Elution behaviour of sand based AAC

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Abstract: The paper summarizes available data of leaching tests of sand based AAC. It covers data obtained by tank tests according to NEN 7375 and shaking tests mainly according DEV S4 as produced for the German "Forschungsvereinigung Porenbeton" and for Xella. More than 100 substances were tested in total. These substances originate the following groups of compounds: polycyclic aromatic hydrocarbons, lightly volatile halogenated hydrocarbons, polychlorinated biphenyls, alkylated benzenes, pesticides, substances typically connected with explosives and inorganic parameters of course. Modern AAC formulations mainly release $\text{SO}_4^{2-}$; the concentration of the great majority of other substances is extremely low and in most cases not even traces were detectable.

Keywords: AAC, autoclaved aerated concrete, leaching, elution

1. INTRODUCTION

During the recent decades a large number of elution tests were carried out in order to detect the amount of soluble substances within autoclaved aerated concrete (AAC). Most of these tests describe the dilution behaviour of crushed AAC as relevant for dumping in landfills. In context to the law in the Netherlands, the elution behaviour was described using blocks in a tank test according to NEN 7375. This test method was adopted by TC 351 Dangerous Substances to describe the nature of a building material during the use phase. TC 351 introduced three categories of testing the materials. Most interesting is "WT" – Without Testing. On the way to get this classification the existing data of AAC was evaluated and discussed.

There are two ways to comply with existing regulations. The first way proofs point by point: property of the product and its relation to a limit value, always stated by an expert. At the end, there is a list of regulated attributes and the statement “All requirements fulfilled!” or “Special attributes fulfilled and some others not.” In case of any change in the regulation the product has to be checked again and its compliance reassessed. The second way to obtain a “WT”-status bases on a list of assessed values obtained from product tests regardless existing regulations and limit values. The values and their correctness were stated by experts in this case but not the compliance with legal requirements. This process certainly succeeds, but will not require expert knowledge. Even future changes in the regulation will only result in a comparison of numbers, but not in expert statements any more.

2. EXISTING DATA

Four data sources were evaluated in this paper. They cover different test methods. Most data bases on leaching tests according to DEV S4 of granular material. These tests can easily be carried out. The relative amount of dissolved material is very high and its quantitative determination is often possible. During normal use of AAC and its possible...
disposal, these substances will not even be released in such amounts in landfills. A transfer function has to be established within the next years. However, if substances are not determinable with the DEV S4 method they will not be traceable with any other.

The German “Forschungsvereinigung Porenbeton” initiated in the late 1990s a project (“Munich Study”) to compare different elution methods [4]. AAC from 24 different factories was used and the following tests were performed:
- DEV S4 using fine crushed AAC of 0–4 mm and 0–5 mm
- DEV S4 using AAC of 0–45 mm
- Trough test using AAC of 0–4 and 0–5 mm
- Percolation test using AAC 0–4 and 0–5 mm
- pH 4 steady test using AAC 0–4 and 0–5 mm
- a content analysis of the original material

This study was remarkably broadened by a second one [1] testing 16 samples from 16 factories and covering more than 100 substances. A third study [2] was complemented by tests of Xella [3] displaying information about sulphate and evaporation residue.

2.1. Leaching data obtained from granular material

Percolation and pH 4 steady tests did not show quantitative results except for pH, electrical conductivity, chloride, sulphate and zinc. The trough test gave also an amount for chromium. Chloride was significantly reduced during the first day of percolation (figure 1) but not during the pH 4 steady test. Sulphate behaved similar but not that strong and zinc was mobilized at pH 4.

![Chloride concentration in percolation and pH4 steady test](image)

Our focus is given to the DEV S4 methods. The main results of the “Munich Study” are summarized in table 1, 2 and 3. Quantitative data about the leachate covers mainly pH, electrical conductivity, Cl, SO$_4^{2-}$, Cr, Zn and TOC. The fractions 0-4 and 0-5 mm (table 1) show lower concentrations of dissolved substances in the eluate than fraction 0-45 mm (table 2). This proofs experimental findings about grain sizes above 10 mm reducing the amount of dissolved material as illustrated by figure 2.
The study from Kluge (2007) widened the existing quantitative inorganic data for As, B, Cu and V (table 4). The extensive number of tests for organic compounds proved very low concentrations, generally below the detection limit (table 5).

In 2010 the relation between sulphate content and evaporation residue in DEV S4 cluates was studied by Kluge [2] and [3], figure 3 left diagram. The sulphate content reached 1650 mg/l and the evaporation residue was below 2.6 wt-%. On the basis of 22 samples the following relation was calculated:

\[
\text{Sulphate content in mg/l} = \text{evaporation residue in wt-\%} \times 643
\]

Using this factor a sulphate content of additional 57 AAC products was calculated, figure 3 right. The highest residue of 2.64 wt-% corresponded to a calculated sulphate value of just below 1700 mg/l.

![Graphs](image)

Fig. 3. The context sulphate and evaporation residue (left) used in calculations of sulphate concentration (right). DEV S4 of fraction 0-4 mm
2.2. Tank tests according to NEN 7345 and NEN 7375

This method is used to describe the leaching behaviour of inorganic components in building materials. The test specimen were stored in a tank filled with a solution from distilled water and HNO₃ displaying a pH-value of 4. The eluent has to be renewed several times over a period of 64 days. The leachate is tested for pH-value, electrical conductivity and released components. The cumulative emission is calculated after 64 days. The main difference to other methods is the use of well shaped test specimen being in contact with a still eluent and the calculation of a cumulative emission attributed to one square metre of the building material. The summarised results of testing AAC in 2004 and 2006 by INTRON are given in tables 6 and 7. Selected data are displayed in figure 4.

The leaching results obtained in 2006 are generally lower than the ones from 2004 and they normally do not show any spreading of values. Wijs & Cleven described the calculation rules, if substances were not traceable. However, that modified data was handled like real quantitative results and release rates were given.

3. SUMMARY

Extensive leaching tests of AAC were carried out within recent years. The results proof extremely low concentrations of organic and very low concentrations of inorganic substances. The only known exception is sulphate, released from the matrix but not being dangerous. It is important for the industry to get a transmission model DEV S4 leachats to the leaching tests according NEN 7345/7375 and the future European standard.
Table 1. Results of testing 24 AAC samples from 24 factories by DEV S4 method using a fraction of 0-4 mm and 0-5 mm [4]

<table>
<thead>
<tr>
<th>Symbol / name</th>
<th>Unit</th>
<th>Minimum value</th>
<th>Maximum value</th>
<th>Mean value</th>
<th>Number of samples above detection limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH-value</td>
<td></td>
<td>9.6</td>
<td>11.8</td>
<td>10.6</td>
<td>24</td>
</tr>
<tr>
<td>electrical conductivity</td>
<td>mS/cm</td>
<td>0.4</td>
<td>2.8</td>
<td>2.0</td>
<td>24</td>
</tr>
<tr>
<td>Cl</td>
<td>mg/l</td>
<td>4.88</td>
<td>47.8</td>
<td>14.0</td>
<td>24</td>
</tr>
<tr>
<td>SO$_4^{2-}$</td>
<td>mg/l</td>
<td>46</td>
<td>1689</td>
<td>1050</td>
<td>24</td>
</tr>
<tr>
<td>As</td>
<td>mg/l</td>
<td>&lt; 0.002</td>
<td>&lt; 0.002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pb</td>
<td>mg/l</td>
<td>&lt; 0.020</td>
<td>0.04</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Cd</td>
<td>mg/l</td>
<td>&lt; 0.002</td>
<td>&lt; 0.002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cr</td>
<td>mg/l</td>
<td>&lt; 0.005</td>
<td>0.096</td>
<td>0.017</td>
<td>16</td>
</tr>
<tr>
<td>Cu</td>
<td>mg/l</td>
<td>&lt; 0.002</td>
<td>0.008</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Ni</td>
<td>mg/l</td>
<td>&lt; 0.010</td>
<td>0.019</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Hg</td>
<td>mg/l</td>
<td>&lt; 0.0002</td>
<td>&lt; 0.0002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zn</td>
<td>mg/l</td>
<td>&lt; 0.010</td>
<td>0.076</td>
<td>0.026</td>
<td>18</td>
</tr>
<tr>
<td>cyanide if</td>
<td>mg/l</td>
<td>&lt; 0.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fluoride</td>
<td>mg/l</td>
<td>&lt; 0.10</td>
<td>0.28</td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>ammonium-N</td>
<td>mg/l</td>
<td>&lt; 0.05</td>
<td>0.12</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>hydrocarbons / KW</td>
<td>mg/l</td>
<td>&lt; 0.05</td>
<td>0.1</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>adsorbable organic halogen / AOX</td>
<td>mg/l</td>
<td>&lt; 0.01</td>
<td>0.014</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>total organic carbon / TOC</td>
<td>mg/l</td>
<td>1.1</td>
<td>13.7</td>
<td>4.7</td>
<td>24</td>
</tr>
<tr>
<td>phenolindex</td>
<td>mg/l</td>
<td>&lt; 0.01</td>
<td>0.116</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

Note: The mean value is calculated using the quantified amounts and half of the value of the detection limit if not quantifiable. It was only calculated if more than 50% of samples could be quantified.

Table 2. Results of testing 24 AAC samples from 24 factories by DEV S4 method using a fraction of 0-45 mm [4]

<table>
<thead>
<tr>
<th>Symbol / name</th>
<th>Unit</th>
<th>Minimum value</th>
<th>Maximum value</th>
<th>Mean value</th>
<th>Number of samples above detection limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH-value</td>
<td></td>
<td>8.9</td>
<td>11.9</td>
<td>10.0</td>
<td>24</td>
</tr>
<tr>
<td>electrical conductivity</td>
<td>mS/cm</td>
<td>0.3</td>
<td>1.8</td>
<td>1.2</td>
<td>24</td>
</tr>
<tr>
<td>Cl</td>
<td>mg/l</td>
<td>2</td>
<td>29.3</td>
<td>7.6</td>
<td>24</td>
</tr>
<tr>
<td>SO$_4^{2-}$</td>
<td>mg/l</td>
<td>46</td>
<td>919</td>
<td>452</td>
<td>24</td>
</tr>
<tr>
<td>As</td>
<td>mg/l</td>
<td>&lt; 0.002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pb</td>
<td>mg/l</td>
<td>&lt; 0.020</td>
<td>0.038</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Cd</td>
<td>mg/l</td>
<td>&lt; 0.002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cr</td>
<td>mg/l</td>
<td>&lt; 0.005</td>
<td>0.088</td>
<td>0.015</td>
<td>14</td>
</tr>
<tr>
<td>Cu</td>
<td>mg/l</td>
<td>&lt; 0.002</td>
<td>0.005</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Ni</td>
<td>mg/l</td>
<td>&lt; 0.010</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hg</td>
<td>mg/l</td>
<td>&lt; 0.0002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zn</td>
<td>mg/l</td>
<td>&lt; 0.010</td>
<td>0.123</td>
<td>0.034</td>
<td>22</td>
</tr>
<tr>
<td>hydrocarbons / KW</td>
<td>mg/l</td>
<td>&lt; 0.05</td>
<td>0.05</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>phenolindex</td>
<td>mg/l</td>
<td>&lt; 0.01</td>
<td>0.01</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>
Table 3. Results of content analysis of 24 AAC samples from 24 factories [4]

<table>
<thead>
<tr>
<th>Symbol / name</th>
<th>Unit</th>
<th>Minimum value</th>
<th>Maximum value</th>
<th>Number of samples above detection limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>ppm</td>
<td>1.1</td>
<td>9.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Pb</td>
<td>ppm</td>
<td>2.0</td>
<td>16.1</td>
<td>8.1</td>
</tr>
<tr>
<td>Cd</td>
<td>ppm</td>
<td>0.3</td>
<td>3.4</td>
<td>0.9</td>
</tr>
<tr>
<td>Cr</td>
<td>ppm</td>
<td>6.0</td>
<td>153.0</td>
<td>37.7</td>
</tr>
<tr>
<td>Cu</td>
<td>ppm</td>
<td>2.7</td>
<td>24.6</td>
<td>7.6</td>
</tr>
<tr>
<td>Ni</td>
<td>ppm</td>
<td>0.3</td>
<td>15.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Hg</td>
<td>ppm</td>
<td>&lt; 0.03</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Zn</td>
<td>ppm</td>
<td>8.6</td>
<td>86.6</td>
<td>40.4</td>
</tr>
<tr>
<td>SO$_2^-$</td>
<td>g/kg</td>
<td>3.5</td>
<td>39.4</td>
<td>19.6</td>
</tr>
<tr>
<td>hydrocarbons / KW</td>
<td>ppm</td>
<td>46</td>
<td>405</td>
<td>224.5</td>
</tr>
<tr>
<td>total organic carbon / TOC</td>
<td>M-%</td>
<td>0.05</td>
<td>0.27</td>
<td>0.17</td>
</tr>
<tr>
<td>phenol index</td>
<td>ppm</td>
<td>&lt; 0.1</td>
<td>0.39</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>polycyclic aromatic hydrocarbons / PAK</td>
<td>ppm</td>
<td>n.n.</td>
<td>0.16</td>
<td>0.04</td>
</tr>
<tr>
<td>extractible halogens in organic bonding / FOX</td>
<td>ppm</td>
<td>&lt; 0.5</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>polychlorinated biphenyls / PCB</td>
<td>ppm</td>
<td>n.d.</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

Table 4. Results of testing 16 AAC samples from 16 factories by DEV S4 method using a fraction of 0-4 mm [1]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Unit</th>
<th>Minimum value</th>
<th>Maximum value</th>
<th>Mean value</th>
<th>Number of samples above detection limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cl.cond.</td>
<td>µS/cm</td>
<td>9.1</td>
<td>12.2</td>
<td>10.0</td>
<td>16</td>
</tr>
<tr>
<td>As</td>
<td>µg/l</td>
<td>&lt;1</td>
<td>9</td>
<td>0.25</td>
<td>8</td>
</tr>
<tr>
<td>Ba</td>
<td>µg/l</td>
<td>&lt;10</td>
<td>17</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>µg/l</td>
<td>&lt;20</td>
<td>63</td>
<td>32</td>
<td>12</td>
</tr>
<tr>
<td>Cd</td>
<td>µg/l</td>
<td>&lt;0.2</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Co</td>
<td>µg/l</td>
<td>&lt;1</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Cr (III)</td>
<td>µg/l</td>
<td>&lt;2</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td>µg/l</td>
<td>&lt;5</td>
<td>50</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>Hg</td>
<td>µg/l</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Mo</td>
<td>µg/l</td>
<td>&lt;10</td>
<td>10</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Ni</td>
<td>µg/l</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Pb</td>
<td>µg/l</td>
<td>&lt;2</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Sb</td>
<td>µg/l</td>
<td>&lt;1</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Se</td>
<td>µg/l</td>
<td>&lt;1</td>
<td>5</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Ti</td>
<td>µg/l</td>
<td>&lt;0.5</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>µg/l</td>
<td>&lt;2</td>
<td>25</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>Zn</td>
<td>µg/l</td>
<td>&lt;10</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Cl$^-$</td>
<td>mg/l</td>
<td>2.3</td>
<td>14.7</td>
<td>6.5</td>
<td>16</td>
</tr>
<tr>
<td>CN$^-$</td>
<td>µg/l</td>
<td></td>
<td></td>
<td>&lt;5</td>
<td>0</td>
</tr>
<tr>
<td>F$^-$</td>
<td>µg/l</td>
<td>&lt;100</td>
<td>250</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>SO$_2^-$</td>
<td>mg/l</td>
<td>104</td>
<td>1420</td>
<td>943</td>
<td>16</td>
</tr>
</tbody>
</table>
Table 5. Results of testing 16 AAC samples from 16 factories by DEV S4 method using a fraction of 0.4 mm [1]. The detection limit of the substances is given in brackets, with one exception none of these substances was traced; the dimension is μg/l

<table>
<thead>
<tr>
<th>Substance Description</th>
<th>Limit (μg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>polynuclear aromatic hydrocarbons (PAH) (0.2); anthracene (0.005); benzo(a)pyrene (0.005); dibenz(a,h)anthracene (0.005); benzo(b)fluoranthene (0.01); benzo(k)fluoranthene (0.01); benzo(g,h,i)perylene (0.01); fluoranthene (0.01); indeno(1,2,3-c,d)pyrene (0.01); naphthalene + methyl-naphthalene (0.1)</td>
<td>5 samples exceeded the detection limit displaying a maximum of 0.3 μg/l; chloroethene (0.2); dichloromethane (1); cis-1,2-dichloroethene (0.5); cis-1,2-dichloroethane (0.5); trichloromethane (0.05); 1,1,1-trichloroethane (0.05); carbon tetrachloride (0.05); 1,2-dichloroethane (0.5); trichloroethene (0.05); tetrachloroethene (0.05); 1,1,2-trichlorofluorocrane (0.2); dichlorodifluoromethane (0.2); trichlorofluoromethane (0.2); bromodichloromethane (0.05); dibromochloromethane (0.05); tribromomethane (0.1)</td>
</tr>
<tr>
<td>polychlorinated biphenyls (PCB): PCB-28 (0.005); PCB-52 (0.005); PCB-101 (0.001); PCB-138 (0.001); PCB-153 (0.001); PCB-180 (0.001); hydrocarbons (100); methylbenzene (0.5); ethylbenzene (0.3); m+p-dimethylbenzene (0.5); o-dimethylbenzene (0.5); isopropylbenzene (0.5); n-propylbenzene (0.5); m-ethylmethylbenzene (1); p-ethylmethylbenzene (1); o-ethylmethylbenzene (1); 1,3,5-trimethylbenzene (0.5); 1,2,4-trimethylbenzene (1); 1,2,3-trimethylbenzene (1); benzene (0.5); methyl tert-butyl ether (10); phenol index (8); nonyl phenol (0.05); chlorophenoles (1); hexachlorobenzene (0.001); chloride (0.01); dichlorinated (0.01); dieldrin (0.01); endosulfan (0.01); parathion-ethyl (0.01); chlorodane (0.003); diuron (0.05); hexazinone (0.05); malathion (0.02); parathion-methyl (0.01); pentachlorphenol (0.05); heptachlor (0.02); organotin compounds (0.01)</td>
<td></td>
</tr>
<tr>
<td>plant protecting agents and biocides: aldrin (0.01); azinphos-methyl (0.01); dichlord (0.01); dieldrin (0.01); endosulfan (0.01); para-thion-ethyl (0.01); chlorodane (0.003); diuron (0.05); hexazinone (0.05); malathion (0.02); parathion-methyl (0.01); pentachlorphenol (0.05); heptachlor (0.02); organotin compounds (0.01)</td>
<td></td>
</tr>
<tr>
<td>traces of explosives: nitro-penta (PETN) (0.5); all other substances have a detection limit of 0.1 μg/l: 2-nitrotoluene; 3-nitrotoluene; 4-nitrotoluene; 2-amino-4,6-dinitrotoluene; 4-amino-2,6-dinitrotoluene; 2,4-dinitrotoluene; 2,6-dinitrotoluene; 2,4,6-trinitrotoluene; hexogen; 2,4,6-trinitrophenol (picric acid); nitrobenzene; 1,3,5-trinitrobenzene; 1,3-dinitrobenzene; hexanitrodiphenylamine (hexyl); tetryl: octogen</td>
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</table>

Table 6. Results of diffusion analysis of Intrion [5]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Minimum value</th>
<th>Maximum value</th>
<th>Mean value</th>
<th>N</th>
</tr>
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<tr>
<td>As</td>
<td>0.84</td>
<td>0.98</td>
<td>0.91</td>
<td>7</td>
</tr>
<tr>
<td>Sb</td>
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<td>12</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>Ba</td>
<td>2</td>
<td>2.4</td>
<td>2.3</td>
<td>7</td>
</tr>
<tr>
<td>Cd</td>
<td>0.2</td>
<td>0.24</td>
<td>0.23</td>
<td>7</td>
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<tr>
<td>Cr</td>
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<td>3.5</td>
<td>2.7</td>
<td>7</td>
</tr>
<tr>
<td>Co</td>
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<td>2.4</td>
<td>2.3</td>
<td>7</td>
</tr>
<tr>
<td>Cu</td>
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<td>6</td>
<td>2.8</td>
<td>7</td>
</tr>
<tr>
<td>Hg</td>
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<td>0.07</td>
<td>0.069</td>
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</tr>
<tr>
<td>Pb</td>
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<td>5.8</td>
<td>7</td>
</tr>
<tr>
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<td>1.2</td>
<td>1.2</td>
<td>7</td>
</tr>
<tr>
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<td>0.23</td>
<td>7</td>
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<tr>
<td>Se</td>
<td>0.84</td>
<td>0.98</td>
<td>0.91</td>
<td>7</td>
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<tr>
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<td>9.8</td>
<td>9.1</td>
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<tr>
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<tr>
<td>Zn</td>
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<td>72000</td>
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N: Number of samples.
Table 7. Results of content analysis of Intron [5]

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<tr>
<th></th>
<th>Minimum value</th>
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<tbody>
<tr>
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<tr>
<td>xylenes</td>
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<td>NaF</td>
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<tr>
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<tr>
<td>BkF</td>
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<tr>
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<tr>
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<tr>
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<td>mineral Oil 2006</td>
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BIBLIOGRAPHY


