Chapter 10

Cadmium in Soils and Plants
Summary and Research Perspectives

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1. INTRODUCTION

Cadmium can be a potential threat to a wide range of biota because (i) it is non-essential and non-metabolic, (ii) it is toxic to humans at concentrations lower than those toxic to plants, (iii) it is more mobile and bioavailable than other metals, and (iv) its effects on humans are cumulative. The major source of Cd entry to the human body is food but smoking and occupational exposure to Cd are also important sources of this metal. Since food crops grown on Cd-contaminated soils or on soils naturally rich in this metal (for example, black shales) are the main source of Cd burden to the human body, an understanding of Cd behaviour in the soil-plant system is of great importance.

Cadmium in soils originate either from geological parent materials (Adriano, 1986; Jeng, 1992) or from anthropogenic pathways (Kabata-Pendias and Pendias, 1992; Singh, 1994). Cadmium addition to soils through anthropogenic emissions may exceed the input of this metal from natural sources by two-fold or more (Nriagu and Pacyna, 1988) and thus anthropogenic sources are dominant. Nriagu and Pacyna (1988) estimated the world-wide input of Cd to soils through different anthropogenic sources (Table 10.1). Such estimates of natural Cd inputs (for example, weathering of Cd containing parent materials) to soils are not available. It has, however,
been also pointed out that the uncertainty in such estimates is great enough
to prevent accurate partitioning of any global Cd emissions into natural and
anthropogenic categories (Rasmussen, 1996).

Besides atmospheric deposition, the other two important sources of Cd
applied to agricultural soils are phosphatic fertilisers and sewage sludges.
The concentration of Cd in both these materials can vary considerably and
hence the total load of Cd through these materials will vary from place to
place.

Table 10.1 World-wide emissions of Cd (10^6 kg yr^{-1}) the proportional input (%) in
parenthesis from different sources

<table>
<thead>
<tr>
<th>Sources</th>
<th>Emission</th>
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<tbody>
<tr>
<td>Agricultural and animal wastes (including fertilisers)</td>
<td>0.23–4.5  (11.7)</td>
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<tr>
<td>Logging and wood wastes</td>
<td>0.2–2.2   (5.8)</td>
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<tr>
<td>Urban refuge and sludge</td>
<td>0.7–7.8   (20.5)</td>
</tr>
<tr>
<td>Fly-ash</td>
<td>1.5–13    (34.2)</td>
</tr>
<tr>
<td>Atmospheric deposition</td>
<td>2.2–8.4   (22.1)</td>
</tr>
<tr>
<td>Others</td>
<td>0.77–2.15 (5.4)</td>
</tr>
<tr>
<td>Total input to soil</td>
<td>5.6–3.8</td>
</tr>
</tbody>
</table>

Extracted from Nriagu and Pacyna (1988).

2. CADMIUM IN SOILS

2.1 Chemical state

Cadmium concentrations in soil range from low in uncontaminated soils
to high in soils receiving large quantities of Cd through agricultural and
industrial activities or in soils naturally rich in Cd. In spite of the level of Cd
in soils, the speciation and fate of Cd is controlled to a greater extent by
parent material composition and the intrinsic soil properties. Knowledge of
chemical forms or speciation of Cd in solution phase as well as in solid
phase in soils is potentially valuable in predicting bioavailability, leaching
rates and transformations between chemical forms in contaminated and non­
contaminated soils. Solution speciation can include element identification,
oxidation state, empirical formula and molecular structure whereas the solid
phase speciation can identify the specific solid responsible for the aqueous
solubility and the chemical and biological lability of the metal. A number of
methods such as polarography, radiochemical trace analysis, electronic
spectroscopy (UV-VIS-NIR), nuclear magnetic resonance (NMR), x-ray
absorption spectroscopy (XANES, EXAFS) and x-ray fluorescente
(microprobe) are suitable for solution speciation and solid-phase speciation
(Brown, 1995). Some of them, such as polarography and radiochemical trace