH 7, the CSC weight of 0.6 g, the contact time of 60 min and the initial arsenic concentration of 2.78 mg.l⁻¹, while the optimum condition for arsenic removal by RHA was at pH 7, the RHA weight of 1.8 g, the contact time of 45 min and the initial arsenic concentration of 3.4 mg.l⁻¹. Comparing the removal efficiency, it was found that the removal efficiency of RHA adsorbent for the arsenic in synthetic solution was higher than that of CSC adsorbent. Results suggest that both CSC and RHA can remove the minimal amount of arsenic in solution.

Keywords: Arsenic adsorption, Removal efficiency, Coconut shell char, Rice husk ash, Adsorbent.

I. INTRODUCTION

Arsenic is a heavy metal with extremely high toxicity. It normally found in earth's crust. Arsenic can enter into the environmental by both natural and human activities and be accumulated in soil, air, water, groundwater, plant and living organism [1]. Although human can expose to arsenic by contacting to contamination soil, inhalation and ingestion, people mostly exposes to arsenic from the contaminated ground water used for cooking, washing, drinking, etc.. Arsenic can cause adverse health effect to human who exposed arsenic in long term [2] which evidenced by many cases in several countries around the world e.g., India, Cambodia, Bangladesh, Taiwan [3],[4],[5],[6].

In Thailand, the well known is the case of Aumper Ron Phibun, Nakhon Si Thammarat province [7]. The Pollution Control Department reported the situation of arsenic contamination in abandoned mine area. The report showed that the arsenic concentration in groundwater ranging from 0.005 to 0.146 mg.l⁻¹, the highest contamination found in Kanjanaburi's abandoned mine area. The standard of ground water quality for drinking purposes in Thailand was set up that the acceptable arsenic in the water is at 0.05 mg.l⁻¹ whereas the WHO's drinking water standards 1993 is at 0.01 mg.l⁻¹.

Nowadays, there are several methods for removing heavy metal from water such as oxidation, reduction, precipitation, adsorption, ion exchange and membrane filtration [9]. However, these methods are costly and are required a skillful operation. Adsorption is one of the methods that is well-known, quite low cost and not difficult to operate. The office of agricultural economics reports the agricultural statistics of Thailand 2011 that showed the coconut and rice product in 2011 are 1,055 and 31,474 tons, respectively. These products can generate waste such as coconut husk, coconut shell, rice husk, etc. To use coconut shell char and rice husk ash as adsorbent is the alternative choice to reduce agricultural waste and also remove arsenic from contamination ground water. The aim of this study is to investigate the removal efficiency of arsenic from synthetic solution by using coconut shell char and rice husks ash in varies of weight of adsorbent, pH, initial arsenic concentration and contact time.

II. MATERIALS AND METHODS

Reagent used: Reagent grade and deionized water was used to prepare all solution. The stock solution with As(III) concentration of 1,000 mg.l⁻¹ was prepared by dissolving 0.1734 g of sodium arsenite (Unilab) with deionized water and adjusted to 100 ml with volumetric flask with deionized water. The arsenic solution (As(III)) in this experiment was prepared by diluting the stock solution as required.

Adsorbent preparation: The CSC was obtained from CGC carbon.Co.Ltd. and the RHA was obtained from Nakornpathom, Thailand. The adsorbents were ground and sieved with 16 mesh sieves. Then, they were washed with tap water before soaked in 0.1% nitric acid overnight to remove salt in the porous. Again, the adsorbents were washed with tap water until the pH value become to 6.5-7.5. After that the adsorbents were dried with hot air oven at 105°C and kept in desiccators until use.

Batch adsorption experiment: Batch studies were carried out using 100 ml of synthetic As(III) solution in orbital shaker with agitation rate of 150 rpm. Adsorbent weights of 0.2-5.4 g, the pH value of initial As(III) solution of 5-8, the contact time of 15-90 min, and the initial As(III) concentration of 0.05-3.2 mg.l⁻¹ were tested for optimum condition to adsorb As(III) by CSC adsorbent and RHA adsorbent. The pH value was adjusted by using 0.1N HNO₃ and 0.1N NaOH. The solution was filtered with Whatman filter paper No.5 for analysis. The As(III) concentration measured by graphite furnace atomic absorption spectrometer (GFAAS) (Model Varian SpectrAA-600).

Statistical Analysis: Data analysis was done by using One-way ANOVA. Mean comparison was conducted by using Least Significant Difference Test (LSD) with a significant level of α 0.05.

III. RESULTS AND DISCUSSIONS

The results of the optimum weight of CSC and RHA adsorbent were presented in Table 1 and 2. The results suggested that both of adsorbent had a similar adsorption trend of synthetic As(III) solution. It can be noted that the removal efficiency of As(III) increased due to the increase in the weight of adsorbent. The percentage removal of As(III) by CSC adsorbent were 14.48%, 19.31%, 19.07% and 22.39% and the percentage removal of As(III) by RHA adsorbent were 3.48%, 6.96%, 10.23% and 12.02% for the weight of 0.20, 0.60, 1.80 and 5.4 g, respectively. However, the optimum weight of CSC adsorbent and RHA adsorbent for As(III) removal were 0.6 g and 1.8 g, respectively, since there were no significant difference in efficiency among there higher weight. The results suggested when the weight of adsorbent increased, the percentage removal of metal ion in the solution will be increased [10],[11]. These may be explained by the availability of larger surface area which increased the adsorption sites. However, the surface area may not be the primary factor for arsenic adsorption. Other factors including metal oxide from ashes in the adsorbent such as Fe₂O₃ and Al₂O₃ may need to be further investigated [12]

Table 1: As(III) removal efficiency of CSC Adsorbent at various weights

Weight of adsorbent (g)	Initial conc. (mg.l ⁻¹)	Final conc. (mg.l ⁻¹)	Mean Removal (%)	n	p-value	F
0.2	3.16	2.70±0.15	14.48±4.62 ^a	4	0.038	3.865
0.6	3.16	2.55±0.09	19.31±3.00 ^b	4		
1.8	3.16	2.56±0.11	19.07±3.41 ^b	4		
5.4	3.16	2.45±0.05	22.39±1.43 ^b	4		

Note : 1. Initial concentration: measured values from the preparation.

2. The difference of alphabets in each column statistically showed the significant difference with the confidential of 95% by LSD.

Table 2: As(III) removal efficiency of RHA adsorbent at various weights

Weight of adsorbent (g)	Initial conc. (mg.l ⁻¹)	Final conc. (mg.l ⁻¹)	Mean Removal (%)	n	p-value	F
0.2	3.16	3.05±0.08	3.48±2.53 ^a	3	0.002	10.095
0.6	3.16	2.94±0.05	6.96±1.61 ^a	4		
1.8	3.16	2.84±0.08	10.23±2.65 ^b	3		
5.4	3.16	2.78±0.06	12.02±2.05 ^b	4		

Note: 1. Initial concentration: measured values from the preparation.

2. The difference of alphabets in each column statistically showed the significant difference with the confidential of 95% by LSD.

The effect of the pH on As(III) removal by CSC and RHA adsorbent were presented in Table 3 and 4. Both CSC and RHA adsorbent had the same trend of the adsorption of synthetic As(III) solution. The removal efficiency increased when the initial pH of synthetic solution increased from 5 to 7. However, the unexpected result of As(III) removal efficiency by RHA adsorbent at pH 7 may come from the experimental units or analytical instrument which needed the further investigated. The result showed that the percentage removal of As(III) by CSC adsorbent were 5.32%, 6.16% and 6.29% while RHA adsorbent were 6.48%, 5.80% and 17.91%, respectively. The adsorption by CSC adsorbent at pH 5 to 7 was insignificant difference but the RHA adsorbent was able to adsorb As(III) higher at pH 7. This is because the pH value is the most important factors controlling arsenic speciation. The arsenic in form $H_2AsO_4^-$ is dominant at pH less than 6.9 [12], thus making the removal efficiency not differ at the pH ranging from 5 to 7. However, the result of this study was corresponded with the finding of Chuang, *et al.*, 2005 [13] and Vitela-Rodriguez and Rangel-Mendez, 2013[14] showing that the reduction of the removal efficiency decreased a little at pH value between 5 to 7. The pH 7 was chosen in the study because it was the neutral pH of water.

Table 3: As(III) removal efficiency of CSC adsorbent at various initial pH

pH	Initial conc. (mg.l ⁻¹)	Final conc. (mg.l ⁻¹)	Mean Removal (%)	n	p-value	F
5	3.29	3.12±0.14	5.32±2.72	3	0.873	0.138
6	3.33	3.13±0.07	6.16±1.76	3		
7	3.10	2.91±0.08	6.29±2.76	4		

Note: Initial concentration: measured values from the preparation.

Table 4: As (III) removal efficiency of RHA adsorbent at various initial pH

pH	Initial conc. (mg.l ⁻¹)	Final conc. (mg.l ⁻¹)	Mean Removal (%)	n	p-value	F
5	3.29	3.08±0.16	6.48±4.85 ^a	3	0.016	7.847
6	3.33	3.14±0.19	5.80±5.80 ^a	3		
7	3.10	2.55±0.10	17.91±3.38 ^b	4		

Note: 1. Initial concentration: measured values from the preparation.

2. The difference of alphabets in each column statistically showed the significant difference with the confidential of 95% by LSD.

The results of the optimum initial As(III) concentration for As(III) removal by CSC and RHA adsorbent were presented in Table 5 and 6. The results suggested that the removal efficiency of As(III) increased according to the increase in the As(III) concentration. The percentage removal of As(III) by CSC adsorbent were 6.25%, 11.76%, 10.99% and 13.19% for the initial As(III) concentration of 0.08, 0.17, 0.66 and 2.78 mg.l⁻¹, respectively. While, the percentage removal of As(III) by RHA adsorbent were 0.00%, 5.26%, 6.85% and 16.57% for the initial As(III) concentration of 0.05, 0.19, 0.73 and 3.4 mg.l⁻¹, respectively. The optimum initial As(III) concentration for As(III) removal by CSC adsorbent was 2.78 mg.l⁻¹ whereas by RHA adsorbent was 3.4 mg.l⁻¹ (p-value < 0.05). The results corresponded with the finding of Li *et al.*, 2014[12] that the removal efficiency of the arsenic by the adsorbent increased when the initial concentration increased from the ranging from 0.01 to 0.50 mg.l⁻¹. This was because the higher concentration offered more driving force to the adsorption process. However, Wu Y, *et al.*, 2008[15] reported the removal efficiency was decreased when the initial concentration increased from the ranging from 5 to 10 mg.l⁻¹. This is because the adsorption process reached to the equilibrium point the adsorbent could not adsorb the metal ion anymore. So, the removal efficiency would be dropped when the arsenic concentration increased over the adsorption capacity of the adsorbent.

Table 5: As (III) removal efficiency of CSC adsorbent at various initial As(III) concentration

Initial conc. (mg.l ⁻¹)	Final conc. (mg.l ⁻¹)	Mean Removal (%)	n	p-value	F
0.08	0.07±0.01	6.25±7.22	4	0.203	1.843
0.17	0.15±0.01	11.76±3.40	3		
0.66	0.59±0.02	10.99±2.27	4		
2.78	2.41±0.11	13.19±4.01	3		

Note: Initial concentration: measured values from the preparation.

Table 6: As(III) removal efficiency of RHA adsorbent at various initial As(III) concentration

Initial conc. (mg.l ⁻¹)	Final conc. (mg.l ⁻¹)	Mean Removal (%)	n	p-value	F
0.05	0.05±0.00	0.00	-	0.005	12.459
0.19	0.18±0.01	5.26±4.30 ^a	4		
0.73	0.68±0.02	6.85±2.37 ^a	3		
3.40	2.84±0.03	16.57±0.74 ^b	3		

Note: 1. Initial concentration: measured values from the preparation.

2. The concentration of 0.05 mg.l⁻¹ was not tested for statistical analysis.

3. The difference of alphabets in each column statistically showed the significant difference with the confidential of 95% by LSD.

The results of the optimum contact time for As(III) removal by CSC and RHA adsorbent were presented in Table 7 and 8. The results suggested the removal efficiency of As(III) increased according to the increase in the contact time. The mean percentage removal of As(III) by CSC adsorbent were 8.13%, 9.35%, 11.38%, 17.48%, 20.73 and 19.92% and those by RHA adsorbent were 3.51%, 8.61%, 8.59%, 10.13, 13.07 and 13.27% for the contact time of 15, 30, 45, 60, 75 and 90 min respectively. The optimum contact time for As(III) removal by CSC adsorbent and RHA adsorbent were 60 min and 45 min respectively (p-value < 0.05). The increase of contact time is suitably to improve contact between adsorbent and the arsenic solution. However, the removal efficiency will not increase when the adsorption process reached the equilibrium [16],[10].

Table 7: As (III) removal efficiency of CSC Adsorbent at various contact times

Contact time (min)	Initial conc. (mg.l ⁻¹)	Final conc. (mg.l ⁻¹)	Mean Removal (%)	n	p-value	F
15	2.46	2.26±0.09	8.13±2.33 ^a	4	0.001	8.615
30	2.46	2.23±0.12	9.35±4.85 ^a	3		
45	2.46	2.18±0.05	11.38±2.06 ^a	4		
60	2.46	2.03±0.10	17.48±4.00 ^b	4		
75	2.46	1.95±0.09	20.73±3.46 ^b	3		
90	2.46	2.00±0.06	19.92±2.35 ^b	3		

Note: 1. Initial concentration: measured values from the preparation.

2. The difference of alphabets in each column statistically showed the significant difference with the confidential of 95% by LSD.

Table 8: As (III) removal efficiency of RHA Adsorbent at various contact times

Contact time (min)	Initial conc. (mg.l ⁻¹)	Final conc. (mg.l ⁻¹)	Mean Removal (%)	n	p-value	F
15	3.29	3.02±0.11	8.21±2.86 ^a	3	0.043	2.410
30	3.29	3.01±0.11	8.61±3.25 ^a	3		
45	3.29	3.01±0.10	8.59±3.11 ^a	4		
60	3.29	2.96±0.17	10.13±5.10 ^b	3		
75	3.29	2.86±0.06	13.07±1.90 ^b	3		
90	3.29	2.85±0.13	13.27±4.04 ^b	3		

Note: 1. Initial concentration: measured values from the preparation.

2. The difference of alphabets in each column statistically showed the significant difference with the confidential of 95% by LSD.

IV. CONCLUSION

This study investigated the removal efficiency of As(III) by using CSC adsorbent and RHA adsorbent. The result demonstrated that the optimum condition for arsenic removal by CSC was at pH 7, the CSC weight of 0.6 g, the contact time of 60 min and the initial arsenic concentration of 2.78 mg.l⁻¹, while the optimum condition for arsenic removal by RHA was at pH 7, the RHA weight of 1.8 g, the contact time of 45 min and the initial arsenic concentration of 3.4 mg.l⁻¹.

RHA adsorbent showed higher As(III) removal efficiency than the CSC adsorbent. Results suggest that both CSC and RHA can remove the minimal amount of arsenic in solution.

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