ENVIRONMENTAL EFFECTS OF HEAVY METALS DIS-TRIBUTED FROM POWER PLANTS

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Increased prices on oil have resulted in the search for other energy sources, eg coal, peat, biomass, different types of waste a.s.o. Combustion especially of waste, coal and peat emits large quantities of air pollutants such as heavy metals but also harmful organic substances. Heavy metals are not easily separated from the smoke, and the concentrations are often high in the emissions even with advanced fly-ash separators.

Ecological investigations carried out around a coal burning power plant in Finland using mosses and pine needles as parameters are presented in the paper. Increased concentrations of Pb, Cd, Cr, Ni, Cu, and V have been found near the plant. Often a clear gradient was found with increased concentrations at decreased distance from the power plant.

INTRODUCTION

high concentrations of heavy metals.

particles to be ionized in an electrone filter Several pilot studies recently, using lime tools to carry out effect studies.

Compared to oil most solid fuels as for stabilization and textile filters, have improved example coal, peat, biomass, different types the separation results but only to a certain of waste a.s.o. contain higher concentrations extent and with a low statistical significance. of heavy metals, and mostly the emissions of The concentrations of heavy metals vary organic polyaromatic compounds are high. considerably in different types of coal and Especially coal, peat and solid waste contain peat depending on their geographical origin.

The fact that heavy metals are accumulated Even with advanced dust separation and in living organisms and in the ecosystem as a stack gas cleaning heavy metals might whole is a reason to pay especial interest to constitute a severe environmental problem. these elements and to their atmospheric and Heavy metals are mostly bound to too small biological distribution and effects. Biological parameters as moss- and pine-needleand are not souluble in a wet scrubber. investigations as used in this study are good

COMPARISON OF ENVIRONMENTAL EFFECTS FROM DIFFERENT SOLID FUELS

Combustion of solid waste or material concentrations in different fractions of solid separated from solid waste mostly emit waste and where it can be seen that paper and considerable amounts of heavy metals mostly plastics make up for a high percentage. The exceeding the concentrations obtained from heavy metals derive from bleaching and other solid fuels (BRAMRYD 1979). This can stabilizing processes in paper industry and be verified from table 1 showing heavy metal from printing. Plastics have especially high

Table 1. Metal concentrations in different fractions of solid household waste (in %)

Fraction	Metal (%)											
	Cd	Со	Cr	Cu	Hg	Mn	Ni	Pb	Zn			
Plastics	26	1	5	2	10	1	1	5	1			
Paper	4	5	7	11	13	18	3	3	11			
Textiles	1	1	1	2	4	1	1	1	1			
Rubber and leather	4	1	42	1	3	1	1	2	3			
Plant residues and food wastes	3	2	3	4	8	5	4	3	5			
Metals	60	88	43	22	60	74	87	85	68			
Others	3	4	3	63	3	4	6	4	6			

Table 2. Heavy metal emissions from two solid waste incinerators in Stockholm compared with emissions caused by heating of houses in the whole city. About 200 x 106 kg solid waste burned each year. Incinerators equipped with electrone filters for the stack gases.

Metal	Emissions Kg/year								
	Solid waste incineration	Heating of houses							
Pb	2 000	170							
Cd	100	20							
Cu	240	150							
Cr	100	30							
Hg	40	6							
Ni	30	300							
Zn	5 000	160							

of some heavy metals from two big from peat burning often can reach the same incinerators in Stockholm, Sweden, with the order of magnitude as the emissions from emissions caused by heating of houses in the coal fired power plants.

whole city. The incinerators were handling approximately 200 000 ton solid household garbage per year and were equipped with electrone filters for the stack gas cleaning (Stockholm Environment and Health Administration 1975).

The concentrations of heavy metals in coal from different parts of the world vary considerably as well as often the results from different analyzes of the same type of coal depending on different analyzation techniques and inhomogenity in the coal layers (Council for Energy production Research 1977) (BRAMRYD et al 1980). This is illustrated in table 3 which presents average values based on several recent calculations for some heavy metals in the most discussed

The heavy metal concentrations in peat depend mainly on geographical region from concentrations of Cd and Cr (HOVSENIUS where it originates and type of peatland. 1977). Table 2 compares the total emissions Calculated per energy unit the emissions

Table 3 Heavy metal concentrations in different types of solid fuels in ppm.

Metal	Fuel												
	Oil	Coal	Peat	Wood	Solid waste								
Cd	> 0.01	0.01-2.0	> 0.2	1.0	2.0-5.5								
Co	0.5	1-40	> 0.3	0.3	2-7								
Cr	0.03	2-50	>1.0-6.0	0.1-3.0	10-60								
Cu	0.3	0.4-40	3.0-15.0	2.0-25	100-1500								
Hg	0.002	0.07 - 1.5	0.05	0.05	0.5-3.0								
Mn	0.1	25-100	10-170	5-100	400-1400								
Ni	20	4-60	1.0-4.0	0.5-1.5	5-30								
Zn	0.5-1.0	5-100	5-50	50-100	600-1600								

The metal concentrations in wood depend strongly on which fraction of the tree biomass that is being burnt. Bark and fine twigs mostly contain considerably higher amounts of reliable gas purification techniques are urgent heavy metals than for example the stem also when these types of fuels are used. In wood. Some deciduous tree species as for example many Salix- and Populus species might be able to selectively accumulate heavy metals deriving from air pollution (TYLER

pers comm). It is thus important to note that also wood and peat can cause heavy metal problems and that increased efforts to find addition to heavy metals the emissions of harmful polyaromatic compounds are much more accentuated for solid fuels than for oil.

ECOLOGICAL INVESTIGATIONS AROUND A COAL FIRED POWER PLANT

Study area

around Inkoo coal fired power plant in were taken for Hylocomium splendens and Finland. The power plant is situated in the Pleurozium schreberi. Pine needles were archipelago at the Finnish Bay about 60 km collected from about 10-15 trees in each west of Helsinki. The power plant has 4 coal locality, where possible from four directions fired units each of about 265.5 MW and of each single tree. Two year old needles were equipped with electrone filters for stack gas selected and dried for chemical analyzes. The cleaning. The first unit was started in 1973 trees were chosen at the outer SW part of the and the fourth in 1978. Mostly coal from forest stand in order to avoid an air-filtrating Poland or the Soviet Union is used. The effect from the forest. chimneys are 150 m and with a velocity of the The three latest year segments of the stack gases of approximately 20 m/s at the mosses were selected and dried. 1 g of the

The surrounding areas are mostly dominated by spruce- and pineforests interupted with agricultural lands.

Material and Methods

In order to map heavy metal accumulation Pleurozium schreberi as well as pine needles FOLKESSON (1978). were used to investigate the heavy metal accumulation. Sampling localities were chosen at the distances 0.2 km, 0.7 km, 1.2 Results and discussion km, 1.8 km, 3.0 km, 5.0 km, 8.4 km, 15.0 km, 23.0 km, and 33.0 km from the power plant. direction.

Within each locality moss samples were collected from about 15 areas and were put Ecological investigations were carried out together in one sample. Separate samples

moss fractions and 3 g of the dried pine needles were oxidized in a mixture of concentrated nitric- and perchloric acid in the proportions 4:1. After wet oxidation and filtration the heavy metal concentrations were analyzed using atomic absorption spectrophotometri. Analyzes were made for Cd, Cr, Cu, Ni, Pb, V and Zn. The obtained values were compared with background values for around the power plant a gradient was chosen southern Finland (TYLER pers comm). The in a NE direction from the plant as this was background values for Pleurozium schreberi the dominating wind direction. Samples of have been calculated using correlation the mosses Hylocomium splendens and coefficients being worked out by

Table 4 summarizes the results of the heavy Locality 11 and 12 were chosen 1 km east and metal investigation. Almost all heavy metals 0.3 km west of the power plant respectively, in are found in higher concentrations in the five order to compare concentrations with the localities nearest the power plant than in the corresponding values in the dominating wind five localities more remote. All analyzed metals, except zinc, are above the background

Table 4. Heavy metal concentrations for localities 1-12. Mean values for the localities 1-5, 6-10, and 1-10 are shown together with the standard deviation. BF are background values for the metal concentrations in Southern Finland using the different plant species (in ppm).

ylocomium sple	ndens															
Sampling site	1	2	3	4	5	MV 1-5	6	7	8	9	10	MV 6-10	MV 1-10	11	12	BF
Dist.in km from the power plant	0,2	0,7	1,2	1,8	3,0		5,0	8,4	15,0	23,0	33,0					
Zinc Zn	83,2	45,0	51,2	_		59,4 ±16,8	46,8	55,0	60,9	58,4	68,4	57,3 ±7,9 ±	58,6	46,0	62,0	70-75
Cadmium	2,7	2,8	2,2	_	2,4	2,5 ±0,3	3,4	0,9	0,7	1,1	1,3	1,5 ±1,1		1,8	2,0	0,5
Copper	18,0	12,5	13,0	_	17,2	15,2 ±2,8	16,7	13,0	14,0	15,0	17,3	15,2 ±1,8	15,2 ±2,1	11,0	14,0	9,0
Nickel	23,6	14,3	14,2			16,5 ±4,7	11,5	8,3	7,1	8,3	12,3	9,5 ±2,3	12,6 ±5,0	9,4	13,0	5,0
Chromium	7,6	19,1	6,8	_	9,0	10,6 ±5,7	7,1	5,1	6,0	7,6		6,0 ±1,2	8,6 ±4,3	6,8	4,7	4,0
Lead Pb	140,0	127,4	_		131,9	133,1				97			119,3	60,0	43,0	60,0
Vanadium	69,2	52,9	31,1	-	41,1	48,6 ±16,4	24,1	20,8	17,3		31,1	22,8 ±5,2	34,3 ±17,3	35,0	55,0	10,0
Pleurozium sc	hreber	i														
Sampling	1	2	3	4	5	1-5	6	7					1-10		12	BF
Zinc	55,0	60,9	63,4	63,8	_	60,8 ±4,1	81,5	59,4	53,0	60,9		63,2 ±10,8		50,0	66,0	74-79
Cadmium	1,8	2,2	1,6	1,1		1,7 ±0,5	1,8	3,0	1,9	2,0	2,2		2,0 ±0,5	2,7	0,0	0,3
Copper	11,0	11,0	12,0	9,0		13,3 ±3,9	12,6	15,1	11,0	11,0	14,4		13,0 ±2,7	12,0	17,0	7,0
Nickel Ni	18,0	18,0	14,0	17,0		16,8 ±1,9	14,4	18,9	13,3	3 11,0	11,0		15,1 ±3,0	16,0	13,0	3,0
Lead Pb	30,0	60,0	40,0	60,3		47,5 ±15,0	52,0	57,0	42,0	70,0	50,0	54,2 ±10,4	51,0 ±12,3	44,0	43,0	46,0
Vanadium	65,7	24,2	34,5	34,5	-	39,7 ±18,0		26,1	21,8	3 17,5	3 27,7		31,5 ±14,1	41,(59,0	

Sampling site	1	2	3	4	5	1-5	6	7	8	9	10	6-10	1-10	11	12	BF
Zinc Zn	46,2	56,0	49,4	51,2	44,8	49,5 ±4,4	49,2	45,0	56,0	46,6	58,7	51,1 ±6,0		38,0	66,0	_
Cadmium Cd	1,6	1,2	1,0	1,2	1,0	1,2 ±0,3	0,9	1,2	0,8	1,3	1,9		1,2 ±0,3	1,4	1,0	0,02-
Copper	3,9				3,1	3,6 ±0,3	3,2	4,0	3,4	3,5	4,4	3,7 ±0,5		3,4	3,6	
Nickel Ni	2,0	1,7	2,3	2,0	1,7	1,9 ±0,3	1,8	1,5	1,3	1,7	2,0	1,7 ±0,3		1,5	1,7	
Chromium Cr	2,3	0,6	1,1	2,3	0,8	1,4 ±0,8	1,7	2,0	1,1	1,1	1,7	1,5 ±0,4		1,7	2,0	0,6- 4,4

for Cd clearly exceed the background values for Finland. As can be seen from figure 1, a tendency of decreasing values can be seen at increasing distances from the power plant. The weak increase at distances between 20-30 km from the power plant can be explained by urban influence from Helsinki. The Cd concentrations found between 0.8-2.0 ppm in this investigation are however relatively low compared to smelting industries and other cadmium emitting factories, where concentrations in the surroundings with up to 2-25 ppm often are found (Stockholm Environment and Health Authority 1975).

Similar trends as for Cd can be found within the gradient for most investigated heavy metals, where the locality most remote from the Inkoo plant often seems to be influenced by Helsinki urban area.

localities 0.2-1.0 km from the plant are surprising taking the high chimney into consideration but can probably be explained by dust and exhaust from the coal- and ash-transportations around the power plant. Transportation of fly ash on open lorries probably make up for a large quantity of the added heavy metals. Especially the vanadium and nickel concentrations in Hylocomium splendens moss were significantly raised close to the power plant (figure 1).

Air pollution and dust are not the only

values for southern Finland. The mean values sources of heavy metals around a power plant. Investigations by BRAMRYD et al (1980) have found clearly increased concentrations of heavy metals in drainage water from ash dumps. Especially high concentrations were found for vanadium.

Heavy metal emissions from power plants are mostly coupled with emissions of acidifying substances. Reaching the plants and the soil as inorganic salts the penetration of heavy metals into aboveground plant tissues as well as the mobility in soil is faciliated by a decreased pH.

Conifers are especially sensitive to acidification and high amounts of heavy metals (GRESZTA 1972) which can decrease the productivity significantly in such areas. Close to the Inkoo power plant necroses were found on spruce, probably due to dust application.

The mobility in soil and plants is different The high metal concentrations found in for different heavy metals depending on the transport mechanisms for the metal. Heavy metal pollution have disturbing effects on soil mechanisms with a decreased decomposition rate at increasing concentrations of some heavy metals. The activity of urease, an enzyme active in the nitrogen mineralization process, is reduced with increasing metal pollution. Concentrations of Cu exceeding 50-300 ppm, or about 2-10 times the background values, and of Zn exceeding about 1200 ppm, or about 6 times the background values, significantly reduce the nitrogen

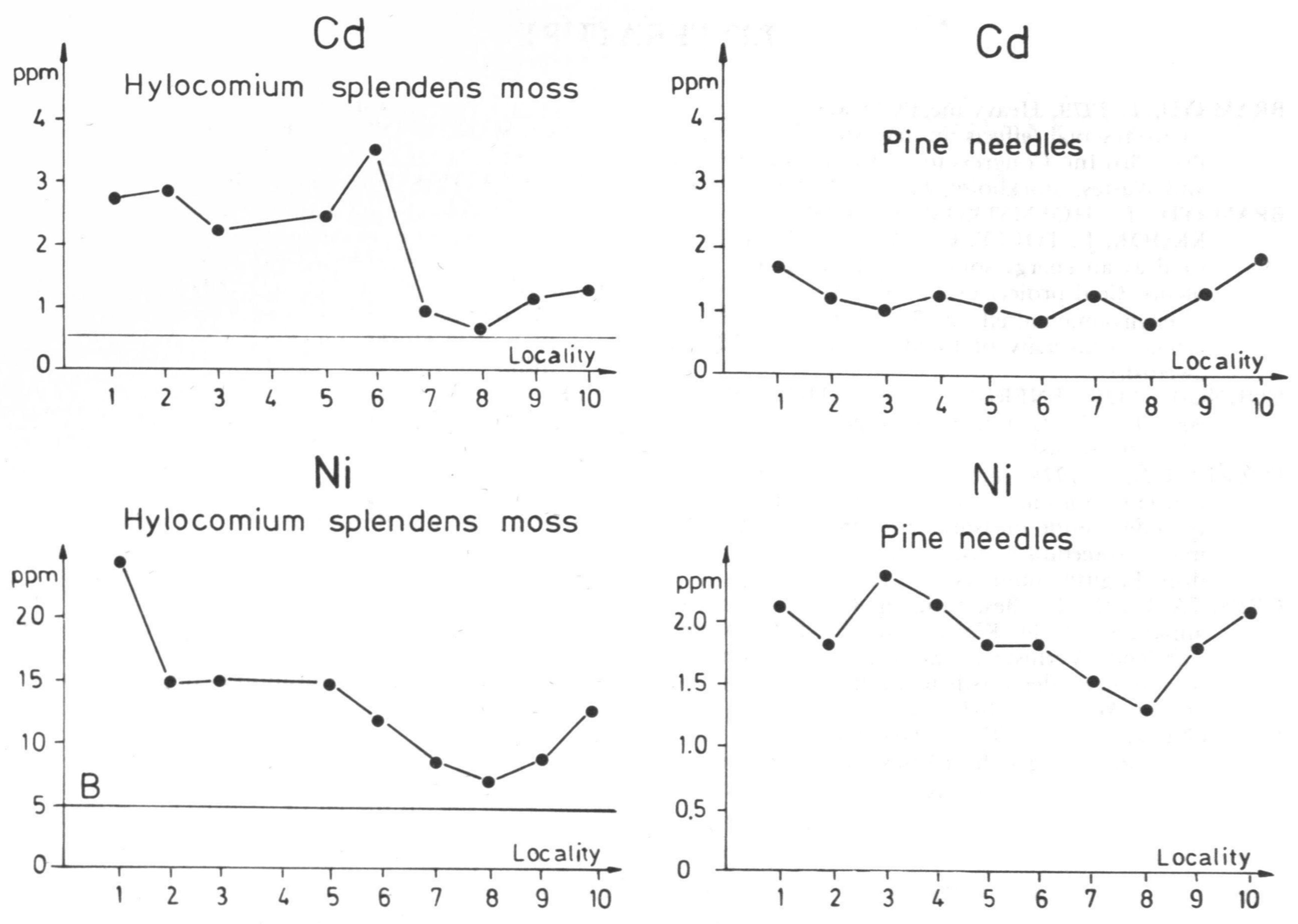


Figure 1. Concentrations of Cd, and Ni at increating distances from the Inkoo power plant, Accumulated in Hylocomium splendens moss and pine needles respectively. Concentrations in ppm.

mineralization WILSON 1977).

A close correlation can further be found between heavy metal concentrations and extractable phosphate available in the soil. The activity of phosphatase-hydrolytic enzymes in soil which are of great importance for phosphorus mobilization seems to be correlated with heavy metal concentrations in soil. The correlation with copper concentration is significant already in the interval 30-200 ppm Cu (TYLER 1974). Increased concentrations of vanadium strongly decrease the enzymatic activity already at low concentrations (TYLER 1977). A relatively high pH value of the soil may counteract the heavy metal effects to some extent (TYLER 1976).

Effects on higher fungi can also be caused by heavy metal pollution. Both the number of the emissions of other pollutants.

species and the number of fruit bodies generally are lower in heavily polluted areas (RÜ-HLING 1978). The fact that some mushrooms, for example many Psalliota species, easily take up and accumulate high concentrations of heavy metals increase the risk for a distribution of metals to the fauna.

Although the heavy metal concentrations around the Inkoo coal-fired power plant are relatively low compared to older power plants, waste incinerators, and other heavy metal emitting industries it is essential to investigate the distribution of metals, considering not only the air emissions but also the distribution by dust and leaching water. It is of especial importance in all effect studies to investigate the synergistic effects of different heavy metals, acidification and of

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