Adsorptive Property of Refuse Carbide and Effect for Purification of Leachate of MSWI Bottom Ash

Kiyoshi Omine¹, Hidetoshi Ochiai¹, Noriyuki Yasufuku¹, Toshimasa Kuroda¹, Jyunji Sasaki²
and Ryuuo Watanabe²

¹Department of Civil Engineering, Kyushu University, Fukuoka, Japan
²Kurimoto, LTD., Japan

ABSTRACT: This study investigated adsorption property of refuse carbide produced in carbonization facility and effect for purification of leachate of municipal solid waste incineration (MSWI) bottom ash by the refuse carbide. Batch adsorption test for lead and batch/column tests for MSWI bottom ash were performed. It was indicated that the refuse carbide has high adsorptivity for lead as much as bentonite or activated carbon. The value of pH and concentrations of Ca, Pb and TOC (Total Organic Carbon) leached from MSWI bottom ash can be reduced by using the refuse carbide. It was clarified that the refuse carbide is effective for purification of leachate of MSWI bottom ash. It is therefore suggested that the refuse carbide may be useful as intermediate cover soil in final disposal site.

1 INTRODUCTION

In accordance with the Guidelines concerning the precautions of dioxins emission due to the disposal of refuse issued by the former Ministry of Health and Welfare in 1997, guidelines for the disposal of refuse have provided that local governments, which dispose of refuse of 100 tons/day or less (have a population of approximately 100,000), shall dispose of refuse through widening the region, or applying system of Refuse incineration Ash melting or RDF (i.e., Refuse Derived Fuel). Refuse carbonization facility has been developed as a technology enabling thermal recycling/material recycling, intended for regions that dispose of refuse of 100 tons/day or less and further are unable to be widened. Refuse carbide produced in the facility has been used as a fuel substitute material in cement manufacturing industry or vice-material of steel industry. However, it is expected to use it as recycling material from a viewpoint of geotechnical engineering.

The authors have studied on utilization of waste carbides in geo-environmental engineering (Kuroki et al., 2005, Omine et al., 2006). It is generally known that the carbide has a high adsorptive capability for heavy metals due to fine pores. Therefore, it is considered that the refuse carbide may have also an adsorption property. In this study, batch adsorption test for lead is performed and batch and column tests for municipal solid waste incineration (MSWI) bottom ash with the refuse carbide are also performed. Adsorptive property of the refuse carbide and leaching property of MSWI bottom ash with the refuse carbide are clarified based on the test results (Kuroda et al., 2005). Furthermore, an application for utilization of the refuse carbide as intermediate cover soil in final disposal site is discussed.

2 ADSORPTIVE CAPACITY OF REFUSE CARBIDE FOR HEAVY METAL

2.1 Material Used and Testing Method

The material used in this study is the refuse carbide, which was produced in the carbonization facility. The refuse carbide is made by the following processes. Refuse (i.e., municipal solid waste) is crushed and incombustible materials such as metals or glass are removed from it. After having dried it to water content of approximately 10%, it is compressed and molded. The molded material is carbonized under 500 ~ 600 °C in rotary kiln. After the carbide is crushed in a size of less than 500 μm, it is washed and dried. SEM micrograph of the carbide is shown in Figure 1 and The grain size distribution is shown in Fig.2. Particles of the carbide is fine, because it was
crushed and washed for controlling chlorine content of less than 0.5 %.

In order to evaluate adsorptive property of the refuse carbide for heavy metal (Pb), batch adsorption test was performed. Aqueous solution of Pb was prepared at concentrations of 100, 300 and 600 mg/l, respectively. The refuse carbide with 10 g was added into the solution of 100 ml and the mixture was shaken on a reciprocating shaker for 6 hours. The supernatant was separated by centrifugation. Concentrations of Pb in the filtrates after passing through 0.45 μm membrane pore size filters were analyzed using atomic absorption photometry. For comparison with the carbide, the batch test was also performed on various materials, namely, bentonite, activated carbon, Ariake clay, Kaolin and decomposed granite soil.

2.2 Test results and discussions

Adsorptive property for heavy metals is generally evaluated by adsorption isotherm. Amount of adsorbed metal, $q$, is calculated from the following formula:

$$q = (C_0 - C)V / M$$

where $C_0$ : initial concentration, $C$ : final concentration, $V$ : volume of solution and $M$ : dry mass of sample.

3 PURIFICATION OF LEACHATE OF MSWI BOTTOM ASH

3.1 Leaching Property by Batch Test

(a) Materials and testing method

Leachate from MSWI bottom ash contains various components, so that adsorptive property of the refuse carbide for heavy metal is considered to differ from that of the batch adsorption test. In order to leaching property of MSWI bottom ash with the refuse carbide, batch test was performed on those mixtures according to the Notification No. 46 of the Japan Environmental Agency. Instead of the refuse carbide, activated carbon was also used. The mixtures with different contents of the refuse carbide or activated carbon were prepared. Concentrations of Pb, Cr and Cd were analyzed using ICP Mass Spectrometer, Zn, Fe, Cu and Ca were analyzed using atomic absorption photometry, and K, Na, Cl and SO₄ were analyzed using ion chromatograph.

(b) Test results and discussions

Physical property and leachate components of the MSWI bottom ash and refuse carbide is shown in Table 1. Used MSWI bottom ash and refuse carbide were obtained from different facilities, respectively. Concentration of Pb from the MSWI
Table 1 Physical property and leachate components of MSWI bottom ash and refuse carbide

<table>
<thead>
<tr>
<th></th>
<th>MSWI bottom ash</th>
<th>Refuse carbide</th>
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<tbody>
<tr>
<td>Particle density (g/cm³)</td>
<td>2.585</td>
<td>1.739</td>
</tr>
<tr>
<td>Water content (%)</td>
<td>44.15</td>
<td>4.1</td>
</tr>
<tr>
<td>Ignition loss (%)</td>
<td>6.69</td>
<td>26.72</td>
</tr>
<tr>
<td>pH</td>
<td>12.24</td>
<td>8.44</td>
</tr>
<tr>
<td>EC (mS/m)</td>
<td>196</td>
<td>106</td>
</tr>
<tr>
<td>Pb (mg/l)</td>
<td>0.65</td>
<td>0.011</td>
</tr>
<tr>
<td>Cr (mg/l)</td>
<td>0.01</td>
<td>0.004</td>
</tr>
<tr>
<td>Cd (mg/l)</td>
<td>0.006</td>
<td>0.006</td>
</tr>
<tr>
<td>Zn (mg/l)</td>
<td>0.15</td>
<td>0.013</td>
</tr>
<tr>
<td>Fe (mg/l)</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Cu (mg/l)</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>K (mg/l)</td>
<td>160.7</td>
<td>88.7</td>
</tr>
<tr>
<td>Na (mg/l)</td>
<td>275.3</td>
<td>128.3</td>
</tr>
<tr>
<td>Ca (mg/l)</td>
<td>383</td>
<td>152</td>
</tr>
<tr>
<td>Cl (mg/l)</td>
<td>400</td>
<td>194.5</td>
</tr>
<tr>
<td>SO₄ (mg/l)</td>
<td>50</td>
<td>45.74</td>
</tr>
</tbody>
</table>

Figure 4. Concentration of Pb in leachate of the mixtures of MSWI bottom ash and carbide on the batch test.

bottom ash exceeds considerably the environmental standard. This is the result for the fresh MSWI bottom ash performed on the day. It has been confirmed that the concentration of Pb decreases remarkably with increase in curing time at normal storage condition. Although the leachate of the refuse carbide contains various components, the values are less than those of the MSWI bottom ash.

Figure 4 shows the results of batch test on the mixtures of MSWI bottom ash and refuse carbide or activated carbon. Content of carbide is defined as percentage of the carbide for total dry mass of the mixture. In the case of refuse carbide, the concentration of Pb decreases gradually with increase in the content of carbide. The value was reduced by a one-sixth at the content of carbide of 30%. The effect on reduction of the concentration of Pb by mixing the activated carbon is higher than that of the refuse carbide. However,

Table 2 Conditions of the column test

<table>
<thead>
<tr>
<th></th>
<th>Case 1</th>
<th>Case 2</th>
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</thead>
<tbody>
<tr>
<td>Layer I</td>
<td>MSWI bottom ash</td>
<td></td>
</tr>
<tr>
<td>Layer II</td>
<td>Refuse carbide or Decomposed granite soil</td>
<td></td>
</tr>
<tr>
<td>Water flow rate</td>
<td>36 mm/week</td>
<td>18 mm/week</td>
</tr>
</tbody>
</table>

Figure 5. Column equipment for leaching test

concerning the adsorption of Pb, it is confirmed that the refuse carbide has a capacity for purification of leachate of MSWI bottom ash.

3.2 Leaching Property by Column Test

(a) Testing method

In order to simulate leaching from final disposal site with intermediate cover soil, column test with a diameter of 100 mm was performed. Figure 5 shows the column test apparatus and Table 2 summarizes the conditions of the column test. MSWI bottom ash was filled in layer I with a height of 300 mm. The refuse carbide or decomposed granite soil was used in layer II with a height of 50 mm as an intermediate cover soil. For comparison, the column test without intermediate cover soil was also performed. Two types of water flow rate were selected for investigating the effect of speed of water flow. Values of pH and ORP, and concentrations of Ca, Na, K and Pb were measured continuously. Concentration of TOC (Total Organic Carbon) was also measured using total organic carbon analyzer.

(b) Test results and discussions

In the column test, various leachate components were measured for approximately three months.
oxidation potential of water, and the water changes into the plus side if it is in aerobic condition and changes into the minus side if it is in anaerobic condition. The measured ORP at the condition without cover soil indicates low values between -50 and 0 mV, and increases slightly during three months. The ORP at the condition of using decomposed granite soil shows high value more than 250 mV at initial stage, but it decreases at 50 mV after 40 days. On the other hand, when the refuse carbide was used, it is in the range of 150 to 200 mV and keeps the level for three months. It is observed that there is a correlation between ORP and pH.

From Figs 6 and 7, it is found that the leachate of MSWI bottom ash can be improved more in aerobic condition by using the refuse carbide as the intermediate cover soil.

Relationship between released Ca and elapsed time at Case 1 is shown in Fig.8. The released Ca shows high value at the condition without cover soil or with decomposed granite soil at initial stage until 30 days. However it decreases at the condition of using the refuse carbide. It is considered that the refuse carbide has adsorptive capacity for Ca. At a long term after 60 days, there was no clear difference of the released Ca.
for kinds of the materials. And also differences in leaching behavior of Na or K were not observed clearly for kinds of the materials.

Leaching behavior of Pb at Case 1 is shown in Fig. 9. Released Pb of the condition without cover soil indicates high concentration and it decreases gradually with the elapsed time. On the other hand, the concentration of Pb can be reduced by using the refuse carbide or granite decomposed soil. Although there was no difference of the adsorptive capability between these materials in this condition, it is considered that the refuse carbide has a potential for adsorption of Pb at the condition of high release level, as shown by the adsorption test results in chapter 2.

Reduction of organic matters from MSWI bottom ash is also important problem at final disposal site. In this study, TOC is used as an index for the organic matters. Relationship between released TOC and elapsed time at Case 1 is shown in Fig.10. The released TOC shows high value more than 200 mg/l at the condition without cover soil at initial stage, and decreases gradually with the elapsed time. There is no difference of the released TOC for the conditions without cover soil or with decomposed granite soil except the initial stage. However the value decreases at the condition of using the refuse carbide for all the elapsed time. It is considered that refuse carbide has also adsorptive capacity for TOC.

Figs 6–10 show only the test results on the condition of Case 1. Influences of the water flow conditions of Case 1 and Case 2 are shown as relationships between cumulative mass of leachate components and liquid to solid ratio, L/S, below.

As shown in Fig. 11 (a) and (b), the cumulative mass of leached Ca at the condition of using the refuse carbide is lower than that of the condition without cover soil or with decomposed granite soil at the same L/S. The reduction effect of the cumulative mass of Ca using refuse carbide is much larger at low water flow rate.

Figure 12 (a) and (b) shows the cumulative mass of Pb leached from MSWI ash in the column test. Leaching behavior of Pb without cover soil is influenced significantly by the water flow rate. The cumulative mass of leached Pb at Case 1 and without cover soil is large, and the value at Case 2 is very small. It is considered that this reason is due to the decrease of pH with carbonation at
Case 2 of low water flow rate. The cumulative mass of Pb can be reduced greatly by using the intermediate cover soil such as the refuse carbide or granite decomposed soil. As described above, it is estimated that the refuse carbide has a high potential for adsorption of Pb.

The relationship between cumulative mass of leached TOC and L/S is shown in Fig. 13 (a) and (b). The value of TOC at the condition without cover soil increases gradually with increase in L/S. At the same L/S, it is possible to reduce the cumulative mass of leached TOC by using the intermediate cover soil. The reduction effect of TOC for the refuse carbide is greater than that of decomposed granite soil. The effect depends on the condition of water flow rate, as shown in Fig 13 (a) and (b). Influence of the water flow rate on the cumulative mass of TOC at L/S = 0.3 is shown in Fig. 14. In each material as intermediate cover soil, the cumulative mass of leached TOC decreases at the condition of low water flow rate. The decreasing tendency of TOC for the low water flow rate is clear at the case with the refuse carbide. It is therefore said that the cumulative mass of leached TOC can be reduced by using the refuse carbide as intermediate cover soil in final disposal site.

4 CONCLUSIONS

In this paper, adsorptive property of refuse carbide and leaching property of MSWI bottom ash with the refuse carbide was discussed based on the results of batch and column tests. The main conclusions are summarized as follows.

1) Refuse carbide has high adsorptivity for lead as much as bentonite or activated carbon.

2) The value of pH and concentrations of Ca, Pb and TOC (Total Organic Carbon) leached from MSWI bottom ash can be reduced by using the refuse carbide.

Figure 13. Cumulative mass of TOC leached from MSWI ash in the column test

Figure 14. Influence of water flow rate on cumulative mass of TOC

3) The refuse carbide is effective for purification of leachate of MSWI bottom ash. It is therefore suggested that the refuse carbide may be useful as intermediate cover soil in final disposal site.

REFERENCES

