Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

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Waste Incineration — A Potential Danger?

Bidding Farewell to Dioxin Spouting

IT'S OUR FUTURE.

Waste Incineration — A Potential Danger?

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In the eighties of the previous century, waste incineration plants (WIPs) came to be *the* symbol of environmental contamination: citizens were beginning to put up a fight against the throw-away society and 'dioxin spouting' on the outskirts of cities. That protest was a success. Today, more than half of all household waste (55%) is recycled as bio-waste, waste paper, waste glass, or packaging waste. Since June 1, 2005, untreated waste is no longer landfilled. And because of stringent regulations (cf. the chapters at the end of this paper), waste incineration plants are no longer significant in terms of emissions of dioxins, dust, and heavy metals. And this still applies even though waste incineration capacity has almost doubled since 1985 (cf. Table 1).

Year	Number	Capacity, in 1,000 tonnes per year (1,000 t/a)
1965	7	718
1970	24	2,829
1975	33	4,582
1980	42	6,343
1985	46	7,877
1990	48	9,200
1995	52	10,870
2000	61	13,999
2005	66	16,900
2007	72	17,800

Table 1: Waste incineration capacity in Germany

Source: Federal Environmental Agency, 2005

Dioxins and Furans

Dioxin from waste incineration plants reduced to one thousandth

Emissions of toxic contaminants from waste incineration have been drastically reduced since 1990. Total dioxin emissions from all 66 waste incineration plants in Germany has dropped to approx. one thousandth as a consequence of the installation of filter units stipulated by statutory law: from 400 grams (cf. explanation below) to less than 0.5 grams.

In other industries, too, there have been marked declines in dioxin emissions: in metal extraction and processing, for instance, from 740 to 40 grams — approx. one twentieth. The decline, however, has nowhere been as drastic as in the incineration of household waste. The consequence is that whereas in 1990 one third of all dioxin emissions in Germany came from waste incineration plants, for the year 2000 the figure was less than 1%. Chimneys and tiled stoves in private households alone discharge approximately twenty times more dioxin into the environment than waste incineration plants[1]. This is also evident from the fact that in winter airborne dioxin loads are up to five times higher than in summer when heating systems are out of operation[2]. The most extensive dioxin emissions, however, are attributable to metal extraction and processing.

	Emissions per year in g TU (toxicity units)		
	1990	**1994**	**2000**
Metal extraction and processing	740	220	40
Waste incineration	400	32	0.5
Power stations	5	3	3
Industrial incineration plants	20	15	<10
Domestic firing installations	20	15	<10
Traffic	10	4	<1
Crematoria	4	2	<2
Total emissions, air	1,200	330	<<70

Table 2: Dioxin emission sources in Germany, annual dioxin loads, in grams per toxicity unit (g TU); data for the year 2000 are estimates by the Federal Environmental Agency.

Explanatory Note:

'Dioxins' and 'furans' are generic terms for a group of more than 200 individual chemical compounds, all of which are of different toxicity. They cause chloric acne and are cancerogenic. Dioxins and furans will form spontaneously from chlorine atoms, carbon that has not been fully oxidised, and various catalysts in cooling smoke; hence, the process is the same for waste incineration plants and tiled stoves alike. Each of the 200 dioxin and furan compounds is of a different degree of toxicity; for that reason, their so-called toxicity units (TUs) are determined and summarised into units of grams per toxicity unit (g TU).

[1] Source: www.umweltbundesamt.de/uba-info-daten/daten/dioxine.htm

[2] Cf. the *Third Report on Environmental Dioxin Loads, Chapter 6, Air,* by a study group comprised of members of German federal and state administrations; according to that report, emissions from domestic heating will build up especially during low-exchange weather situations.

Cancerogenic Toxicants / Fine Dust

Without waste incineration plants, there would be more toxicants in the air

Dioxins are formed in the smoke gases of fires; it is only in very small proportions that they occur in waste from the very beginning. Arsenic, cadmium, nickel, and other cancerogenic toxic heavy metals, on the other hand, enter waste incineration plants together with waste. In order to prevent them from leaving any waste incineration plant via its chimney, under the 17th Ordinance on the Implementation of the Federal Immission Control Act ("17th BImSchV") expensive filtering devices were installed by 1996. The result: prior to 1990, contaminants of a toxicity comparable to that of 188 tonnes of arsenic were distributed into the air; today[3], at least 3 tonnes are *extracted* from the air. Admittedly, this is an idea that needs some getting used to. But that credit is a result of the power and heat generation produced by the incineration of household waste[4]. If that energy were generated using traditional power stations, there would be three more tonnes of toxicant in the air.

The same is true for particulate matter. Prior to 1990, all waste incineration plants taken together were still emitting 25,000 tonnes of dust (or a maximum of 30 milligrams per cubic metre [mg/m^3] of exhaust air). In 2001, that figure dropped to less than 3,000 tonnes. At present, waste incineration plants may emit a maximum concentration of 10 mg/m^3 of dust in their flue gas; in practice, however, that figure is usually approx. 1 mg/m^3. If we include in the calculation avoided emissions of particulate matter by traditional power stations, the emissions prevented will total approx. 5,000 tonnes[5]. In any event, compared with the 171,000[6] tonnes of fine dust emitted annually in Germany, waste incineration plants are of no consequence.

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[3] The Institute of Energy and Environmental Research: (German abbreviation, "IFEU"): The Contribution of Waste Management to Sustainable Development in Germany, November 2004 — a study commissioned by the Federal Environment Office. Abbreviation used below: "IFEU 2004".

[4] IFEU 2004, p. 88.

[5] According to IFEU 2004, p. 51, table 3-2, and IFEU 2004, p. 90, illustration 4-8.

[6] Reducing emissions of particulate matter — a public-health concern. Cf. U. Lahl, W. Steven, Hazardous Substances — Keeping the Air Clean, Issue 7/8 — 2004, p. 326, table 2.

Explanatory Note:
Arsenic is approx. twice as toxic as cadmium, five times as toxic as chromium, and 500 times as toxic as benzene. To find one single standard for the toxicity of cancerogenic heavy metals and organic compounds, individual toxicity values are converted into values for arsenic. Two kilograms of cadmium are as toxic as one kilogram of arsenic, or are equal to one kilogram of arsenic equivalent. The toxicity of dioxins, too, is 'converted' to that of arsenic, and included in this paper. The equivalence model has been taken over from climatologists, who work using CO_2 equivalents.

Non-Cancerogenic Toxicants

Other heavy metals, such as lead and mercury, are also retained in the filtering devices of waste incineration plants. Unlike the substances mentioned above, they are non-cancerogenic (cf. explanation below). Whether or not they are poisonous for human beings will depend on whether they reach their thresholds of effectiveness.

For these substances, too, there has been an impressive decline in emissions: whereas in 1990, emissions amounted to as much as 57,900 kilograms (kg) of lead and 347 kg of mercury from the incineration of household waste, the respective levels declined to 130.5 kg (equivalent to 0.2% of initial emissions) and 4.5 kg (1.3% of initial emissions) in the year 2001[7]. Thus, lead and mercury emissions from the incineration of household waste are also no longer significant for human exposure to emissions of toxic substances. It is true that there are no very recent figures as to the amounts of lead and mercury emissions for 2005, but according to information from the Federal Environmental Agency, emissions by all polluters — from passenger cars to heating plants — have been 624,000 kg for lead, and 31,000 kg for mercury[8]. Hence, that would be a thousand times the emissions produced by waste incineration.

What, however, is the situation for people who live in the vicinity of waste incineration plants? In the case of new waste incineration plants, and upgraded waste incineration plants, concentrations of airborne toxic heavy metals, even

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[7] IFEU calculation based on measured emission values and information from operators, in mg/m³ exhaust air; cf. IFEU 2004, page 51, table 3-2.

[8] Statements for mercury and lead in 1995 are based on the Federal Environmental Agency's research report 94-104 03 524, "The Development of Heavy-Metal Emissions in the Federal Republic of Germany from 1985 to 1995"; www.umweltbundesamt.de/luft/emissionen/bericht/aktuelle_daten/schadstoffe/daten_schwermetalle/schadstoff_schwermetalle_prio.pdf.

in the immediate vicinities, are so low that they will reach one to two percent of the effectiveness threshold at the most[9].

> Explanatory Note:
> For toxicants, certain dosages are required so that toxic action can take effect. Below such a threshold value, toxicants are usually harmless, and may even be of a healing nature. A toxicant is "a substance that may inflict harm on living organisms through metabolic processes". In the present case, we take lead and mercury as representative of all non-cancerogenic heavy metals. Cancerogenic substances may, even in extremely low concentrations, cause tumours. Together with dosages and periods of exposure, (only) the likelihood of cancer will vary but, strictly speaking, cancerogenic substances are never really harmless.

German Law

Practice outperforms the law

With the Ordinance under the Federal Immission Control Act on Incinerators Facilities for Waste and Similar Combustible Materials — the "17th BImSchV" — a regulation took effect on 1 December 1990 which laid down emission limit values for waste incineration plants in Germany which were the most stringent in the world. This was particularly true for dioxins, furans and heavy metals.

This had become necessary because in some cases dramatic pollutant concentrations were being measured in the exhaust air of waste incineration plants ("WIPs"): in individual cases, up to 400 nanograms per toxicity unit (ng TU) of dioxin per cubic metre of exhaust air. And there were several types of particulate matter and all conceivable heavy metals. Through waste incineration, the pollutants were distributed evenly from the waste into the atmosphere.

Within a transitional period of six years, existing plants were required to be either upgraded or decommissioned. New facilities were required to comply with the specified limits from the very beginning. In addition, stringent requirements as to emissions monitoring were already in place. There were specifications as to minimum temperatures and minimum retention periods for contaminants in combustion furnaces, to enable pollutants to be destroyed

[9] Experiences gained from dispersal calculation in the course of approval procedures, according to unpublished information from IFEU.

completely. These requirements have remained in force up to the present day, in both European and German law.

Since 1996 at the latest, all facilities have complied with stringent emissions requirements. Dioxin is only permitted in exhaust air up to a concentration of 0.1 ng TU per cubic metre. Requirements as to levels of heavy metals, dusts, and acid gases such as sulphur dioxide, hydrogen chloride, etc., have been similarly tightened, and theses gases are consequently no longer relevant in terms of public health. For many contaminants, limits applicable to waste incineration plants are more stringent than would be possible for other state-of-the-art facilities subject to Technical Instructions on Air Quality Control ("TA Luft") or the Ordinance on Large Firing Installations ("13th BImSchV").

Contaminant	**"TA Luft", General Requirements**	**13th BImSchV Large Firing Installations for, e.g., coal >300 megawatts**	**17th BImSchV for WIPs**	**Real WIPs, measured values**
Organic substances (C, total)	50	—	40	1
Carbon monoxide (CO)	—	200	50	10
Hydrogen chloride (HCI)	30	not relevant	10	1
Hydrogen fluoride (HF)	3	not relevant	1	0.1
Sulphur dioxide (SO_2)	350	200	50	1.5
Nitrogen oxides (NO_2)	350	200	10	1
Particulate matter (dust)	20	20	10	1
Dioxins	0.1 ng TU	—	0.1 ng TU	**0.005 ng TU**
Dioxins in facilities of the metal industry	0.4 ng TU	—	—	—

Table 3: A comparison of exhaust air values under the "General Requirements as to Emissions Limitation" of TA Luft, 13th BImSchV, and 17th BImSchV[10], as well as from values measured at real installations, in mg/m³, unless otherwise stated.

As regards limits for dioxins and other contaminants relevant to health, TA Luft and the 17th BImSchV have meanwhile attained equal significance. The metal industry is an exception here, and for this reason too is now by far the largest dioxin emission source. The table also demonstrates that in waste incineration plants emissions for all pollutants currently fall well below the limit values of the 17th BImSchV. The Heidelberg-based Institute for Energy and Environmental Research ("IFEU") investigated the 'real' emission data of just under half of all incineration plants in Germany and found figures of between 0.001 and 0.01 ng TU per cubic metre of exhaust air for dioxin; i.e. between

[10] Cf. www.bayern.de/lfu/abfall/einwirk/emi2.htm, and "TA Luft".

one tenth and one hundredth of the emission limit value. For Germany, the IFEU expects an average dioxin concentration of only 0.005 ng TU per cubic metre of exhaust air. From this, the IFEU has computed total emissions from household waste incineration of 0.2 g TU for the year 2001[11]; the Federal Environmental Agency estimates 0.4 g TU for the year 2000. While the figures stated by IFEU and the Federal Environmental Agency deviate slightly from each other, they are within the same order of magnitude.

European Law

Co-incineration now subject to waste incineration requirements

The 17th BImSchV was a major influence behind the EU Directive of the year 2000 on the incineration of waste. The Directive specifies consistent limits for waste incineration plants Europe-wide. For the co-incineration of waste in industrial firing plants, the Directive's requirements are clearer and more stringent than those of the German regulation of 1990. The Directive must be implemented by all Member States, and will ensure that waste incineration and co-incineration meet the highest standards of immission control legislation on a European scale as well.

Therefore, the 17th BImSchV was last amended in August 2003. One effect of the "Directive on the Incineration of Waste" (Directive 2000/76/EC) of December 2003 is that the stringent limit values in the 17th BImSchV will also apply to cement kilns or power stations where household waste replaces the fuels coal or oil.

Large industrial firing installations and, in particular, cement kilns have for a long time incinerated discarded tyres or used oil, and thus replaced fossil oil — the term "thermal recovery" is justified here. In future, depositing untreated waste in landfills will no longer be permitted. For that reason, it is expected that in addition to discarded tyres, individual substances with a high calorific value, or mixtures of such substances from household waste will be offered to power stations and cement plants for incineration — also an appropriate type of thermal recovery. In addition to cement plants, metal blast-furnace processes (for pre-sorted plastics) and coal-fired power stations are also being considered.

[11] IFEU-computed pursuant to combustion calculation for WIPs, using emission factors for dioxin (IFEU 2004, table 3-2, p. 51) and the amounts of household waste in the WPI (9 million tonnes, IFEU 2004, table 2-18, p. 41)

The adaptation of the 17th BImSchV to European law now guarantees that even these facilities will be required to meet the stringent limit values applicable to waste incineration. It would appear, however, that at present, coal-fired power stations in particular are not especially keen on processing waste. As fuel, household waste and parts thereof is difficult to calculate: chlorine proportions may be high; the hydrochloric acid that would form might destroy the expensive boilers of power stations. The exact gross calorific value is not known in advance, and transportation, storage, and dosage of waste-derived fuel — unlike that of coal dust for instance — would be difficult, and require capital expenditure on new technology. For these reasons, it has been impossible so far to predict the extent to which such waste will find its way into power stations. This might change when trading in CO_2 emission rights is fully underway.

Explanatory Note:

Until August 2003, the following was applicable to co-incineration: if approximately one quarter of waste and three quarters of fuel (coal, oil, etc.) were used, then the stringent 17th BImSchV would apply to one quarter of the exhaust gas (in relation to heat input), and the less stringent 13th BImSchV to three quarters. Thus, the entire installation was in practice subject to an averaged limit value (calculation using a compound formula). According to the amended 17th BImSchV of August 2003, especially contaminants relevant to health (for instance, heavy metals and dioxins) are subject to the same limit value as the mono-incineration of waste. Where untreated, mixed municipal waste is used, the same limit values applicable to mono-incineration will apply in principle to all parameters, irrespective of the quantities used.