

MOBILIZATION OF HEAVY METALS FROM COAL-FIRED POWER PLANTS : POTENTIAL IMPACT ON GROUNDWATER

L. GOETZ, G. BIGNOLI and E. SABBIONI

Commission of the European Communities, Joint Research Centre - Ispra Establishment
Radiochemistry and Nuclear Chemistry Division
21020 Ispra (Va) - Italy

ABSTRACT

Heavy metal content in power plant coals was determined by neutron activation analysis. The obtained data were the basis of an assessment of the mobilization of heavy metals by coal-fired power plants situated in the territory of the Member States of the European Communities.

A dynamic compartmental model was applied to assess the migration of stack emitted Cd through soil to groundwater in the surroundings of a reference power plant. Results indicate a small time dependent increase (< 1%) of Cd groundwater concentration over endogenous levels.

INTRODUCTION

Electricity generation in the countries of the European Communities (EC) by coal burning is likely to increase substantially in the next decades. As coal contains traces of nearly all heavy metals (HM), which could be enriched in various combustion products and dispersed into the biosphere, the environmental impact of HM mobilized by coal-fired power plants must be assessed.

The aim of the present study is the assessment of the potential impact of HM from atmospheric stack emissions of coal-fired power plants on groundwater.

In order to reach this goal, the following investigations were performed:

- (i) the assessment of the quantities of HM mobilized by hard coal-fired power plants situated in the territory of the Member States of the EC;
- (ii) the assessment of the amounts of HM contained in atmospheric stack emissions;
- (iii) the assessment of the potential impact of stack emitted HM on groundwater using Cd as a reference case.

RESULTS

Total mobilization of HM by coal-fired power plants

Neutron activation analysis was applied for the determination of HM contents in 29 power plant hard coal samples, both indigenous and imported. The values obtained were compared with data from the literature and reasonable weighted mean values for coals burnt in each of the Member States of the EC were calculated (ref. 1).

Table 1 reports the weighted mean values (ppm) of HM content in hard coals presently burnt in coal-fired power plants in the Member States of the EC. As the work was performed before 1981, values for Greece are not yet included.

Starting from the most recent forecasts of electricity generation by hard coal burning in the Member States of the EC, total mobilization of HM for the years 1978, 1980, 1985 and 1990 could be calculated (ref. 2). Mo, As, Cu, Cr, Ni, Pb, V and Zn are mobilized in amounts varying from 1,000 to 20,000 metric tons per year, Hg, Cd, Tl, U, Se, Sb and Th in amounts from 50 to 1,000 metric tons per year (Fig. 1).

TABLE 1

Weighted most reasonable mean values (ppm) of HM contents in hard coals burnt in power stations situated in the territory of the EC

Constituent	Member State								
	B	D	DK	F	I	IRL	LX	N	UK
As	6.5	14.5	10	9.7	10	10	10	10	16.8
Cd	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3
Cr	60	25	44	36	44	44	44	44	32
Cu	42	33	22	8.4	22	22	22	22	18
Hg	0.38	0.4	0.28	0.2	0.28	0.28	0.28	0.28	0.28
Mo	2.2	14	4.6	4.6	4.6	4.6	4.6	4.6	3
Ni	55	45	38	38	38	38	38	38	38
Pb	85	68	53	44	53	53	53	53	22
Sb	1.9	1.4	2.2	3.4	2.2	2.2	2.2	2.2	3.3
Se	1.6	1.5	1.7	1.3	1.7	1.7	1.7	1.7	2.8
Tl	1	1	1	1	1	1	1	1	1
Th	4.4	2.1	4.0	6	4.0	4.0	4.0	4.0	3.8
U	2.1	1.0	2.2	3.1	2.2	2.2	2.2	2.2	2
V	72	75	65	65	65	65	65	65	48
Zn	165	73	107	172	107	107	107	107	57

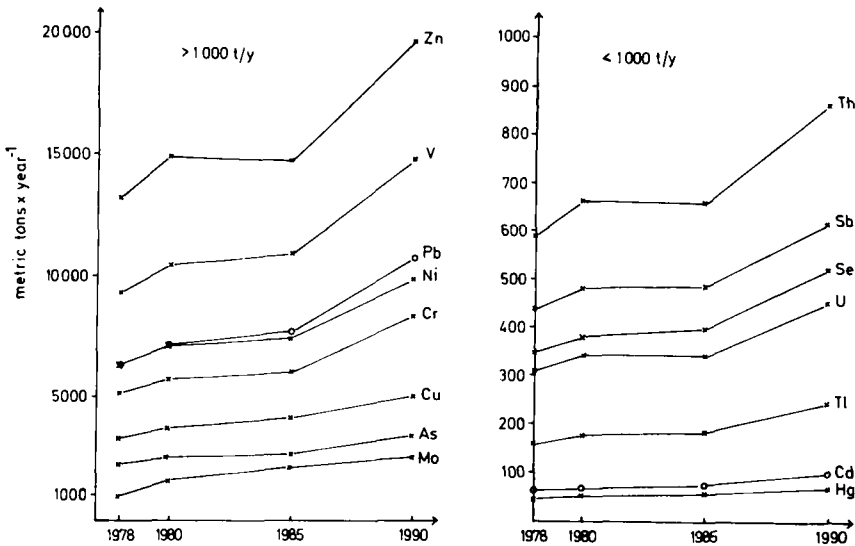


Fig. 1. Calculated total HM mobilization by hard coal-fired power stations in the territory of the European Communities.

HM contained in atmospheric stack emissions

Assuming that the coal-fired power plants were of the dry bottom boiler type (90% fly ash, 10% bottom ash) equipped with electrostatic precipitators with an efficiency of 99.5% and using the weighted means of enrichment factors of HM in emitted fly ash particles and gaseous stack emissions, as derived from US mass balance data for coal-fired power plants, the amount of HM in atmospheric stack emissions could be assessed (Table 2).

TABLE 2

Calculated HM content in particulate and gaseous stack emissions for the year 1985 in the Member States of the EC [metric tons]

Element	Member State									EUR-9
	B	FRG	DK	F	I	IRL	LX	N	UK	
As	1.08	20.9	3.2	4.4	2.2	0.18	3×10^{-4}	1.0	44.6	77.5
Cd	0.08	0.68	0.15	0.21	0.10	0.008	1.4×10^{-5}	0.05	0.73	2.0
Cr	3.4	12.2	4.7	5.5	3.3	0.26	4×10^{-4}	1.5	28.7	59.6
Cu	1.6	11.1	1.6	0.88	1.14	0.09	1×10^{-4}	0.52	11.1	28.1
Hg	1.96	17.8	2.7	2.8	1.9	0.18	2.7×10^{-4}	0.89	22.6	50.8
Mo	0.15	8.4	0.6	0.86	0.43	0.034	6×10^{-5}	0.19	3.3	14.0
Ni	1.26	8.9	1.64	2.34	1.16	0.09	2×10^{-4}	0.53	13.8	29.7
Pb	8.7	60.5	10.3	12.2	7.3	0.58	1×10^{-3}	3.35	35.9	138.8
Sb	0.26	1.65	0.57	1.25	0.41	0.03	5×10^{-5}	0.18	7.1	11.5
Se	1.3	10.6	2.6	2.9	1.9	0.14	3×10^{-4}	0.86	36.3	56.6
Th	0.10	0.42	0.17	0.37	0.12	0.01	2×10^{-5}	0.057	1.40	2.65
Tl	0.17	1.45	0.32	0.45	0.22	0.018	1.3×10^{-4}	0.10	2.65	5.38
U	0.14	0.57	0.28	0.56	0.20	0.015	2×10^{-5}	0.090	2.12	3.98
V	4.24	38.3	7.3	10.4	5.1	0.40	7×10^{-4}	2.4	45.1	113.2
Zn	16.5	63.3	20.3	46.5	14.3	1.1	2×10^{-3}	6.6	90.7	259.3

Impact of emitted HM on groundwater using Cd as a reference case

To predict the time dependent movement of HM from atmosphere to surface soil and through the soil column to groundwater, a system analysis model (ref. 3) has been applied. This models the environmental system as separate interconnected compartments. Cd emitted from the stack (150 m) by a 500 MW_{e1} coal-fired power plant unit (50% annual full load) was chosen as a reference case. Compartmental concentrations of Cd in surface soil, sub soil column and groundwater are given in Fig. 2.

The time of appearance of Cd originating from stack emissions of the reference coal fired power plant, despite variables such as soil compartment sizes, vertical pore water velocity, etc., is mainly dependent upon the specific soil water distribution coefficients of the various compartments. Velocity of groundwater longitudinal movement is the parameter which mainly determines the following time dependent increase of Cd concentration in the groundwater compartment.

Finally, Cd concentration in the groundwater of the Member States of the EC and its increase over the total endogenous level as a consequence of 40 years of coal-fired power plants stack emissions were calculated using the parameters adopted for the reference case. Obtained values show an increase of 7×10^{-4} % (Ireland) to 0.023% (United Kingdom and Denmark) over the normal endogenous level of 0.0007 ppm (ref. 4), whereas the recommended maximum permissible Cd concentration for drinking water in the EC is fixed at 0.005 ppm (ref. 5).

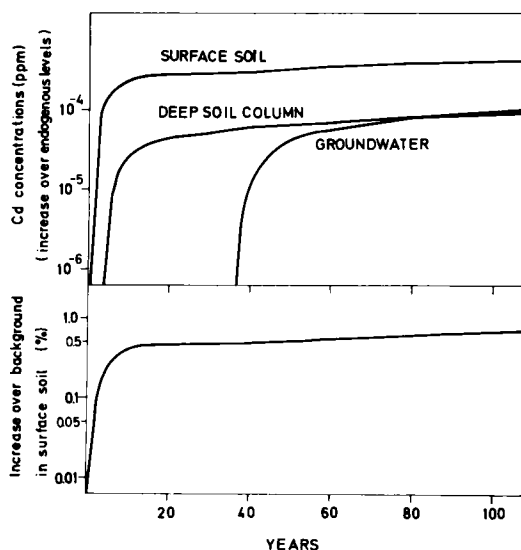


Fig. 2. Prediction of concentrations in soil compartments and groundwater as well as of the increase over background surface soil levels (0.06 ppm) of Cd which should be emitted from the stack in the surroundings ($r = 10$ Km) of a hypothetical coal-fired power plant unit of 500 MW_el.

CONCLUSIONS

This study supports the prediction of only limited impact on groundwater of HM released in atmospheric stack emissions of coal-fired power plants, because HM input is minimized by the high grade of dilution and dispersion by the stack and by the high efficiency of electrostatic precipitators. This shifts the burden of potential HM contamination to local landfills. Therefore, not only HM contained in the stack emissions but also the bulk of land disposed fly and bottom ashes should be included in the assessment of the potential impact on groundwater quality of HM from coal-fired power plants.

Values of Cd concentrations in groundwater as a consequence of stack emissions from coal-fired power plants reported here are clearly not site specific. They are intended only to indicate the type of results one may reasonably expect to obtain from the application of the model.

Chemical forms of HM in emitted fly ash and gases and the water leaching processes of HM from surface and matrix of fly ash particles have not been taken into consideration because only poor data are available.

Better knowledge of soil water distribution coefficients of the single HM and their different chemical forms and knowledge of influencing parameters such as pH variation, co-precipitation, oxidation-reduction, complexation, effects of other competitive ions, etc., is absolutely necessary in order to introduce values into the model which conform as closely as possible to reality.

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