AFTER INCINERATION: THE TOXIC ASH PROBLEM

IPEN Dioxin, PCBs and Waste Working Group

Re-print from April 2005 Report

ARNIKA

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Prague – Manchester

Acknowledgements

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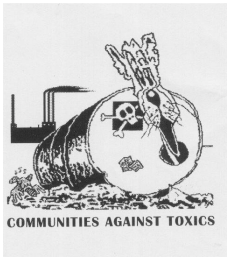

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IPEN also acknowledges the essential help of Arnika staff members, Hana Kuncova, Martin Skalsky, Lenka Maskova and Kristina Beranova in the preparation of this report and Pat Costner, Senior Science Advisor, IPEN, USA.

Contents

Executive Summary and Recommendations

The Dioxin, PCBs and Waste WG of IPEN report demonstrates that waste incineration residues represent a serious threat to both local and global environment as they contain high quantities of unintentionally produced persistent organic pollutants (U-POPs) listed under Annex C of the Stockholm Convention (dioxins, PCBs and hexachlorobenzene). This study also shows that especially waste incineration fly ash and APC residues contain also high levels of other POPs not listed under Stockholm Convention (for example polychlorinated naphthalens or polybrominated dibenzo-p-dioxins and dibenzofurans etc.). It summarizes studies showing leachability of dioxins from fly ashes under conditions they are disposed off. Hot spots case studies shows that levels of dioxins in ashes from waste incineration below the level established as a provisional limit for low POPs content in wastes are too high to prevent serious contamination of the environment by U-POPs.

Recommendations concerning crucial decisions on U-POPs policy

POPs levels in wastes:

Cases of dangerous contamination of the environment don't support approval of "low POPs content levels" and "levels of destruction and irreversible transformation" as they were proposed by the documents prepared within the framework of the Basel Convention.

Basel Convention Technical Guidelines and Stockholm Convention BAT/BEP Guidelines:

High levels of POPs in waste incineration residues raise the importance of using techniques other than waste incineration and/or landfilling of wastes in these guidelines. It also raises the importance of material substitution – the replacement of materials such as PVC, a material whose presence in the combustion processes helps to create more dioxins.

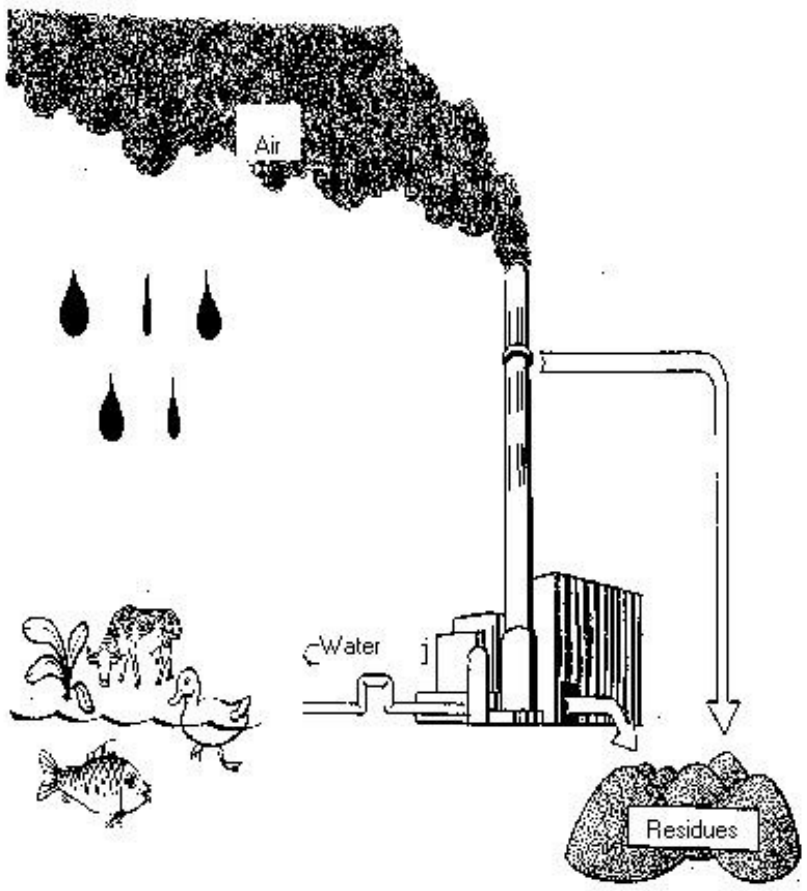
1. Introduction: Persistent organic pollutants (POPs)

Persistent organic pollutants (POPs) harm human health and the environment. POPs are produced and released to the environment predominantly as a result of human activity. They are long lasting and can travel great distances on air and water currents. Some POPs are produced for use as pesticides, some for use as industrial chemicals, and others as unwanted byproducts of combustion or chemical processes that take place in the presence of chlorine compounds.

Today, POPs are widely present as contaminants in the environment and food in all regions of the world. Humans everywhere carry a POPs body burden that contributes to disease and health problems. Dioxins, DDT or polychlorinated biphenyls (PCBs) are capable of causing hormonal defects in very low quantities and they threaten reproduction systems of people and animals. (They have for instance a negative impact on male fertility). They also damage the human immune system and some of them cause cancer. They are not soluble in water, but in lipids. This characteristic helps them bioaccumulate in the fatty tissue of animals.

The international community has responded to the POPs threat by adopting the Stockholm Convention in May 2001. The Convention entered into force in May 2004.

The Stockholm Convention is intended to protect human health and the environment by reducing and eliminating POPs, starting with an initial list of twelve of the most notorious, the "dirty dozen." Among this list of POPs there are four substances that are produced unintentionally (U-POPs): polychlorinated biphenyls (PCBs), hexachlorobenzene (HCB), polychlorinated dibenzo-p-dioxins (PCDDs)



Picture 1: Basic POPs releases flows from waste incinerator.

and dibenzofurans (PCDFs) The last two groups are simply known as dioxins.

The goal of the ***"continuing minimization and, where feasible, ultimate elimination"*** was established for U-POPs listed in Annex C of the Stockholm Convention.[a] There are several steps that should help Parties to Stockholm Convention to comply with this goal. Almost all are under Articles 5 and 6 of the Stockholm Convention.

Several key topics will be discussed at COP that reflect how the Convention will work:

1) **Guidelines on Best Available Techniques and Best Envi-ronmental Practices - BAT/BEP (related to Article 5 of the Stockholm Conven-tion),**

2) **Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (related to Article 5 of the Stockholm Convention) and**

3) **"levels of destruction and irreversible transformation of POPs in waste" and "low POPs levels in waste" (related to Article 6 of the Stockholm Convention).**

These three topics are also very closely related to fly ash and other waste incineration residues and will be discussed in the final parts of this report.

Annex 1 to this report includes more detailed profiles of the group of U-POPs listed in Annex C of the Stockholm Convention.

[a] polychlorinated biphenyls (PCBs), hexachlorobenzene (HCB), polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs), last two groups are called simply as "dioxins"

2. POPs and waste incinerators

A wide range of POPs is produced in waste incinerators, as unwanted by-products of the combustion process. Therefore, the Stockholm Convention lists waste incinerators in Annex C among *"source categories have the potential for comparatively high formation and release of these chemicals[b] to the environment"*. The basic possibilities of releases of toxic substances from waste incinerators are demonstrated at Picture 1. The incinerators themselves are usually much more complicated devises, as shown by the diagram at Picture 2, and in any incinerator many ways can be identified through which POPs may get further into the environment. The amounts of dioxins and further POPs produced by a specific waste incinerator also differ, depending on the conditions of the incineration of wastes. A number of studies investigated formation of dioxins in incinerators.

Three pathways have been proposed so far to explain the formation of PCDDs/PCDFs during incineration:
- high temperature pyrosynthesis[1];
- low temperature de novo formation from macromolecular carbon and organic or inorganic chlorine present in the fly ash matrix[2], and
- formation from organic precursors[3] in which fly ash has an important role as a catalyst.

Although all these mechanisms have been known for many years, some detailed reaction mechanisms were studied in more recent studies due to the extreme complexity of the fly ash matrix.[4, 5]

Formation of further POPs during incineration of wastes was not examined in such detail as it was done in the case of dioxins. Some studies focusing on examination of coplanar PCBs, which are included into the value of the total TEQ[6], concluded that these chemicals might be formed by similar reactions as PCDD/Fs[7].

Similar imbalance exists concerning the attention paid to releases into the various components of the environment. Until now, the highest attention has been paid to releases into the air, whereas the content of POPs in wastes and waste waters has been left aside for a long time. A help in solving this problem should have been provided by the Stockholm Convention, which, in contrast to protocol on POPs to the LRTAP Convention, concentrates on releases into all components of the environment, and does not deal solely with releases into the air. In spite of that, the tool prepared by UNEP Chemicals for national inventories of POPs in many cases still ignores or underestimates releases to water, land and in residues, as will be shown in one of the following chapters.

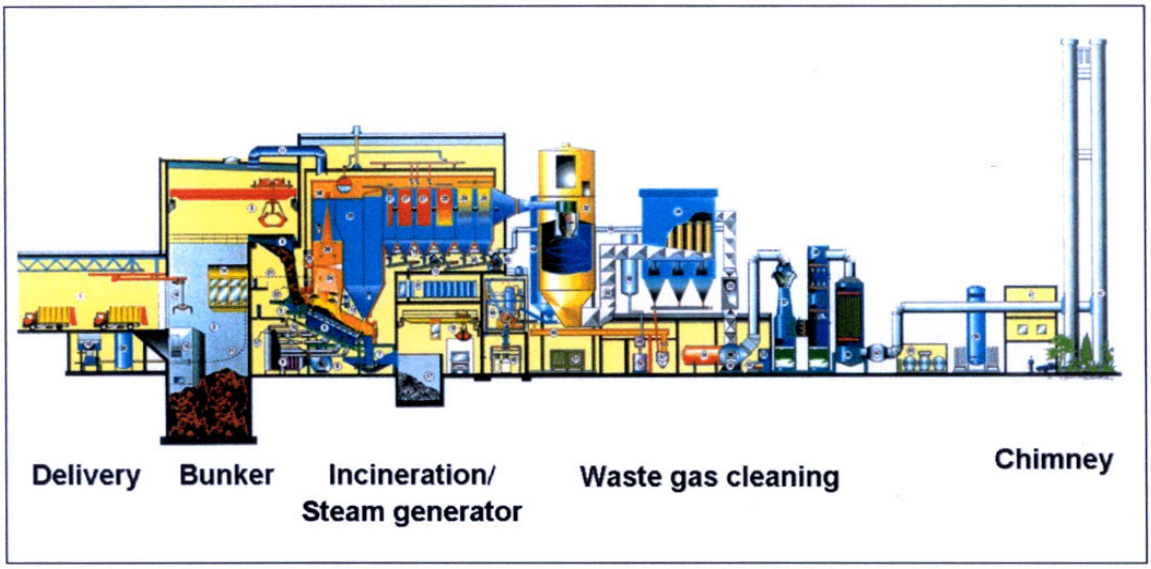
[b] Chemicals listed in Annex C of the Stockholm Convention, which are PCDD/Fs, PCBs and hexachlorobenzene so far.

3. Waste incineration residues

Combustion is a thermal process during which organic waste materials change their chemical composition and break down into basic atoms after being exposed to high temperatures in the presence of oxygen. The flue gases, as well as dust particles which are not captured by filters are emitted into the air by the stack (chimney). And, large quantities of waste water from wet flue gas filter devices as well as from fly ash treatment are discharged in the environment.

up in the bottom ash at the end of the incineration process. Approximately 25% of the quantity of municipal solid waste (MSW) fed to the grate furnaces ends up as bottom ash after the combustion process. Bottom ash is also known as "slag".

Fly ashes are small dust particles in flue gases, and are captured by electrostatic precipitators (ESP-filters) after the flue gases leave the boiler.



Picture 2. Typical municipal solid waste incinerator Source: European Commission 2004.

Inert materials in the solid waste stream, such as stony materials, and most metals, which are incinerated together with the organic waste fraction are not combustible, and will fall through the grate slits of the furnace, and end

Fly ashes are also known as 'ESP-ash'. Approximately 1 to 5 % of the quantity of municipal solid waste fed to the grate furnaces ends up as fly ash after the combustion process. [8]

Table 1: Modern incinerators produce a range of residues[c].

Generic Residue	Origin	Specific Residue
Bottom Ash / Slag	Heterogeneous material discharged from the burning grate of the incinerator.	Grate Ash
	Material that falls through the burning grate to be collected in hoppers below the furnace	Grate riddlings

[c] Adapted from WRc/ETSU Report. Reports on potential for use of MSWI bottom ash, for the DTI Ref B/RR/00368/REP/. Harwell, Oxford 1996

Heat Recovery Ash	Particulate ash removed from heat recovery systems	Boiler ash Economiser ash Superheater ash etc
Fly Ash	Particulate matter removed from the flue gas stream prior to the air pollution control (APC) system, not including the heat recovery ashes	Electrostatic precipitator (ESP) dust Cylcone dust
APC (Air Pollution Control) Residues	Dry and semi dry scrubber systems involving the injection of an alkaline powder or slurry to remove acid gases and particulates and flue gas condensation/reaction products. Fabric filters in bag houses may be used downstream of the scrubber system to remove the fine particulates	Scrubber residue Bag house filter dust
Combined Ash	Combination of any of the above residues, most common is mixing of bottom ash with APC residues.	Mixed ash

A third residue of waste incineration is boiler ash. Small ash particles attach to the boiler, and are removed by mechanical knocking devices, or are manually removed during periods of maintenance work. Less than 0,1% of the quantity of municipal solid waste fed to the grate furnaces is collected as boiler ash.

If an incinerator is equipped with (wet) flue gas filter devices (scrubbers), various (solid) residues are produced, i.e. scrubber salts, filter cake, sludge, and gypsum.

Summarizing: After incineration approximately 26 - 40 % of combusted solid waste will remain as solid residues. Quantification of residues will be discussed more detailed in Chapter 4.

Combustion of liquid (toxic) waste results in much lower quantities of solid residues, because of the lower amount of solid substances in the liquid waste.

What types of wastes are produced can be understood also from the three following examples of incinerators operated in the Czech Republic:

SPOVO Ostrava. Industrial wastes incinerator SPOVO in Ostrava is the only incinerator in the Czech Republic which holds a license to incinerate wastes with high content of PCBs. Data about the incinerator are taken from its operating rules. The technology consists of a combustion chamber - rotary kiln, electrostatic filter, acidic and alkaline gas washer, hose filter and of the technology for capturing of nitrogen oxides (so-called DENOx).

The incinerator produces the following wastes:
- *slag and boiler ash from the rotary kiln (cat. No. 190111)*
- *fly ash, captured by the electrostatic filter (cat. No. 190113)*
- *sludge with the content of heavy metals from the filter press located after treatment of waters from the acidic gas washer (cat. No. 190105)*
- *gypsum from the alkaline washer (cat. No. 190105)*
- *used activated carbon from the bag filter (cat. No. 190110)*
- *wastes formed during repairs of lining (cat. No. 190111)*

The incinerator with the capacity of 10.000 tons per year consumes 1.134 tons of calcium hydroxide and 140 tons of activated carbon and transforms them into hazardous waste. The contaminated activated carbon is incinerated in the incinerator itself.

Medical waste incinerator in the Hospital of Rudolph and Stephanie in Benešov u Prahy.
This incinerator is an example of a small facility with a capacity of 1000 tons per year. Data thereon are taken from the plan for reduction of emissions, because the technology does not meet all requirements arising from transposition of European regulations concerning waste incinerators. Its equipment should be completed by the end of the year 2004.

The technology consists of pyrolysis and combustion chamber, textile bag filter for capturing solid particles and simple two-stage treatment of flue gases. This treatment consists of quench (cooling of flue gases by water), and of alkaline lye washer.

The incinerator produces the following wastes:
- *waste from pyrolysis (cat. No. 190118)*
- *boiler ash (cat. No. 190104)*
- *solid waste from APC devices (cat. No. 190107)*
- *waste waters are discharged by the incinerator into the sewer system without treatment*

The facility was built in the year 2000. In spite of that, the limit for emissions of dioxins was not met. In the year 2001, the limit of 0.1 ngTEQ/m^3 was exceeded ca 19x, in the year 2002 even 65x.

Hazardous waste incinerator in Lysá nad Labem. This incinerator has the maximum capacity of 3500 tons per year. Data thereon are taken from the plan for reduction of emissions and from the operating rules. At present, also the EIA process for completion of its waste management equipment is under way. The incineration space consists of a rotary kiln and two post-combustion chambers. Treatment of flue gases has several stages. At first, the flue gases are cooled, then a sorbent (a mixture of lime and activated carbon, trade name Sorbalite) is added thereto. Subsequently, the mixture is introduced into a reactor, where flue gases and sorbalite are mixed with each other. From the flue gases, solid portions (fly ash and sorbalite) are filtered off in a textile bag filter. Finally, the flue gases enter quench and alkaline washer, where they are washed with water and lye. Wash waters from the washer are further treated in a filter press and by filtration through CINIS ash.

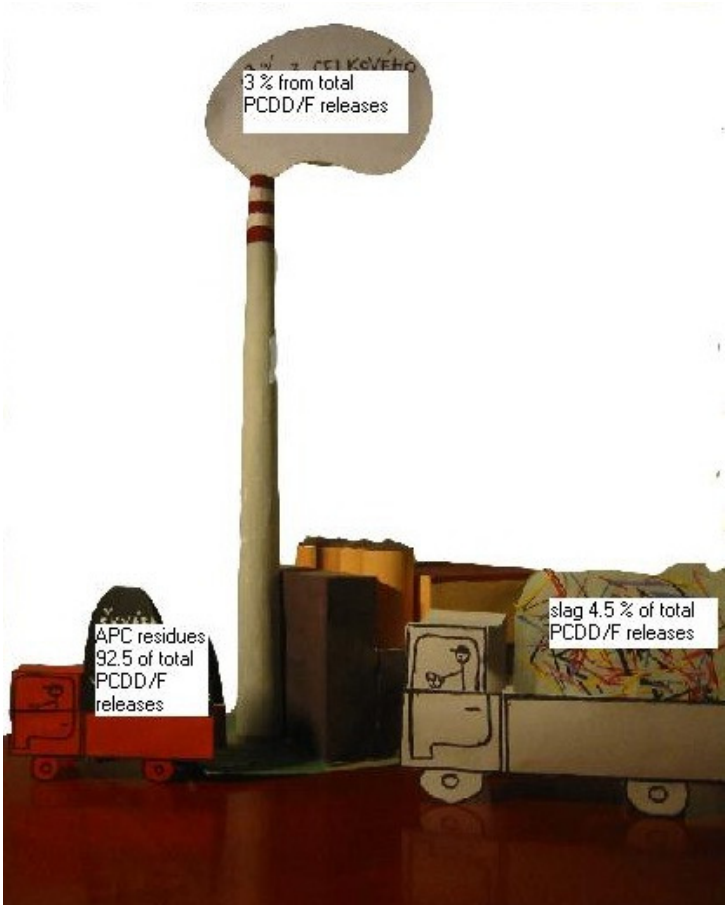
The incinerator produces the following wastes:
- *ash and slag and fly ash from the post-combustion chambers (cat. No. 190111, 190113)*
- *mixture of sorbalite and fly ash from the sleeve filter (cat. No. 190107)*
- *sludge with the content of heavy metals from the filter press located after treatment of waters from the gas washer, it is re-burnt (cat. No. 190105)*

The incinerator with the capacity of 3500 tons per year consumes 40 tons of sorbalite and 2 tons of CINIS ash (it is part of sludge from the filter press). Wastes, produced during repair works, are not specified.

Physical properties of ash residue fractions may be affected by such factors as:
- MSW composition;
- front-end processing of the waste prior to incineration;
- facility design and operation including combustion temperature;
- air pollution control (APC) measures etc.[9]

Higher content of dioxins and further POPs in wastes produced by incinerators may be, naturally, expected in air pollution control residues (APCR). Their content in slag and ash is increased by mixing with fly ash or with boiler ash. But this is a relatively frequent practice, as will be shown on several examples. Boiler ash contains higher concentrations of POPs, which, however, by far do not reach the concentrations found in APCR. On the other hand, ash and slag may contain relatively high concentrations of heavy metals.

P. Littaru and L. Vargiu studied process of dioxins formation in fly ash in two municipal waste incinerators in Italy[10]. They concluded that "*The highest PCDD/F contents have been found in fly ash at temperatures of 150-200 °C below the de novo synthesis peak temperature, so that the enrichment of particulates in PCDD/Fs must be caused by adsorption from gas to solid phase. PCDD/F ratios in fly ash tend to increase with decreasing temperatures until reaching values well in excess of 1.7, the average furan/dioxin ratio for MSWI emissions, revealing that a major portion of PCDF is adsorbed on the solid phase… These phenomena of adsorption/desorption on fly ash deposits in flue gas treatment lines must be accounted for in the mass balance and in the evaluation of PCDD/F emission levels…… PCDD/Fs appear to be generated on fly ash deposits in flue gas treatment lines of MSWIs by the de novo synthesis mechanism. PCDD/F content in fly ash increases as temperatures in the treatment lines decrease, confirming previous findings about temperature as the major controlling parameter in PCDD/F formation.*"



Picture 3: Balance of PCDD/Fs releases into different environment compartments from MWI Liberec

The Italian study confirmed that combustion is not the main source of PCDD/Fs in MSWIs, and that PCDD/Fs do not seem to be generated directly only by waste combustion. Based on its findings the effectiveness of post-combustor units in destroying PCDD/Fs needs to be reconsidered. This conclusion is supported by findings of the M. Chang and J. Lin who studied influence of activated carbon injection on total dioxins releases[11]. They came to the conclusion that activated carbon injection can indeed effectively decrease concentrations of dioxins in gas, but it increases the total emissions of dioxins (including dioxins in fly ash and gas) from municipal waste incinerators.

Similarly as in waste incinerators, POPs are formed also in other combustion facilities. Therefore, also wastes produced, for example, by metallurgical plants, present serious risk of contamination of the environment by POPs. Use of slag from metallurgical plants caused one of „dioxins scandals" in Germany[12].

4. How much dioxins do the wastes from incinerators contain?

An important question, which has to be answered when we speak about wastes produced by incinerators, is: How much dioxins do these wastes contain? The magnitude of problems connected with these wastes depends on the answer to this question. If the amount was negligibly small, then it would not be necessary to be further concerned with the problems of these wastes. Answers to this question are different.

For example, Dyke and Foal[13] identified MSW incinerator residues as the largest dioxin release to land in the U.K., noting as follows: *"Residues from the incineration of MSW can lead to significant releases."*

Table 2: Results of the analysis of combustion gases and ashes from the incineration of medical waste in Poland.

Incinerator	PCDDs/PCDFs in pulverulent gases [ngTEQ/Nm^3]	PCDDs/PCDFs in gas phase [ngTEQ/Nm^3]	Temperature of combustion gases [°C]	PCDDs/PCDFs in ash [µgTEQ/kg]	Incineration temperature [°C]
1	0.015	0.010	60	8.5	650 - 750
2	0.02	0.012	80	14.5	780 - 850
3	0.022	0.020	45	20.0	670 - 900
4	0.027	0.020	55	7.8	750 -1000
5	0.047	0.040	75	12.1	500-600
6	0.055	0.040	40	12.5	650 - 850
7	0.075	0.050	90	15.0	550 - 780
8	0.09	0.075	105	22.0	600-700
9	0.13	0.12	65	19.0	575 - 800
10	0.215	0.215	140	29.0	550 - 700
11	0.32	0.085	40	9.5	780 - 900
12	0.42	0.15	60	19.5	550 - 700
13	3.9	2.5	120	9.0	650 - 800
14	9.7	4.2	80	18.4	600-650
15	12.1	8.5	200	22.5	580 - 650
16	18.5	11.5	170	43.0	750 - 900
17	26.0	24.2	270	35.0	600-700
18	32.0	21.5	250	30.0	500 - 850

Source: Grochowalski, A. 2000.[14]

Sakai and Hiraoka[15] determined the total dioxin output per metric ton of municipal solid waste (MSW) incinerated when fly ash was treated by a thermal dechlorination process. However, their findings also allow calculation of the total dioxin output per ton MSW when fly ash is not detoxified, as is typically the case in most countries. With untreated fly ash, a dioxin output factor of 857.8 µg TEQ/ton MSW can be calculated for one set of samples and 507.7 µg TEQ/ton MSW for the other. In the first case, flue gas contributes 0.05 percent of the total TEQ output while fly ash contributes 99.9 percent. In the second case, flue gas contributes 0.0004 percent of the total TEQ output and fly ash, 99.5 percent. These values can be compared to a study of European MSW incinerators by Huang and Beukens[16] in which flue gas was found to contribute 11.8

percent of total dioxin output, while fly ash contributed about 56.7 percent.

We have tried to calculate this balance roughly also for municipal waste incinerator in Liberec (see Chapter 8.2.1). We can say for sure that gaseous emissions contribute ca 3 % to the total dioxins production of this incinerator. The remaining 97 % are present in mixed bottom ash. In this case, it is complicated to estimate the exact contribution of APC residues.

But it is possible to roughly estimate the contribution of dioxins contained in the separated slag, which is ca 4.5 %. This would mean that APC residues contribute ca 92.5 %. Similar calculation for dioxin-like PCBs is not available, as PCBs are not commonly measured even in air releases.

Fly ashes and further residues from flue gases treatment form the highest proportion of dioxins releases to the environment: between 56 and 99.5 %. Usually, gaseous emissions contribute to dioxins burden from waste incinerators by the lowest per cent (this can be estimated between 0.0004 and 12 %). Releases of dioxins contained in fly ashes represent a serious threat to the environment. Therefore, it is important to determine *„low POPs level"* for the content in wastes according to Article 6 of the Stockholm Convention, in order to prevent releases of these toxic substances into the environment. Success of the Stockholm Convention in elimination of POPs can be based on correct setting of this limit. As shown by the case studies in Chapter 8., *„low POPs levels"*, as they were approved and adopted at the sixth Conference of Parties (COP6) of the Basel Convention, 25–29 October 2004, do not guarantee protection of the environment from POPs contamination.

Talking about dioxins and dioxin-like PCBs observed in ashes we find a wide range of measured levels. For PCDD/Fs we found in previous studies observed levels between 36 ng I-TEQ/kg dry matter[17] to 82,400 ng I-TEQ/kg d.m.[18] Boiler ash contains lower levels of dioxins (level of 11.3 ng I-TEQ/kg was measured in Liberec).[19] Mixed bottom ash can carry high levels of dioxins (up to 2300 ng I-TEQ/kg d.m.[20]), while bottom ash and/or slag doesn't have such high levels: 0.64 - 150 ng I-TEQ/kg d.m. were observed in municipal waste incinerators in England and Wales.[21] We did not find a lot of data about dioxin-like PCBs in fly ash, only from Taiwan where measurements with results ranging from 61.1 to 2,983.4 ng I-TEQ/kg,[22] were recorded, and from Germany with levels found in the range of between 10 - 640 ng WHO-TEQ/kg. Also PCBs in general are seldom measured in waste incineration residues. In fly ash their levels were measured from less than 1,000 to 23,000 ng/g d.m. in UK[23]. Table 2 shows PCDD/Fs levels measured in flue gases and ashes of Polish medical waste incinerators.

5. Leaching question of POPs in fly ash

After emissions of dioxins into the atmosphere were successfully lowered in the up-to-date incinerators, the idea has predominated that these toxic substances are fixed in fly ash to the extent that it is essentially unnecessary to pay too high attention to management of wastes produced by the incinerators. During negotiations on permits for waste incinerators, this argument is often stated in official documents, and it is passed on among officials who issue the corresponding permits. Authorities in a significant number of countries thus do not pay any attention to the facts where APC residues end and how they are treated. The authorities are satisfied with submission of a certificate confirming that the incinerator handed over the material to an authorized company. They are satisfied with the same statement also in documentation submitted during procedures of permit granting in (= Environmental Impact Assessment) or IPPC (= Integrated Pollution Prevention Control) processes.

The idea of a complete impossibility of leaching of toxic substances from slag, ash, and APC residues is based on a number of studies which have worked, and repeatedly work, at leachability of heavy metals from these materials.

The leachability tests performed recently may not be applied to substances of dioxin type, because their behavior changes depending on the changes of the characteristics of the environment. The leachability tests of wastes performed commercially are, in most cases, generally carried out in ideal laboratory conditions and do not correspond to the behavior of wastes in the environment where they are deposited. Therefore, the chemists themselves call for change of these procedures. For example, M. Podhola from Institute of Chemical Technology, Prague in his study of stabilized wastes stated: *„A specifically prepared leachability test may be considered more suitable. Such test should stimulate conditions of subsequent deposition of the waste, if these conditions are known. Obviously, it is not possible to carry out these tests exclusively in the commercial manner. Apparently, they will have to be carried out in cooperation with research establishments.“*[24]

Older studies on behavior of dioxins in soils supported the original idea of strong fixing of dioxins in fly ash and ash. Italian study from 1986 reported that the Seveso soil profiles did not show a significant translocation of the PCDD/F in the soil environment.[25] German study from 1992 showed that only a little movement was found within 8 years in the surroundings of two industrial plants in southwest Germany and there was no appreciable loss of PCDD/F.[26] Another German study asserted that only highly chlorinated congeners were detected in the solution obtained from leaching experiments following the method of the German DIN 38414 test etc.[27]

However, newer studies disprove the idea of strong fixing of dioxins in fly ash and ash or slag. Takeshita and Akimoto[28] proposed the leachability of PCDD/F from fly ash by rain using a fly ash column. They showed that PCDD/F associated with water-soluble salts such as NaCl and $CaCl_2$ in the ash were eluted in the beginning of the elution, whereas those associated with slightly water-soluble particles such as calcium hydroxide were eluted in the latter half. Another report from 1995 focused on leaching of dioxins from fly ash and soils under fire-extinguishing water activity suggested that fire-extinguishing water use resulted in significant amounts of PCDD/F in the leachate.[29]

Korean scientists Yong-Jin Kim, Dong-Hoon Lee a Masahiro Osako studied PCDD/Fs leachability under circumstances comparable to those in landfills theoretically and in laboratory conditions. In theoretical review, it was shown that dissolved humic matters (DHM) could influence the actual solubility and leachability of PCDD/F. The higher concentration of DHM showed the higher leachability of PCDD/F. In the leaching test, three different DHM concentrations and pHs of solutions were adopted to fly ash samples imaging the various characteristics of municipal solid waste leachate. It was proved experimentally that the leachability of PCDD/F increased with increasing DHM concentration in all pH conditions. The highest leachability was shown at the highest pH. Isomer distribution patterns of PCDD/F in all leachates were similar.[30]

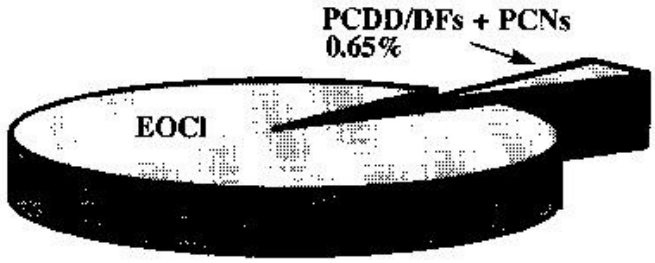
A previous study of these scientists states that a mixture of bottom ash and fly ash shows a higher leachability of dioxins.[31] This leads to the opinion that DHM are formed due to the presence of non-combusted carbon in bottom ash. The results also show several shortcomings in procedures of waste testing, because dioxins behave differently than heavy metals. Because of that, the authors of the study propose to rethink certain methods of testing.[32]

Sakai, Urano and Takatsuki published another study focused on leaching of dioxins and PCBs from fly ash. Leaching tests with and without surfactants were conducted in order to understand the influence of surfactant-like substances on POPs leaching. In those tests, LAS (Linear Alkylbenzene Sulfonate) and humic acid was used as surfactant-like substances. Shredder residues from car/electrical goods recycling and fly ash from a municipal solid waste (MSW) incinerator were used in content analyses and leaching tests. Furthermore, an experiment was carried out to understand the influence of fine particles to the leaching concentration of POPs. The results of the leaching tests indicate that surfactant-like substances increase the leaching concentration of POPs, and fine particles related closely to the transporting behavior of POPs.[33]

6. Other POPs observed in ashes

Waste incineration residues are formed by process of combustion of different kinds of wastes. They should contain plenty of chemicals as such. There will be difference in distribution of different chemicals between slag/bottom ash and fly ash/APC residues. It is necessary to say that if analysis for PCDD/Fs and/or PCBs content in ashes is rare, than analysis for other chemicals is very sporadic. There are several studies filling this gap a bit.

Picture 4. Distribution of PCDD/Fs and PCNs value comparing to rest of EOXs found in fly ash sample from one of Japanese municipal waste incinerators. Source M. Kawano et al.[39]



Japanese experts team led by M. Kawano studied distribution of PCDD/Fs, polychlorinated naphthalens (PCNs) and EOX in waste incineration ashes (fly ash and bottom ash). [34] PCNs have high chronic toxicity potential in animals[35] and exhibit the same binding affinity with the aryl hydrocarbon receptor (AhR) as non-ortho PCBs[36]. Kawano et al. found that order of content of these chemicals was EOX> PCDD/Fs>PCNs in the fly ash samples from MWI. Picture 4 shows balance between studied chemicals in one of fly ash samples. "The results of calculation show a very small amount of known organochlorines like PCDD/Fs and PCNs to have been present as a fraction of EOCI (see Picture 4). This is implies that a large part of EOCI is composed of unknown compounds." stated M. Kawano et al.

Noma et al. studied PCNs formation during Neoprene FB combustion in simulated MWI conditions and measured levels in fly ash as well as bottom ash in a range from 0.17 to 0.96 ng/g and from 0.95 to 1.7 ng/g respectively.[37]PCNs in ashes[d] sampled from Japanese incinerators ranged from 0.74 ng/g to 610 ng/g.[38]

In German study focused on a comparison between chemical analysis data and results from a cell culture bioassay was found that with MWI fly ash samples the bioassay of the extract resulted in a two- to fivefold higher estimate of TCDD equivalents (TEQ) than the chemical analysis of PCDDs/Fs and PCBs. However, the outcome of both methods was significantly correlated, making the bioassay useful as a rough estimate for the sum of potent PCDDs/Fs and dioxinlike PCBs in extracts from MWI fly ash samples. The remaining unexplained inducing potency in fly ash samples probably results from additional dioxinlike components including certain polyaromatic hydrocarbons (PAHs) not analyzed in this study. The hypothesis that emissions from MWI of hitherto unidentified dioxinlike compounds are higher by orders of magnitude than emissions of potent PCDDs/Fs and dioxinlike PCBs could not be confirmed.[40]

Levels of PAHs observed in waste incineration fly ashes by M. Till et al. ranged between 0.05 µg /g and 0.99 µg/g. Higher levels were found in fly ashes from cematorium, wood combustors and noble metal recycling facility (up to 536.4 µg/g).[41]

[d] both bottom and fly

H. R. Buser et al. conducted study focused on polychlorodibenzothiophenes (PCDTs), the sulfur analogues of the PCDFs. In H. R. Buser et al. study from 1991 is stated: *"Since incineration is one of the main sources for the environmental occurrence of PCDDs and PCDFs, the additional presence of PCDTs may have some implication , particularly because of the presence of 2,3,7,8-tetra-CDT."*[42] Tetra- and penta-CDTs were detected in fly ash from two MSWIs and from an electric-arc furnace of a car shredding facility. Rather complex isomeric profiles were found with tetra- and penta-CDTs predominating, at levels up to 25 and 30 ng/g.[43]

Picture 5: Surrounding of Turkish hazardous waste incinerator Izmit with sampling site of free range chicken eggs, which were found highly contaminated by PBDEs. Photo by: Bumerang and Greenpeace.

The toxicology of the PCDTs is not yet known but it can be supposed that like chlorinated dioxins and furans these compounds are biologically active.[44]

Also other organic compounds were observed in waste incineration residues from Izmit HWI. Some of them are listed in analytical results of chemical analysis of sampled ashes conducted by Greenpeace Research Laboratories.[45] See them in Appendix 2.

Burning of the waste containing brominated flame retardants quite often presented in the waste of plastic consumer products leads to formation of polybromodibenzodioxins and polybromodibenzofurans (PBDD/Fs) and/or to polybromochlorodibenzo-dioxins and polybromochlordibenzo-furans (PBCDD/Fs). Burning of polybrominated diphenylethers (PBDEs) in waste incinerators can lead to significant releases of this persistent organic pollutant, because they are not decomposed by waste incineration under low temperatures for example. High levels of these compound were found recently in chicken eggs sampled nearby HWI in Izmit (Turkey) at site on Picture 5.[46]

Chatkittikunwong & Creaser studied flyash from three municipal and medical waste incinerators for chlorinated as well brominated dioxins in 1994 for example. They found total PBDD/PBDF and polybromochloroDD/DF levels detected in MWI ranged between 2.3 to 3.5 ng/g and in medical waste incinerator 1.2 ng/g.[47]

It is clear that waste incineration residues contain whole range of organic pollutants and we can count many of them to the family of persistent organic pollutants. Some of them appear in ashes because of their presence in wastes (PBDEs for example) while the others can occur in ashes as POPs by-products. PCNs, PBDD/Fs , PCBDD/Fs and PCDTs are examples of second case. Some of these compounds were found in significant levels in the environment and waste incineration residues can be their significant source.

The pattern of toxicity of PCNs resembles that of TCDD. Recent work has been done to

determine the relative potency of PCNs - mixtures as well as individual congeners - in fish, birds and mammals. The potency of several PCN congeners is in the same range as some PCB congeners.[48] These findings about PCNs toxicity call for listing at least this group of chemicals under Annex C of the Stockholm Convention and for their inclusion into national POPs inventories.

7. Country case studies

7.1 Waste incineration residues in Netherlands

7.1.1 History of dioxins in Dutch milk

The Lickebaert polder is an agricultural area north-east of Rotterdam-harbour in the Netherlands. In 1989, tests showed high levels of dioxin in milk and cheese samples. As a result of the enormous media coverage and publicity, the Dutch government promptly ordered cow's milk and meat from the affected Lickebaert area to be collected systematically and destroyed.[49] A health protection measure that lasted until the end of 1994. During these five years the production and sales of dairy products in the Lickebaert area was prohibited. And, the government started a nationwide research program to get detailed information about dioxin contamination of cow's milk in other regions. For this purpose cow's milk was examined in the vicinity of all Dutch waste incinerators and cable burn facilities. [50]

The nationwide research program showed that dioxin output of all waste incinerators have been too high as well as dioxin levels of cow's milk. Further, the research program suggested that the high dioxin output from waste incinerators could be responsible for toxic dioxin contamination of cow's milk and meat. In February 1990, Dutch government ordered that cow's milk and meat from a second contaminated area (near the waste incinerator of the city of Zaanstad, north of Amsterdam) should be collected systematically for destruction. Further, the production and sales of dairy products in that 'Zaanstad-area' was prohibited. [51, 52]

As a result of the nationwide research program four municipal waste incinerators were ordered to close down immediatedly. And, in 1993 and 1994 two other municipal waste incinerators had to shut down. Surprisingly, the AVR-Rotterdam incinerator that was held responsible for the contamination of dairy products in the Lickebaert area received permission to continue its operation. The amount of waste incinerated dropped from about 2983 kilotons in 1990 to 2957 kilotons in 1995 (because of re-use and prevention and because of incineration capacity available, the incinerator of Roosendaal was out of business for renewal in 1995).[53]

Despite the serious concerns of citizens against waste incineration, the Dutch government continued their policy to triple the incineration capacity in 2000.[54, 55] However, strong citizens protests forced government to drop a few new incinerator proposals, and to close down another existing incinerator. Although citizens protest have been successful in preventing the building of a few new incinerators, others have been build. And, despite the fact, that the government was not successful in increasing the incineration capacity as initially planned, waste incineration has become a major route for waste disposal in the Netherlands.

We try to show the problems related to handling waste incineration residues in developed European country in this case study. This case study and data in it are based on study conducted for IPEN Dioxins, PCBs and Waste WG. [56]

7.1.2 Waste incineration residues in Netherlands: introduction to the real issue

The Netherlands incinerates roughly 38% of its municipal waste yet has relatively high rates of recycling of municipal waste at approximately 25%.[57, 58] In 1999 a total of 6,965 ktonnes of

waste (excluding contaminated soil, dredging spoil and manure) was incinerated.[59] The Netherlands have the largest installations in Europe for municipal waste incineration with a medium capacity of 460 kt/a.[60] In 2000 there were 11 MWI in operation in the Netherlands.

In 1995, the Dutch government issued a directive with environmental specifications for construction materials, which include all materials that are used for building houses, offices, factories and roads.[61] Although waste incineration fly ash and bottom ash should come to meet the limits (like all other construction materials and residues), the government decided that fly ash and bottom ash are exempt from this obligation. As a result, fly ash and bottom ash can be used almost without any restriction.[62] Looking at levels of different chemicals in waste incineration residues from Netherlands showed in Table 3 this is not a good practice for protection of environment.

7.1.3 Fly ash

The annual production of fly ash is ranging from 79000 - 81000 tons in the Netherlands. The fly ash production is quite steady because the quantity of incinerated waste has not been changed for the past few years. The annual production of boiler ash has decreased from 8800 tons in 1999 to 3800 tons in 2002.[63]

Approximately 35000 - 40000 tons of annual fly ash production is used as filler material for asphalt production. However, since fly ash is produced during the year, but asphalt is manufactured mainly during summer, and other filler materials compete with fly ash, not all fly ash can be disposed of as filler material in asphalt.[64, 65] During the life time of asphalt toxic substances can be dispersed into the environment, as a result of leachate. To our knowledge no study was carried out on this topic.

Table 3. Average composition of fly ash and bottom ash from Dutch waste incinerators in 1997 (in milligrams per kilogramme). For bottom ash numbers of analyzed samples were not available.[a, a, a, a]

Substance	Average levels in fly ash (mg/kg)	Number of samples analyzed	Average levels in bottom ash (mg/kg)
aluminium (Al)	30,294	17	not defined [b)]
arsenic (As)	97	17	19 - 23
cadmium (Cd)	379	17	2 - 8
chromium (Cr)	231	31[a)]	235 - 296
copper (Cu)	1,154	17	669 - 3212
mercury (Hg)	2	17	0,03 - 0,2
lead (Pb)	7,671	17	1086 - 1637
molybden (Mo)	50	17	5 - 11
nickel (Ni)	88	30[a)]	40 - 86
selenium (Se)	9	17	0,4 - 0,5
strontium (Sr)	245	17	not defined [b)]
tin (Sn)	1,007	17	62 - 77
vanadium (V)	30	27[a)]	40 - 52
wolfram (W)	77	17	not defined [b)]
zinc (Zn)	22,488	17	1239 - 2125
bromine (Br)	997	17	not defined [b)]
chlorine (Cl)	74,471	17	1050 - 2445
fluor (F)	57	17	not defined [b)]
dioxins (PCDD) and furans (PCDF)	0.0024 (in I-TEQ)	17	below detection limit

[a)] between 1986-1995
[b)] Not defined = no measurement carried out

Approximately 44000 - 46000 tons of annual fly ash production is landfilled in the Netherlands, or exported to Germany and dumped in old salt and coal mines. [66] In 2002, 29500 tons were exported, in 2003, 45000 tons. Most of the boiler ash is exported to Germany as well.[67, 68]

For the landfill disposal route, the fly ash is packed in so called large plastic bags and piled up in separate sections of common landfill sites. To stabilize the big bags, sand is squirted, or washed between the bags to fill the hollow spaces. Alternatively, a fly ash mixture is used as top cover for common landfill sites.

After the big bags are piled up in the separate sections of the landfill site, the water that is used to squirt, or wash the sand between the bags get into contact with the fly ash, accellerating the leachate process. Moreover, heavy pressure exerted on the landfill can make big bags burst, increasing the leachate process any further. Also the fly ash mixture that is used as top cover for common landfill sites can rupture after heavy pressure exerted on the lower layers of the landfill will increase tension in the top cover. As a result, rain water easily get in contact with the waste landfilled below the cover layer, reinforcing the process any further.[e]

7.1.4 Bottom ash

In the Netherlands, the annual production of bottom ash is approximately 1.200.000 tons. The bottom ash production is quite steady because the quantity of incinerated waste has not been changed for the past few years.

In 2002, 770.000 tons were used for road beddings, and hardening surfaces of industrial sites. This is much lower compared to previous years, when 820.000 up to 1.340.000 tons have been dumped under roads. Waste incinerators have storage facilities for periods during which road building activity is lower. However, the drop in 2002 is not a result of a small demand for road works, but because of growing concern about the negative environmental impact of dumping bottom ash under roads. Road constructors have been increasingly reluctant to further use bottom ash for road construction. In consequence of this growing concern, the quantities in stock at incinerators have increased to 1.028.000 tons by the end of 2002, which is almost as much as annual production.[69]
Small quantities of bottom ash are landfilled on common landfill sites and exported respectively. In the past few years the annual quantities landfilled ranged from 700 to 12.500 tons. In 2002 and 2003 3,200 and 2,300 tons of bottom ash respectively were exported.

Similar with fly ash, the use of bottom ash as a bedding for roads brings the ash easily into contact with other (non hazardous) materials used for road construction, like sand and stones. But, inevitable, roads need to be reconstructed, or repaired, and the old road debris that need to be removed contains elevated levels of toxic substances. Mixture of bottom ashes, fly ashes and other materials can increase leachability of dioxins from these materials as dissolved humic matters content increases. [70]

7.1.5 Inventories of dioxins in fly ash and bottom ash

In the Netherlands, fly ash is a major route for dioxin releases from waste incineration to the environment. In 1991, the National Institute of Public Health and Environmental Protection (Dutch EPA) estimated the quantity of dioxins in fly ash and bottom ash for 1020 g I-TEQ/year and 8.5 g I-TEQ/year respectively. Since 1991, the incineration capacity has been increased from 2760 kilotons to 5200 kilotons in 2000. For 2000 the quantity of dioxins in ash is estimated 2671[f] g I-TEQ/year.[71, 72]

Compared to fly ash, which is the main carrier for dioxins in residues from waste incineration, dispersion of dioxins in the environment by bottom ash was considered to be small. Heavy metals in bottom ash pose a much bigger burden for the environment.

[e] for more information about leaching fly ash ability look at Chapter 5

[f] this figure includes dioxins in bottom ash and filter residues.

According to information from the operators of the Dutch waste incinerators in 1997 [73], and based on annual production of fly ash, annual dioxin quantity in ashes is estimated 190 - 195 g I-TEQ. These figures differ strongly from the official estimates from Dutch EPA, and University of Amsterdam.

7.1.6 Conclusion

The disposal of fly ash and bottom ash, in asphalt, road beddings, landfill sites and salt and coal mines contributes to an increased dispersion of hazardous substances in the environment, some of them, like dioxins, classified as persistent organic pollutants (POPs). It is not surprisingly that with this on-going annual burden, the background levels of dioxins in the Netherlands remain high, and, according to the Health Council of the Netherlands, the recommended (health protecting) levels for humans and in some cases for ecosystems are being exceeded. [74]

7.2 Other EU Member States

Economic expenditures connected with management of residues produced by incinerators differ in the individual EU Member States, depending on differing practice in the individual countries, and also depending on differing conditions (including economic ones). These differences are shown in Table 4. The following two Chapters summarize information on legislation concerning management of waste incineration residues in two EU Member States, Austria and Sweden, information concerning this issue in both the United Kingdom and the Czech Republic are present in Chapter 8 „Hot spots case studies“.

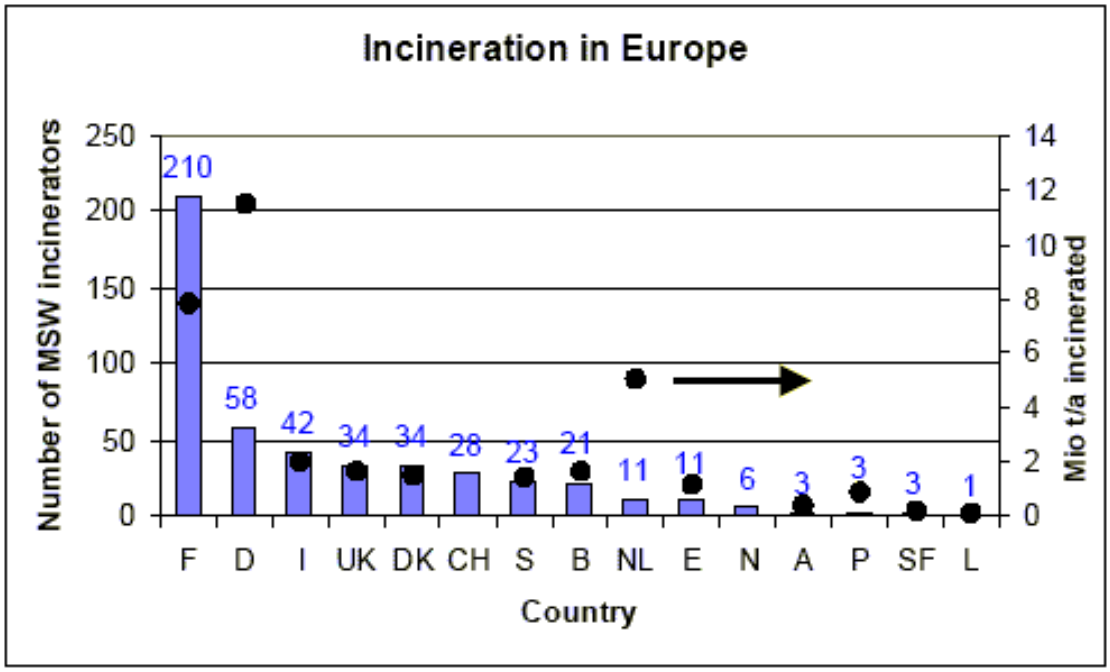
Table 4: Costs of operators of municipal waste incinerators connected with treatment of bottom ash and wastes resulting from flues gases treatment in EU countries. Source: Eunomia 2001.[a]

Country	Bottom ash, slag EURO/t	APC residues EURO/t	Note
Austria	63	363	-
Denmark	34	134	-
Germany	28.1	255.6	including fly ashes
Italy	75	129	including fly ashes
Luxembourg	16	8	-
United Kingdom	used as construction material	90	-

7.2.1 Austria

In Austria, management of wastes produced by incinerators is regulated by two directives, namely by the Directive on Waste Incineration, and by the Directive on Landfilling. The first of these Directives[75] requires facilities incinerating and co-incinerating wastes to minimise the amount and harmfulness of wastes produced by them, and to carry out analyses thereof (determining the amount of harmful substances both in the wastes and in the leachate from the wastes). Documents concerning the analyses must be kept for one year, at least, and must be given at disposal to authorities. In the case that the limit for dioxins (100 ng I-TEQ/kg) in the wastes is exceeded, then the wastes must be treated in order to reduce this value below the limit. Further, according to the Directive, formation and dispersion of dust from these wastes must be prevented during transport and intermediate storage.

According to a communication from the Austrian Ministry of the Environment, dated May 2004, filter cake from treatment of gases, and a part of fly ash, are handed over to Germany. The second part of fly ash, as well as bottom ash, are landfilled, or solidified and then landfilled. Activated carbon from flue gases treatment is incinerated. Gypsum from wet flue gas washers is landfilled, solidified and then landfilled, or used as a construction material.[76]



Picture 6: Number of municipal waste incinerators and amount of incinerated municipal waste in European countries in 2000. Source: UBA 2002.[a]

7.2.2 Sweden

In 1999, 22 incinerators were in operation in Sweden. They incinerated, in total, 1.9 million tons of waste. This amount included 1.3 million tons of municipal waste and 100 thousand tons of waste wood. The remainder was formed by hazardous (industrial) waste. In the same year, the incinerators produced 370.000 tons of bottom ash which contained 5 to 10 I-TEQ PCDD/Fs. Further, ca 50 thousand tons of wastes from flues gases treatment were produced by the incinerators. These wastes contained, in average, 2 to 3 ng/g PCDD/Fs. In 1999, all Swedish incinerators released 3 g I-TEQ PCDD/Fs into the atmosphere (in 1985, this was 90 g Eadon TEQ PCDD/Fs). The amount of dioxins (PCDD/Fs) in wastes from flue gases treatment was many times higher: 110 - 120 g I-TEQ.

According to results of analyses of wastes from flue gases treatment produced by 6 Swedish incinerators, carried out in 2002, the average concentration of dioxins in the wastes was 0.2 ng I-TEQ/g (median being 0.22 ng I-TEQ/g).[77]

7.3 Pakistan - medical waste incineration

Medical waste incineration is quite a common treatment for medical wastes in Pakistan. Medical waste is burned in small scale waste incinerators without any air pollution control devices (APC) and/or with a very simple one.[78] The residual ash is buried at general dump sites like this near Charsadda road (near Peshawar) which this study focuses on and/or in deep holes with very poor or no insulation to prevent the leaching (leaking) of toxic substances from the ashes into underground water resources (for example in Shifa Internationals Hospital, Islamabad or in SK Cancer Hospital, Lahore - see photos at Pictures 7 - 11).

A small scale waste incinerator located in LRD Hospital, Peshawar (Pictures 7 and 8) contributes to the quantity of residual ash dumped at the Charsadda road dump site, where this ash was observed to be a potential

source of dioxin contamination in free range chicken eggs collected from near village. [79]

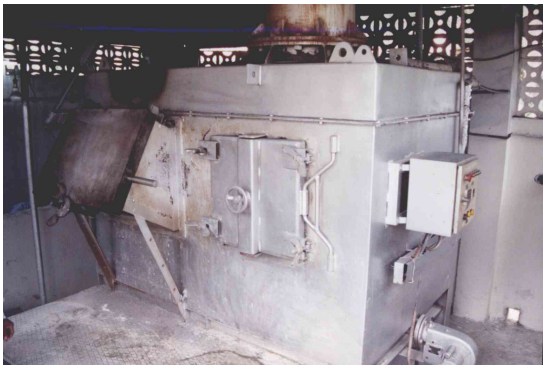
The LRD Hospital incinerator is one of 4 located within the North Western Frontier Province. It was built using the Chinese company Minama technology with two chambers without any air pollution control equipment (APC). It burns selected infectious waste from the hospital and runs for 4 - 8 hours per day with the exception of Sunday when it does not work at all. This is common in almost all other medical waste incinerators in Pakistan resulting in many start up and cool down operations occurring during the week. The LRD Hospital waste incinerator was built in 2001 and is already obsolete. It burns about 250 kg of infectious waste per day. These are figures for small scale medical waste incinirators using one kiln.

There are non-combustion alternatives to waste incineration which can avoid U-POPs releases as required by one of major aims of the Stockholm Convention. In Tabba Heart Institute, Karachi there is already a suitable alternative to an incinerator installed, an autoclave. Findings of this study support this method of dealing with medical wastes as a solution that makes Stockholm Convention aims achievable.

Situation in Pakistan gives representative picture of more developing countries (in India and/or Kenya).

Pictures 7 and 8: Medical waste incinerator in LRD Hospital, Peshawar. Small scale medical waste incinerator, typical for Pakistani hospitals. Photo by: Jindrich Petrlik.

Pictures 9 - 11: Waste incineration residue in the deep hole - storage built in the area of hospital. Cover of similar hole in another hospital. Double chamber kiln in one of Pakistani medical waste incinerators. Photos by: Jindrich Petrlik



8. Hot spots case studies

8.1 Hot spots and incineration residues in United Kingdom

There are currently 17 municipal waste incinerators in the UK[g], of which Edmonton is the biggest. Thirty-three new ones were under construction or in various stages of planning at the beginning of 2001[80]. The Byker Combined Heat and Power waste incinerator located in the city of Newcastle upon Tyne burnt refuse-derived fuel (RDF).

Since 1998, waste companies in UK have been using less hazardous 'bottom ash' collected in incinerator grates and selling it to be mixed with asphalt or concrete and used in building projects.

The operators of both Byker and Edmonton incinerators had been illegally mixing this bottom ash with the more toxic fly ash from the air pollution control devices (APC).

The scandal surrounding the dumping of toxic incinerator ash on Newcastle upon Tyne allotments and footpaths in 2001 revealed that incinerator operators across Britain may have been breaking the law while avoiding the cost of disposing of toxic ash in special hazardous waste landfills by selling it to be "recycled" into building projects.

Amazingly while the UK's Environment Agency was gathering evidence to procecute the operators of the Byker incinerator for spreading a mixture of fly and bottom ash in areas around Newcastle upon Tyne, it had full knowledge that the operators of the Edmonton

[g] 2 in Scotland, 1 in Jersey, 1in Wales and rest is located in England. About two-thirds of incineration capacity in England was according to study carried out by Environment Agency in 2002 concentrated around London and the West Midlands.

Table 5: PCDD/F levels in ash, soil and eggs in allotments with poultry in I-TEQ in pg/g (source Pless-Mulloli et al.[a])

Allotment name	Ash	Soil 30cm	150cm**	Eggs No.	Type	Fat basis	Distance from ash in m
• Allotments, which have received incinerator ash							
Blaney Row	150	7	N/A	3	H	4.4	0,20
				1	H	0.8	0
				1	H	8.9	20
Branxton A	3000	95	49	3	H	25	0
				3	B	56	0
Branxton B	3000	272	90	3	H	17.5	10,15
Brunswick	373	11	N/A	3	H	7	20
Coxlodge	4224	27	28**	3	H	1.5	30
Denton Dene	1636	34	N/A	2*	H	25	0,0
Hulne Terrace	910	14	N/A	3	H	31	0,10,20
				1	H	29	0
				1	H	0.4	10
				1	H	3.6	20
St. Anthony's	20	23	25**	2*	H	27	0,20
				2	D	9	0,0
Westmacott Street	2123	45	20	3	H	18	0,0,30
				1	H	5.6	0
				1	H	19.4	0
				1	H	2.9	30
Controls							
Hawthorn Farm	na	-	-	3	H	0.2	na
Pets Corner***	na	-	-	3	H	20	na

Notes to Table 4: H= Hen, B= Bantam, D= Duck, *one egg broken in transport, **samples from Environment Agency (EA) analysis program, sampling was done in parallel to this study, but strategy for analysis was to include all 30cm and 150cm samples, na=150cm samples only analyzed if 30cm sample above 40pg/g I-TEQ, ***The egg sample at Pets Corner was taken as control, but turned out to have contamination with PCDD/F. This was due to overflows of a stream contaminated with sewage sludge.

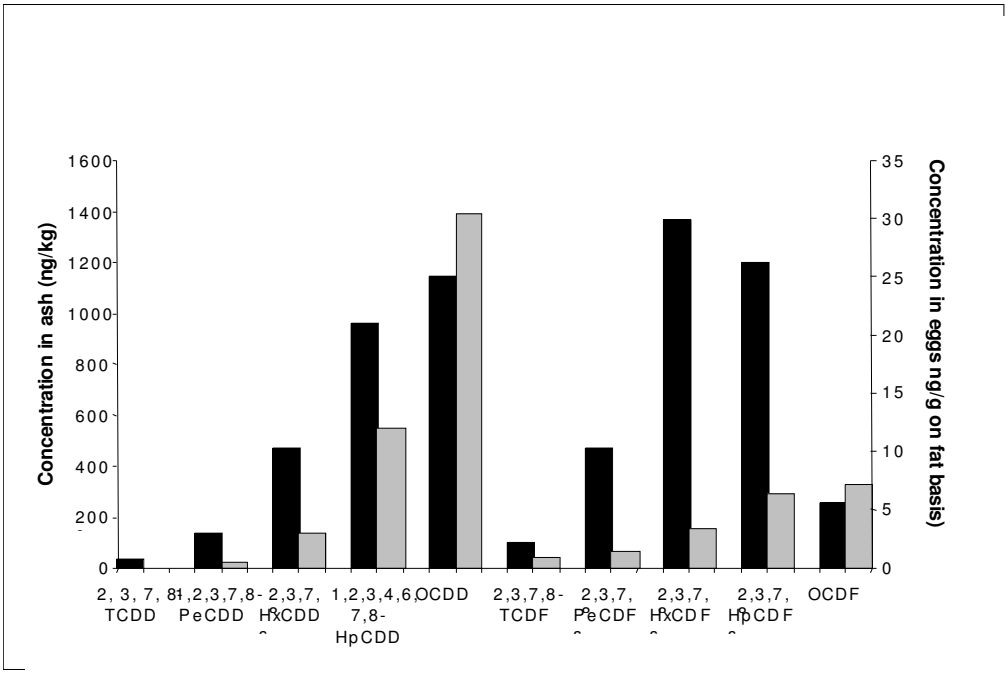
incinerator in North London had been mixing fly and bottom ash for 30 years (until August 2000) and was simultaneously sitting on a working Ash Group with the operators encouraging the use of similar mixed ash as road aggregate, breeze block type building bricks, and hard core in car parks.[81]

In December 2001, air pollution control residues leaked during unloading at the Castle Environmental plant due to a fault in the pipework. The dust was damped down after instructions from the Agency.

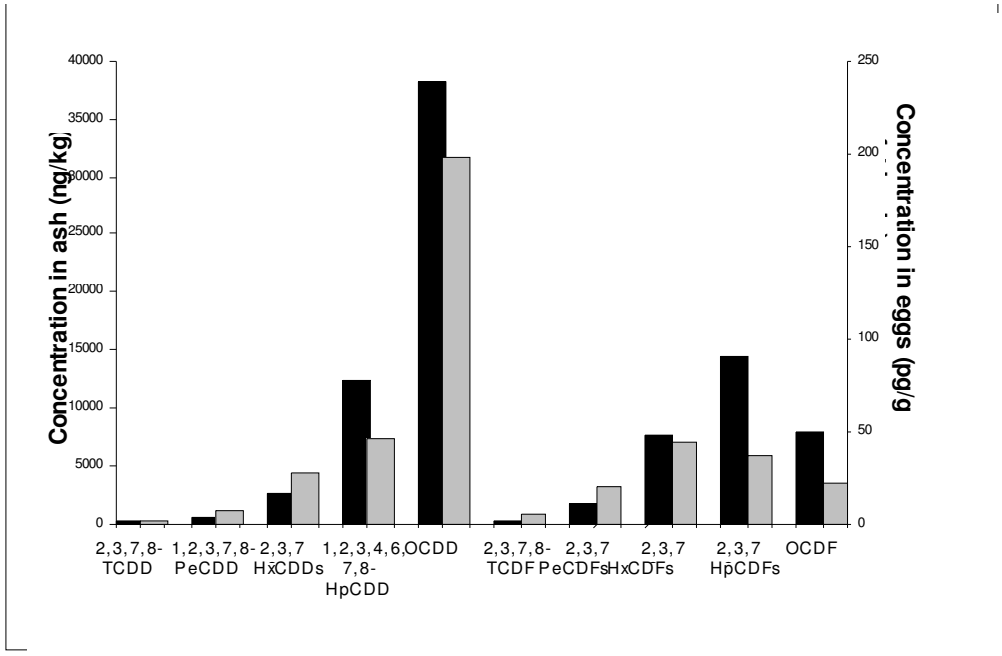
The plant installed for mixing wastes and powders were provided, in 4 cases, with suitable extraction and dust abatement equipment; in the other plant, no extraction was installed, but other dust suppression procedures were used. One plant had been the subject of occasional dust complaints from members of the public.

8.1.1 Newcastle

In the years 1994 - 1999, an estimated 2000 tons[82] of fly ash and bottom ash from the Byker incinerator were spread on food producing land, farms, flower beds, school playing fields, bridal pathways and footpaths around Newcastle. Tanja Pless-Mulloli et al.[83] of Newcastle University studied the influence



Picture 13: Coxlodge: ash 4,224 ng/kg I-TEQ incinerator pattern, eggs 1.5 pg/g I-TEQ lipid basis non-incinerator pattern, chicken do not have access to ash



Picture 12: Westmacott Street: ash 2123ng/kg I-TEQ, incinerator pattern, eggs 18pg/g I-TEQ lipid basis, incinerator pattern, chicken have access to ash

of its use on contamination of soil and poultry. They examined a number of factors that could influence the level of dioxins contamination. The results of their study are summarized in Table 5. Concentrations of dioxins found in the mixed ash ranged from 0.02 to 9500 ng/kg d. m. (in I-TEQ).

Seventeen out of 19 egg samples from allotments which had received ash showed levels of of its use on contamination well in excess of barn held supermarket eggs. 17 out of 19 egg samples from

allotments, which had received incinerator ash showed influence of ash in the pattern of contamination (see Picture 12). The weighted average of all egg samples was 16.4pg/g I-TEQ. The weighted average for those samples, which showed the incinerator pattern in the egg samples was 22.2pg/g I-TEQ.

Wastes showing dioxins concentrations 750 - 3.5-times lower than "low POPs level" for dioxins[84] set out by the Basel Convention, used in Newcastle for reconstruction of footpaths, have resulted in contamination of poultry eggs which on average, exceeded 5.5 to 7-times the limit for the content of dioxins in eggs set out later in the European Union.

8.1.2 Edmonton

The operators of Edmonton MWI were supplying mixed ash to construction block manufacturers and to replace aggregate for road construction and car parks knowing full well it contained as much as 3,600ng/kg to 10,800ng/kg of dioxins. Therefore the level of dioxin contamination in this fine mixed ash would be in excess of 1100ng/kg, significantly higher than the 200ng/kg, (peaking at 900ng/kg) left as a result of spraying Agent Orange in Vietnam, where they are still reporting birth defects and elevated dioxin levels in human tissues 30 years after the spraying ceased. [85]
Typically, the mixed ash was mixed with 1 – 3% cement, 25 – 50% furnace bottom ash, for example from a power station, 25% aggregates and water. The amount of mixed ash in a typical block varied from about 10% to 25%. Blocks containing mixed ash from two different manufacturers have been identified, sampled and analysed for dioxins.

There is evidence of fly ash from Edmonton as high as 10,800ng/kg I-TEQ and calculations showing the final levels of dioxin in mixed ash as being 771ng/kg I-TEQ. Further tests on dioxins in fly ash from UK plants were in the region of 6,600 and 31,000ng/kg[86].

Results of four analyses show a range 117 – 390 ng ITEQ/kg of dioxins in the blocks. Tests conducted by the BBC documentary programe *Newsnight* 7 on a sample block made from 30% of Edmonton ash showed 343ng/kg. [87] By contrast, blocks incorporating Edmonton bottom ash with no electrostatic precipitator ash, would be expected to contain less than 4ng ITEQ/kg. Table 6 shows the dioxin concentrations found in a range of construction blocks and bricks in Edmonton

Table 6: Dioxin concentrations in construction materials

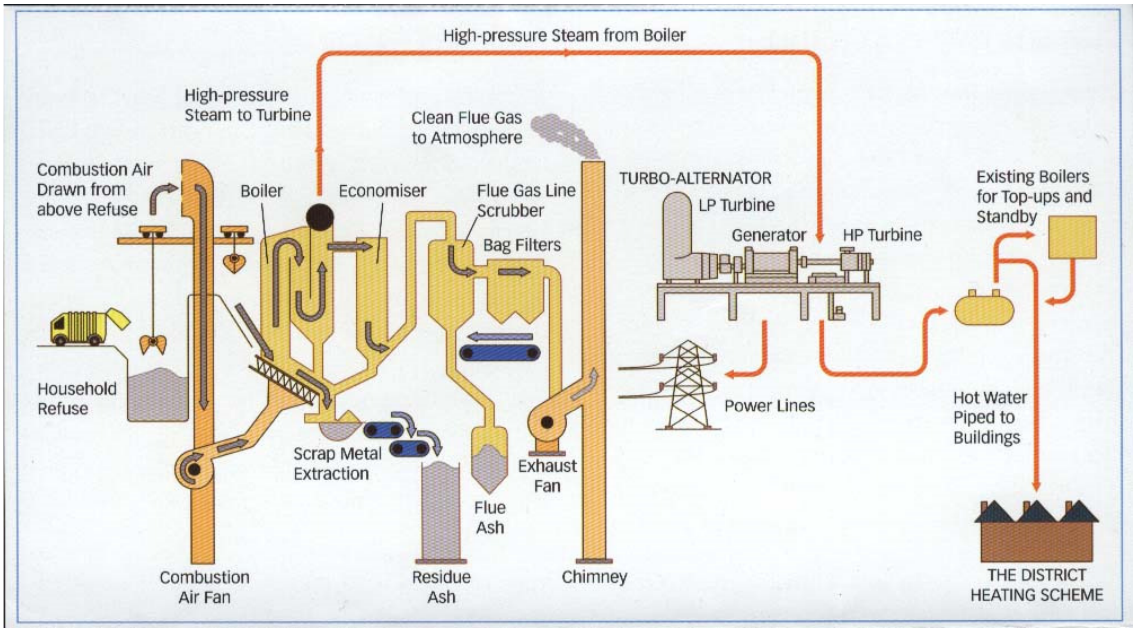
Construction blocks	ng ITEQ/kg	Bricks	ng ITEQ/kg
Thermalite	1.5	Chesterton	1.4
Hem PQ/7a	3	Leicester	1.7
Lignicite	1	Fletton	0.9
GGBS Ash	1	Other	
Celcon	2	Ordinary Portland Cement	0.5 to 1
Stock Brothers. Breeze	12	Pfa ex Ratcliffe	6.7
Durox	10	Pfa ex Drax	2.8
blocks from Edmonton mixed ash	117 to 390	blocks from Edmonton bottom ash	expected 4* measured 23**

Notes: * Calculated by EA report[88] authors. Based on the average dioxin concentration in Edmonton bottom ash of 10 ng/kg ITEQ[h].

** One block reported only to contain bottom ash from Edmonton was analysed and found to contain 23 ng/kg ITEQ dioxins.

[h] See Annex 18 in EA 2002: Solid Residues from Municipal Waste Incinerators in England and Wales. A report on an investigation by the Environment Agency, May 2002

Picture 14. Edmonton. Most current UK plants have a conventional grate, superheater, economiser, semi-dry scrubber with lime and activated carbon injection followed by a bag house as shown in the schematic below (with the generally optimistic addition, in this case, of the district heating system!). Edmonton is an unusual configuration because the acid gas removal plant and the new bag house were 'bolted onto' the existing electrostatic precipitator system.



8.2 Hot spots and incineration residues in the Czech Republic

Fly ash, bottom ash and other wastes from incinerators in the Czech Republic have been deposited in hazardous waste landfills for many years. In 1997 a decree of Law on wastes set a limit on the dioxin content in wastes of 10 ng/g. Wastes exceeding this limit would have to be stabilised and then deposited in a speacialised hazardous waste only landfill. Simultaneously with the introduction of this law, the fees for depositing wastes on hazardous waste landfills increased significantly.

The sum of these measures have resulted in the operators of waste incinerators looking for ways to avoid paying these high landfill fees for fly ashes and for the means to avoid measurements of dioxins in fly ashes. Due to the benevolence of the state authorities they have been successful in both these aims as documented by the case of the municipal waste incinerator in Liberec in further text.

Arnika Association in its previous report on waste incineration residues estimated amounts of dioxins content in produced waste incineration ashes in 2002. Municipal waste incinerators released 20 g I-TEQ of dioxins in residues. Estimation of dioxins level released in ashes from hazardous waste incinerators[i] in the Czech Republic ranged between 7.5 and 150 g I-TEQ. These calculations were based on the official figures about waste production in the Czech Republic for 2002 and the range of measured levels of dioxins in waste incineration residues.[89] Large range of measured levels of dioxins in fly ashes from hazardous waste incinerators (see Annex 2) is the reason for large range of dioxins produced by hazardous waste incinerators.

8.2.1 Liberec

The municipal waste incinerator in Liberec began operations in 1999. It is designed in such a way that fly ash is mixed with bottom ash. The incinerator, having a capacity of

[i] including medical waste incinerators too

Picture 15: Municipal solid waste landfill in Košťálov, where the mixed ashes from MWI in Liberec were dumped for long time without any pretreatment.
Photo by: Vítězslav Roušal.

96.000 tons of wastes per year, produces between 25 and 40 thousand tons of this ash mixture yearly[j]. Despite this mixture exceeding the limit for dioxin contamination as set out in the law[90], the incinerator was allowed to deposit the ashes on a municipal waste landfill in the year 2000.

The situation has changed since then as new law on wastes and a decree have cancelled the limit set for the content of dioxins in wastes. They have set out that fly ashes from waste incinerators must be, without any measurements, stabilised and then deposited on hazardous waste only landfills. Simultaneously, the operators of the Liberec incinerator, the company Termizo, obtained a certificate allowing the mixture of fly ash and bottom ash to be sold as a construction material.

The Ministry of the Environment of the Czech Republic set out orientation limits for the decontamination of old ecological burdens in 1996. There is no doubt that if sometime in the future the sites where the mixed ashes from the Liberec incinerator has been deposited are checked for the content of dioxins, they will most certainly exceed the limit B[k] set out by the binding methodical instruction of the Ministry. Exceeding limit B in soils is considered a serious pollution problem having a negative influence on human health and individual components of the environment and as such requires further measures being taken.

Increased levels of dioxins in eggs and meat of free-range poultry have been caused by concentrations of dioxins that were 10x (and sometimes even 100x) lower than this limit.

It is impossible at this moment in time to establish whether the described use of the mixture of ashes from the incinerator in Liberec has resulted in increased concentrations of dioxins in soils and animals because the location of the dumping sites is secret and known only to Termizo, the incinerator owner. These sites are unknown even to state authorities in charge of environmental supervision.

8.2.1.1 The case of the incinerator in Liberec, Guidelines on BAT/BEP and limits for the content of POPs in wastes

Concerning the treatment of residues from municipal waste incinerators, the "Guidelines on Best Available Techniques and Best Environmental Practices (BAT/BEP)", proposed to be adopted by COP 1 of the Stockholm Convention, state the following: *"Bottom and fly ash from the incinerator must be properly handled, transported and disposed*

[j] Specific amounts for years 2001 - 2003 are shown in Table 8.

[k] Limit B = 0.1 ng I-TEQ/g dry weight

of. Covered hauling and dedicated landfills are a common practice for managing these residues. Particularly if reuse of the residues is contemplated, an evaluation of the content and potential environmental mobility of chemicals listed in Annex C is required, and guidelines adopted by the Basel Convention and subsequently adopted by the Conference of the Parties of the Stockholm Convention should be followed. Periodic analysis of the ash can also serve as an indicator of incinerator performance or the introduction of illegal or unpermitted wastes or fuels (for example, the detection of high metal content in the ash as a result of burning construction debris in an incinerator permitted to burn only virgin wood).

Scrubber effluents, including the filter cake from wet flue gas cleaning, is regarded as hazardous waste in many countries and must be properly treated and disposed of. If the concentration of chemicals listed in Annex C or other toxic materials (for example, heavy metals) is sufficiently high, these materials may be consigned to landfilling as hazardous waste."

In the case of the Liberec incinerator, satisfying this text in practice will not result in any change to the better. It will continue to be able to use the mixture of bottom ash and fly ash as a construction material. Why? Because the "Guidelines on BAT and BEP" refer to the "*guidelines adopted by the Basel Convention"*. According to them, it is not necessary to treat the waste in any special way if it does not contain dioxins in concentrations higher than 15 µg I-TEQ/kg dry weight. Table 6 shows levels of dioxins found in wastes produced by the Liberec municipal waste incinerator. In the case of the adoption of the POP levels according to Basel Convention, the Stockholm Convention will fail to protect public health and the environment from releases of dioxins from fly ashes produced by the waste incinerator in Liberec.

The BAT principle is also used in the EC Directive about Integrated Pollution Prevention Control. In the case of the incinerator in Liberec, an operating license has been already issued according to this Directive[91]. Not only did the competent authority fail to prevent the mixing of fly ash and bottom ash, it failed to establish a duty to make measurements of hexachlorobenzene and PCBs in fly ash and other wastes produced by the incinerator.

8.2.1.2 Calculation of releases of PCDD/Fs contained in wastes produced by the incinerator into the environment

In contrast to similar plants in the Czech Republic, measurements of dioxin contents were carried out in wastes produced at the Liberec incinerator. The basic results of these measurements are shown in Table 7. In addition to these, the level of 0.2136 ng I-TEQ/g was found in the mixture of fly and bottom ash[92]. The operator of the incinerator somehow had the mixture of ashes reclassified as waste that does not have hazardous characteristics and since the year 2001 have possessed a certificate according to which this mixture can be marketed as a construction material.

Any mixture of fly ash and bottom ash will contain high concentrations of dioxins, which, in the case of fly ash used in Newcastle, resulted in the contamination of eggs and poultry in the vicinity of where it was spread.[93]. Therefore, such ashes should be

Table 7. : Results of measurements of dioxin contents in bottom ash and fly ash in Liberec[a, a].

Type of waste	Measurement No. 1 ng I-TEQ/g	Measurement No. 2 ng I-TEQ/g
bottom ash (2911)	0.00437	0.0197
treated fly ash (2912)	0.362	0.363
mixed bottom ash with treated fly ash (2913)	0.062	0.066
boiler ash (11249)*	0.0113	-

included into the calculation of total releases of PCDD/Fs into the environment.

UNEP prepared a proposal of "Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases", with an attached 'tool' for the calculation of total releases of dioxins into the environment with emission factors. We have tried to use this Toolkit to calculate the amounts of PCDD/Fs in the wastes produced by the Liberec incinerator. The result is shown in Table 8. Following this we made the same calculation using known information concerning the amounts of wastes produced by the Liberec incinerator on the levels of dioxins found in these wastes. Data for waste waters, as well as for filter cake, are not available[1].

For calculations concerning the year 2003, only estimates of releases of PCDD/Fs in product/material, for which the mixture of fly and bottom ash was certified could be made. Our calculations were based on data of waste production given by the incinerator in an application for issuance of IPPC certificate. Information on the calculations are contained in Table 9.

Table 8: Calculation of PCDD/Fs releases per year for MWI in Liberec based on UNEP's Toolkit and on real measurements.

	Annual release						Total annual release in g TEQ/a
	g TEQ/a Air	g TEQ/a Water[a]	g TEQ/a Land[a]	g TEQ/a Products	g TEQ/a Fly ash	g TEQ/a Bottom Ash	
Toolkit	0.048	0	0	0	1.44	0.144	**1.584**
Reality 2002a	0.0898	?	?	0	0.3828	8.2780	**8.7506**
Reality 2002b	0.0898	?	?	0	0.3828	2.4030	**2.8756**
Reality 2003a	0.037	?	?	8	0.4203	0.1440	**8.6013**
Reality 2003b	0.037	?	?	2.25	0.4203	0.1440	**2.8513**

In each of the cases calculation according to real values has been carried out in two variants designated "a" and "b", in view of the fact that levels of dioxins found out in the mixture of fly ash with bottom ash differ significantly. The real amount of dioxins contained in this waste is likely to be somewhere between both variants.

Table 9: Amounts of residues produced by MWI in Liberec per year[a].

Type of waste	Amounts of produced waste per year in		
	2001	2002	2003
Filter cake (19 01 05)	1085,22	1051,44	1154,8
Waste water from flue gases treatment etc. (19 01 06)	106,12	121,54	21,5 *
Bottom ash (19 01 12) **	33 703,92	38 754,17	2316,09 ***
Other ashes (mainly boiler ash; 19 01 13)	128	113	92

* only amount transferred out of the plant included - waste water treated at plant's waste water treatment facility is not included in this number

** there is also treated fly ash included in this figure

*** biggest part of this waste has been used as product (construction material) since the beginning of 2003, so the amount of this "product" is not included here.

[1] For our calculation, we have used the concentration of dioxins found in treated fly ash and for the filter cake. In reality, it can be expected that the filter cake contains much higher level of dioxins than in our calculation.

In the case of the calculation according to the Toolkit[94], in comparison with calculation based on measured values vastly different numbers

were obtained. This was a result of several factors:

1) The Toolkit supposes much lower amount of residual wastes after the combustion of one ton of solid municipal waste.

2) The Toolkit does not consider the mixing of fly and bottom ash. This resulted in much lower level of dioxins in bottom ash being set.

3) Emission factors for releases of PCDD/Fs into the environment are given as simple numbers without ranges.

The difference between the calculation according to the Toolkit and reality will continue to increase after concentration of dioxins in waste waters from Liberec are known. These are not taken into account in the case of municipal waste incinerators in the Toolkit.

Picture 16: Sampling of sediments in surroundings of an old coal mine Jan Šverma near Lampertice at the beginning of 2004. Photo by: Jindřich Petrlík.

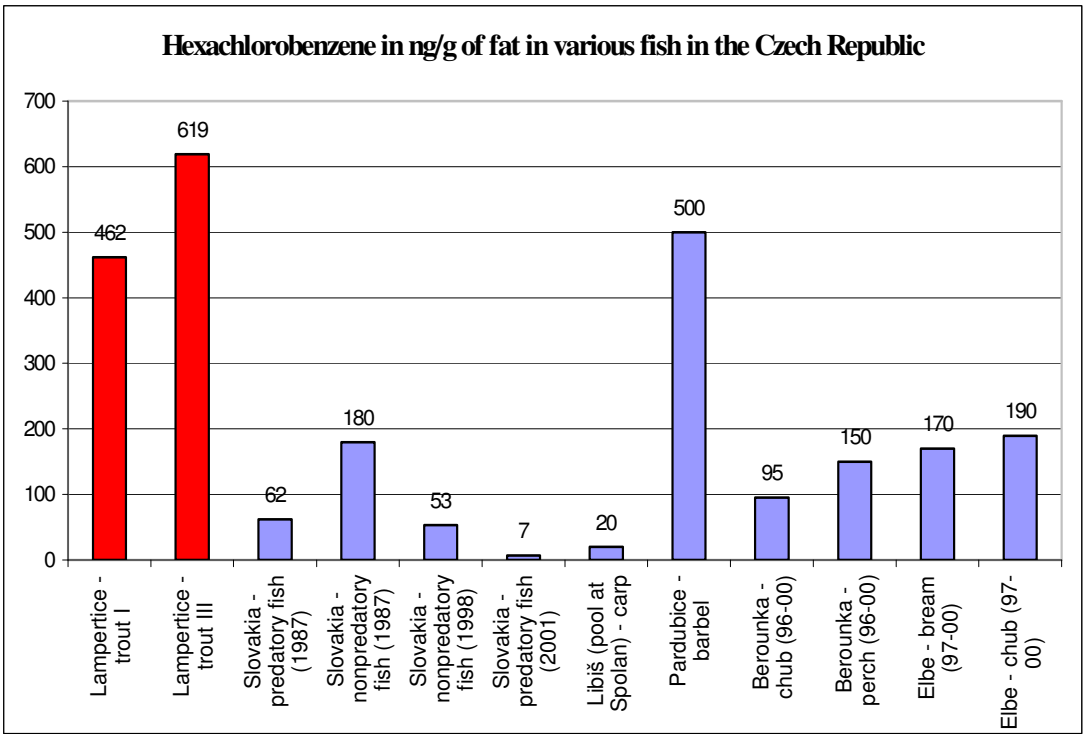
8.2.2 Lampertice

There have been black coal mine workings under the highest Czech mountains Krkonose (German synono-nyma Riesengebirge) in the northeast part of the Bohemia since the 16th century. The oldest underground mine was later called Mine Jan Šverma and is located between the town of Žacléř and the village of Lampertice. This mine was closed sometime around 1990.

The mine is located in an area with typical under-mountain landscape with a wild Lampertický creek. There is also a complicated underground water system that, according to the experts of the GEMEC Union company (working on the mine reclamation), doesn't leak from the mine. However local people who worked in the mine don't trust this opinion and say that the situation is much more complicated than most people believe. The Mine itself is located next to the Czech - Polish boarders, so any changes in the environment could well have transboundary impact.

It is common practice that these old mines are filled with different materials to prevent surface landscape movements. We have chosen this particular mine for our hot spot report as it has been filled with different types of wastes, including wastes showing POPs patterns. According to records of state environment control insitutions the waste incineration residues were stored in this mine in amounts up to 7000 tons per year.[95]

The basic argument of the GEMEC Union company is that the technology used is safe and that the leaching of toxic substances deposited in the mine does not occur. However, the results of tests of sediments from Lampertice stream showed that in one place (below a discharge from the waste water treatment plant in the premises of the mine), the dioxins concentration is ten times the amount of the lowest value found in the area (this is a tributary of Lampertice stream "U Kirschů", which drains the south part of the spoil heap). The measured values show without doubt the necessity and importance of a thorough environmental impact assessment of the



Picture 17: Graph showing comparison of concentrations of hexachlorobenzene measured in fat of fish from different localities.

chosen method of re-cultivation or liquidation of the underground mine.

At the first half of year 2004 the Arnika Association published results of analysis of four trout samples for different POPs. From the analyzed substances, the trout from Lampertice contained the highest values of hexachlorobenzene in comparison with the other locations in the Czech Republic as showed from the comparison presented in the graph at Picture17.[96] Also the value of indicator congeners of PCBs in the case of trout I was relatively high. Trout III values were lower, but also significant in comparison with values found in Slovakia in the years 1987 - 2001.[97]

8.3 Barangay Aguado, Philippines

Barangay Aguado is "home" to a controversial "Thermal Oxidizer Plant" operated by Integrated Waste Management Inc. (IWMI). A typi-cal incinerator had operated in the same site for over four years. The IWMI incinerator is a "pyrolytic waste oxidizer" from Canada-based EcoWaste Solutions Inc., with a capacity of 10 tons/day. Apart from treating biomedical waste coming from client hospitals in Metro Manila, the IWMI incinerator also accepts and burns illegal drugs such as amphetamines seized from drug syndicates.

The IWMI "Thermal Oxidizer Plant" was formally inaugurated in September 2003, in apparent defiance of the ban on medical waste incineration that took effect under the Clean Air Act in July 2003.

The IWMI claims that the residual ash from its facility is safe based on test procedures that do not measure dioxins. Tests conducted in 1998 for EcoWaste Solutions technology show significant levels of dioxins in the ash at 23 ng TEQ/kg of waste. [98]

NGO representatives present at the official launch of the IWMI facility were told that the bottom ash is mixed with cement to make concrete blocks. The hollow blocks, as they are called in the Philippines, are also mixed with industrial waste, i.e., shredded computer hardware scraps, which could also be the

Picture 18: Protest action opposing the construction of the IWMI waste incinerator in Barangay Aguado, Philippines. Photo by: Green Cavite.

source of high levels of polybrominated diphenyl ethers (PBDEs) [99] observed in free range chicken eggs sampled near IWMI's facility in Barangay Aguado, Philippines.

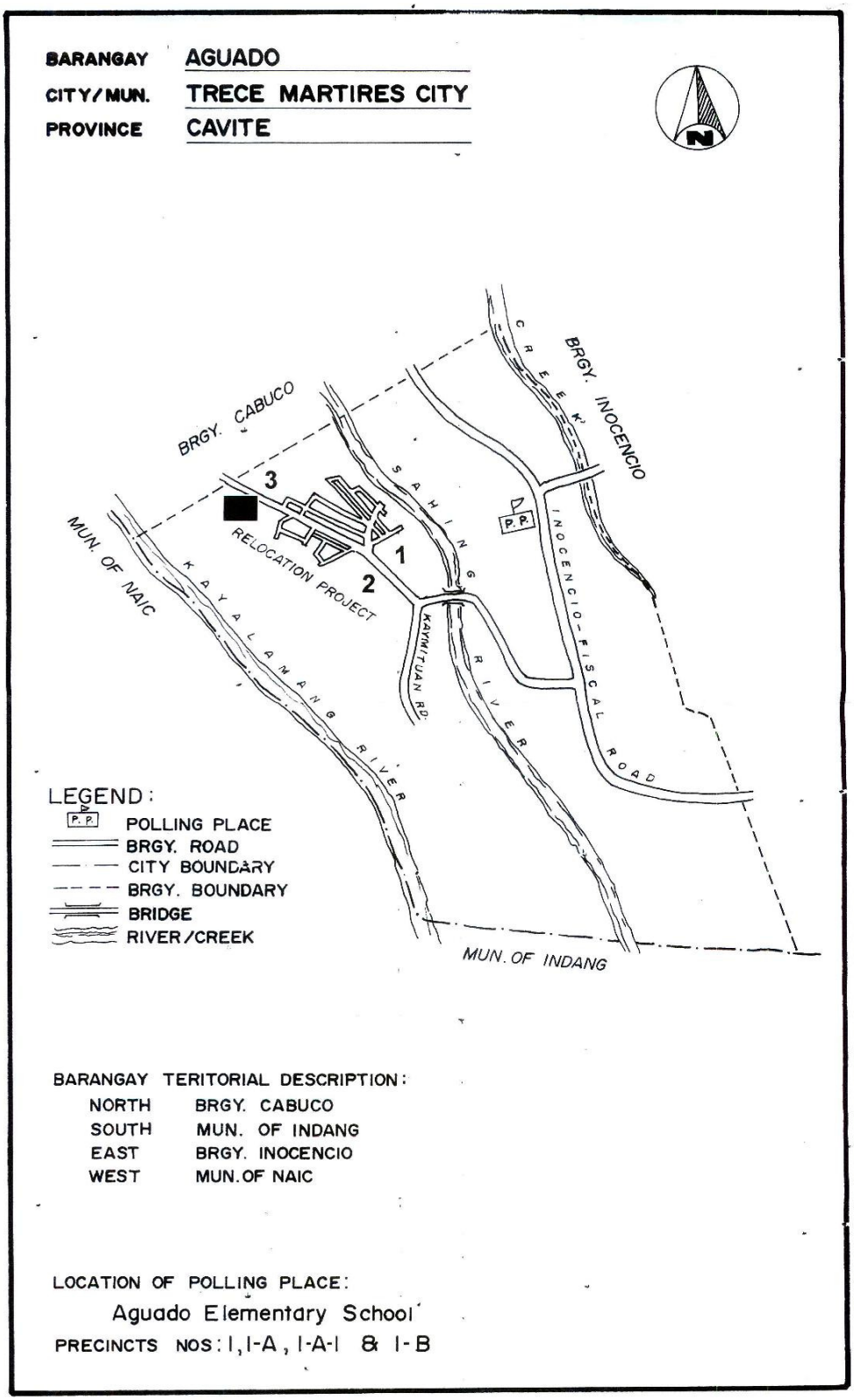
The communities, including Barangay Aguado and nearby Barangays, are possibly the most affected by the continued operation of the IWMI waste incinerator. The lack of a secured facility for containing the incinerator ash, and its use for making concrete blocks could only aggravate the spread of toxic pollutants into the air, water and soil. The vicinity map shows the existence of waterways (two rivers and a creek), a common source for water and fish, not far from the IWMI waste treatment plant (see Picture 19). [100]

Free-range chicken eggs collected near the medi-cal waste incinerator in Barangay Aguado showed levels of dioxins[m] that exceeded the European Union (EU) limit by more than 3-fold. Additionally the level of PCBs in the eggs[n] exceeded the proposed EU limit. The levels of 7 PCB congeners did not exceed regulatory limits but were the seventh highest observed among 20 samples analyzed during IPEN's global biomonitoring project.[101] The reasons for this substantial level of PCBs are not clear. The three egg sampling sites were approximately half a kilometer northeast of the incineration plant.

Comparing the dioxin congener pattern from eggs collected in Barangay Aguado with data measured for different kinds of sources from other countries indicates that medical waste incineration (including fly ash and air releases) is the likely source of the dioxins found in the eggs. Data from other types of dioxin sources such as metallurgy and/or local heating using wooden materials show different patterns of dioxin congeners.

[m] 9.68 pg WHO-TEQ/g of fat

[n] 3.30 pg WHO-TEQ/g of fat



Picture 19: Map showing the Barangay Aguado detailed situation. The black spot is the IWMI medical waste incinerator and numbers 1, 2 and 3 are marked sampling sites of free-range chicken eggs. The map shows also waterways – a possible pollution pathway.

9. Waste incineration residues questions and the Stockholm Convention

9.1 How much is a "LOW" content of POPs?

The content of POPs in waste is one of focuses of the Stockholm Convention in which Article 6 states: "Measures to reduce or eliminate releases from stockpiles and wastes" -- instructs the Stockholm Conference of Parties to cooperate closely with the appropriate bodies of the Basel Convention to:
"*establish levels of destruction and irreversible transformation necessary to ensure that the characteristics of persistent organic pollutants … are not exhibited";*
"determine what they consider to be the methods that constitute environmentally sound disposal"; and
"work to establish, as appropriate the concentration levels of the chemicals listed in Annexes A, B and C in order to define the low persistent organic pollutant content" below which POPs wastes need not undergo destruction or irreversible transformation, but are to be disposed of in an environmentally sound manner.

In response to Article 6, the Basel Convention Open Ended Working Group (OEWG) undertook the task of preparing a series of guidelines on wastes consisting of or containing POPs. The first two guidelines in the series – "General Technical Guidelines for Environmentally Sound Management of Wastes Consisting of, Containing or Contaminated with Persistent Organic Pollutants," and "Technical Guidelines for Environmentally Sound Management of Wastes Consisting of, Containing or Contaminated with Polychlorinated Biphenyls, Polychlorinated Terphenyls or Polybrominated Biphenyls" -- were approved and adopted at the sixth Conference of Parties (COP6) of the Basel Convention, 25–29 October 2004. [102, 103]

The Basel Convention Technical Guidelines has proposed levels of most POPs in wastes/residues that trigger the requirement for destruction or irreversible transformation of 15 ppb (in I-TEQ) for PCDD/Fs and 50 ppm for all other POPs listed in Annexes to Stockholm Convention. Low POP content levels as required in Article 6 of the Stockholm Convention are proposed at the same levels. Delegates at COP will have the opportunity to tighten these guidelines so that they provide greater protection to human health and the environment.

The proposed levels are not based on practical experience or on current knowledge about the levels in POPs wastes in relation to recorded examples of high environment and food chain contamination.

It is shown in this study that the majority of residues from waste incineration contain levels of dioxins that are below the proposed low POP content as well as bellow the level that requires further treatment to ensure that "*the characteristics of persistent organic pollutants … are not exhibited"*. Does this mean that use of waste incineration residues cannot harm the environment and public health?

Looking at the examples in this study the clear answer on this question is NO! The level established for dioxins (PCDD/Fs) at 15 ng I-TEQ/g is very high if we consider one example from UK, where waste incineration fly ash was spread on the allotments and poultry was contaminated by unacceptably high levels of dioxins. Fly ash spread on the allotments contained levels of dioxins in the range of 0.020 - 4.224 ng I-TEQ/g dry matter and contamination by this waste led to contamination of poultry eggs, up to 56 pg WHO-TEQ/g on lipid base.[104] EU limit set up for dioxins content in eggs is at 3 pg WHO-TEQ/g on lipid base which was exceeded by almost all eggs samples from Newcastle upon Tyne measured after that accident.

There are more documented cases of unsafe treatment of the wastes containing POPs which led and/or contributed to increased levels of POPs in the environment and food chain. Some of these were recently documented by series of studies on hot spots in different countries. These studies showed elevated levels of dioxins and other U-POPs in collected free

range chicken eggs sited near the hot spots. In some of these cases the high levels of dioxins were found to be related to wastes containing POPs. For example: the case of chicken eggs sampled in Philippines near a medical waste incinerator in Barangay Aguado where incineration residues are used for production of concrete "hollow blocks". The eggs collected near the incinerator showed very high levels similar to the waste incineration residues pattern of dioxin congeners. [105] Another case of eggs found with high dioxin contents in the mentioned studies is those taken from near the chlorinated waste disposal area of the poorly controlled chlorine chemical industries in Dzerzhinsk.[106]

The case of the village Lampertice in the Czech Republic shows that to allow POPs waste to be stored in the areas of old coal mines and the handling of these wastes in these areas can lead to serious threats of the environment. Here one of the highest levels of hexachlorobenzene in fish was recorded, a find that is most probably a result of the dumping of large quantities of wastes containing POPs, the including waste incineration residues and sewage sludge from the chlorine chemical industry.[107]

The myth about non-leachable dioxins (and other U-POPs) from ash, (which is to blame for new findings as shown in this study), together with the proposed limits for POPs content in waste under the Stockholm Convention can and will (if accepted), undoubtedly lead to unacceptable contamination by POPs and goes against the very essence of the treaty. Not only that. The Basel Convention Technical Guidelinse proposed levels of POPs in waste undermines some national legislation efforts.

In Japan, after a few serious dioxin incidents at incineration facilities, resulting in some facilities shut down, the government published a new act, effective since April 2000, in which levels of dioxins and coplanar PCBs in fly ash are regulated.

The limit for dioxins and dioxin-like PCBs content in fly ash was set by that regulation at level of 3 ng TEQ/g, what is 5-times lower in comparison to the proposed level for adoption at COP of the Stockholm Convention.[108] Similarly "destruction and irreversible transformation" level for dioxins content in waste is contrary to the Czech legislation. Levels of PCDD/Fs content in the soils which requires clean up of the area where this limit is not met is 10 ng/g[o] for industrial zones and 0.5 ng/g for living urban zones, both in I-TEQ. For seven PCB congeners these limits are 30 and 5 mg/kg. respectively, for organochlorine pesticides these levels are 10 and 2.5 mg/kg.[109]

9.2 Dioxins in ashes according to Dioxin Toolkit

UNEP has developed a basic tool to help parties to the Stockholm Convention develop their national POPs inventories which focused on dioxins. This Dioxin 'Toolkit' get its name from the longer "Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases".[110] Countries can calculate basic dioxins releases from different sources on this inventory and address major sources to comply with the aims of the Stockholm Convention to minimize and where feasible, to eliminate U-POPs. From these consequences we can see how important the Toolkit is.

There was published a comprehensive number of data about waste incineration residue production and dioxin levels in them in England and Wales.[111] We used this data to calculate dioxin releases in waste incineration residues produced by eleven municipal waste incinerators in England and Wales and their emission factors[p] for incineration residues. This calculation was based on measured maximum levels of dioxins in the residues is in Table 10.

[o] This and following Czech limits are per kg of dry matter.

[p] "emission factors" describe release of PCDD/PCDF to each medium per unit of activity (*e.g.,* µg I-TEQ/ton) - this is definition in UNEP Toolkit. These emission factors are calculated from measured levels of PCDD/Fs, quantitaties of emmitted medium for which the emission factor is calculated and quantitative data about activity (= burnt waste per year for waste incineration)

We have tried to compare the emission factors calculated from the average and maximum levels of dioxins in waste incineration residues from England and Wales with those used for state of art municipal waste incinerators in UNEP Toolkit (= MWI class 4). The emission factors calculated from the real life data are quite different from emission factors used in UNEP Toolkit (see Table 11). For fly ash the emission factor used in UNEP Toolkit is 15 µg I-TEQ/t of burned waste, while the emission factors calculated from real life data is between the range of 23 to 70 µg I-TEQ/t of burned waste.

10. Conclusions and Recommendations

Waste incineration residues represent a serious threat to both local and global environment as they contain high quantities of persistent organic pollutants (POPs) listed under Annex C of the Stockholm Convention (dioxins, PCBs and hexachlorobenzene) as unintentionally produced POPs. A goal of the ***"continuing minimization and, where feasible, ultimate elimination"*** was established for these chemicals in the Convention. There are several steps that should help Parties to the Stockholm Convention to comply to this goal. Almost all are under articles 5 and 6 of the Stockholm Convention (see Annexes to this text) and are discussed at the Conference of Parties to the Convention.. Topics discussed in this study are related to several of these steps.

1) Basel Convention versus Stockholm Convention

"Levels of destruction and irreversible transformation of POPs in waste" and "Low POPs levels in waste"

POPs require guidelines for management and disposal but the proposed Basel Convention levels of most POPs in wastes that trigger the requirement for destruction or irreversible transformation are quite permissive at 15 ppb (in I-TEQ) for PCDD/Fs and 50 ppm for all other POPs listed in Annexes to Stockholm Convention (see "General technical guidelines …."). Delegates at COP will have the opportunity to tighten these guidelines so that they provide greater protection to human health and the environment.

For example, level established for dioxins (PCDD/Fs) at 15 ng I-TEQ/g is really high if we consider the example from the UK. Here waste incineration fly ash was spread on the allotments and poultry kept on these sites was contaminated by high levels of dioxins. The fly ash spread contained levels of dioxins in the range of 0.020 - 4.224 ng I-TEQ/g dry weight and its consumption by the chickens led to the contamination of poultry eggs up to 56 pg WHO-TEQ/g on lipid base.[112] The EU limit for dioxins content in eggs is 3 pg WHO-TEQ/g on lipid base, which was exceeded by almost all the eggs samples from Newcastle measured after this irresponsible action.

The decision taken by Conference of Parties to Basel Convention on the levels of destruction and irreversible transformation is equally as irresponsible and doesn't comply with the Stockholm Convention definition and requirements in its article 6. No ***"levels of destruction and irreversible transformation"*** were established ***"to ensure that the characteristics of persistent organic pollutants as specified in paragraph 1 of Annex D are not exhibited;"*** as required in article 6 of the Stockholm Convention. Basel Convention technical guidelines redefined ***"levels of destruction and irreversible transformation"*** instead.

The myth about non-leachable dioxins (and other U-POPs) from ash, which is to blame for new findings as shown in this study, together with limits for POPs content in waste under the Stockholm Convention proposed can lead to unacceptable contamination by POPs, going against the aim of the treaty. Not only that. By the Basel Convention Technical Guidelinse proposed levels of POPs in waste undermine some national legislation efforts.

3) BAT/BEP Guidelines

Looking at these facts it is unbelievable how the use of these materials is out of control to the extent they are in many countries. There are plenty of studies showing the use of waste incineration fly ash as construction materials based on leaching analysis for heavy metals. This practice is in strong disagreement with one of goals of the Stockholm Convention and several hot spots cases presented in this study shown that uncontrolled use of fly ash as construction materials can lead to serious damage of the environment and threaten the health of communities living in the vicinity and surrounding areas where this material was used and/or where this material is produced. Therefore we suggest to incorporate the use of non-combustion chemical treatment methods that lead to real POPs destruction into BAT/BEP Guidelines.

4) New POPs

Dioxins were not the only toxic organic chemical studied in waste incineration residues. PCBs and hexachlorobenzene in waste incineration residues were also look at. Many of these chemicals show the same and/or similar behavior as those already listed under Annex C of the Stockholm Convention. These findings suggest these should be added those listed in Annex C, especially the polychlorinated naphthalens (PCNs), polybrominated dioxins and furans (PBDD/Fs and PCBDD/Fs) and polyaromatic hydrocarbons (PAHs).

5) The precautionary principle is included in the Convention and applied to the issue of waste incineration residues. This leads to the recommendation that the best available technique and best environmental practice are used to prevent the production of such wastes. It also means the preferencial use of technologies other than waste incineration and/or landfilling and that chlorinated and brominated compounds lead to chlorinated and brominated POPs occuring suggesting the substitution of materials containing these chemicals.

Table 10: Measured maximum levels of dioxins in waste incineration residues from municipal waste incinerators, other data about MWI residues and calculated maximal emission default factors for MWI in England and Wales. Based on data published in EA 2002. [113]

Municipal waste incinerator	Bolton	Coventry	Dudley	Edmonton	Nottingham	Lewisham	Sheffield	Stoke on Trent	Teesside	Birmingham	Wolverhampton	Sums (average) *
Waste burnt in tonnes	30300	201446	99492	500730	159817	437850	103644	201752	213839	335959	119011	2403840
Bottom ash in tonnes	11904	33148	21132	157582	37938	107923	39852	50001	76724	77054	28830	642088
Bottom ash in % of burnt waste	39.29	16.46	21.24	31.47	23.74	24.65	38.45	24.78	35.88	22.94	24.22	26.71
APC residues in tonnes	1353	7194	4178	15858	7328	14840	3333	6472	5848	8717	4650	79771
APC residues in % of burnt waste	4.47	3.57	4.20	3.17	4.59	3.39	3.22	3.21	2.73	2.59	3.91	3.32
PCDD/Fs in bottom ash in ng I-TEQ/kg	13.0	10.5	7.8	23.0	4.9	4.3	52.0	21.0	12.0	7.4	6.4	4.3 - 52.0
PCDD/Fs in bottom ash g I-TEQ/year	0.15	0.35	0.16	3.62	0.19	0.46	2.07	1.05	0.92	0.57	0.18	9.74
PCDD/Fs in APC residues in ng I-TEQ/kg	330	2591	1125	5800	697	720	1200	823	370	1364	2753	330 - 5800
PCDD/Fs in APC residues in g I-TEQ/year	0.45	18.64	4.70	91.98	5.11	10.68	4.00	5.33	2.16	11.89	12.80	167.74
Emission factor / bottom ash in µg I-TEQ/t	5.11	1.73	1.66	7.24	1.16	1.06	19.99	5.20	4.31	1.70	1.55	4.05
Emission factor / APC residues in µg I-TEQ/t	14.74	92.53	47.24	183.68	31.96	24.40	38.59	26.40	10.12	35.39	107.57	69.78

Notes: * average of % of residues of burnt waste (both APC and bottom ash), range of maximum levels of PCDD/Fs measured in residues, (both APC and bottom ash), **average default factors**

Table 11: Emission default factors calculations for MWI in England and Wales based on data from EA 2002.[114] Comparison with emission default factor and basic data for its calculation from UNEP Toolkit. [115]

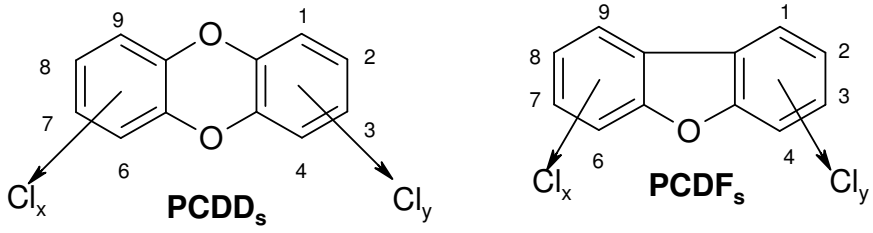
Type of estimates / calculations	Based on measured max. levels	Calculated from average max. level	Calculated from median max. level	Based on measured average levels	Calculated from medium of average levels	Calculated from median of average levels	UNEP Toolkit - class 4
Waste burnt in tonnes	**2403840**	2403840	2403840	**2403840**	2403840	2403840	**2403840**
Bottom ash in % of burnt waste	**26.71**	26.71	26.71	**26.71**	26.71	26.71	**10 - 20**
APC residues in % of burnt waste	**3.32**	3.32	3.32	**3.32**	3.32	3.32	**1 - 2**
PCDD/Fs in bottom ash in ng I-TEQ/kg	**4.3 - 52.0**	14.8	10.5	**2.5 - 25**	7.4	5.0	**5.0**
PCDD/Fs in bottom ash g I-TEQ/year	**9.7**	9.5	6.7	**4.8**	4.7	3.2	**3.6**
PCDD/Fs in APC residues in ng I-TEQ/kg	**330 - 5800**	1615.7	1125.0	**270 - 2800**	993.2	700.0	**1000.0**
PCDD/Fs in APC residues in g I-TEQ/year	**167.7**	128.9	89.7	**94.3**	79.2	55.8	**36.1**
Emission factor / bottom ash in µg I-TEQ/t	**4.1**	3.9	2.8	**2.0**	2.0	1.3	**1.5**
Emission factor / APC residues in µg I-TEQ/t	**69.8**	**53.6**	**37.3**	**39.2**	**33.0**	**23.2**	**15.0**

Annex 1. Chemical profiles of U-POPs

Dioxins and Furans

Structure and properties

Dioxins (polychlorinated dibenzo-p-dioxins, or PCDDs) and furans (polychlorinated dibenzofurans, or PCDFs) are two groups of chemicals with similar chemical structures **(Picture 2.1)** each varying according to the number and position of chlorine atoms attached to the dioxin or furan moiety. There are 75 different dioxins and 135 different furans. The number and placement of their chlorine atoms also determines their physical, chemical, and toxicological properties.



Picture 2.1 Structure of polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDDs/Fs)

Dioxins show very low solubility in water (especially the ones that are highly chlorinated), and low volatility, they are readily absorbed on the surface of solid particles, and decompose very slowly. As a result of these characteristics, Dioxins are found primarily in soil, sludge and sediments, and in very limited amounts in the dissolved form in surface or other waters. Due to a high distribution coefficient, (known as Kow), they are able to bioaccumulate in the adipose tissues of animals and people.

Sources

Among the most significant dioxin sources are waste incinerators (including municipal waste incinerators), iron ore sintering plants, production and use of the wood preservative pentachlorophenol, and pulp and paper mills using chlorine for the bleaching process. PCBs are the most significant potential source of furans, a fact that underlies the concern about accidental burning of PCBs.

Toxicity

A number of types of cancers, as well as total cancer incidence, have been related to accidental and occupational exposure to one particular dioxin, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), the most toxic of the dioxins. (See references at the end of the Annex) In their recently published book, Schecter and Gasiewicz note that recent data ". . . provide evidence for reproductive, developmental, and immunotoxic effects in humans." In addition, an increased prevalence of diabetes and increased mortality due to diabetes and cardiovascular diseases has been reported. In children exposed to dioxins, effects on neurodevelopment, neurobehavioral and effects on thyroid hormone status have been reported at exposures at or near background levels. At higher exposures, due to accidental exposure (Yusho and Yu Cheng populations), children exposed transplacentally to dioxins show skin defects (such as chloracne), tooth mineralization defects, developmental delays, behavior disorders, decrease in penile length at puberty, reduced height among girls at puberty and hearing loss.

Dioxins and furans persist for long periods and everyone is exposed to them. They enter the human body by ingestion, inhalation, and skin penetration. The most important route for human exposure to dioxins is food consumption, contributing more than 90% of total exposure, of which products of fish and other animal origins account for approximately 80%.

Forty specialists from 15 countries met at the headquarters of the World Health Organization (WHO) in Geneva from 25 to 29 May 1998 to

evaluate the risks which dioxins might cause to health. After ample debate, the specialists agreed on a new tolerable daily intake range of 1 to 4 picogrammes/kilogram body weight. The experts, however, recognized that subtle effects may already occur in the general population in developed countries at current background levels of 2 to 6 picogrammes/kilogram body weight. They therefore recommended that every effort should be made to reduce exposure "…to the lowest possible level."

Polychlorinated biphenyls (PCBs)

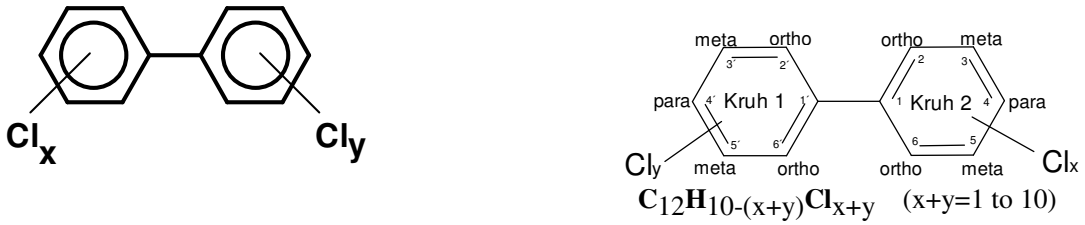
Structure

PCBs are organic compounds which have hydrogen atoms on the biphenyl skeleton replaced, to various extents, by chlorine atoms. The number of chlorine atoms in the molecule can range from 1 to 10, and theoretically 209 isomers (congeners) of PCBs can exist (Picture 2.2). However, only about 100 congeners prevail in industrially produced mixtures of

In the 1970s, countries of the Organization for Economic Co-operation and Development (OECD) restricted the use of PCBs to closed systems. Manufacture for export to non-OECD countries continued in Europe until 1983. Currently, 16 countries prohibit the import of PCBs, whereas six others allow the import of PCBs only under special circumstances. However, PCBs are in use in numerous countries worldwide.

Monsanto, Bayer, DSW-VEB, Caffaro, S.A. Cros, Prodelec and others produced PCBs intentionally under various trade names including "Arochlor", "Pyrochlor", "Asbestol", "Askarel", "Bakola", "Chlorinol", "Chlorphen", "Fenochlor", "Dykanol", "Orophene", "Clophen", "Pyranol", "Saft-T-Kuhl" and "Sovol".

PCBs are created as unintentional by-products from many of the sources that generate dioxins. They are produced during the combustion of organic materials containing chlorine as well as during the manufacture of various chlorine-containing chemicals, such as



Picture 2.2 Structure of polychlorinated biphenyls

PCBs. The proposed Toxic Equivalency Factors from the World Health Organization for dioxin-like PCBs range over four orders of magnitude.

Sources

The chemical stability and heat resistance of PCBs led to their extensive intentional use in two types of applications:

1) closed uses – dielectric fluids in electrical equipment such as transformers, capacitors, heat transfer and hydraulic systems; and
2) open uses – as pesticide extenders, sealants, in carbonless copy paper, industrial oils, paints, adhesives, plastics, flame retardants and to control dust on roads. This use was widely banned in the 1970s.

ethylene dichloride. A study of PCB release from unintentional sources found that industrial coal combustion produced significant levels of PCBs expressed as TEQ, though they represented only a small fraction of the total PCBs. [116] Other unintentional sources include municipal waste incineration, electric arc furnaces, shredders, sinter plants, cement plants, crematoria, and coal-based power stations. [117 118 119]

Releases

A major source of PCBs expressed either as mass or TEQ is leakage from capacitors and transformers. Ongoing releases of PCBs to the environment occur from fires, spills, and leaks from closed systems; evaporation or leakage

from landfills or PCB storage sites; incineration of waste containing PCBs (which were once used in a wide array of consumer products); and incomplete incineration of waste PCBs. PCBs released to the environment can be accompanied by the presence of dioxins.

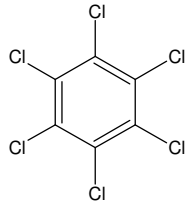
Toxicity

PCBs are classified as probable human carcinogens (group 2A) by IARC and produce a wide spectrum of adverse effects in animals, including reproductive toxicity and immunotoxicity. Prenatal exposure to PCBs is associated with reduced concentration and poorer verbal, pictorial, and auditory working memory in humans. The most common route of PCB entry into humans is ingestion of contaminated food, including fish; however, PCBs may also be inhaled and absorbed through the skin. PCBs are extremely persistent and accumulate, especially in adipose tissues. They are bioaccumulated from water and river sediments by algae and plankton and thereby enter food chains. The distribution coefficients between water and fat for the individual congeners of PCBs are so high that experimental fish kept for a longer time in water contaminated by trace concentrations of PCB concentrated these substances in their bodies up to a thousand-times. The distribution of PCBs in the bodies of fish is not uniform. For example, in carp, they accumulate especially in adipose tissues, head, central nervous system, gallbladder, and other internal organs. In contrast, concentrations in blood and smooth muscles are significantly lower.

Hexachlorobenzene - HCB

Structure and properties

HCB (Picture 2.3) is a white crystalline solid or crystal and is used as a fungicide.



Picture 2. 3: Stucture of HCB

HCB is a very stable, low volatile compound of lipophilic nature showing low solubility in water, and considerable ability to accumulate in adipose tissues of organisms and to absorb on surfaces of solid particles. It decomposes only very slowly in the environment. In the scientific literature, chlorinated phenols are mentioned as its decomposition products. These properties of HCB result in long persistence in the environment and its entry into food chains.

Sources

HCB was originally introduced in 1940's as a seed-dressing for cereal crops to prevent fungal disease. HCB is used as fungicide, disinfectant, and as a starting or intermediate raw material during production of certain chemicals (pentachlorophenol, some chlorinated aromatic compounds). As an industrial chemical, it is used, for example, in production of pyrotechnic products, synthetic rubber and aluminum. For its fungicide properties it was used for treatment of wheat and onion, and for seed treatment. HCB has also been used in various industrial processes, for example, as a fluxing agent in the manufacture of aluminum and as a dispersing agent in the production of rubber for tires. HCB was voluntarily cancelled for use as a pesticide in 1984 in the U.S. and is no longer commercially manufactured as an end product in that country. It is also banned in India and Japan and its use is restricted in several other countries. However, it may still be in use in several countries.

HCB also produced as an unintentional by-product of combustion processes involving chlorinated compounds (for example, during waste incineration or in metallurgy) and as a by-product in the manufacture of certain chlorinated pesticides (such as lindane) and industrial chemicals (for example, in chlorine chemistry or during chlorine bleaching of pulp). In this latter group are chlorinated solvents, such as carbon tetrachloride, perchloroethylene, trichloroethylene and chlorinated benzenes.

Toxicity

HCB is toxic to both humans and animals when long-term exposure occurs. Its main health effect is liver disease. HCB is also

known as an endocrine disruptor and probable human carcinogen (2B category according to IARC ranking). Human exposure to HCB may occur through several pathways including consumption of dairy products or meat from cattle grazing on contaminated pastures; consuming low levels in food, eating or touching contaminated soil; drinking small amounts in contaminated water; inhaling low levels in contaminated air; drinking contaminated breast milk from exposed mothers; occupational exposure from the use or production of HCB; and exposure to HCB as a by-product from other industrial processes, such as waste incineration.

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Annex 2: Overview of POPs content in ashes

Table 1: PCDD/Fs - Fly ash

Country	Type of incinerator	Year/date of measurement	Specification	Type of value (mean, med, max, min etc.)	Measured level in ng/kg (I-TEQ) of dry weight	Source of information
Turkey – Izmit	haz./medical waste	April 2000	ESP ash		280	13
Thailand	MWI	1997 - 2001	APC residue		228	10
Thailand	MWI	1997 - 2001	APC residue		380	10
Thailand	MWI	1997 - 2001	APC residue		686	10
Thailand	MWI	1997 - 2001	fly ash	average conc.	431	10
Thailand	MWI	1997 - 2001	fly ash	average conc.	468*	10
Czech Republic	Haz. waste incinerator	not specified	fly ash		860	
Russia – Moscow	MWI	1998	electrostatic filter ash		1160-5890	21
Russia – Moscow	MWI	1998	ceramic filter ash		8590-12050	21
Russia – Moscow	MWI	1998	heat exchanger ash		950	21
Czech Republic	Haz. waste incinerator	before 2003	fly ash		82400	19
Czech Republic	waste incinerator	1999	fly ash		1153,1	2
Czech Republic	waste incinerator	2000	sorbalit (APC residue)		1400	2
Czech Republic - Lysa nad Labem	Haz. waste incinerator	2000	sorbalit (APC residue)	range	2190-6310	25
Czech Republic – Liberec	MWI	2000	fly ash after it was treated		362	27
Czech Republic – Liberec	MWI	1999	boiler ash		11,3	2
Czech Republic	waste incinerator	2000	fly ash	range	1100-3000	2
Czech Republic	waste incinerator	2004	fly ash		930	7
UK – Bolton	waste incinerator	2001	fly ash		460	2
Germany	MWI	1994	fly ash	range	110-2300	9
UK Byker/Blucher allotment – Newcastle	MWI	199?	fly ash		9500	24
Germany	MWI	1997	fly ash	range	440-11200	26

Table 1 continued

Japan	small scale incinerators and MWI	1998	fly ash	range	2000-2100000	11
Taiwan	MSW, 450 t/24 hours, dry scrubber + fabric filter	1998	fly ash	range	256-2526	14
Taiwan	MSW, 300 t/24 hours, electrostatic precipitators+ wet scrubber	1998	fly ash		6953	14
Taiwan	MSW, 300 t/24 hours, electrostatic precipitators+ wet scrubber	1998	fly ash		1592	14
Taiwan	MSW, 75 t/24 hours, semidry scrubber + fabric filter	1998	fly ash		23795	14
Taiwan	MSW, 30 t/16 hours, semidry scrubber + ESP	1998	fly ash		28917	14
Taiwan	Medical waste incin., 3.6 t/8 hours, venturi wet scrubber	1998	fly ash		13266	14
UK - England and Wales	MWI	2002	fly ash	range	200-5800	5
Sweden	waste incinerators	1999		range	2000-3000	20
Japan	MWI	2001	fly ash pellets		862	12
Sweden	MWI	2002	APC residue	average conc.	200	1
Netherlands	waste incinerators		fly ash		2400	17
Italy	MWI	2003	fly ash		58056	15
Italy	MWI	2003	fly ash		6473	15
Italy	MWI	2003	fly ash		36	15
Czech Republic - Klasterec nad Ohri	HWI/MWI	1999	fly ash		21400	23
Korea	MWI	2003	fly ash		6726	22
UK	waste incinerators	1996	fly ash	range	191-1820	8

Table 2: PCDD/Fs - Bottom ash and mixed ashes

Country	Type of incinerator	Year/date of measurement	Specification	Type of value (mean, med, max, min etc.)	Measured level in ng/kg (I-TEQ) of dry weight	Source of information
Thailand	MWI	1997 - 2001	bottom ash		10	9
Thailand	MWI	1997 - 2001	bottom ash		5	9
Thailand	MWI	1997 - 2001	bottom ash		6	9
Thailand	Medical waste incinerator	1997 - 2001	mixed bottom ash		1410-2300	10
Thailand	MWI	1997 - 2001	bottom ash	average conc.	7	10
Thailand	MWI	1997 - 2001	bottom ash	average conc.	8*	10
Thailand	Medical waste incinerator	1997 - 2001	mixed bottom ash	average conc.	1390	10
Thailand	Medical waste incinerator	1997 - 2001	mixed bottom ash	average conc.	1980*	10
Russia _ Moscow	MWI	1998	bottom ash/slag		30-55	21
Czech Republic – Liberec	MWI	2000	bottom ash/slag		4,37	27
Czech Republic – Ostrava	Haz. waste incinerator	2000	furnace slag		0.16-0.17	18
Czech Republic – Ostrava	Haz. waste incinerator	2000	furnace slag		2.9-3.6	18
UK – Bolton	waste incinerator	2001	bottom ash		1,6	3
UK - England and Wales	MWI	2001	bottom ash	range	0.64-23 (150)	5
Sweden	waste incinerators	1999	bottom ash/slag	average conc.	13.5-27	20
UK – Shefield	MWI	2001	bottom ash/slag	max. levels	122, 150	5
Thailand	Crematory	1997 - 2001	composite ash	individual sample	44	10
Czech Republic – Liberec	MWI	2000	mixed fly ash/bottom ash	individual sample	213,6	6
Czech Republic – Liberec	MWI	2000	mixed fly ash/bottom ash	individual sample	62	27

Table 3: PCDD/Fs - Waste water treatment sludge + other residues

Country	Type of incinerator	Year/date of measurement	Specification	Type of value (mean, med, max, min etc.)	Measured level in ng/kg (I-TEQ) of dry weight	Source of information
Thailand	Medical waste incinerator	between 1997 - 2001	sludge from the wastewater treatment		517-708	10
Thailand	Brass smelter	between 1997 - 2001	wastewater treatment sludge	average conc.	8625	10
Thailand	Brass smelter	between 1997 - 2001	wastewater treatment sludge	average conc.	9168*	10
Thailand	Medical waste incinerator	between 1997 - 2001	mixed flyash sludge	average conc.	629	10
Thailand	Medical waste incinerator	between 1997 - 2001	mixed flyash sludge	average conc.	703*	10
Thailand	Brass smelter	between 1997 - 2001	wastewater treatment sludge	range	8567-8683	10

Table 4: Other POPs measurements in different residues

Country	Measured chemical	Type of incinerator	Year/date of measurement	Specification	Type of value (mean, med, max, min etc.)	Measured level in ng/kg (I-TEQ) of dry weight	Source of information
Germany	PCB (ng WHO-TEQ/kg)	MWI	1997	fly ash	range	10-640	26
Germany	EROD (ng TEQ/kg)	MWI	1997	fly ash	range	660-49970	26
Japan	PCN	small scale incinerators and MWI	1998	fly ash	range	740-610000	11
Taiwan	Coplanar PCB (ng I-TEQ/kg)	MSW, 450 t/24 hours, dry scrubber + fabric filter	1998	fly ash	range	61.06-405.54	14
Taiwan	Coplanar PCB (ng I-TEQ/kg)	MSW, 75 t/24 hours, semidry scrubber + fabric filter	1998	fly ash		2942,44	14
Taiwan	Coplanar PCB (ng I-TEQ/kg)	MSW, 30 t/16 hours, semidry scrubber + ESP	1998	fly ash		2983,42	14
Taiwan	Coplanar PCB (ng I-TEQ/kg)	Medical waste incin., 3.6 t/8 hours, venturi wet scrubber	1998	fly ash		590,85	14
Taiwan	Total I-TEQ	MSW, 450 t/24 hours, dry scrubber + fabric filter	1998	fly ash	range	320-2932	14
Taiwan	Total I-TEQ	MSW, 75 t/24 hours, semidry scrubber + fabric filter	1998	fly ash		26737	14
Taiwan	Total I-TEQ	MSW, 30 t/16 hours, semidry scrubber + ESP	1998	fly ash		31900	14
Taiwan	Total I-TEQ	Medical waste incin., 3.6 t/8 hours, venturi wet scrubber	1998	fly ash		13857	14
Taiwan	Total I-TEQ	Electrical power plant	1998	fly ash		605	14
Taiwan	Total I-TEQ	Electrical power plant	1998	fly ash		63	14
UK	PCB	Waste incinerators	1996	bottom ash	range	less than 1000-8900	8
UK	PCB	Waste incinerators	1996	fly ash	range	less than 1000-23000	8

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Annex 3: Analytical results for individual samples taken in Izmit Hazardous Waste Incinerator (Turkey) by Greenpeace Research Laboratories

Sample Number: MI0064

REFERENCE NUMBER: TU001

SAMPLE TYPE: INCINERATOR BOTTOM ASH

Location: Kocaeli, Izmit, Turkey

Sampling Date: 05.04.00

Sample Information: Sample collected from slag/bottom ash commercial rotary kiln slagging plant type, Izmit Solaklar Koyu Mevkii waste incinerator.

ORGANIC ANALYTICAL RESULTS

Analysis method: GC/MS screen

Number of compounds isolated: 60

Compounds identified to better than 90%:

1,1'-Biphenyl, 2,2',3,4,4',5'-hexachloro- (PCB-138)	SIM only
1,1'-Biphenyl, 2,2',4,4',5,5'-hexachloro- (PCB-153)	SIM only
1H-Indene, 2,3-dihydro-	
Benzene, 1,2,3,5-tetramethyl-	
Benzene, 1,2,3-trimethyl-	
Benzene, 1,2,4-trimethyl-	
Benzene, 1,2-dimethyl-	
Benzene, 1,3,5-trimethyl-	
Benzene, 1,3-diethyl-	
Benzene, 1,4-dichloro-	SIM only
Benzene, 1-ethyl-2-methyl-	
Benzene, 1-ethyl-3,5-dimethyl-	
Benzene, 1-methyl-2-(1-methylethyl)-	
Benzene, 1-methyl-4-(1-methylethyl)-	
Benzene, 2-ethyl-1,3-dimethyl-	
Benzene, 2-ethyl-2,3-dimethyl-	
Benzene, propyl-	
Bicyclo[4.2.0]octa-1,3,5-triene	
Cycloeicosane	
Diphenylmethylene-cyclopropane	
Eicosane	
Heneicosane	
Heptacosane	
Naphthalene	
Naphthalene, 1,3-dimethyl-	
Naphthalene, 1,5-dimethyl-	

Naphthalene, 1,6-dimethyl-
Naphthalene, 1-methyl-
Naphthalene, 2,3,6-trimethyl-
Naphthalene, 2-methyl-
Phenanthrene, 4-methyl-
Phenol, 3-methyl- SIM only

Compounds tentatively identified:

1-Octadecene
1-p-Menthen-8-yl acetate
28-nor-17beta(h)-Hopane
Benzene, (1-methylpropyl)-
Benzene, 1,2,3,4-tetramethyl-
Benzene, 1-ethyl-2,3-dimethyl-
Benzene, 1-ethyl-3-methyl-
Benzene, 1-methyl-2-propyl-
Benzene, isopropyl-
Decane, 2-methyl-
Decane, 2-methyl-
Docosane
Eicosane, 9-octyl-
Heptadecane
Heptane, 2,6-dimethyl-
Hexadecane
Isoquinoline, 1,2,3,4-tetrahydro-
Octadecanoic acid, 2-[(1-oxohexadecyl)oxy]ethyl ester
Pentadecane, 2-methyl-
Tetradecane
Tricosane

Sample Number: MI0065

REFERENCE NUMBER: TU002

SAMPLE TYPE: INCINERATOR ASH (ESP)

Location: Kocaeli, Izmit, Turkey

Sampling Date: 05.04.00

Sample Information: Sample collected from electrostatic precipitator, Izmit Solaklar Koyu Mevkii waste incinerator.

ORGANIC ANALYTICAL RESULTS

Analysis method: GC/MS screen

Number of compounds isolated: 13

Compounds identified to better than 90%:

1,1'-Biphenyl, 2,2',3,4,4',5'-hexachloro- (PCB-138) SIM only
1,1'-Biphenyl, 2,2',4,4',5,5'-hexachloro- (PCB-153) SIM only

Compounds tentatively identified:

5-Eicosene, (E)-
5-Undecanone, 2-methyl-
6H-Purin-6-one, 1,7-dihydro-
Hydroxylamine, O-decyl-
Nonadecane
Octadecane

Sample Number: MI0067

REFERENCE NUMBER: TU004

SAMPLE TYPE: ECONOMISER ASH

Location: Kocaeli, Izmit, Turkey

Sampling Date: 05.04.00

Sample Information: Sample collected from incinerator heat exchanger, Izmit Solaklar Koyo Mevkii waste incinerator.

ORGANIC ANALYTICAL RESULTS

Analysis method: GC/MS screen

Number of compounds isolated: 12

Compounds identified to better than 90%:

1,1'-Biphenyl, 2,2',3,4,4',5'-hexachloro- (PCB-138) SIM only
1,1'-Biphenyl, 2,2',4,4',5,5'-hexachloro- (PCB-153) SIM only
Benzene, 1,4-dichloro-

Compounds tentatively identified:

Octadecane, 3-ethyl-5-(2-ethylbutyl)-

Abbreviations:

AhR - aryl hydrocarbon receptor

APC - Air pollution control system.

APCR - Air pollution control residues including all types of fly ashes, sorbalite etc.

BAT - Best Available Techniques, term used according to the Stockholm Convention

BEP - Best Environmental Practices, term used according to the Stockholm Convention

COP - Conference of the Parties, meeting of nations that have signed and ratified an international convention (here used for the Conference of the Parties to the Stockholm Convention

DHM - dissolved humic matter

EIA - Environmental Impact Assessment

EOCl - extractable organic chlorinated compounds

EOXs - extractable organic halogens

HCB - hexachlorobenzene

HR-GC/MS - high resolution gas chromatography, mass spectroscopy, analytical method to detect dioxins/furans

HpCDD - heptachlorodibenzodioxins; dioxin with seven chlorine atoms

HpCDF - heptachlorodibenzofurans; furan with seven chlorine atoms

HWI - hazardous waste incinerator

HxCDD - hexachlorodibenzodioxins; dioxin with six chlorine atoms

HxCDF - hexachlorodibenzofurans; Furan with six chlorine atoms

IPEN - International POPs Elimination Network, international network of NGOs (http://www.ipen.org)

IPPC - Integrated Pollution Prevention Control

I-TEQ - International Toxicity Equivalents; summary measure of toxic dioxins and furans that does not include dioxin-like PCBs, broadly similar to WHO-TEQ, but not the same

IWMI - Integrated Waste Management Inc.

mg/kg - milligram (10^{-3} g) per kilogram; equivalent to a teaspoon of salt in a bathtub

LAS - Linear Alkylbenzene Sulfonate

LRTAP - Long Range Transboundary Air Pollution (short name of specific international convention)

MSW - municipal solid waste

MWI - municipal waste incinerator (and/or incineration in some context)

MSWI - municipal solid waste incinerator (and/or incineration in some context)

ng/kg - nanogram (10^{-9} g) per kilogram, equivalent to a teaspoon of salt in a small lake, this is the same as pg/g

NGOs - non-governmental organizations

OCDD - octachlorodibenzodioxins, dioxin with eight chlorine atoms

OCDF - octachlorodibenzofuran, furan with eight chlorine atoms

PAHs - polyaromatic hydrocarbons

PBCDD/Fs - polybromochlorodibenzodioxins and polybromochlordibenzofurans

PBDD/Fs - polybromodibenzodioxins and polybromodibenzofurans

PBDEs - polybrominated diphenylethers

PCBs - polychlorinated biphenyls

PCDD/Fs - polychlorinated dibenzodioxins/polychlorinated dibenzofurans

PCDTs - polychlorodibenzothiophenes, the sulfur analogues of the PCDFs

PCNs - polychlorinated naphthalens

PeCDD - pentachlorodibenzodioxin, dioxin with five chlorine atoms

PeCDF - pentachlorodibenzofuran, furan with five chlorine atoms

POPs - persistent organic pollutants

RDF - refuse derived fuel

TCDD - tetrachlorodibenzodioxin, dioxin with four chlorine atoms

TCDF - tetrachlorodibenzofuran, furan with four chlorine atoms

TEQ - Toxicity equivalents

UNEP - United Nations Environment Programme

U-POPs - unintentionally produced POPs

WG - working group

WHO-TEQ - World Health Organisation Toxicity Equivalents, summary measure of toxicity that includes dioxins, furans, and dioxin-like PCBs; broadly similar to I-TEQ, but not same

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