Greenpeace Research Laboratories

Incineration and Human Health

State of Knowledge of the Impacts of Waste Incinerators on Human Health (Executive Summary) *

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After pollutants from an incineration facility disperse into the air, some people close to the facility may be exposed directly through inhalation or indirectly through consumption of food or water contaminated by deposition of the pollutants from air to soil, vegetation, and water. For metals and other pollutants that are very persistent in the environment, the potential effects may extend well beyond the area close to the incinerator. Persistent pollutants can be carried long distances from their emission sources, go through various chemical and physical transformations, and pass numerous times through soil, water, or food. National Research Council (2000)

Management of municipal and industrial waste is a growing problem throughout the world. In the European Union, while waste output is continually increasing, new regulations are imposing more stringent restrictions on the amount of waste permitted to go to landfill. At the same time, many incinerators have been closed over the past few years because of stricter regulations on their atmospheric emissions. In Europe, all incinerators will soon have to comply with new standards set out in a recent EC draft directive.

Fortunately, there are alternative solutions to turn around the waste crisis on a long-term basis. Primarily, this means the implementation of waste prevention strategies, and in conjunction with this, waste re-use and recycling. Despite this option, there is an emerging trend for constructing, and planning to construct, new incinerators in an attempt to provide a 'quick fix' solution to the waste crisis. Incinerators are deemed as favourable in this respect because they are perceived as reducing waste to one tenth of its original volume, and therefore reduce the volume of waste going to landfill sites.

Incinerators, however, are controversial in terms of their potential impacts on the environment and human health, as well as in terms of the economic considerations which do not favour this technology. They are known to emit numerous toxic chemicals into the atmosphere and produce ashes and other solid waste residues. One country, the Philippines, has taken serious note of the many concerns about incineration at a governmental level. Following strong public opposition to incinerators, the Philippine Clean Air Act of 1999, banned the incineration of municipal, medical and hazardous waste.

Waste reduction, re-use and recycling are being promoted while non-burn technologies are recommended for waste that needs some form of treatment. Meanwhile, some governments in Europe are advocating the construction of even more incinerators.

This report was undertaken to draw together scientific findings on incinerator emissions and their impacts on human health. A broad range of health effects have been associated with living near to incinerators as well as with working at these installations. Such effects include cancer (among both children and adults) adverse impacts on the respiratory system, heart disease, immune system effects, increased allergies and congenital abnormalities. Some studies, particularly those on cancer, relate to old rather than modern incinerators. However, modern incinerators operating in the last few years have also been associated with adverse health effects.

Despite reductions of some chemicals in stack emissions, modern incinerators nevertheless still emit numerous toxic substances to the atmosphere as well as in other residues such as fly ash and bottom ash. Moreover, reductions of dioxins and other chemicals in stack gases commonly leads to increased releases of these same chemicals in the other incinerator residues. In most cases, health effects which have been associated with incinerators cannot be tied down to a particular pollutant, Together with the limited data available, it is, therefore, impossible to predict health effects of incinerators including new or updated installations. With such factors in mind, this report demonstrates that there is an urgent need for the complete phase out of incineration and the implementation of sound waste management policies based on waste prevention, re-use and recycling.

Incinerators – Waste Generators

It is a common misconception that things simply disappear when they are burned. In reality, matter cannot be destroyed – it merely changes its form. This can be exemplified by looking at the fate of some substances in wastes which are

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burned in municipal solid waste (MSW) incinerators. These incinerators are typically fed mixed waste streams that contain hazardous substances, such as heavy metals and chlorinated organic chemicals. Following incineration, heavy metals present in the original solid waste are emitted from the incinerator stack in stack gases and in association with tiny particles, and are also present throughout the remaining ashes and other residues. Incinertation of chlorinated substances in waste, such as polyvinyl chloride (PVC) plastic, leads to the formation of new chlorinated chemicals, such as highly toxic dioxins, which are released in stack gases, ashes and other residues. In short, incinerators do not solve the problems of toxic materials present in wastes. In fact they simply convert these toxic materials to other forms, some of which may be more toxic than the original materials. These newly created chemicals can then re-enter the environment as contaminants in stack gases, residual ashes and other residues.

All types of incinerators release pollutants to the atmosphere in stack gases, ashes and other residues. A multitudinous array of chemicals is released, including innumerable chemicals that currently remain unidentified. The chemicals present in stack gases are often also present in ashes and other residues. Such chemicals include dioxins, polychlorinated biphenyls (PCBs), polychlorinated napthalenes, chlorinated benzenes, polyaromatic hydrocarbons (PAHs), numerous volatile organic compounds (VOCs), and heavy metals including lead, cadmium and mercury. Many of these chemicals are known to be persistent (very resistant to degradation in the environment), bioaccumulative (build up in the tissues of living organisms) and toxic. These three properties make them arguably the most problematic chemicals to which natural systems can be exposed. Some of the emitted chemicals are carcinogenic (cancer-causing) and some are endocrine disruptors. Others such as sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) as well as fine particulate matter, have been associated with adverse impacts on respiratory health.

It is a popular misconception that the weight and volume of the original raw waste are reduced during incineration. It is often quoted that the volume of waste is reduced by about 90% during incineration but the actual figure is closer to 45%. The weight of waste is supposedly reduced to about one-third during incineration. However, this refers only to ashes and negates other in-cinerator emissions in the form of gases, which result in an increased output in weight. In sum, if the mass of all the outputs from an incinerator, including the gaseous outputs, are added together, then the output will exceed the input.

Environmental and Human Exposure to Incinerator Releases

The research carried out on environmental contamination and human exposure to pollutants released by incinerators is limited and has focused mainly on dioxins and heavy metals. Research has demonstrated that both older and more modern incinerators can contribute to the contamination of local soil and vegetation with dioxins and heavy metals. Similarly, in several European countries, cow's milk from farms located in the vicinity of incinerators in has been found to contain elevated levels of dioxins, in some cases above regulatory limits.

Populations residing near to incinerators are potentially exposed to chemicals through inhalation of contaminated air or by consumption of contaminated agricultural produce (e.g. vegetables, eggs, and milk) from the local area and by dermal contact with contaminated soil. Significantly increased levels of dioxins have been found in the tissues of residents near to incinerators in the UK and Japan most likely as a result of such exposure. Two studies in the Netherlands and Germany however, did not find increased levels of dioxins in body tissues of residents living near incinerators. At an incinerator in Finland, mercury was increased in hair of residents living in the vicinity, most likely due to incinerator releases.

Several studies have reported elevated levels of dioxins (total TEQ), and/or certain dioxin congeners, in the body tissues of individuals employed at older incineration plants. This is thought most likely to be a consequence of exposure to contaminated ashes in the workplace. Similarly, some studies have reported increased levels of chlorinated phenols, lead, mercury and arsenic in the body tissues of incinerator workers.

Health Impacts

Experimental data confirm that incinerators emit toxic substances and that humans will be exposed as a consequence. Studies on workers at incinerator plants, and populations residing near to incinerators, have identified a wide range of associated health impacts (see the tables p. 143). These studies give rise to great concerns about possible health impacts from incinerators even though the number of studies (particularly those that have been conducted to appropriately rigorous scientific standards) is highly limited. These should be seen, however, as strongly indicative that incinerators are potentially very damaging to human health.

Incinerator Releases and Regulation

Stack Gases. As previously mentioned, numerous chemicals are emitted to the atmosphere from incinerators through the stack gases. Important points regarding some of these chemical emissions are given below.

Dioxins. Extensive research has demonstrated that dioxins can cause a diverse array of toxic effects. They have become widespread contaminants throughout the globe and are present in the body tissues of human beings across the whole globe. Research suggests that, in industrialised countries, dioxins have now reached levels in tissues of the women which may cause subtle, adverse effects upon the immune system, and nervous system of their babies.

Summary of Studies on Occupational Health

Health impact	Comments
Elevated mutagens in urine	Incinerator ashes and stack emissions are mutagenic (have the ability to damage DNA). Workers are therefore exposed to mutagenic compounds. Elevated mutagens in urine indicate exposure to mutagenic compounds. (Study dates 1990 & 1992).
Health impact	**Comments**
Elevated levels of hydroxypyrene in urine	Hydroxypyrene is an indicator of internal exposure to PAHs. The result suggests elevated exposure to PAHs. (Study date 1992).
Increased quantity of thioethers in urine	Thioethers in urine are an indicator of exposure to electrophilic compounds such as PAHs. The results suggest exposure to electrophilic compounds. (Study date 1981).
3.5-fold increased probability of mortality from lung cancer	Workers who were employed at a Swedish MSW incinerator in Sweden at sometime between 1920 and 1985. (Study date 1989).
Increased mortality from ischemic heart disease	Workers who were employed at a Swedish MSW incinerator in Sweden at sometime between 1920 and 1985. The result was statistically significant in workers with greater than 40 years employment. (Study date 1989).
1.5-fold increased likelihood of mortality from oesophageal cancer	Workers who were employed at a Swedish MSW incinerator in Sweden at sometime between 1920 and 1985. In conjunction with evidence from other research, the result implies an increased health threat to workers. (Study date 1989).
2.79-fold increase in gastric cancer	Workers employed at an MSW incinerator in Italy at sometime between 1962 and 1992. Some of the increase may have been due to other confounding factors.
Excess hyperlipidemia. A significant association between blood dioxin levels and natural killer cell activity (immune system effect).	Workers employed at an incinerator in Japan, that operated between 1988 and 1997. Excess of hyperlipidemia was significant. Change in immune system cells. (Study date 2000).
Excess of proteinuria (urine abnormality) and hypertension. Possible increased incidence of small airway obstruction (unconfirmed diagnosis).	Workers at a MSW incinerator in the US. An excess of workers with significant proteinuria. (Study date 1992).
Chloracne (a skin condition due to dioxin-exposure)	Chloracne found in one worker from an old incinerator in Japan, who had high blood levels of dioxin. (Study date 1999).

Summary of Studies on Health of Populations Living in the Vicinity of Incinerators

Health effect	Comments
Cancer	
44% increase in soft tissue sarcoma and 27% in non-Hodgkin's lymphoma.	Significant clusters of these cancers in residents living close to an incinerator in France. Possibly due to exposure to dioxin from the incinerator, but more research is needed to confirm if this is the case. (Study date 2000).
6.7-fold increase in likelihood of mortality from lung cancer	Significant increased occurrence in residents living close to a MSW incinerator in an urban area of Italy. (Study date 1996).
Increased incidence of cancer of the larynx	Found around one UK hazardous incinerator of waste solvents (1990), but not nine others. In Italy, excess mortality from this cancer was found in residents living near to an incinerator, a waste disposal site and an oil refinery.
37% excess of liver cancer	A study on 14 million people living within 7.5 km of 72 MSW incinerators in the UK. Further research to eliminate possible confounders found the increased probability of liver cancer to lie between 20 and 30%. Social deprivation could not be totally ruled out as a confounder. (Study dates 1996 and 2000).
2-fold increased probability of cancer mortality in children	A study conducted on 70 MSW incinerators in the UK (1974-87) and 307 hospital waste incinerators (1953-1980). These results are consistent with another study in which an increased probability of childhood cancer was observed for hospital incinerators and large-scale, high-temperature combustion industries (Study date 1998).
Respiratory Effects	
Increased purchase of medicine for respiratory problems.	A study at a village in France that had a MSW incinerator. Results suggest increased use of medicine for respiratory illness but a cause-effect relationship cannot be concluded (Study date 1984).
Increased respiratory symptoms, including 9-times increase in reporting of wheezing or cough.	A study in the US on residents living near to a hazardous waste incinerator. The results are of limited utility because of methodological concerns about the study. (Study date 1993).
Adverse impacts on lung function of children.	A study on children living near to a wire reclamation incinerator in Taiwan. Results indicate that higher air pollution, but not the incinerator itself, is linked to altered lung function in children. (Study date 1992).
Increased respiratory symptoms including lung disease, wheezing, persistent cough and bronchitis.	A study on 58 individuals living near to cement kilns burning hazardous waste in the US. Significant increase in respiratory symptoms. (Study date 1998).
No adverse effect on the prevalence or severity of asthma in children.	A study on children living near to sewage sludge incinerators in Australia. (Study date 1994).
No increase in respiratory effects or decrease in lung function	A study on 3 communities (6963 individuals) living near to a municipal, hazardous and hospital waste incinerator in the US. The lack of association between exposure to particulate air pollution and respiratory health in this study should be interpreted cautiously due to limitations in data on individual exposures.
Sex Ratio	
Increase in female births	A study on populations living near to 2 incinerators in Scotland, UK. The effect was found in the area potentially most exposed to incinerator releases. Other studies have found an increase in female births among fathers who were accidentally exposed to high levels of dioxins. (Study dates 1995 and 1999).
Congenital Abnormalities	
Increased incidence in orofacial clefts Other midline defects including spina bifida and hypospadias (genital defect)	The significant increase in orofacial clefts was observed for births in an area located near to an incinerator site where open burning of chemicals took place 1960-69. A link between the conditions and living near the incinerator is likely but not confirmed.
1.26-fold increased probability congenital malformations among new born infants	A study conducted on a population living near to 2 MSW incinerators in Wilrijk, Belgium. (Study date 1998).
Increased congenital eye malformations (anecdotal report)	Reported at an area near two chemical waste incinerators in Scotland, UK. Further research in the UK found no link, although the study was hampered by lack of data on the condition. (Study date 1989).
Multiple Pregnancy	
Possible increase in rate of twinning/multiple pregnancy.	An increase in twinning was significant in 1980 in a population living near to an incinerator in Scotland, UK. A 2.6-fold probability of multiple pregnancy found near incinerator in Belgium (Study date 2000). No impact on multiple pregnancy found on a survey of an incinerator in Sweden. Data from different studies is conflicting and inconclusive.
Other Effects	
Increased allergies, increased incidence of common cold, increased complaints about health in general, increased use of medication in school children	A study conducted on school children living near to two MSW incinerators in Wilrijk, Belgium. (Study date 1998).

Incineration, particularly MSW incineration, was identified as a major source of dioxins during the 1980s and early 1990s. It has been estimated as accounting for between 40 and 80% of atmospheric dioxin emissions in various industrialised countries. The true figure may be even greater because there are several methodological flaws in nearly all of the dioxin inventories that estimate atmospheric emissions from incineration.

Considerable improvement in air pollution control technologies that have been installed in new or updated incinerators during the 1990s is thought to have led to substantial reductions in the quantity of dioxins released to the atmosphere from incinerator stacks. However, recent estimates suggest that MSW incinerators are still a main source of dioxins in the environment. In the UK, it was estimated that MSW incinerators were responsible for 30-56% of dioxin emissions while in Denmark a recent mass balance study identified MSW incineration as the dominant source of dioxins to atmosphere and a highly significant contributor (via ash residues) to landfill. Moreover, reduction of dioxins emitted in stack gases has most likely resulted in a corresponding increase in dioxins emitted as contaminants of ash residues.

While measurements taken from some new or modernised incinerators have shown that they comply with limits set by the new EC directive, others have not. Those not fulfilling the EC regulatory limit include incinerators that have recently been tested in Spain, Poland, Sweden, and Belgium. In Belgium, testing was carried out on an incinerator using the routine technique of taking 'point measurements' which involves monitoring dioxin levels over a period of several hours. However, when testing was carried out by 'continual monitoring', over a 2 week period, the results were substantially different. The point measurement technique underestimated dioxin emissions by a factor of 30 to 50. It is therefore of great concern that very few incinerators are tested using continual monitoring or tested under their normal operating conditions. Moreover, the new EC regulations do not stipulate that measurements should be taken using this technique, so current routine monitoring of incinerator stack gases, using point measurements, could be grossly inaccurate and underestimate dioxin emissions to air.

Other Organic Compounds. For regulatory purposes, the EC has proposed a limit for total organic carbon emissions to atmosphere to regulate all the organic chemicals emitted. This regulation, however, fails to take into account the toxicity/health impacts of known organic chemicals that are emitted from incinerator stacks. Similarly it totally ignores unknown chemicals of unknown toxicity and the potential health effects they could cause.

Heavy metals, including lead and cadmium, are emitted in stack gases from incinerators. Many heavy metals are persistent and exert a wide range of adverse impacts on health.

With the exception of mercury, the levels of heavy metals released in stack gases from incinerators have decreased considerably over the past decade due to improvement in air pollution abatement technologies. Nevertheless, the quantities in which they are still emitted from modern incinerators potentially add to current background levels in the environment and in humans. As is the case with dioxin emissions to the atmosphere, the reduction of levels of heavy metals emitted in stack gases causes a corresponding increase in levels in the ashes, which will, ultimately, result in contamination of the environment when these are disposed of.

Particulate Matter. Incinerators of all types emit particulate matter into the atmosphere. The majority of this particulate matter is ultrafine in size. Current air pollution control devices on incinerators only prevent 5 to 30% of the 'respirable' (<2.5 μm) sized particles from entering the atmosphere, and can do very little to prevent ultrafine (<0.1 μm) particulates from escaping. It is these respirable particles, and especially the ultrafine particles, which can reach the deepest regions of the lungs, and which are thought to be responsible for causing adverse impacts on human health. Incinerators therefore contribute to the type of particulate air pollution that is the most dangerous for human health. In addition, recent evidence suggests that particles containing heavy metals, such as those emitted from incinerators are especially of concern with regard to health. Incinerators are, therefore, likely to produce particulate air pollution which is even more toxic than, for example, that emitted from a coal-fired power station.

The new EC Draft Directive does not set any limits for the release of fine particulate matter. Given the scale of the health impacts resulting from such particulate air pollution, this can be considered as an outstanding neglect of factors relevant to human health, and which requires rigid control and regulation.

Ashes. Fly ashes from air filtration equipment on incinerators and the bottom ashes that remain after incineration contain numerous hazardous chemicals. Despite the potential toxicity of ashes, there are no EC limits for levels of persistent organic chemicals and heavy metals in ashes.

Because of their contamination, disposal of incinerator ashes presents significant environmental problems. The majority of ash is landfilled. This can result in contamination of sub-soils with toxic compounds. In some cases, the contamination of groundwater by compounds that have leached from the waste, in particular, heavy metals like lead and cadmium from fly ash has been documented. In an attempt to reduce leaching, fly ash is sometimes stabilised in cement before disposal. Although this method reduces the immediate leaching of heavy metals and other toxic chemicals, weathering and erosion over time will ultimately cause their release back to the environment.

There has been a recent tendency in some European countries to use bottom ashes and/or fly ashes for construction purposes, a practice that reduces the financial costs of 'secure' ash disposal. Ash has been used in road and path construction. Again, however, the future releases of persistent toxic substances due to erosion over time could result in the release of substances back to the environment and, therefore, potentially to human exposure. This has recently been exemplified in Newcastle, UK where fly ash and bottom ash from a presently operating, modern incinerator, were used for path making and also spread over allotments as fertiliser between 1994 and 1999. Recent analysis of ash from the allotments found that it is contaminated with extremely high levels of heavy metals and dioxins. Clearly, the

use of ashes from incinerators represents a potential threat to human health, but this practice is not being discouraged either by the EC or at a national level by the regulatory regimes proposes or currently in place.

The Way Forward. A limited amount of epidemiological research has been directed at investigating the health impacts of incinerators. Despite this, scientific studies reveal that MSW and other incinerators have been associated with detrimental impacts on health.

The new EC draft directive on incinerators is not formulated to take human health impacts into account in relation to the regulation and control of these facilities. Rather, the regulatory limits that are set for the permissible release of substances are based on what is considered to be technically achievable. In any case, the draft EC directive on incinerators, not yet in force, can be regarded as already outdated. Many European countries have already committed themselves at the OSPAR Convention to phase out all releases of hazardous substances to the environment by 2020. In this context no emissions of hazardous chemicals would be allowable in stack gases or ashes. This is likely to prove impossible for incineration technology to ever achieve.

In addition, at the Fifth Intergovernmental Negotiating Committee Meeting (INC5) on the Elimination of Persistent Organic Pollutants (POPs), held in December 2000, a worldwide agreement was reached to reduce total dioxin releases, with the ultimate aim of their elimination. Incineration is listed as one of the main industrial source categories for dioxins, and requires the use of BAT (Best available Techniques) for new installations and substantially modified existing facilities. It was also agreed to promote the development and, where deemed appropriate, require the use of substitute or modified materials, products and processes to prevent the formation and release of dioxins. In this context, incineration is acknowledged as a significant source of dioxins that, in the longer term, should be replaced by alternatives.

To comply with the provisions of the OSPAR agreement and of the emerging POPs Convention implies a radical rethink of industrial and manufacturing processes. Instead of waste-generating 'dirty' technologies, which rely upon incineration and other environmentally dubious waste disposal techniques, OSPAR implies the need to develop and use 'clean-production' technologies which eliminate toxic waste. The adoption of 'zero-waste' as a central tenet of environmental regulation also implies that the Precautionary Principle of environmental protection will occupy an equally key position in the development of policy and regulatory frameworks. The precautionary principle requires that the burden of proof should not be laid upon the protectors of the environment to demonstrate conclusive harm, but rather on the prospective polluter to demonstrate no likelihood of harm. On this premise of precautionary regulation it can be argued that there is already sufficient evidence of environmental contamination and adverse human health impacts to call for a complete phase out of incineration.

In the case of waste management, adoption of a zero releases strategy and the reduction of health impacts from waste management means a move towards an environmental management paradigm based upon the three axioms of reduce, re-use and recycle in relation to the generation of both municipal and industrial wastes.

Greenpeace Demands

A drive towards waste prevention, re-use and recycling, and therefore also towards lessening the adverse health impacts from waste management, should include the following measures:

- The phase out of all forms of industrial incineration by 2020, including MSW incineration. This is in line with the OSPAR Convention for the phase out of emissions of all hazardous substances by 2020.
- Financial and legal mechanisms to increase re-use of packaging (e.g. bottles, containers) and products (e.g. computer housings, electronic components).
- Financial mechanisms (such as the landfill tax) used directly to set up the necessary infrastructure for effective recycling.
- Stimulating markets for recycled materials by legal requirements for packaging and products, where appropriate, to contain specified amounts of recycled materials.
- Materials that cannot be safely recycled or composted at the end of their useful life (for example PVC plastic) must be phased out and replaced with more sustainable materials.
- In the short term, materials and products that add to the generation of hazardous substances in incinerators must be prevented from entering the the waste stream at the cost of the producer. Such products would include electronic equipment, metals and products containing metals such as batteries and florescent lighting and PVC plastics (vinyl flooring, PVC electrical cabling, PVC packaging, PVC-*u* window frames etc) and other products containing hazardous substances.

and more generally:

- Further the development of clean production technologies which are more efficient in terms of material and energy usage, produce cleaner products with less waste and which, ultimately can be designed to operate in a 'closed loop' configuration in order to fulfil the needs of society in a more equitable and sustainable manner;
- Fully implement the Precautionary Principle, such that, in the future, problems are avoided before they occur. The continuation and further development of scientific research has a fundamental role to play in identification of potential problems and solutions. Nonetheless, we must be ready to take effective precautionary action to prevent environmental contamination and degradation in the face of the considerable and often irreducible uncertainties associated with determination of health and other environmental impacts from incineration.

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