

INTERNAL EXPOSURE TO PREDIOXINES AND OTHER ORGANIC SUBSTANCES IN WASTE INCINERATION PLANTS

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Introduction

Waste incinerators and their emissions of hazardous chemical substances are of great public concern. The amount of internal exposure and of potentially resulting health effects for the workers of the plant and of the general population is a matter of controversy. Especially the polychlorinated dibenzodioxines and dibenzofurans cause anxieties.

When organic matter is burned aromatic systems are formed. On the one side these are benzene, polyaromatic hydrocarbons (PAH) and phenols. In the presence of chlorine or chlorine compounds chlorobenzenes are produced which give rise to the formation of chlorophenols and polychlorinated biphenyls (PCB). Chlorophenols and PCB are predecessors of polychlorinated dibenzodioxins and dibenzofurans. Chlorophenols and PCB are therefore indicators for the formation of PCDDs and PCDFs¹.

Collectives and methods

During the health supervision of the employees of two waste incineration plants in southern Germany, Franconia, we had the opportunity to examine the workers according to their internal exposure to benzene, polyaromatic hydrocarbons (PAH), chlorophenols, PCB and hexachlorobenzene (HCB). In the three incinerators of plant A the waste from households was burned mainly. The furnaces are of the mass burn type. To a minor extent solvents, plastics waste, oil, sewage sludge etc. was also incinerated. 50 men and 3 women of this plant were examined. The workers were between 22 and 52 years old and had been employed in the plant between 0.5 and 14 years. In the furnaces up to 135000 t of waste are incinerated per year at temperatures between 800 and 1000°C. The temperatures were maintained by blowing air through the furnaces. Each of the furnaces must be attended at least once a month. In plant B a rotary tube incinerator was used. About 30000 t of waste mainly from industry, solvents, plastics and waste oil was burned. The temperatures inside the combustion tube are between 1050 and 1150°C. 114 men and 14 women between 21 and 59 years old were examined. The workers had been employed in the plant between 1 and 24 years. For reference purposes altogether 515 men and women living in north and south Germany have been examined.

To estimate the internal exposure we determined the benzene level in blood, the elimination of hydroxypyrene in urine, the concentrations of mono-, di-, tri- and tetrachlorophenols and pentachlorophenol in urine and the concentrations of PCBs and HCB in plasma. Five different analytical procedures have been used. Sophisticated clean up and enrichment steps had to be used to determine concentrations down to the ppt-range. Contamination problems were omitted or controlled carefully.

PCB

For the determination of benzene in blood a dynamic head space procedure was used in combination with capillary gas chromatography². Hydroxypyrene was enriched on a reversed phase column after enzymatical hydrolysis. The separation took place on HPLC³. Mono-, di-, tri- and tetrachlorophenols were separated from the matrix by cation exchange followed by a reversed phase column after steam distillation and acidic hydrolysis. After reaction with diazomethane the methyl ethers are separated by capillary gas chromatography. Pentachlorophenol was after hydrolysis separated from the matrix by liquid liquid extraction. After derivation with diazomethane capillary gas chromatography served for separation. PCBs and HCB were extracted from plasma with heptane. The lipids were removed by a silicagel column followed by capillary gas chromatography. Electron capture detection, mass spectrometry and fluorescence detection served for the quantitative determination of the different substances⁴⁻⁶.

Results and discussion

The level of benzene in blood is under diagnostic aspects the most sensitive and specific parameter for an exposure to this known human carcinogen. The results of our examinations are presented in Table 1. Because smoking is a prominent source of internal benzene exposure workers and controls are subdivided according to their smoking habits.

Table 1: Concentration of benzene in blood ($\mu\text{g} / \text{l}$)

	inc. plant A m; 95 % (n)	inc. plant B m; 95 % (n)	controls m; 95 % (n)
smoker	0.37 ; 0.86 (17)	0.39 ; 0.95 (28)	0.30 ; 0.58 (26)
non-smoker	0.20 ; 0.40 (37)	0.09 ; 0.23 (63)	0.22 ; 0.56 (67)

The benzene blood levels of smoking and non-smoking workers defer statistically significant as it was expected. Though the benzene levels in blood samples of smoking and non-smoking control are not different under statistical aspects they show the same tendency. According to the benzene concentrations in blood there was no difference between the two groups of smoking workers and there was no difference between these groups and the smoking controls. These observations mean that smoking habits dominate the concentration of this aromatic hydrocarbon in blood. The influence of waste incineration on this parameter seems to be of minor importance. That the benzene concentrations in blood samples of non-smoking workers of plant A are higher than the corresponding results of plant B deserves attention. Though both sets of values are well within the concentration range of the benzene blood level of the normal population, this might be a hint that incineration in plant A contributes to the exposure of benzene.

The concentration of hydroxypyrene in urine meanwhile turned out to be a practicable indicator for an occupational exposure to polyaromatic hydrocarbons. The results of our examinations are shown in Table 2. Because again the smoking habits have an effect on the elimination of hydroxypyrene, we subdivided workers and controls in smokers and non-smokers.

On watching these results we can draw almost the same conclusions as for the benzene level in blood. Smoking habits obviously have a predominating influence on the elimination of hydroxypyrene in urine. Smokers generally have higher concentrations in urine than non-smokers. Again smoking workers of both incineration plants have not higher PAH-exposures than the smoking controls. Comparing the hydroxy-

pyrene elimination of non-smoking workers and controls we again have the effect that the workers of plant A have higher values than those of plant B. Moreover the values of plant A workers are higher than those of the non-smoking controls. Though these results show that there might be an elevated exposure to PAH-inside an incinerator of this additional exposure is very small. The difference in the median values of non-smoking workers and non-smoking controls is about 0.1 $\mu\text{g/l}$. For comparison at other working places with occupational PAH-exposure, i.e. in creosote works or during the production of aluminium hydroxypyrene concentrations up to 225 $\mu\text{g/l}$ have been determined.

Table 2: Elimination of hydroxypyrene in urine ($\mu\text{g} / \text{g}$ Creatinine)

	inc. plant A m; 95 % (n)	inc. plant B m; 95 % (n)	controls m; 95 % (n)
smoker	0.42 ; 0,57 (17)	0.27 ; 0.69 (29)	0.23 ; 0.55 (21)
non-smoker	0.25 ; 0.73 (36)	0.10 ; 0.38 (64)	0.12 ; 0.33 (28)

Table 3 shows the concentrations of chlorphenols in urine. Let us first compare the values of the municipal waste incineration plant A with that of plant B where industrial waste is burned. We got outstandingly higher results for plant A workers with respect to dichlorophenols. The median value for the sum of both dichlorophenols, 10.5 $\mu\text{g/l}$, is about four-times higher than that in the industrial waste incinerator 2.7 $\mu\text{g/l}$. The cumulative frequency distribution moreover clearly shows that the workers of plant A have higher dichlorophenol eliminations over the whole range than the controls. The 95 percentile of the workers excretion which is 87 $\mu\text{g/l}$ is about twice as high than that of the controls. This increase of dichlorophenol excretion is due to the fact that dichlorobenzenes, the predecessors of chlorphenols, are preferably produced under combustion conditions. The elimination of 2,4,5 trichlorophenol of workers of plant A is also higher than that of plant B workers. In this case the increase is moderate. The median value is only about twice as high.

Table 3: Elimination of chlorphenols in urine ($\mu\text{g} / \text{g}$ Creatinine)

	inc. plant A (53 workers) m; 95 %	inc. plant B (97 workers) m; 95 %	controls (246 persons) m; 95 %
4-MCP	1.2 ; 3.8	n.e.	1.7 ; 6.6
2,4-DCP	2.9 ; 8.0	1.0 ; 4.5	n.e.
2,5-DCP	7.1 ; 78.2	1.4 ; 13.5	n.e.
Σ DCP	10.5 ; 86.6	2.7 ; 15.1	4.0 ; 46.4
2,4,5-TCP	1.2 ; 3.4	0.5 ; 1.3	0.8 ; 4.1
2,4,6-TCP	0.9 ; 2.5	0.7 ; 8.9	0.6 ; 3.8
Σ TECP	0.3 ; 1.5	0.4 ; 4.1	1.2 ; 31.3
PCP	2.2 ; 5.8	1.7 ; 6.1	2.2 ; 8.7

As in the case of benzene and hydroxypyrene the internal exposure to organic substances seems to be higher in plant A than in plant B. It may be concluded that chlorinated aromatic compounds are produced under the conditions of waste

PCB

combustion. This conclusion is further supported by the fact that the controls eliminate significantly minor di- and tri-chlorophenol amounts than the workers of the municipal waste incinerator.

A further point deserves explanation. Chlorophenol concentrations in the urine samples of the controls are in most cases higher than that of the workers in plant B. All controls are from the coastal region. According to our newest results the population in the coastal region of northern Germany seems to have greater internal exposures to chlorinated aromatic hydrocarbons than in the southern part of the country. The next slide shows an example. The excretions of 2,4,5-trichlorophenol of the management employees of plant B are lower than controls living at the coast. We think that this is due to nutrition habits.

A last remark concerning tetrachlorophenol and pentachlorophenol. According to our experiences the elimination of these parameters is clearly determined by other factors than incineration. Wood preservation in the domestic region could act a prominent role in this context.

The results of PCBs and HCB measurements in plasma samples of workers and controls are presented in Table 4.

Table 4: Concentration of polychlorinated biphenyls in serum ($\mu\text{g} / \text{l}$)

	inc. plant A (54 workers) m; 95 %	inc. plant B (96 workers) m; 95 %	controls (63 persons) m; 95 %
PCB 138	1.6 ; 3.5	0.9 ; 1.5	1.5 ; 5.0
PCB 153	2.5 ; 5.7	1.2 ; 2.0	1.9 ; 6.5
PCB 180	1.4 ; 2.7	0.7 ; 1.2	1.2 ; 4.8
Σ PCB	5.7 ; 12.0	2.8 ; 4.8	4.2 ; 16.9
HCB	4.4 ; 12.3	1.7 ; 8.6	2.8 ; 15.6

Again the internal exposure is higher in the municipal waste incinerator than in the chemical waste combustion plant B. This again is a hint that waste incineration seems to be a source for PCBs and HCB as well as it was proposed in our first slide.

As in the case of chlorophenols the controls which were inhabitants of the coastal region have higher PCB and HCB plasma levels than the employees of the industrial waste incinerator. The next slide shows that the management employees of the incinerator B have systematically lower levels than the control population. This is possibly caused by a greater consumption of fish in the coastal region.

Conclusions

In incineration plants there seems to be an additional exposure to organic substances being generated by the pyrolysis of organic matter, i.e. benzene, PAH, PCB, HCB, chlorophenols and chlorobenzenes. This additional exposure is small and not relevant under aspects of occupational health.

Because this additional exposure to chlorophenols and PCBs is small, polychlorinated dibenzodioxins and dibenzofurans obviously do not act a role under occupational health aspects.

That the exposure to organic compounds in plant A is higher than in plant B may be due to the fact that greater amounts of waste are burned there and that the performance of combustion is better in the industrial waste incinerator.

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