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# Strontium Adsorption Properties of Rice Hull Charcoal Treated with Inorganic Component Elution

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The relationship between the potassium content in rice hull charcoal and strontium ion adsorption was investigated. Potassium elution treatment was performed on rice hull charcoal, wherein the rice hull charcoal was stirred with distilled water. The pore distribution and specific surface area of the processed rice hull charcoal were measured. Significant change was not observed in the mesopore volumes of rice hull charcoal subjected to elution treatment for 1 h. The specific surface area increased as the elution time became longer. Based on the result of the pore distribution, it was assumed that the macropores increased. Potassium was eluted at 56.0 mg/L from rice hull charcoal subjected to elution treatment for 3 h. This eluted approximately 83% of potassium content. In the strontium ion adsorption experiment, the adsorption amount of the eluted rice hull charcoal was approximately 40% lower than that of untreated rice hull charcoal. High correlation was observed between the potassium content and the strontium ion adsorption amount. Thus, this paper confirmed that it is possible to show a higher adsorption ability by using rice hull charcoal with high potassium content.

Keywords: Rice hull charcoal, Strontium, Potassium

## 1. INTRODUCTION

Radioactive substances, such as cesium and strontium, which are released in nuclear accidents, contaminate the air, soil, and water for long periods of time. The reduction of radioactive material can lead to the recovery of affected living organisms and the environment. Currently, zeolite is used to adsorb radioactive substances from water and soil [1].

On the other hand, rice hull, which is agricultural waste, is a naturally abundant resource. Therefore, the establishment of an effective utilization method is required. According to the survey by the United Nations Food and Agriculture Organization (FAO), the annual harvest of the rice plant in Japan amounts to approximately eight million tons [2]. Approximately two million tons of rice hulls are generated from the rice plant as waste. Regarding the treatment of rice hulls, field burn can be carried out, but has been regulated in recent years owing to problems such as air pollution and foul odors.

Rice hull charcoal is one of the effective utilization of rice hull. It is known that rice hull charcoal has effects such as deodorization, water purification, and soil conditioning. Furthermore, it has also been reported that the adsorption of aldehyde gas, or a similar process, can be conducted by using the adsorption performance of rice hull charcoal [3-4].

In a previous paper, we reported the adsorption characteristics of cesium ion and strontium ion in aqueous solution as an effective use of rice hull charcoal [5] to solve the problem of radioactive substance and large-scale waste. However, their adsorption ability is inferior to that of zeolite.

After decontamination treatment, the rice hull charcoal can be greatly reduced simply by burning the carbon component. However, volume reduction is difficult with zeolite, which is an inorganic substance. Therefore, if the adsorption capacity is improved, the rice hull charcoal could substitute fully or partially for zeolite.

Physical adsorption and chemical adsorption have been considered for the rice hull charcoal. Physical adsorption is thought to occur by the countless pores in the rice hull charcoal. Chemical adsorption is thought to adsorb to the acidic functional groups on the surface of the rice hull charcoal.

The inorganic component of the rice hull charcoal mostly contains silicon, with potassium having the second largest abundance. Rice hull charcoal contains approximately 96.5% silicon mass and approximately 3.7% potassium mass [6]. Venecio et al. has reported that rice hull charcoal and charcoal have water soluble inorganic components and exchangeable inorganic components [7]. Moreover, it has been reported that the exchangeable potassium of the rice hull charcoal is contained approximately six times as much as the exchangeable silicon [7].

Therefore, in this study, to develop materials with higher adsorption performance, the relationship between the potassium content in the rice husk coal and the strontium ion adsorption ability were investigated. The rice hull charcoal was agitated in distilled water, and the physical properties of the rice hull charcoal subjected to the elution treatment of the inorganic components were evaluated. The strontium ion adsorption ability of the treated rice hull charcoal was also evaluated, and its relationship with the potassium content in the rice hull charcoal was investigated.

## 2. EXPERIMENTAL METHOD

### 2.1 Preparation of rice hull charcoal

Dried rice hulls (10.0 g, Aichinokaori, manufactured in Aichi Prefecture, 2018) were placed in a 100-ml alumina crucible, and the lid was covered. The heating rate was 18.0 °C/min and a separator type tabletop electric furnace was used (AMF 20-D, manufactured by Hitachi High-Technologies Corporation). After the set temperature of 800 °C was reached, it was held for one hour to carbonize [8]. Subsequently, the rice hull charcoal naturally cooled and was used as a sample (hereafter termed as RHC).

### 2.2 Elution treatment method

In 300 ml of water, 3.00 g of RHC pulverized to 250 μm or less was added and stirred. The stirring time was 1 h, 2 h, and 3 h. Subsequently, the RHC was removed, naturally cooled, and used as a sample (hereafter termed as ET-RHC). The samples used in this study are listed in Table I.

Table I. List of Prepared Samples

| Method of processing | Assrviation |
|---|---|
| Untreated rice hull charcoal | RHC |
| Inorganic component elution treatment 1h | ET-RHC1 |
| Inorganic component elution treatment 2h | ET-RHC2 |
| Inorganic component elution treatment 3h | ET-RHC3 |

### 2.3 Evaluation of physical properties

In 300 mL of water, 3.00 g of rice hull charcoal pulverized to 250 μm or less was added and stirred. The sampling time was 1 h, 2 h, and 3 h. The solution was filtered and the elution amount of the potassium or silicon in the filtrate was measured using a polarized Zeeman atomic absorption spectrophotometer (Z-2300, Hitachi High-Technologies Corporation).

The potassium content was calculated from the peak value using a fluorescent X-ray analyzer (EDXL 300; manufactured by Rigaku Corporation, XRF). Measurement was carried out by placing 1.00 g of each sample in a polyethylene sample container with a propylene film adhered to the bottom surface. Powdered titanium oxide was used as a reference sample, while Cu was used as the target.

The pore distribution was measured from the amount of adsorbed nitrogen at the liquid nitrogen temperature and each relative pressure, using a pore distribution measuring apparatus (manufactured by Autosorb-1 Quantachrome). The measurement was carried out after drying the sample at 117 °C for 3 h to obtain the weight. Degassing occurred under the reduced pressure at 120 °C.

The specific surface area was measured by the flowing of the nitrogen and helium gases into the area measuring apparatus (manufactured by Monosorb Yuasa Ionics Co., Ltd.), using the BET one point method.

### 2.4 Strontium ion adsorption experiment

Experiments were conducted using 100 mg/L of a strontium ion aqueous solution, according to the experimental method described in the database of the Division of Nuclear Fuel Cycle and Environment (NUCE) of the Atomic Energy Society of Japan (AESJ) [9].

In 100 ml of an aqueous strontium chloride solution, which was adjusted to have a strontium ion concentration of 100 mg/L, 1.00 g of rice hull charcoal pulverized to 250 μm or less was added and stirred for 1 h. Thereafter, the solution was filtered, and the strontium concentration in the filtrate was measured using a polarized Zeeman atomic absorption photometer (Z-2300, Hitachi High-Technologies Corporation).

## 3. RESULTS AND DISCUSSION

### 3.1 Rice hull charcoal treated by elution.

#### 3.1.1 Potassium elution amount and content of rice hull charcoal

Fig. 1 shows the potassium elution amount of the rice hull charcoal at the potassium elution treatment time, and Fig. 2 shows the potassium content. When the treatment time was long, the elution amount increased, and the potassium content in the rice hull charcoal decreased.

Additionally, the potassium content of ET-RHC 3 was significantly reduced to 44% of RHC.

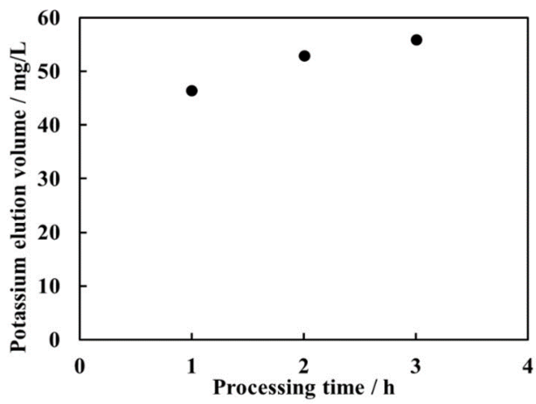


Fig. 1. Potassium elution amount of each sample

Fig. 3 shows the silicon elution amount of RHC. Fig. 4 shows the relationship between the elution amount of silicon and the elution amount of potassium. It can be seen from Fig. 3 that not only potassium but also silicon is removed from rice hull charcoal by the elution process. However, the amount of silicon elution was approximately half the elution amount of potassium. It was found that potassium is more likely to elute than silicon, which is contained most in rice hull charcoal.

Moreover, the reaction between the silica and the potassium content in the rice hull has been reported to form compounds, such as potassium polysilicate, when carbonizing [10]. In this study, a high positive correlation was found between the correlation coefficient of 0.9995 and the elution amounts of potassium and silicon shown in Fig. 4. Because this is consistent with the molecular formula of the potassium silicate, the potassium polysilicate generated at the time of carbonization was assumed to have been dissolved by the elution treatment.

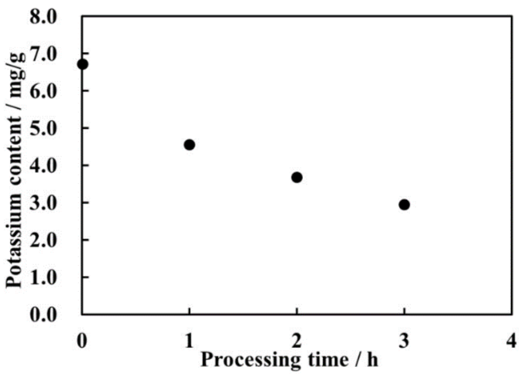


Fig. 2. Potassium content of each sample

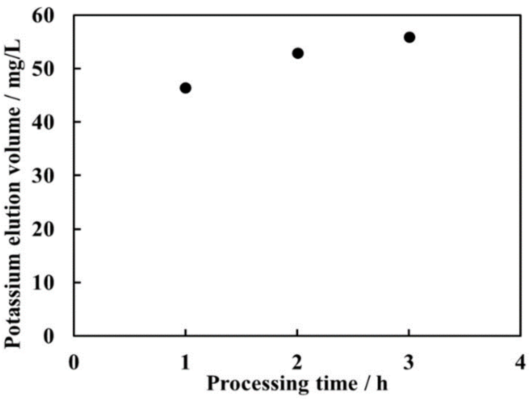


Fig. 3. Silicon elution amount of each sample

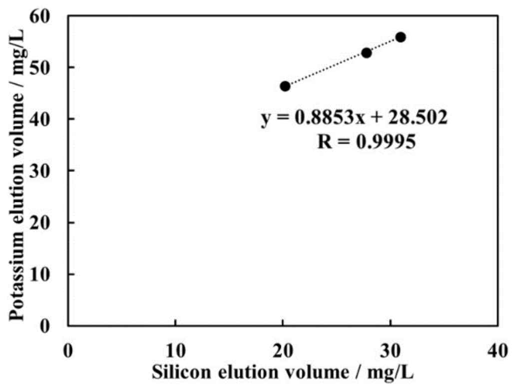


Fig. 4. Relationship between potassium elution volume and silicon elution volume

3.1.2 Pore volume and specific surface area

Fig. 5 shows the result of the RHC and ET-RHC1 pore volumes. It has been reported that mesopores present in rice hull charcoal are effective for the adsorption of cations such as strontium[11]. However, a significant change was not observed in the amount of mesopores by elution treatment method form Fig. 5. Therefore, the influence of mesopores on adsorption is considered to be small.

The specific surface area of each sample is shown in Fig. 6. The specific surface area increased by the elution treatment. For ET-RHC3, the specific surface area increased 1.5 times.

Muraishi et al. have reported that the elution of silica in the rice hull skin part contributes to the generation of rice hull charcoal macropores [11]. From the results presented in Fig. 5, the macropores are considered to have increased by the potassium elution treatment in this study, too.

Additionally, as shown in Figs. 1 and 2, the potassium and silicon were removed from the RHC by the potassium elution treatment. Fukumoto et al. have reported that the specific surface area of the activated charcoal removed ash by water washing increased [12]. Based on the above considerations, in this study, the potassium and silicon were removed from the rice hull charcoal by elution treatment, and the macropores and specific surface area increased.

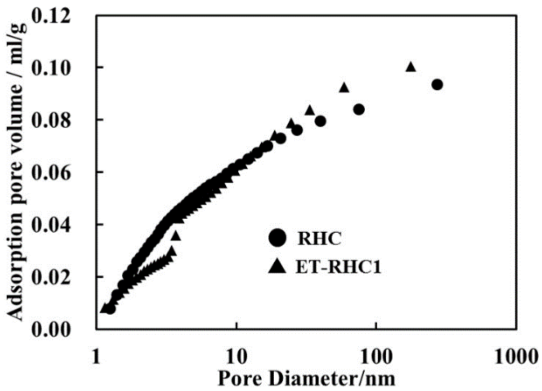


Fig. 5. Pore volume of RHC and ET-RHC 1

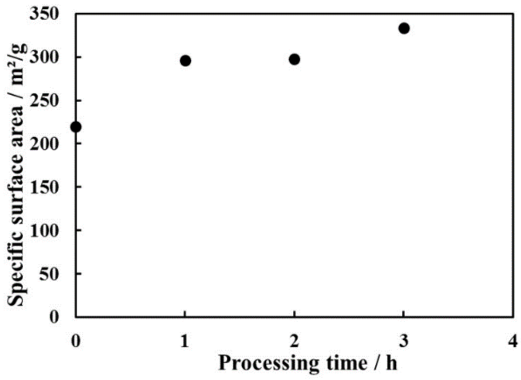


Fig. 6. Result of specific surface area of RHC and each ET-RHC

3.2 Adsorption result

Fig. 7 shows the result of the strontium ion adsorption. The adsorption amount decreased as the processing time of the rice hull charcoal became longer. RHC adsorbed 80 mg/L, whereas ET-RHC 3 adsorbed 48.5 mg / L, which marks a decrease of the adsorbed amount by approximately 40%.

Fig. 8 shows the relationship between the adsorption amount of strontium ion and the potassium content. The correlation coefficient was 0.9920, and a high positive correlation was observed. Similarly, the correlation coefficient between the rice hull charcoal elution amount and the strontium adsorption amount was as high as 0.9899, which suggests a high negative correlation. Thus, it is possible that the presence of the potassium content in rice hull charcoal plays an important role in the adsorption of strontium ions.

Although further investigation is necessary, it is possible that the same tendency will be exhibited for cations other than strontium. This result will be useful in clarifying the adsorption principle of cations.

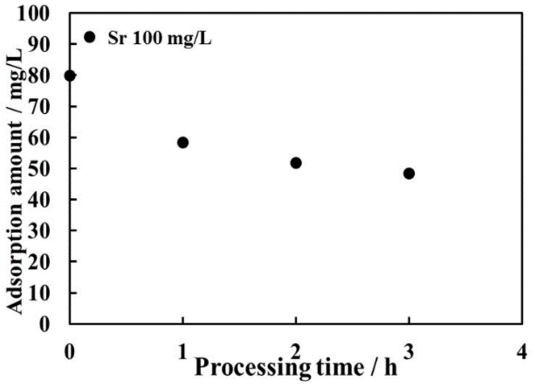


Fig. 7. Result of strontium ion adsorption

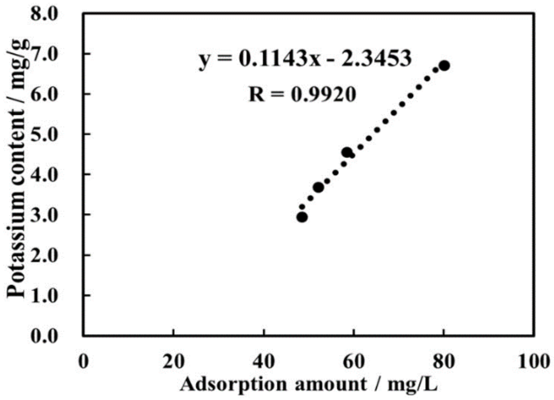


Fig. 8. Relationship between strontium ion adsorption and potassium content

## 4. CONCLUSION

In this study, we evaluated the strontium ion adsorption ability of rice hull charcoal subjected to elution treatment, and the following conclusions were drawn.

1. The rice hull charcoal eluted silicon and potassium in water, and the specific surface area increased. In particular, potassium had a very high dissolution ratio with respect to its content.
2. The amount of strontium adsorption for the rice hull charcoal subjected to elution decreased with the elution time.
3. A high correlation existed between the potassium content in the rice hull charcoal and the strontium adsorption.

## 5. ACKNOWLEDGMENTS

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