UDC 631.95: [543.632.22:546.17

Hiromu OKAZAWA* and Tomonori FUJIKAWA [1]

NITROGEN ADSORPTION ABILITY IN CLINKER ASH AND UTILIZATION OF NITROGEN−ADSORBED CLINKER ASH TO PROMOTE VEGETATION GROWTH

SUMMARY

Clinker ash is a type of coal ash that is an industrial by-product from coal thermal power plants. This study clarified the nitrogen adsorption ability of clinker ash by grain size. In addition, the possibility of returning nitrogen-adsorbed clinker ash for crop cultivation was also examined.

Clinker ash was sorted by using sieves with mesh sizes of 0.6 mm, 1.15 mm and 2.36 mm. Uncontrolled clinker ash and/or clinker ash of one grain size (130 g) and nitrogen solution (6 L) were put in each tank and the solution was circulated by circulation pump. The hydraulic retention time was 120 seconds. The solution in the tank was circulated for 30 days. The nitrogen concentration of the solution in the tank was measured every 2 to 3 days. The initial nitrogen concentration of the solution was 10 mg/L. Two types of nitrogen were used: NO_3-N and NH_4-N. After the end of the experiment, the amount of nitrogen adsorbed to the clinker ash was measured.

For a vegetation experiment, *Japanese mustard spinach* was planted on the clinker ash that had been used in the nitrogen adsorption experiment. The stem height of the plant was measured every day.

The amount of nitrogen adsorbed by the clinker ash was examined. It was found that clinker ash with smaller grain size adsorbs more NH_4-N. In the vegetation experiment for *Japanese mustard spinach* using nitrogen-adsorbed clinker ash, it was found that the plant cultivated in clinker ash of 0.6 mm in grain diameter showed the greatest growth.

Keywords: Clinker ash, Nitrogen, Adsorption, Reuse, Vegetation growth.

INTRODUCTION

Approximately 20% of Japan’s total energy is provided by coal-fired thermal generation. In 2003, thermal generation produced a total of 7.47 Mt of coal ash, which is roughly categorized into fly ash and clinker ash. Fly ash constitutes the majority of coal ash and is recycled as construction material such as roadbed material, one of the concrete mixture, etc. Although as much as 0.22 Mt of clinker ash is generated each year, most of it ends up in landfills; thus recycling of clinker ash is an important issue to address (JETA et al., 2005).

[1] Hiromu OKAZAWA (corresponding author: h1okazaw@nodai.ac.jp) and Tomonori FUJIKAWA, Faculty of Regional Environment Science, Tokyo University of Agriculture, JAPAN.
Paper presented at the 5th International Scientific Agricultural Symposium "AGROSYM 2014".
Notes: The authors declare that they have no conflicts of interest. Authorship Form signed online.

Since the surface of clinker ash has numerous pores of 1-20 μm in diameter (Photo. 1) and has a large specific surface area, it has good potential as a water purification material (Yamamoto et al., 2011).

In Japan, a nuclear disaster occurred at the time of the Great East Japan Earthquake in 2011. Since the closures of nuclear power stations, thermal power generation has accounted for a high proportion of power generation. Increases in use of coal ash have been called for, because thermal power generation's high proportion of all power generation results in the production of coal ash, which has been increasing since 2011.

Nitrogen is an essential element in crop cultivation. For example, Nakova (2013) reported that the rate of nitrogen application is an important factor and the increase in nitrogen rate to 200 kg ha^{-1} and 300 kg ha^{-1} resulted in mainly increases in wheat density and grain yield. Esfahani et al (2014) also mentioned that nitrogen fertilization is an important agronomic practice to obtain high corn forage yield and quality and corn forage dry matter yield showed positive response to N fertilization. In Japan, where natural resources are scarce, nitrogen fertilizers are imported in large amounts every year. However, some scientists reported that about half of the fertilizer applied to farmland is not taken up by the crops but is washed into rivers (e.g. Okazawa, et al. 2000 and Yoshinaga, et al. 2007). If it is possible to construct a nitrogen cycle system in which the nitrogen running off of farmland is captured and returned to the farmland, then agriculture with low economic and environmental burdens would be possible.

This study clarified the nitrogen adsorption ability of clinker ash by several grain size. In addition, the possibility of returning nitrogen-adsorbed clinker ash for crop cultivation was also examined.

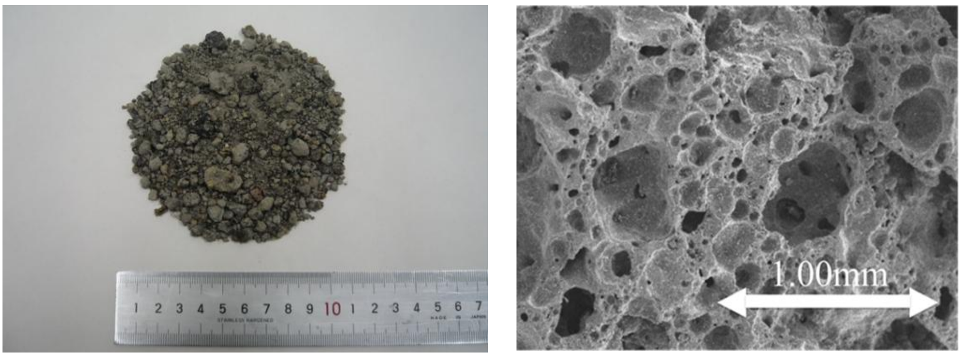

Photo 1. Clinker ash

MATERIAL AND METHODS

Table 1 shows the physical property of clinker ash, which is provided by coal-fired thermal generation. Clinker ash was sorted by using sieves with mesh sizes under 0.6 mm, 1.15 mm and 2.36 mm in order to use two kinds of experiments.

Nitrogen adsorption by clinker ash was examined in an experiment using uncontrolled clinker ash (Uncontrolled) and clinker ash grains of three-grain sizes (*D*>0.6 mm, *D*>1.15 mm and *D*>2.36 mm). Clinker ash of one grain-size (130 g) and nitrogen solution (6 L) was put in sub tank and main tank (W24cm×D16cm×H25cm), respectively (Fig.1). The nitrogen solution was circulated by circulation pump. The hydraulic retention time (HRT) was 120 seconds. The solution in the main tank was circulated via sub tank for 30 days. The nitrogen concentration of the solution in the tank was measured every 2 to 3 days. The initial nitrogen concentration of the solution (0 day) was 10 mg/L. Two types of nitrogen solutions were used: NO_3-N and NH_4-N. These were analyzed using ultraviolet spectrophotometry in accordance with the Japanese Industrial Standards (JIS). After the end of the experiment, the amount of nitrogen adsorbed to the clinker ash was measured.

For a vegetation experiment, *Japanese mustard spinach* (*Brassica rapa var. perviridis*) was planted on the clinker ash that had been used in the nitrogen adsorption experiment by using only NH_4-N solution water (Fig.2). The height of the plant stem was measured every day, and the use of nitrogen adsorbed by the plant was examined based on growth indicated by height.

Table 1 Physical property of Clinker ash (Uncontrolled)

Specific gravity (g/cm^3)	Particle size distribution (%)			Soil texture
	Sand (2mm>*D*>0.02mm)	Silt (0.02mm>*D*>0.002)	Cray (0.002mm>*D*)	
2.19	94	6	1	Sandy

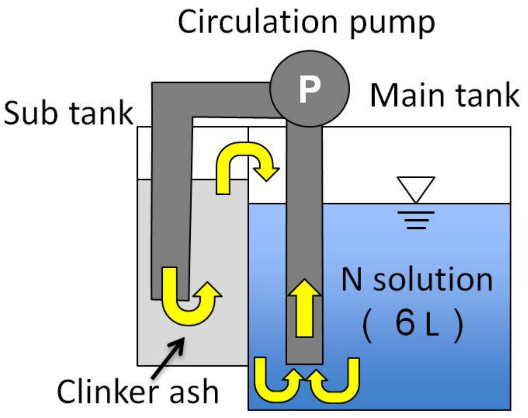

Fig.1 Nitrogen adsorption experiment

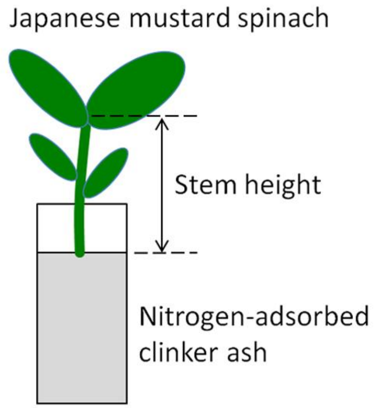

Fig.2 Vegetation experiment by plant

During the experiment, the laboratory was kept at the room temperature of 25 degree Celsius. Each experiment has been carried out three times under the each condition.

RESULTS AND DISCUSSION

Nitrogen adsorption experiment

The amount of nitrogen adsorption on the clinker ash was examined by nitrogen adsorption experiment. Figs.3 and 4 shows the relationship between the number of days elapsed and the nitrogen concentration of two kind of solutions in the main tank. In the case of NO_3-N solution, NO_3-N concentration in solution water remained approximately 5 mg/L. It seems that almost NO_3-N already adsorbed to clinker ash at 1st day.

In the case of NH_4-N solution, on the other hand, recorded the highest NH_4-N concentrations of each experiment condition at 1st day. Then, the concentrations gradually decreased until 9th days. After 10 days, the concentrations stabilized at 5 to 6 mg/L. It was clarified that clinker ash with a grain size of 0.6 mm or smaller seems to be effective in mitigating nitrogen pollution of water.

Fig.5 shows the amount of NH_4-N adsorbed by clinker ash in each grain-size, which analyzed after the end of the nitrogen adsorption experiment. The amount of nitrogen adsorbed by clinker ash (D>0.06 mm) was 0.052 mg/g. Therefore, it was clarified that clinker ash (D>0.06 mm) is most effective in NH_4-N adsorption on the clinker ash.

Vegetation experiment

Fig.6 indicates the relationship between the numbers of days elapsed and stems height of *Japanese mustard spinach*, which was planted in the nitrogen-adsorbed clinker ash. In the vegetation experiment for *Japanese mustard spinach* using nitrogen-adsorbed clinker ash, it was found that the plant cultivated in clinker ash (D>0.06 mm) showed the greatest growth. However, the planted *Japanese mustard spinach* was unable to grow in the uncontrolled clinker ash and clinker ash with grain size less than 1.15 mm (D>1.15 mm) and 2.36 mm (D>2.36 mm).

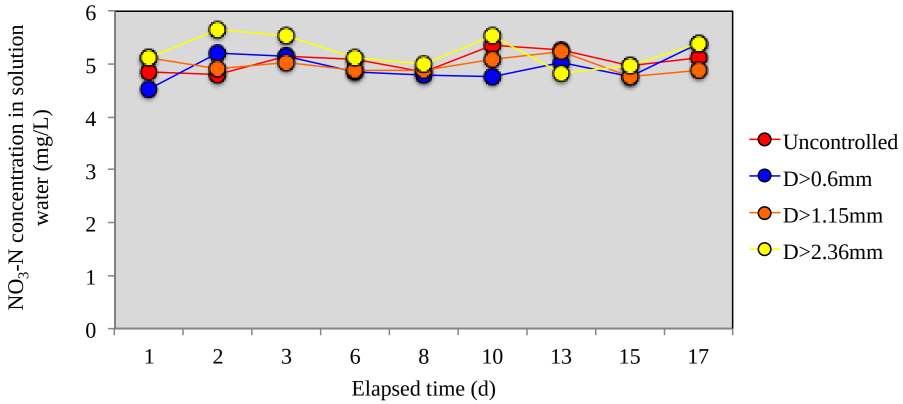

Fig.3 Relationship between the numbers of days elapsed and the nitrogen concentration of NO_3-N solution in the main tank

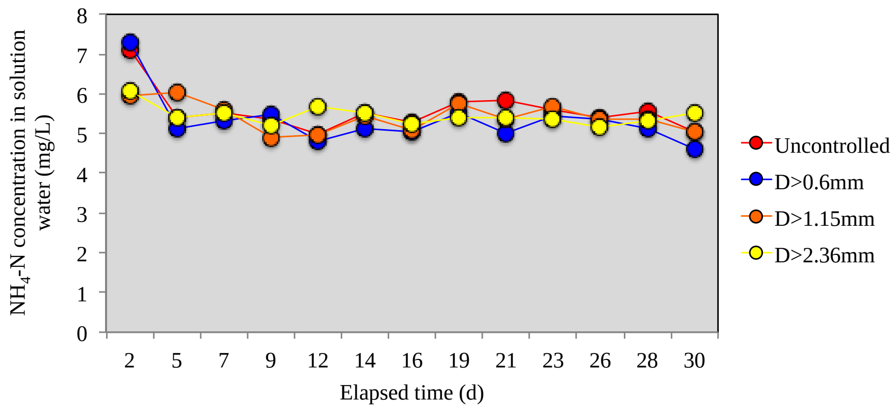

Fig.4 Relationship between the numbers of days elapsed and the nitrogen concentration of NH_4-N solution in the main tank

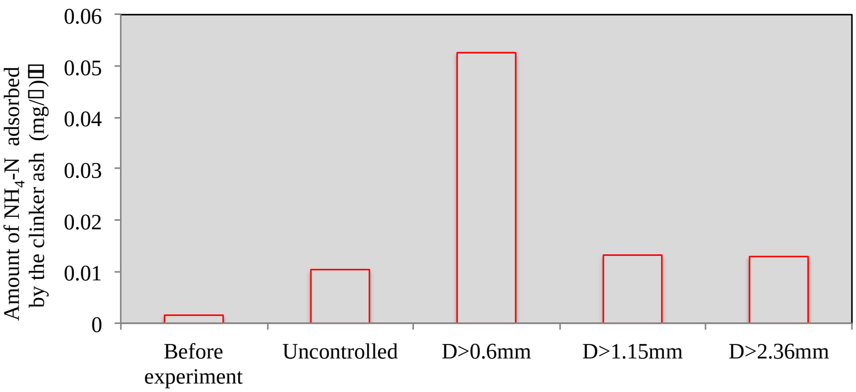

Fig.5 Amount of NH_4-N adsorbed by the clinker ash after nitrogen adsorption experiment

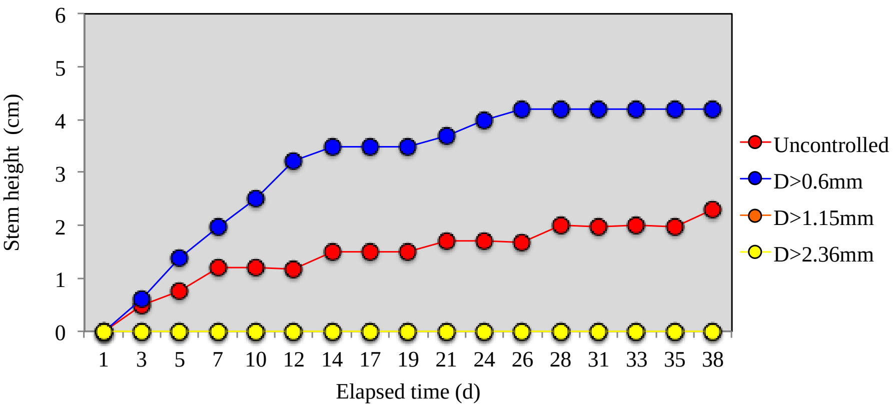

Fig.6 Relationship between stem height of Japanese mustard spinach using nitrogen-adsorbed clinker ash and elapsed time

CONCLUSIONS

It was clarified that clinker ash has a great capacity to adsorb NH_4-N. It was also found that fine-grained clinker ash is able to adsorb large amount of nitrogen, which can be used by plants. It is necessary to examine whether nitrogen-adsorbed clinker ash can be used to support crops other than Japanese mustard spinach. It is also necessary to investigate the safety of clinker ash, because coal ash contains heavy metals.

ACKNOWLEDGEMENT

This research was supported by JSPS KAKENHI, Grant-in-Aid for Scientific Research (C), Grant Number 26450347, 2014 and the grant-aid from Tokyo University of Agriculture (TUA), Japan. I would like to express my gratitude to International Society of Environmental and Rural Development, Prof. Dr. Machito MIHARA (TUA) and Prof. Dr. Yasushi TAKEUCHI (TUA). The authors are also grateful for the research assistance provided by the students of the laboratory of Hydro-structure Engineering, Tokyo University of Agriculture.

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