Environmental pollution by dispersion of solid residues from waste incineration; the legacy of ignorance

Case study of persistent hazardous pollutants in fly ash and bottom ash in the Netherlands

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February 2004

This report has been prepared by Waste & Environment on request of the IPEN Dioxins, PCBs and Wastes Working Group.

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SUMMARY

From the mid 1980s, the Dutch government strongly promoted waste incineration as a "state of the art" alternative to landfilling. However, high levels of dioxin found in milk and cheese from cattle grazing near municipal waste incinerators in 1989, radically changed public opinion about incineration.

Despite serious concerns of citizens against waste incineration, the Dutch government continued their policy to increase incineration capacity. Strong citizens protests forced government to drop a few new incinerator proposals, and to close down a few existing incinerators, but others have been build. Despite the fact, that the government was not able to increase the incineration capacity as initially planned, waste incineration has become a major route for waste disposal in the Netherlands.

Toxic heavy metals contained in waste, are not destroyed, but are emitted via stack gases or discharged to surface water or remain in the bottom ash, fly ash and filter residues. Other toxic substances, such as dioxins and furans, are produced as a result of the combustion process.

After incineration, approximately 28% of combusted solid waste remain as solid residues, from which bottom ash and filter ash are the largest fractions. These residues are contaminated with numerous hazardous substances. Some of the organic substances found in residues of incineration, i.e. dioxins and furans are classified as persistent organic pollutants (POPs), a class of toxic chemical pollutants that are harmful to human health and wildlife.

Much efforts have been undertaken by the Dutch government to find disposal routes for incinerator residues, other than common landfilling. In addition, a deceptive vocabulary has been introduced to conceal the real nature of the alternative disposal routes. Consequently, dumping of toxic fly ash and bottom ash in the Dutch environment is promoted under the cloak of "recycling", and "useful application".

The incinerator companies are consequently looking for the cheapest disposal routes. Roughly 45% of fly ash is used as a filler material in asphalt, and 55% is landfilled or exported to Germany and dumped in old salt and coal mines, since legislative restrictions for incinerator operators to export fly ash do not exist, or fail to be effective. The lack of effective measures to prevent persistent toxic substances in fly ash entering the environment is considered a major problem.

Roughly 65% of bottom ash is used for road beddings, and hardening surfaces of industrial sites. This is much lower compared to previous years, 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. Consequently, waste incinerators are saddled with large stockpiles of bottom ash.

In the Netherlands, fly ash is a major route for dioxin contamination of the environment. In 1991, the quantity of dioxins in fly ash has been estimated 1020 grams (in TEQ) per year, which amount has been increased to 2671 grams (in TEQ) in 2000 after a few new incinerators have been build.

Data provided by the operators of the Dutch waste incinerators in 1997 reveal an annual dioxin quantity of 190 - 195 grams (in TEQ). If these data are correct, this could indicate that the electrostatic precipitators (ESP-filters) are operating far below set standards and/or suffer upsets which strongly reduce dioxin capture rate of ESP-filters. And, air emissions can be expected to be much higher than the official estimates (which are based on the assumption that Dutch waste incinerators would operate to set standards).

Although the Dutch government, and operators of waste incinerators consequently denied technical failures appearing on a larger scale, a survey by Waste & Environment in 1995 revealed that technical failure frequently occurs, often resulting in deliberate by-passes of the air pollution control equipment, during which the fouled flue gases leave the flue stack without adequate filtering.

Although all Dutch waste incinerators are equiped with sophisticated air pollution control equipment, the background levels of dioxin in the Netherlands are very high. In 1996, the Health Council of the Netherlands announced that given current concentration of dioxin-like substances in the Dutch

environment, the recommended (health protecting) levels for humans and in some cases for ecosystems are being exceeded. The Health Council deems this to be a matter of concern and believes that it constitutes an argument for further reducing existing concentrations.

1 INTRODUCTION

In many countries, waste is disposed of simply by dumping or landfilling, and until the 1970s this was the common practice of waste disposal in the Netherlands as well. Until the early 1970s only a few municipal solid waste incinerators (MSW-incinerators) have been built. With the closing of ocean disposal, exhaustion of landfill capacity, and growing concern of landfill sites that appeared to have been heavily contaminated with toxic pollutants, the Dutch government introduced a policy to move away from landfilling, and promoted waste incineration as a "state of the art" solution to the growing waste disposal problems. The proposals for building seven new municipal waste incinerators in the period 1971 - 1976, and one hazardous waste incinerator, received little public attention and concern. However, citizens concerns mushroomed in 1989, after the Lickebaert dioxin scandal received much publicity.

The Lickebaert polder is an agricultural area north-east of Rotterdam-harbour. In 1989, tests showed high levels of dioxin in milk and cheese samples. As a result of the enormous media coverage and publicity, the government promptly ordered cow's milk and meat from the affected Lickebaert area to be collected systematically and destroyed.[1] 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.[2][3]

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 held 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.[2][3]

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!

Despite the serious concerns of citizens against waste incineration, the Dutch government continued their policy to triple the incineration capacity in 2000. [4][5] 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.

Hazardous waste, but municipal and industrial waste as well, contains a great variety of toxic substances. Much of these toxic substances cannot be destroyed by incineration. Combustion merely changes the chemical composition and the toxicity of the substances burned. Combustion transforms solid and liquid waste into toxic residues, airborne emissions and contaminated waste water effluents, all of which seriously endanger public health and the environment. Toxic heavy metals contained in waste, are not destroyed, but are emitted via stack gases or discharged to surface water or remain in the bottom ash, fly ash and filter residues. In every case they constitute to health threatening discharges of toxic substances in the environment.

Other toxic substances, originally not present within the waste stream, are produced as a result of the combustion process. Incinerators act as chemical synthesizers. At temperatures ranging from 400 tot 1600oC, complex organic molecules break down into basic atoms. But, as the combustion gas cools on its way up the chimney and out of the stack, some atoms recombine to form new and often more hazardous compounds. These chemical re-combinations or 'products of incomplete combustion' (PICs) can be even more toxic than the original combusted waste. Dioxins and furans are beyond any doubt the most hazardous of these kind of substances. Dioxins is the collective name for numerous toxic chlorinated compounds that are undesirable by-products of combustion processes and chlorine industry. Waste incineration constitutes the greatest point source of emissions of dioxins and furans. In 1994, the National Institute of Public Health and Environmental Protection (a Dutch governmental research institute) estimated that waste incinerators can be held responsible for over 80% of all dioxin emissions into the air in the Netherlands.[3]

Despite the serious environmental pollution and the negative impact of air emissions to public health, the dispersion in the environment of solid residues, notably fly ash and bottom ash, may have an even more serious negative impact on the environment and public health. Yet, the risks of dispersion and exposure to fly ash and bottom ash are greatly underestimated, and receive little attention from governments, citizens, and environmental organisations.

This report is addressing the persistent hazardous pollutants in fly ash and bottom ash from waste incinerators in the Netherlands. The data provided in this case study have been taken from (Dutch) governmental reports, scientific studies and expert findings to identify the types of risks of dispersion in the environment and human exposure to toxic substances from solid residues from incineration.

2 ASH AND FILTER 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 oxygene. 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 are discharged in the environment.

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 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 ash are small dust particles in flue gases, and are captured by electrostatic precipitators (ESP-filters) after the flue gases leave the boiler. Fly ash are also known as 'ESP-ash'. Approximately 1,6% of the quantity of municipal solid waste feeded to the grate furnaces ends up as fly ash after the combustion process.

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 feeded 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, sludges, and gypsum. Less than 1% of the quantity of municipal solid waste fed to the grate furnaces remain as filter residues.

Summarising, after incineration approximately 28% of combusted solid waste will remain as solid residues.

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. However, incineration of liquid (toxic) waste, like chemicals, solvents and obsolete stockpiles of pesticides will produce flue gases with high levels of toxic substances, either in the form of toxic heavy metals and/or products of incomplete combustion, like dioxins and furans.

3 COMPOSITION OF FLY ASH AND BOTTOM ASH

Bottom ash, fly ash, boiler ash, and filter residues are contaminated with numerous hazardous substances. Public health is threatened seriously if human exposure takes place during a longer period of time. In particularly, fly ash, boiler ash, and filter cake contain high levels of toxic substances, such as heavy metals and dioxins/furans.

Some of the organic substances found in residues of incineration, i.e. dioxins and furans are classified as persistent organic pollutants (POPs), a class of toxic chemical pollutants that are harmful to human health and wildlife. In the Netherlands, incinerator companies are not obliged to collect data on PCBs, HCBs or PAHs. As a result, they do not analyze residues for these persistent organic pollutants.

Table 1. Average composition of fly ash from Dutch waste incinerators in 1997 (in milligrams per kilogramme). [6][7]

Substance	Average composition (mg/kg)	Number of samples analysed
aluminium (Al)	30294	17
antimony (Sb)	682	17
arsenic (As)	97	17
barium (Ba)	1000	17
bromium (Br)	997	17
cadmium (Cd)	379	17
calcium (Ca)	143529	17
chloride (Cl)	74471	17
chromium (Cr)	231	31 (from 1986-1995)
cobalt (Co)	19	26 (from 1986-1995)
fluor (F)	57	17
potassium (K)	41376	17
copper (Cu)	1154	17
mercury (Hg)	2	17
lead (Pb)	7671	17
magnesium (Mg)	9765	17
molybdeen (Mo)	50	17
sodium (Na)	36282	17
nickel (Ni)	88	30 (from 1986-1995)
selenium (Se)	9	17
silicon (Si)	30444	26 (from 1986-1995)
strontium (Sr)	245	17
sulphate (SO4)	32041	17
tin (Sn)	1007	17
vanadium (V)	30	27 (from 1986-1995)
wolfram (W)	77	17
zinc (Zn)	22488	17
dioxins and furans (PCDD/F) as TEQ	0,0024	17

Table 2. Composition of bottom ash from waste incineration in the Netherlands in milligrams per kilogramme. [8][9]

Substance	composition (mg/kg)
aluminium (Al)	not defined*
antimony (Sb)	28 - 58
arsenic (As)	19 - 23
barium (Ba)	1275 - 1760
bromium (Br)	not defined*
cadmium (Cd)	2 - 8
calcium (Ca)	not defined*
chloride (Cl)	1050 - 2445
chromium (Cr)	235 - 296
cobalt (Co)	not defined*
fluor (F)	not defined*
potassium (K)	not defined*
copper (Cu)	669 - 3212
mercury (Hg)	0,03 - 0,2
lead (Pb)	1086 - 1637
magnesium (Mg)	not defined*
molybdeen (Mo)	5 - 11
sodium (Na)	not defined*
nickel (Ni)	40 - 86
selenium (Se)	0,4 - 0,5
silicon (Si)	not defined*
strontium (Sr)	not defined*
sulphate (SO4)	5059 - 12642
tin (Sn)	62 - 77
vanadium (V)	40 - 52
wolfram (W)	not defined*
zinc (Zn)	1239 - 2125
dioxins and furans (PCDD/F) as TEQ	below detection limit

* Not defined = no measurement carried out

4 LEACHATE

Toxic substances in fly ash and bottom ash are entering the environment after residues of incineration get in contact with rain water, ground water and in general after exposure to open air conditions. The leachate process can take up many years, although some substances react fast after exposure to water or common atmospheric conditions (like storage in open air). The speed of the leachate process is depending on the type of toxic substance, and the extend of exposure to water and atmospheric conditions.

Table 3 gives figures of leachate for a number of heavy metals in fly ash and bottom ash respectively. Since the figures presented in table 2 are not collected under real outdoor conditons, but derived from tests in laboratories where outdoor conditions are imitated and accellerated, the results should be considered indicative. The actual leachate of (toxic) substances may be quite different under real outdoor conditions.

Table 3. Average leachate for fly ash and bottom ash in mg/kg. [8][9][10]

Substance	Fly ash	Bottom ash
arsenic (As)	<0,06	<0,01
barium (Ba)	3,3	1,5
cadmium (Cd)	3	<0,002
chromium (Cr)	<0,2	<0,2
copper (Cu)	<0,3	5
mercury (Hg)	not defined*	not defined*
molybdeen (Mo)	5	0,5
nickel (Ni)	<1	<0,1
lead (Pb)	158	0,4
antimony (Sb)	not defined*	not defined*
selenium (Se)	not defined*	not defined*
tin (Sn)	<0,4	<0,1
vanadium (V)	not defined*	not defined*
zinc (Zn)	23	<0,6
chloride (Cl)	45363	1588
sulphate (SO4)	18523	3927
phosphate (PO4)	0,3	0,2

< = less than

* Not defined = no measurement carried out

In general, leachate is bigger for fly ash. Notably, heavy metals such as cadmium, lead and zinc in fly ash show very high leachate values, compared to same metals in bottom ash.

5 THE TOXIC WASTE TRAP

Solid waste from households, trading businesses, and public services usually contain small quantities of hazardous waste. However, during combustion the toxic substances get in contact, or start a chemical reaction with the non-contaminated part of the waste, in particular with the inert fraction. To clarify this more in detail, next example will explain the transformation of non-contaminated waste to toxic waste during the incineration process.

Municipal solid waste usually contains food waste. Even when schemes of separate collection of kitchen and garden waste have been introduced, a small amount of food waste will remain in the solid waste, including very small amounts of sodium chloride (NaCl), commonly known as salt and used to prepare food. The food waste, nor the salt, are considered a problem in terms of environmental pollution. However, during combustion the food fraction contributes to incomplete combustion because of the relative high moisture content of this type of waste. In addition, the chlorine content of the salt appear to be a vital element to dioxins and furans formation. This is one of the reasons why incinerators contribute to an enormous increase of toxic residues, and why incinerators are considered a major producer of toxic waste.

In chapter two the solid residues of MSW incineration have been quantified to 28% of combusted waste. In other words, from every 1000 kg of solid waste combusted in an incinerator approximately 280 kilogrammes remain as toxic waste. Incineration reduces the quantity of the waste that need to be disposed of, but the air emissions, waste water discharges and solid residues are a much larger environmental threat than any other type of waste treatment. Incineration gives the illusion of making waste disappear when, in fact, it reappears in different and often more hazardous forms. Indeed, a toxic waste trap.

6 ASH PRODUCTION AND DISPOSAL

6.1 Government policy; deception and concealment

From the mid 1980s, the Dutch government is strongly promoting incineration of waste. However, the government is well aware that the parliament, although still in majority in favor of incineration, may change their point of view if large quantities of incinerator residues would end up on common landfill sites. Much effort has been undertaken to find alternative disposal routes. In addition, a deceptive vocabulary has been introduced to conceal the real nature of the alternative disposal routes. Consequently, dumping of toxic fly ash and bottom ash in the Dutch environment is promoted under the cloak of "recycling", and "useful application".

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. [9] Although 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 used almost without any restriction.

The incinerator companies are consequently looking for the cheapest disposal routes. Since alternative disposal routes often appear cheaper than landfilling, large quantities are just dumped under roads or exported. Legislative restrictions for incinerator operators to export fly ash do not exist, or fail to be effective, while requests to export (non-toxic) municipal solid waste is consequently rejected. This contradictive policy illustrates the attitude of the government to come to meet the interests of the incinerator companies as much as possible.

In the next paragraphs the production and disposal of fly ash and bottom ash are described more in detail.

6.2 Fly ash and boiler ash

In the Netherlands, the annual production of fly ash is ranging from 79000 - 81000 tons. 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. [11]

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. [7][11][12]

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. [7][11] In 2002, 29500 tons are exported, in 2003, 45000 tons. [14] Most of the boiler ash is exported to Germany as well. [11]

For the landfill disposal route, the fly ash is packed in so called 'big bags' (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.

For dumping in old salt mines, two different methods are commonly used.

1. Fly ash is packed in big bags and brought down in old salt mines to fill up mine galleries. The big bags with dry fly ash are piled up until the gallery is completely filled.

2. At the entrance of a mine gallery, first a dam is build. Water from the mine is pumped up to the surface and mixed with fly ash. The mixture is pumped into the mine gallery. The dam prevents the liquid mixture entering other galleries. After a while, the fly ash has sedimented, and the water is pumped up again for making a new batch of mixture.

For dumping in coal mines, the fly ash is mixed with cement, lime, sand and water. The amount of fly ash in this mixture depends on the composition of the fly ash and the technical specifications of the mortar that is needed, and is in the range of 15 - 75%. This mixture is used to build dams in coal mine galleries to prevent these galleries to cave in.

Other use is a mixture of incinerator fly ash (24%), fly ash from electric power plants (46%), and cement (30%) to build a dam at the beginning of a gallery, to enable filling the gallery with waste sludges. [7]

6.3 Environmental impact of fly ash dumping

6.3.1 The asphalt disposal route

Fly ash used in asphalt incorporates a few serious environmental and health risks. Instead of preventing this hazardous residue to get into contact with other materials and entering the environment, it is mixed with other filler material and bitumen, and the asphalt is used for road building. But, after less than 20 years roads need new asphalt, and the old asphalt that need to be removed contains high levels of toxic substances. Result: the problem has been manyfolded!

Second, during the removal of the old asphalt, fly ash will set free as a result of grinding, breaking and transport of the asphalt debris, polluting the environment and endangering the health of the road workers. And, during the life time of asphalt, small amounts of toxic substances will be dispersed into the environment, as a result of leachate.

6.3.2 The landfill disposal route

During handling of the big bags with fly ash, bags often get damaged, and ash is flowing out. 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, accelerating the leachate process. Moreover, heavy pressure exerted on the landfill can make big bags burst, increasing the leachate process any further.

Similar with big bags, 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. Inevitable, the rain water get in contact with heavy metals and other toxic substances and pollute the surface water after discharged to nearby canals at landfill sites that have drainage systems in operation. And, polluted water not discharged, finally reaches the ground water below landfill sites, where ground water flow is dispersing the pollution to a much bigger area.

6.3.3 The salt and coal mine disposal routes

Although the fly ash is dumped in the deep underground, geological processes are likely to enable toxic substances to enter the environment again. Common practice is to only partly fill up old mine galleries. Pressure and tension from the upper layers will make the galleries converge. A full convergency of the galleries may take a few hundred years for instable salt mines up to many thousand years for stable salt mines. During this period of convergency, ruptures enable water from upper or lower layers of ground water to flooding the galleries and getting in contact with toxic waste. The continuing convergency increases the pressure on the polluted water, pressing it upwards. Finally the polluted water will reach the upper layers of ground water, where ground water flow is dispersing the pollution to a much bigger area, and back into the living environment. [14][15][16][17]

Despite the scientific evidence of these geological processes, advocates of hazardous waste dumping in salt mines claim salt mines used for this disposal route are dry, and flooding of mine galleries are not expected because of stable salt formations. However, during the past 140 years over half of all German salt mines have been flooded already. Once a mine has been flooded it is not possible to turn this process. [14][15][16][17]

Coal mines are much more vulnerable for toxic substances to enter the environment again. Unlike salt mines, water is frequently entering the schafts and galleries. During the period of coal production, drainage systems prevent the water to flooding the mine. However, after conclusion of mining, the drainage systems are not used anymore, in particular after mine shafts and galleries have been partly filled to prevent cave in. [14][15][16][17]

6.3.4 Quantity of dioxins in fly ash

In the Netherlands, fly ash is a major route for dioxin contamination of the environment. In 1991, the National Institute of Public Health and Environmental Protection (Dutch EPA) estimated the quantity of dioxins in fly ash 1020 grams (in TEQ) per year.[18] 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 grams (in TEQ) per year. Note: this figure includes dioxins in bottom ash and filter residues. [19]

According to information from the operators of the Dutch waste incinerators in 1997 (table 1) [6], and based on an annual production of 79000 - 81000 tons of fly ash, annual dioxin quantity is estimated 190 - 195 grams (in TEQ). These figures differ strongly from the official estimates from Dutch EPA, and University of Amsterdam.

If the data provided by the operators of the Dutch waste incinerators are correct, this could indicate that the electrostatic precipitators (ESP-filters) are operating far below set standards and/or suffer upsets which strongly reduce dioxin capture rate of ESP-filters. As a result, air emissions can be expected to be much higher than the official estimates (which are based on the assumption that Dutch waste incinerators would operate to set standards).

There have been doubts about the effectiveness of air pollution control equipment since the early 1990s. Although the Dutch government and operators of waste incinerators consequently denied technical failures appearing on a larger scale, a survey by Waste & Environment in 1995 revealed that technical failure frequently occurs, often resulting in deliberate by-passes of the air pollution control equipment, during which the fouled flue gases leave the flue stack without adequate filtering.

Despite the fact that since 1990, all Dutch waste incinerators are equipped with sophisticated air pollution control equipment, the background levels of dioxin in the Netherlands are very high. In 1996, the Health Council of the Netherlands announced that given current concentration of dioxin-like substances in the Dutch environment, the recommended (health protecting) levels for humans and in some cases for ecosystems are being exceeded. The Health Council deems this to be a matter of concern and believes that it constitutes an argument for further reducing existing concentrations. [20]

There is well substantiated evidence that dioxins are not only principal cancer inducing agents, but also cause unpredictable genetic disorders, and disrupt functioning of our immune systems. Recent studies show that concentrations of dioxins in human tissue in the general population of industrial countries are already at or near levels where serious health effects may occur.[21][22][23][24]

6.4 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. [11]

In 2002, 770.000 tons are used for road beddings, and hardening surfaces of industrial sites. This is much lower compared to previous years, where quantities ranging from 820.000 up to 1.340.000 tons have been dumped under roads. Waste incinerators have storage facilities to bridge periods during which only few or small road works are carried out. The quantities in stock are used to supply vast quantities of ash when large road works have to be carried out. [11]

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. This will be described more in detail in the next paragraph about the environmental impact of bottom ash dumping. 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! [11]

Small quantities of bottom ash are landfilled on common landfill sites. In the past few years the annual quantities landfilled range from 700 - 12.500 tons. [11] Only small quantities of bottom ash are exported, in 2002, 3200 tons are exported, in 2003, only 2300 tons. [13]

6.5 Environmental impact of bottom ash dumping

6.5.1 The road bedding disposal route

Similar with fly ash, the use 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. Result: the problem has been manyfolded!

Second, during the reconstruction or repair, bottom ash will set free as a result of digging and removal of parts of the bedding, polluting the environment and endangering the health of road workers. And, during the life time of the road, small amounts of toxic substances will be dispersed into the environment, as a result of leachate. In the Netherlands, the risk of toxic substances getting into contact with ground water is high. In many regions the layers of ground water are close to the surface, sometimes less than 1 meter!

6.5.2 The landfill disposal route

Environmental pollution of landfilling bottom ash mainly takes place through the leachate process, during which small amounts of (toxic) substances leak from the bottom ash. In particulary, if the top cover for common landfill sites rupture after heavy pressure exerted on the lower layers of the landfill increases tension in the top cover. As a result, rain water easily get in contact with the bottom ash below the cover layer, reinforcing the process any further. Inevitable, the rain water get in contact with heavy metals and other toxic substances and pollute the surface water after discharged to nearby canals at landfill sites that have drainage systems in operation. And, polluted water not discharged, finally reaches the ground water below landfill sites, where ground water flow is dispersing the pollution to a much bigger area.

6.5.3 Quantity of dioxins in bottom ash

In 1991, the National Institute of Public Health and Environmental Protection (Dutch EPA) estimated the quantity of dioxins in bottom ash 8,5 grams (in TEQ) per year.[18] 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 is can be considered small. Heavy metals in bottom ash pose a much bigger burden for the environment.

7 Conclusion; the legacy of ignorance

The claimed environmental benefits of reduced landfilling after maximizing waste incineration are ludicrous if the environmental burdon posed by incinerator air emissions and solid residues are put in consideration. The disposal of fly ash and bottom ash, in asphalt, road beddings, landfill sites and salt and coal mines contribute to an increased dispersion of hazardous substances in the environment, some of them, like dioxins and furans, classified as persistent organic pollutants (POPs).

Municipal solid waste incineration (MSW incineration) is the biggest source of dioxins in the Netherlands. Over 2,6 kilograms of dioxins are formed each year by MSW-incineration only! It is not surprisingly that with this on-going annual burden, the background levels of dioxins in the Netherlands are very 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.

And, there are doubts about the effectiveness of air pollution control equipment. Despite official denying, frequent technical failures have been documented, often resulting in deliberate by-passes of the air pollution control equipment, during which the fouled flue gases leave the flue stack without adequate filtering. The discrepancy between data provided by the operators of the waste incinerators, and those of Dutch EPA is giving food for thought that the electrostatic precipitators (ESP-filters) are operating far below set standards and/or suffer upsets which strongly reduce dioxin capture rate of ESP-filters.

The Dutch governmental policy of the past two decades, to consequently ignore or play down early warnings about the drawbacks of waste incineration and its adverse effects on human health and the environment show an utterly lack of responsibility for protecting the environment, which will not only affect todays, but future generations as well. Truly it is a legacy of ignorance.

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