CONTROL OF AN AREA AT POTENTIAL RISK FROM INCINERATION PLANTS BEFORE THEIR START UP AND DURING THE OPERATION

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SUMMARY: The most widespread systems employed in waste management are the disposal in landfill and the incineration. It seems to be that incineration is the less dangerous choice. However, within the time, the fallout from smoke emitted from chimneys could increase the concentrations of hazardous elements and compounds in the area, with consequences on human health. Knowledge of concentration of these elements and compounds before the start up of incineration plant appears to be of great importance in addition to monitoring studies carried out during the period of operation. Both sets of data will allow a more correct management of the plant itself. In this study the areas potentially at risk from the fallout of four incineration plants were investigated: two of these plants were not operating (Trezzo D’Adda (MI) and Parona (PV)), while the other two, (Moraro and Gorizia (GO)), had been working for many years. In the areas where the plants will be built, the results show typical values of urban and industrial areas. In areas where the plants have been working for several years, concentrations of some elements are slightly higher, probably due to the waste incineration activity.

1. INTRODUCTION

The construction of large installations such as thermoelectric power plants, large factories, metallurgical industries, incineration plants, systems for concrete production, roads with heavy traffic, airports etc., should be preceded by studies to estimate the quality of the environment before operations start. The studies can be carried out considering all or some of the components like Biota, Air, Water, Soil-Sediment.
To estimate the concentrations of the elements and compounds investigated at level "zero" (i.e. before the plant is operative), scientific, political and social needs must be considered. This is important to the constructors, designers and operatives since the knowledge of the values "ante operam" will act as incentive for a more careful and good monitoring of the installation of the plant itself. The politicians need to be satisfied that environmental protection laws have been fully respected, while the citizens will expect plant inspections during operation. All this will lead to a greater respect for the environment.

With respect to the incineration plant, the study of the Soil component seems to be acceptable but it is not sufficient for a good evaluation since the accumulation of elements and trace compounds in soil cannot be monitored over short periods. Indeed the trace element concentrations vary from ten to several thousands of mg/kg but during one year the fall out corresponds only to fractions of mg/kg. It’s obvious that many years are necessary in order to quantify correctly the increase of concentration in soils. Therefore the fallout of trace elements has to be evaluated together with the study of a bioindicator (resistant to the polluting agents).

Since the vegetal bioindicator has a higher specific surface than other bioindicators it intercepts great amounts of polluting agents and so it is suitable for this study. Between the bioindicators, moss appears the most suitable (Agorelli et al., 2001).

Knowing the space distribution of the elements in mosses theDeposition Rate can be estimated (Ruhling, 1994). Soil or substrate collection, and its links with mosses allow more accurate predictions and provide information about the origin of the fallout of persistent polluting agents (Puckett and Finegan, 1980; Olmez et al., 1985).

2. MATERIALS AND METHODS

2.1 Sampling points

The area investigated extends from between 20 to 75 km². Sampling was performed on concentric circumferences of increased diameter, where the incineration plant is located at the centre (e.g. see Figure 1).

For the incineration plant of Parona (PV) a uniform grate was used. It was previously prepared and used by experts of ARPA for investigations done using lichens (Faus-Kessler et al., 2001). Every station was georeferenced by a Geographical Information System (GIS). Photos where taken in order to identify precisely the area for eventual and successive sampling.

2.2 Treatment of superficial soils and mosses

All the procedures, from the collection to the analysis of moss and soil samples, were carried out applying the methods published by the National Environment Protection Agency (Cenci, 1999), in order to achieve homogeneous data and to compare them with other experiences.

Altogether 254 samples were collected, one every 1-1,5 km²; each sample was composed of 5 sub-samples collected in a 25 square meters surface. The thickness of the soil was between 0 and 5 cm depth. The grass was previously removed. If possible the soil samples were collected in areas not recently ploughed otherwise they were collected in straight line. The 5 sub-samples were subsequently mixed and immediately homogenised in order to form a composite sample of about 2 kg. Half of the sample was placed in a treated glass container for dioxin analysis. The other half was placed in a polyethylene bag for all other analyses.

The number of soil and moss samples for each area is shown in Table 1.
Inside or in close proximity to each station, 3 cm apexes of moss branches were collected (\textit{Hypnum cupressiforme} species). The total weight of every moss sample was approximately 20 g; the samples were stored in polyethylene bags.

After crushing in a mortar and drying at 40°C, the soil samples for the analysis of trace elements, radioelements and pH, were sieved in polyethylene meshes of 2 mm. The sieved part was micronised using a planetary mortar with zirconium oxide container and spheres in order to minimise the contamination.

A sample aliquot of about 400 mg was mineralised in acid using microwave oven.

The same procedure was used for mosses.

2.3 Analysis in soils and mosses

The total Hg concentration in soil and moss sample was measured by atomic absorption spectrometry (model AMA 254). The analyses were done on the solid sample without any treatment (Cossa \textit{et al.}, 2002).

The concentrations of the inorganic elements Al, As, Cd, Cr, Cu, Hg, Ni, Mn, Pb, Sc, V and Zn in soils and mosses, were estimated by mass spectrometry with plasma source (ICP MS) (Boyle \textit{et al.}, 1982) employing a HP instrument (model 7500, Agilent Technologies, USA).

The concentration of radioelements $^{137}$Cs, $^{134}$Cs and $^{40}$K, were determined by gamma spectrometry using a germanium detector (Juznic \textit{et al.}, 1990), on about 600 g of soil placed in Marinelli plastic containers.

<table>
<thead>
<tr>
<th>Locality</th>
<th>Moraro e Gorizia (Go)</th>
<th>Trezzo D’Adda (Mi)</th>
<th>Parona (Pv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (km$^2$)</td>
<td>40</td>
<td>75</td>
<td>60</td>
</tr>
<tr>
<td>Samples</td>
<td>28+28</td>
<td>58+58</td>
<td>41+41</td>
</tr>
</tbody>
</table>

The pH was measured following Method III.1, published on the \textit{Gazzetta Ufficiale n. 248 21/10/1999}. Double determination soil-water and soil-solution was performed.

In order to estimate the concentration of the dioxins in soils, the samples were preventively frozen and freeze-dried (Heto FD6 Drywinner). The soil was homogenised and sifted (Soil Mill
Pulverisette 8) and fractions smaller than 2 mm were automatically collected. For analysis, about 60 g of soil was used after previous extraction with toluene. Purification of the extracted sample was performed by automated chromatographic adsorption (Dioxin-Power-Prep 5 Clean-Up System, FLUID MANAGEMENT SYSTEMS).

The analyses of dioxins were performed using a gas chromatograph (HRGC, HP-6890) coupled with high-resolution mass spectrometer (HRMS, Autospec Ultima). The content of the microbe biomass was estimated using the method of the fumigation-extraction. The humid soil samples, preserved at 4°C, were sieved to 2 mm, and pre-incubated for 7 days at 25°C in order to restore the microbe mass in the experimental limits (Stotzky et al., 1962). The metabolic quotient qCO₂, defined as specific respiration of the microbe mass, was calculated from the basal breathing measurements of the samples (Anderson and Domsch, 1985).

### 3. RESULTS AND DISCUSSION

In order to estimate the behaviour of mosses as bio accumulators, the Enrichment Factor (E.F.), was calculated. It compares the elements of interest in mosses and soils, using a conservative element like aluminium (Puckett and Finegan, 1980; Olmez et al., 1985) in agreement with the following formula:

$$E.F. = \frac{[X]_{\text{moss}} \times [Al]_{\text{soil}}}{[Al]_{\text{moss}} \times [X]_{\text{soil}}}$$

- $[X]_{\text{moss}}$ is the moss concentration of the element X;
- $[Al]_{\text{soil}}$ is the soil concentration of Aluminium;
- $[X]_{\text{soil}}$ is the soil concentration of the element X;
- $[Al]_{\text{moss}}$ is the moss concentration of Aluminium.

E.F. Values larger than 10 indicate an involvement of the human activities. Lower values however signify that the substrate or the soil are mainly responsible for regulating the concentration in mosses. The Deposition Rate (D.R.), of the elements was estimated using the concentration in mosses (Rhuling, 1994) in agreement with the following formula:

$$D.R. = \frac{[X]_{\text{moss}}}{F \times F \times F \times T \times F}$$

- $[X]_{\text{moss}}$ is the moss concentration of the element X;
- $E.F.F.$ is the specific efficiency factor of mosses (Dabergami e Cenci, 2002);
- $T$ are the years covered by moss cauditus;
- $F.R.$ is the Rhuling factor, equal to around 4

Table 2 shows the mean concentrations of element in mosses collected in the investigated areas. Such values are compared with the mean values obtained from studies carried out else were in Italy. The highest values of the concentrations were found in the area of Trezzo D'Adda.

The reason on such high values is the elevated anthropic degree of the area, due to many industrial activities that result in raising the concentrations of several trace elements. This assertion is supported also by the Enrichment Factors (e.g. see Table 5), where for 7 of the 10 elements, an anthropic origin is indicated. Overtime fallout in the area of Trezzo D' Adda has significantly also influenced soils. The trace elements values (e.g. see Table 3) for Cd, Cu, Pb and Zn are high. This last element (Zn) exceeds the threshold value indicated in Annex 1, Table 1, column A (soils for construction areas/green areas) of D.M. 471/1999 for contaminated sites. A comparative analysis between values of the Deposition Rates (e.g. see Table 5) once again
places the area of Trezzo D’Adda as one containing higher concentrations of all elements than in the other areas. The operation of the two incineration plants of Moraro and Gorizia does not seem to have greatly raised the concentration of the investigated elements in mosses and in soils. All the values of the E.F., which are lower than 11, exclude fallout imputable to the human activities and therefore to the incineration plants.

The ground geology of Gorizia area is particularly rich in As, Hg and other trace elements (“Relazione sullo stato dell’ambiente 2001-2002”) and this seems to play an important role in raising the concentration in mosses. Evaporation from soil and subsequent recondensation of the two elements, are the main causes of the values found in mosses.

The Parona area is subjected to a lower anthropic pressure of industrial origin. The agricultural tradition can be considered predominant for all the territory of the same province. Only the Cd in mosses and the Cr in soils show increased values referred to the investigated areas. The origin of the elements examined in most parts of the land, with the exception of Cd, Hg and Zn, is due to the soil itself.

Where the results are compared with the concentration limits in soils, fixed in DM 471/99 for construction areas/green areas, it can be asserted that for all the 4 sites considered concentrations of elements are acceptable.

The two situations of As and Zn, were concentrations exceed the limits specified in DM 471/99, are shown in column A, Table 1 of Annex 1, referred to a soil standard. If it is evident that in the study area a soil characterised by values of geologic origin (natural background), that are higher than those defined higher concentration limits characteristic of that area will be applied. This is the case of As values in the area of Gorizia. Concerning Zn, the value fixed in D.M. 471/99 is presumably a lower limit with respect to a typical mean value of the Italian soils (Musmeci 2003).

Table 2. Mean element concentrations in mosses (mg/kg) collected in the surveyed areas

<table>
<thead>
<tr>
<th>Area</th>
<th>As</th>
<th>Cd</th>
<th>Cu</th>
<th>Cr</th>
<th>Hg</th>
<th>Mn</th>
<th>Ni</th>
<th>Pb</th>
<th>V</th>
<th>Zn</th>
<th>Se</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.5</td>
<td>0.9</td>
<td>60</td>
<td>13</td>
<td>0.17</td>
<td>204</td>
<td>16</td>
<td>35</td>
<td>11</td>
<td>284</td>
<td>*</td>
</tr>
<tr>
<td>B</td>
<td>*</td>
<td>1.6</td>
<td>19</td>
<td>10</td>
<td>0.15</td>
<td>*</td>
<td>10</td>
<td>19</td>
<td>*</td>
<td>153</td>
<td>*</td>
</tr>
<tr>
<td>C</td>
<td>1.5</td>
<td>0.3</td>
<td>22</td>
<td>8</td>
<td>0.21</td>
<td>12</td>
<td>11</td>
<td>16</td>
<td>84</td>
<td>0.35</td>
<td>*</td>
</tr>
<tr>
<td>D</td>
<td>0.3</td>
<td>0.3</td>
<td>9</td>
<td>3</td>
<td>0.07</td>
<td>2</td>
<td>11</td>
<td>3</td>
<td>42</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

*not evaluated
A: Trezzo D’Adda (Mi) (Cenci et al., 2003)
B: Parona (Pv) Cenci, 2002
C: Moraro e Gorizia (Go) (Cenci et al., 2001)
D: Italian Mean (Rhuling and Steinnes, 1998)

Table 3. Mean trace element concentrations (mg/kg) in soils collected in the surveyed areas

<table>
<thead>
<tr>
<th>Area</th>
<th>As</th>
<th>Cd</th>
<th>Cu</th>
<th>Cr</th>
<th>Hg</th>
<th>Mn</th>
<th>Ni</th>
<th>Pb</th>
<th>V</th>
<th>Zn</th>
<th>Se</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>18</td>
<td>0.67</td>
<td>84</td>
<td>61</td>
<td>0.13</td>
<td>1160</td>
<td>60</td>
<td>88</td>
<td>59</td>
<td>181</td>
<td>*</td>
</tr>
<tr>
<td>B</td>
<td>*</td>
<td>0.31</td>
<td>39</td>
<td>82</td>
<td>0.16</td>
<td>*</td>
<td>45</td>
<td>56</td>
<td>*</td>
<td>128</td>
<td>*</td>
</tr>
<tr>
<td>C</td>
<td>39</td>
<td>0.58</td>
<td>54</td>
<td>58</td>
<td>0.51</td>
<td>*</td>
<td>62</td>
<td>59</td>
<td>79</td>
<td>112</td>
<td>10</td>
</tr>
<tr>
<td>D</td>
<td>*</td>
<td>0.50</td>
<td>51</td>
<td>100</td>
<td>*</td>
<td>*</td>
<td>46</td>
<td>21</td>
<td>*</td>
<td>89</td>
<td>*</td>
</tr>
<tr>
<td>E</td>
<td>15</td>
<td>120</td>
<td>150</td>
<td>1</td>
<td>120</td>
<td>100</td>
<td>100</td>
<td>150</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*not evaluated
A: Trezzo D’Adda (Mi) (Cenci et al., 2003)
B: Parona (Pv) (Cenci, 2002)
C: Moraro e Gorizia (Go) (Cenci et al., 2001)
D: Italian Mean (Ministero dell’Ambiente, 1997)
E: D.M. Nr. 471 of 1999, Annex 1, Table 1, column A
Table 4 shows pH values, some radio element concentrations, dioxins and microbe biomass of Trezzo D'Adda soils. Such values are of great interest, for comparison with surveys that will be carried out in the future years.

As far as the values of dioxins are concerned, their concentrations are generally lower in Italy and in Europe (Cenci et al., 2003). If the dioxins values are compared with the limit concentration fixed in D.M. 471/99 in soils for construction areas/green areas, corresponding to 10 pg/g, the values found in the studied areas are at least an order of magnitude lower.

The activity of the radio elements is comparable with the values obtained in several other European areas (Queirazza and Bozzani, 1998; Volke and Gobert, 1999; D'Alberti et al., 1999; Cenci et al., 2001). Mean values obtained from the analysis of the microbe biomass do not suggest particular stress on the soil. Values obtained here overlap with those found in areas without direct industrial pressure (Trincheria, 2002).

Table 4. Parameters obtained in the collected soil samples in Trezzo D'Adda

<table>
<thead>
<tr>
<th>Parameter</th>
<th>pH</th>
<th>pH</th>
<th>Dioxins</th>
<th>Tc</th>
<th>Cs</th>
<th>Cs</th>
<th>K</th>
<th>Bc</th>
<th>CO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min.</td>
<td>4.5</td>
<td>3.7</td>
<td>0.08</td>
<td>13</td>
<td>0.2</td>
<td>18</td>
<td>75</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Max.</td>
<td>8.1</td>
<td>7.6</td>
<td>1.14</td>
<td>756</td>
<td>3.9</td>
<td>287</td>
<td>711</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>6.6</td>
<td>5.8</td>
<td>0.29</td>
<td>108</td>
<td>0.7</td>
<td>187</td>
<td>276</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grazing ground</td>
<td>&lt;1-43</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cultivable ground</td>
<td>1.9-3.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** in H.O.
*** in KCl
* 2,3,7,8-PCDD/F
b microbe biomass content
c metabolic quotient
d Trincheria, 2002 (a, Pinus pinus forest; b, hydrophilic forest)

Table 5. Abundance of the Enrichment Factor and Deposition Rate

<table>
<thead>
<tr>
<th>Locality</th>
<th>As</th>
<th>Cd</th>
<th>Cu</th>
<th>Cr</th>
<th>Hg</th>
<th>Mn</th>
<th>Ni</th>
<th>Pb</th>
<th>V</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>**Trezzo D'Adda 0-10</td>
<td>60</td>
<td>8</td>
<td>9</td>
<td>58</td>
<td>8</td>
<td>4</td>
<td>7</td>
<td>19</td>
<td>60</td>
<td>15</td>
</tr>
<tr>
<td>**Trezzo D'Adda &gt;10</td>
<td>0</td>
<td>52</td>
<td>51</td>
<td>2</td>
<td>52</td>
<td>56</td>
<td>53</td>
<td>41</td>
<td>0</td>
<td>45</td>
</tr>
<tr>
<td>Paras 1&lt;1</td>
<td>*</td>
<td>4</td>
<td>36</td>
<td>41</td>
<td>11</td>
<td>*</td>
<td>41</td>
<td>35</td>
<td>*</td>
<td>12</td>
</tr>
<tr>
<td>Paras 1&gt;10</td>
<td>*</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>60</td>
<td>*</td>
<td>0</td>
<td>6</td>
<td>*</td>
<td>29</td>
</tr>
<tr>
<td>Gorizia 1&lt;1</td>
<td>28</td>
<td>23</td>
<td>23</td>
<td>28</td>
<td>25</td>
<td>*</td>
<td>27</td>
<td>28</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Gorizia 1&gt;10</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>3</td>
<td>*</td>
<td>1</td>
<td>0</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>**Trezzo D'Adda</td>
<td>6.6</td>
<td>0.9</td>
<td>64</td>
<td>8.1</td>
<td>0.2</td>
<td>255</td>
<td>18</td>
<td>28</td>
<td>11</td>
<td>286</td>
</tr>
<tr>
<td>**Paras</td>
<td>3.3</td>
<td>0.2</td>
<td>20</td>
<td>1.7</td>
<td>0.2</td>
<td>147</td>
<td>11</td>
<td>15</td>
<td>6</td>
<td>208</td>
</tr>
<tr>
<td>**Gorizia</td>
<td>1.5</td>
<td>0.3</td>
<td>61</td>
<td>0.2</td>
<td>*</td>
<td>12</td>
<td>6</td>
<td>7</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

*not evaluated
** Abundance of the Enrichment Factor in the considered areas
*** Deposition Rate (g/ha year)

4. CONCLUSIONS

As expected, the spatial distribution of the elements with the moss method appears variable since it is influenced by the activities of Man carried out on a daily by the soil or the substrate itself, and by the elements transported over from elsewhere long distances.

From these results it clear that some areas are subjected to more consistent specific contamination, even if this does not effect the entire areas studied.
In fact the mean concentrations of the substances studied are always within the limits of quality for soils for construction areas/green areas defined at national level (D.M. 471/99).

Elemental values found in areas with waste incineration plants, that are currently operating and have operated for some decades, do not shown significant enrichment in soils or in mosses compared with areas without such systems. Eventually, emissions of trace elements from chimneys, do not seem to have strongly increases the concentration of those elements in the study areas. It is clear that the industrial activities have modified some environmental parameters.

The monitoring carried out in the four areas provides important environmental results, fixing concentration levels that will be useful as a comparison for future investigations carried out in these areas.

REFERENCES


Decreto Ministeriale 25 Ottobre 1999, n. 471. 1999. Regolamento recante criteri, procedure e modalità per la messa in sicurezza, la bonifica e il ripristino ambientale dei siti inquinati, ai


