Leaching characteristics of PCDDs/DFs and co-PCBs from landfills containing municipal solid waste and incineration residues

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Introduction
As for trends in ratio of treatment/disposal for municipal solid waste (MSW) in Korea, the recycling and incineration rate increase, while final disposal (i.e. landfill) rate decrease. So, it is required to consider the proper disposal of the residues according to increase of incineration rate. At present in Korea, the incineration residues are co-disposed with MSW in landfill by leaching test. From a lot of studies, hazardous pollutants such as inorganic and organic pollutants have been reported to be leached from incineration residues, especially polychlorinated dibenzo-p-dioxin and dibenzofurans (PCDDs/DFs), a kind of endocrine disruptors, are suggested to leaching out with dissolved and suspended solid. Kim et al. [2002] evaluated the leachability of PCDDs/DFs in incineration residue when in coexistence with dissolved humic matter (DHM) in theoretically and laboratory condition. And Sakai et al.[2000] also reported that LAS and humic acid could increase the leaching concentration of PCBs and PCDDs/DFs in some of wastes. Understanding that co-disposal of MSW and incineration residues could accelerate the leaching-out of organic pollutants such as PCDDs/DFs and co-PCBs, we investigate the leaching characteristics of PCDDs/DFs and co-PCBs and evaluate the factors affecting their leachability from co-disposal site in Korea.

Materials and methods
We collected raw leachate samples twice in selected 12 landfill sites in Korea. As shown in Table 1, the age of landfill sites are largely from 1 years to 15 year, and among them, nine landfill sites are still in operation, meanwhile three (BC, UJ, BS-1) had been completely closed. Accepted waste are almost MSW and incineration residues (IR).

For PCDDs/DFs and co-PCBs analysis of leachate samples, the Korea standard testing method for PCDDs/DFs (Ministry of Environment, Republic of Korea) and the Japan standard (JIS 3120) were used for pre-treatment and analysis. All of leachate samples were separated liquid and solid phase by GF/B(1.0μm). After shaking, the concentrations of PCDDs/DFs and co-PCBs were determined by HRGC/HRMS (Autospec Ultima, micromass, UK) with SP-2331 column, respectively.

Table 1. Characteristics of selected MSW landfill sites

<table>
<thead>
<tr>
<th></th>
<th>BC</th>
<th>UJ</th>
<th>CS</th>
<th>SA</th>
<th>SG</th>
<th>GY</th>
<th>GG</th>
<th>BS-1</th>
<th>ST</th>
<th>BS-2</th>
<th>JY</th>
<th>MC</th>
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</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>15</td>
<td>13</td>
<td>13</td>
<td>11</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>8</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Accepted waste types</td>
<td>MSW, IW, IR</td>
<td>MSW, W, IR</td>
<td>MSW, IR</td>
<td>MSW, IR</td>
<td>MSW</td>
<td>MSW</td>
<td>MSW, IR</td>
<td>MSW, IR</td>
<td>MSW</td>
<td>MSW, IR</td>
<td>MSW</td>
<td>MSW, IR</td>
</tr>
<tr>
<td>Accepted waste amount (million m³)</td>
<td>833</td>
<td>437</td>
<td>187</td>
<td>323</td>
<td>1048</td>
<td>78</td>
<td>498</td>
<td>64</td>
<td>91</td>
<td>67</td>
<td>25</td>
<td>18</td>
</tr>
</tbody>
</table>

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Results

Concentration of PCDDs/DFs and Co-PCBs in leachate

Table 2 shows the average concentration of PCDDs/DFs and co-PCBs in raw leachates from selected landfills. The PCDDs/DFs concentration was in the range of 16.220–959.509 pg/l (avg. 48.006 pg/l) and 0.639–5.841 pg-TEQ/l (avg. 1.508 pg-TEQ/l). And the co-PCBs concentration was in the range of 22.720–2,179.683 pg/l (avg. 85.553 pg/l) and 0.020–0.725 pg-TEQ/l (avg. 0.036 pg-TEQ/l). The highest concentration of PCDDs/DFs and co-PCBs was shown in UJ and BS-1 among other sites, respectively. However in the case of JY site, high portion of non-combustibles including incineration residue was buried, very low concentration of PCDDs/DFs were detected in leachate even though high portion of incineration residue, containing comparatively high concentration of PCDDs/DFs than the other components of MSW, was buried.

The distribution of PCDDs/DFs and co-PCBs between solid and liquid phases were shown about 60% and 40%, respectively.

Table 2. The PCDDs/DFs concentrations of leachates from 12 landfills (unit: pg/l, (): pg-TEQ/l)

<table>
<thead>
<tr>
<th>Landfill site</th>
<th>BC</th>
<th>UJ</th>
<th>CS</th>
<th>SA</th>
<th>SA</th>
<th>SG</th>
<th>GY</th>
<th>GG</th>
<th>BS-1</th>
<th>ST</th>
<th>BS-2</th>
<th>JY</th>
<th>MC</th>
<th>YG</th>
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</thead>
<tbody>
<tr>
<td>PCDDs/DFs</td>
<td>6999</td>
<td>9595</td>
<td>25.8</td>
<td>877</td>
<td>1632</td>
<td>868</td>
<td>2792</td>
<td>6183</td>
<td>3225</td>
<td>2913</td>
<td>162</td>
<td>48</td>
<td>308</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(58 )</td>
<td>(28 )</td>
<td>(09 )</td>
<td>(5 )</td>
<td>(34 )</td>
<td>(3 )</td>
<td>(24 )</td>
<td>(47 )</td>
<td>(17 )</td>
<td>(26 )</td>
<td>(0 )</td>
<td>(0 )</td>
<td>(0 )</td>
<td></td>
</tr>
<tr>
<td>Co-PCBs</td>
<td>951</td>
<td>114</td>
<td>25.5</td>
<td>894</td>
<td>3519</td>
<td>1723</td>
<td>2815</td>
<td>2170</td>
<td>1604</td>
<td>9262</td>
<td>227</td>
<td>856</td>
<td>279</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(04 )</td>
<td>(01 )</td>
<td>(0 )</td>
<td>(0 )</td>
<td>(01 )</td>
<td>(0 )</td>
<td>(0 )</td>
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<td>(0 )</td>
<td>(04 )</td>
<td>(0 )</td>
<td>(0 )</td>
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</tr>
</tbody>
</table>

Discussion

1. Relationship between the age of landfill and the PCDDs/DFs in leachate

It is difficult to find the leaching characteristics of PCDDs/DFs depending on the age of landfill because of the differences in kind and amount of disposed wastes and many different conditions of landfills. Thus, we need a normalized independent variable using disposed wastes and their degradation information to be able to apply to all of landfills.

Wastes were divided into biodegradables and non-biogradables, and the biodegradables were divided over again into easy-degradables (food, dead animals and plant, oil), mid-degradables (paper, textile, wood, sludge, etc.), and hard-degradables (rubber, leather, plastic). And then, we calculated the decomposed and remained biodegradables in the divided waste types by assumption of the first order kinetic model and half period of Scroll Canyon Model. We evaluated a relationship of the leaching concentration of PCDDs/DFs and degradation level of landfilled wastes on the assumption that all conditions in landfills are equal. As a result, we could estimate the amount of ready-decomposed and remained fraction of biodegradables. The ready-decomposed fraction would decrease with increasing age, while the remained fraction would increase with increasing age.

Fig. 1(a, b) shows the relationship of ready-decomposed and remained fraction of biodegradables and the leaching concentration of PCDDs/DFs. The concentration of PCDDs/DFs decreased with increasing the age presented as remained biodegradable wastes, and its
determination coefficient \((R^2)\) was 0.763 showing a good correlationship.

2. Relationship between non-biodegradable portion and PCDDs/DFs in leachate

Fig. 1(c) shows the relationship between non-biodegradable portion among disposed waste and the leaching concentration of PCDDs/DFs. The leaching concentration of PCDDs/DFs is decreased with increasing the portion of non-biodegradable waste \((R^2=0.8168)\). Although incineration residue contained comparatively high concentration of PCDDs/DFs than the other components of MSW is classified to non-biodegradables, the leaching concentration was very low.

![Fig. 1 Relationship between the type of waste disposed landfills and the concentration of PCDDs/DFs in leachate](image)

3. Prediction of leaching concentration of PCDDs/DFs

Concentration of PCDDs/DFs in leachate was predicted by using regression analysis model.

The result is as follows;

\[
\text{PCDDs/DFs (pg/l)} = 827.0 -0.7 \times \text{HO-N (ppm)} +8.0 \times \text{TDS (％)} -15.7 \times \text{non-biodegradable portion (％)} \quad \text{---------- (1)}
\]

The regression analysis model with a significance level of 0.05 was adopted; as results, equation (1) constituted HO-N (hydrophobic neutral organic carbons), TDS (total dissolved solid), and the ratio of non-biodegradable waste portion in landfill. And Fig. 2 shows the expected concentration by equation (1) and observed concentration. The relationship of expected and observed concentration was very high \((R^2=0.8935)\). As mentioned previously, the coefficient of contents of non-biodegradable waste showed negative. And the positively high relationship of TDS and PCDDs/DFs in equation (1) could be explained by transfer of PCDDs/DFs to TDS serving as absorbent.

![Fig. 2 The relationship of expected and observed concentration in leachate](image)

References