

Health Effects of Municipal Waste Incinerators

-A Literature Survey-

by

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Contents

	Page
1. Introduction.....	3
2. Exposure.....	4
3. Health Effects.....	8
3.1. Fourth Report of the British Society of Ecological Medicine on the ‘Health Effects of Waste Incinerators’	8
3.2. Greenpeace Report on Incineration and Human Health.....	14
3.3. Publications in peer-reviewed journals.....	19
4. Summary and Conclusions.....	23
5. Literature.....	25

1. Introduction

The general question if residents living in the proximity of waste storage/treatment sites show a higher rate of certain diseases or adverse health effects has been studied in a number of publications. A major drawback of most of these studies is that they provide medical/epidemiological data only, i.e., they do not analyze or even provide evidence for the dose and identity of substances/chemicals which could eventually be responsible for the observed health problems.

A usual procedure in investigating possible health effects related to, e.g., hazardous waste sites is 1.) to list major substances stored at the site and classify the cohort living in the vicinity as 'potentially exposed'. The scientific weakness of such an approach is enormous since the presence of a chemical on a storage site may or may not be related to (an undefined level) of exposure. 2.) The next step in the procedure is the collection of health data such as data from public databases, investigations with local physicians or questionnaires handed out to cohort members. 3.) A frequent bias in this procedure is that people living in the vicinity of an unwanted site show a well-known tendency to blame health effects on this site. This problem may also apply to practising medical doctors. Another problem with such studies is to find an appropriate control group. In particular the impact of the socio-economic status on health is eminent. Furthermore, the socio-economic status in areas where the waste treatment site is located often differs significantly from that of the control group. 4.) In many instances the frequency of certain disease or health defects is low and shows a high rate of fluctuation over time. In addition the prevalence of estimated 'potential exposure' being also low makes the risk estimates highly imprecise.

It is peculiar that many authors of 'waste and health' studies of that type are well aware of these severe drawbacks and list them extensively in their papers (e.g. Orr et al., 2002), but nevertheless do not hesitate to publish their 'findings'. The only substantial conclusion from such studies usually is, that 'more studies are needed'. The motivation for such statements remains obscure.

In the following, a number of studies published in peer-reviewed journals, as well as two reports published by the British Society of Ecological Medicine and by Greenpeace on the issue of exposure, health effects and municipal waste incinerators (MWIs) are summarized and discussed. Citations from the original publications are printed in *italics*.

2. Exposure

The analysis of ‘exposure’ to toxic chemicals originating from modern MWIs has not been successful so far. The reason for this fact is that the additional exposure levels are so low that they cannot be detected as a significant change in environmental levels. Likewise, Fries and Paustenbach (1990) estimated that the potential human health risks due to TCDD (2,3,7,8-tetrachlorodibenzo-*p*-dioxin, the most toxic ‘dioxin’ congener) emissions from incinerators are insignificant compared to other background sources.

Some publications on this matter merely list the chemicals formed or present in the incinerator fly ash. An example is the paper by Rowat (1999) which mentions a number of ‘hazardous’ chemicals present or formed during the incineration process. These lists usually comprise the polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs), polycyclic aromatic hydrocarbons (PAHs), other organic chemicals, metals and heavy metals, and inorganic gases.

In more recent compilations of this type, particulate matter or PM_x (providing information on the size distribution of the particles) have been added. In many instances these publications mix a number of known information on the general toxicity of these groups of compounds with unscientific speculation on their release.

As an example for this type of arguments, the summary of a paper by Rowat (1999) is given below with a few comments:

1. Incinerator chemical reactions are extremely complex, and many of the resultant organic chemicals have not been identified and therefore have not been measured or tested for toxic effects.

This argument is correct but useless. The fact that the chemical reaction of incineration is highly complex is due for almost any type of incineration in particular for wood fires, automobile engines, candlelight, coal and oil burning etc. In none of these cases, all chemicals present or formed during the process of incineration have been identified or tested. If this would be a requirement for the use of fire, any type of burning, a basis of modern civilization, had to be prohibited. Furthermore, the highly advanced technology of flue gas cleaning and the strict regulations make the incineration of municipal waste one of the safest types of incineration. It can be expected that the local unfiltered burning of wood (fireplaces) or candles in homes is a much more relevant source of hazardous compounds, e.g., in homes.

2. Regardless of how well an incinerator operates, metals will still be emitted, often in combination with chlorine (or other halogens such as fluorine or bromine). Insufficient data exists on the amounts and hazards of these metals.

It is a frequent mistake to mention the chemicals ‘emitted’ from certain sources ignoring the dose levels. The fact that a certain compound can be detected at extremely low levels is toxicologically meaningless and depends only on the methods and equipment used for analysis. The combination with traces of chlorine or other halogens also has no toxicological meaning. For the emissions of metals it is well known that their levels clearly are below the EU directive. The toxicology and hazards of major heavy metals are among the most thoroughly investigated in toxicology.

3. Some studies have demonstrated that incinerators often operate at less than peak efficiency, and polycyclic organic emissions can be increased 1000-fold during cold start-up.

The question is not if the incinerator operates at peak efficiency or below but how the emission levels of critical flue gas components are. There is convincing evidence that modern MWIs are in compliance with strict EU regulations on emission levels. Cold start-up is a very rare event which lasts shortly and only happens when the incinerator has been shut-down for cleaning or maintenance. If such emissions were relevant, an increased level in PAHs (not volatile) would be measurable in the vicinity of modern MWI (e.g. in the major wind direction) which is not the case.

4. Some of the emissions are almost invariably dioxins and furans, which are formed in the incinerator stack. These are highly toxic and are apparently building up in the fat tissues of all humans, world-wide, with an estimated 7-year half-life in the human body.

Again the author makes the same mistake as throughout his manuscript namely to describe the chemical identity of the emissions only. From a toxicological point of view such a discussion is useless. The important issue is to know the levels/concentrations released from the MWI and the anticipated or estimated additional exposure due to the MWI’s operation. In spite of the fact that PCDD/Fs can accumulate in the human body, those levels have been declining dramatically over the last decades, in particular in those countries with MWIs. This fact proves the lack of correlation between dioxin exposure and MWIs.

5. Incinerator fly ash and wash-water must at present be regarded as hazardous waste themselves, and no universally adequate solution has been found for their disposal.

It is not necessary to find a ‘universally adequate’ but an adequate solution for the handling of fly ash. It has been shown many times in the past that such a handling/disposal can be carried out in a safe way.

6. Emitted gases such as NO₂ and SO₂ contribute heavily to acid rain and smog, and to the formation of ozone in smog and sunlight. NO₂, SO₂ and ozone have been proved to cause respiratory illness, and smog has been shown to cause increased death rate.

This statement is not relevant for modern MWIs. The author ignores the fact that MWIs are negligible as a source for these gases. It has been described in many instances that automobile exhaust, heating, and other sources are crucial for air pollution by these gases.

7. Toxic effects an build-up in human tissues of other incinerator-emitted organics such as benzene, toluene, PCBs, alkanes, alcohols, and phenols are well documented.

This statement is simply wrong. Benzene is rapidly metabolized in mammals including humans, the same is true for most alkanes, alcohols and phenols. For some PCB congeners there is evidence for accumulation in the body. PCBs are not emitted from modern MWIs in relevant concentrations.

8. As of 1990 reports, more than half of existing incinerators had no pollution control equipment, and no real-time monitor existed for measuring destruction and removal efficiency.

It is surprising to see that the author in a 1999 paper refers to the technical state in 1990. Obviously, he ignores developments and changes in technology. The fact that a number of contaminants cannot be measured on-line is due, e.g., to the extremely low levels present in cleaned flue gas. Long term side-stream collection experiments have proven, however, that the emissions are well below the strict EU regulation levels for emissions.

Sedman et al. (1994) evaluated the exposure to metal emissions from hazardous waste incinerators in California through non-inhalation pathways. They concluded that no facility contributed a significant portion of the reference dose for certain metals including arsenic, cadmium, mercury, lead, chromium, and beryllium. The deposition of these metals from ambient air would result in substantially greater human exposure through non-inhalation pathways than the emissions from most of the facilities.

Deml et al. (1996) determined the concentrations of PCDD/Fs in human blood and in milk from non-occupationally exposed persons living in the vicinity of the MWI in Schwandorf, Germany. The MWI has been in operation since 1983, with a capacity of 350.000 tons of waste per year. As compared to background levels in the general population in Germany it gave no indication of an enhanced body burden of PCDD/Fs. According to the authors, this finding was in agreement with an earlier report showing normal background concentrations of

PCDD/Fs in soil, fruit and vegetable samples from the same area. Thus, no health hazard related to PCDD/F emissions from the MWI is expected.

Boudet et al. (1999) used the maximum emissions measured at the stack of a modern MWI in Grenoble (France) for the pollutants benzene, trichloroethane, nickel, and cadmium. The authors used a Gaussian plume dispersion model to estimate the distribution of the pollutants in the atmosphere throughout the metropolitan area. Major conclusions in this study are 1.) that the relative contribution of modern MWIs to population exposure to significant health-related pollutants is small. The median additional cancer risks after life-long exposure were estimated for benzene as 2.6×10^{-10} , for nickel as 8.6×10^{-8} , and for cadmium as 1.5×10^{-8} . For cadmium this means that, based on theoretical considerations, 1.5 additional cases of cancer were estimated for 10^8 (100 million) persons exposed to the MWI-derived cadmium emissions. Since the Grenoble area has 0.5 million inhabitants, 0.005 cancer cases over a life-long exposure period in the whole area would theoretically be attributable to this emission. It is evident from these considerations that epidemiological studies of any type will be unable to test this hypothesis, i.e., to verify if any additional risk is real or not. Furthermore it strongly indicates that eventual findings of a statistically significant increase in cancer risk 'around modern MWIs' are highly likely to be due to confounders or other sources.

In the same study, inhalation exposure due to MWI emissions of cadmium accounted for less than 1 % of the WHO Air Quality Guideline while the margin of exposure between the exposure estimates and the NOAEL (no observed adverse effect level) for trichloroethane was 10^9 -fold.

Ohta et al. (2000) analyzed PCDDs, PCDFs, and 'dioxinlike' PCB congeners in environmental samples around a MWI near Shintone Village (Japan) where the cancer death rate between 1985 and 1995 was clearly above the average cancer death rate in Japan. The incinerator built in 1971 was not equipped with any gas cleaning devices. Thus more or less untreated incineration products are released into the environment. Under these conditions soil samples collected in the major wind direction (leeward side) showed much higher TEQ levels than samples taken from the windward side. However, the authors claim that residents in the area leeward to the incinerator had 'higher health' compared to residents in other areas. No data on actual blood levels of contaminants such as 'dioxinlike' hydrocarbons have been provided so far for residents living in the vicinity of this incinerator.

Domingo et al. (2000) analyzed soil and herbage samples in the vicinity of an old MWI in Montcada, Spain. The authors found changes in the soil contamination with total I-TEQ between 1996 and 1997. Trends of these changes were different in the main wind directions North-East, North-West, and South suggesting that sources different from the MWI at least had contributed to the soil levels. Air level estimates from the same area (Domingo et al., 2002) were carried out in 2000 when 'technical improvements' had been carried out at the MWI. The authors conclude that airborne exposure to PCDD/PCDFs was markedly reduced after the improvements. However, they also conclude that inhalation exposure to PCDD/PCDFs is almost 'imperceptible' compared with dietary background exposure to these contaminants both in areas closed to or at long distance to MWIs.

Meneses et al. (2004) tried to calculate the cancer risk resulting from PCDD/F emissions of a Spanish MWI. They calculated PCDD/F concentrations in environmental media by means of a simple-compartment-multimedia model. Changes in cancer risk were based on emission measurements before (111 ng I-TEQ/m³) and after (0.086 ng I-TEQ/m³) installation of a modern flue gas cleaning. The major conclusion was that the cancer risk from PCDD/F emissions from the MWI was extremely low, i.e., about 1000-fold below that calculated for PCDD/F emissions from other sources in the same area.

3. Health Effects

3.1. Fourth Report of the British Society of Ecological Medicine on the 'Health Effects of Waste Incinerators'

In this report (2006), moderated by J. Thompson and H. Anthony, the health issues related to MWIs are discussed in detail. In the Introduction the authors already mention that *'some attention has been paid to the concentrations of the major chemicals emitted..* This statement strongly underestimates the amount of data on emissions from modern MWIs and the strict legislation on the emissions of major toxicants which is applied in the EU. Then the authors claim that the limitations of emissions do not take into consideration the point of view that *many chemicals build up over time in the human body...* If this was true, it should be possible to detect these chemicals at significantly higher amounts in the vicinity of modern MWIs. This is, however, not the case (see below).

Then, the authors mention that *ash contains high concentrations of toxic substances such as dioxin....* The fact that toxic substances accumulate in the ash is due to the highly efficient gas cleaning process in MWIs. Since people are not exposed to fly ash but the treatment of fly ash and/or the final safe disposal of fly ash is part of any application to build and establish a modern MWI, this point is irrelevant. At present, techniques are available to either remove or destroy the toxic components or to dispose fly ash under safe conditions.

Epidemiological studies on the occurrence of certain diseases in the vicinity of MWIs are very difficult to carry out. Their interpretation requires great caution. Statements like '*most show higher than expected levels of cancer...*' are misleading. For a scientific interpretation a statistical analysis is required. The fact that a certain figure of cancer incidence or mortality is slightly higher than expected is irrelevant and frequently due to bias or hazard. Usually, in these studies the levels of toxic compounds in air and/or in the body of people living in the area were not analysed.

A major point of caution is that MWIs usually are located in industrialized areas. There the incidence of certain diseases may be higher than in rural areas. The emissions from modern MWIs contribute to the overall burden of toxic compounds to a negligible amount. Further measures have to be taken to reduce emission from relevant sources of exposure such as traffic, heating, heavy industry, old power plants etc.

In Chapter 2 on *Emissions from Incinerators and other Combustion Sources* the authors claim that *incinerators produce huge amounts of fine and ultrafine chemicals*. This statement is unacceptable from a scientific point of view. First it is unacceptable that the authors almost never provide any exact figures which could underline their statements. The term '*huge amounts*' is completely meaningless as long as no exact figures are given and are compared with background or with emissions from other sources. The fact that MWIs produce fine and ultrafine particles is almost meaningless. The important issue is how much particulate matter the MWIs release into the environment. The statement that *common baghouse filters act like a sieve and thus allow the transfer of 'huge amounts' of fine particles* is incorrect. In fact modern MWIs are equipped with washers which can hold back particles. Major sources of fine and ultrafine particles are traffic, heating, farming, heavy industry etc.

The statements on heavy metals, nitrogen oxides and organic pollutants are full of errors and misinterpretations. The authors claim that *the amount of metals emitted will vary hugely*. They do not provide a reference for this statement. The statement that *removal of nitric oxide by incinerators is only about 60% effective* is not supported by any reference. It is meaningless

because the amount of nitrogen oxide emitted from the stack is the relevant figure and not the percentage of NO_x removed from the gas.

The list of qualitative findings on various organic chemicals at the end of the chapter is irrelevant because the dose makes the poison, i.e. the finding of a few molecules of a compound does not mean anything. The question of quantitative analysis of emissions and risk is completely ignored in this chapter.

In Chapter 3, 3.1 on *Health Effects of Pollutants* the authors provide a lengthy discussion of the adverse effects of fine particles. They do not, however, discuss the question what the contribution of modern MWIs to the overall exposure to fine particles is. It is feasible to assume that other sources are much more prominent than modern MWIs.

In subchapter 3.2 - 3.6. the issue of *Heavy Metals* and other toxic compounds is discussed. The toxicology of these compounds is presented based on certain references. A link between these statements and modern MWIs is not provided or discussed here.

In Chapter 4 on *Increased Morbidity and Mortality near Incinerators* the reader expects substantial information.

In Chapter 4.1 on *Cancer* many scientist will be disappointed. The first case mentioned does not have controls. A so-called 'cluster' is mentioned. In this cluster obviously dioxin levels in blood were never measured. Instead dioxin levels in soil are mentioned (which are not directly related to blood levels). The study obviously has never been published in a scientific peer-reviewed journal but is available on the internet only.

The next chapter contains more errors and misinterpretations. An adjusted cancer mortality rate of 1.08 is completely meaningless because of the standard error. That means that the likelihood to obtain an adjusted rate of exactly 1.00 compared to the control cohort is very low. Usually a rate different from 1.00 is due to biological variability. This has nothing to do with increased or decreased cancer risk.

The Knox et al. 1953 paper is on hazard but obviously not on modern incinerators.

The 1980 paper is biased by the fact that other sources of emissions were not considered.

The other studies were carried out in the vicinity of old-technology incinerators. Even there doubts are appropriate because of small case numbers and the lack of blood analysis for dioxins (in particular in the cases where a link to dioxin exposure is claimed).

With respect to birth defects five reports are mentioned. The Sint Niklaas study cannot be considered since it has not been published in a peer-reviewed journal.

The ten Tusscher study (2000) is on 'open chemical combusting' not on modern MWIs.

The French study found defects and anomalies around incinerators. It is not mentioned that defects and anomalies usually occur in humans (and in animals). The epidemiological approach depends on the proper control group which is extremely difficult to define. It appears non-scientific to search for such anomalies around incinerators without convincing statistical evidence. Odds ratios for spina bifida of 1.17 and for heart defects of 1.12 are within background.

The next statement refers to hazardous waste sites. Again this statement is unrelated to modern MWIs.

In Chapter 5 on *Disease Incidence and Pollution* a number of partially wrong or incorrect statements and citations can be found. When, e.g, IARC (the International Agency for Research on Cancer) mentioned that 80% of cancers are due to environmental influences it does not mean environmental pollutants but factors not directly related to heritable genetic disposition. These 'environmental' factors include lifestyle factors such as lack of exercise, over-nutrition, smoking, alcoholic beverages, sexual behaviour etc. In fact leading institutions such as WHO concluded that environmental pollutants play a very minor role in overall cancer incidence probably in the range of a few percent. It is amazing how these facts so well established and recognized in cancer research are ignored in the report by the British Society of Ecological Medicine.

It is unacceptable to correlate the number of cancer cases in the USA with the number of waste sites in the country.

The statement that cancer incidence is higher in industrialized areas explains the 'findings' of a relationship between MWIs and cancer.

The subchapter on so-called links between exposure to pollutants and cancer contains a number of statements which have no scientific basis and are even not feasible for non-experts. Likewise, the liver is mentioned as an organ with a high fat content, which is definitely wrong. Cancer incidences have been increasing in organs such as the prostate which does not have a high fat content either.

What follows is a crude list of historic examples which in some instances in fact showed a correlation between increased cancer risk and air pollution. Again, these statements are unrelated to modern MWIs.

In the next chapter the hazardous 'chemistry' is blamed for causing cancer. The authors ignore that natural products or substances derived from natural products such as the food

contaminant fungi *Aspergillus niger* or heterocyclic aromatic amines formed during frying of fish and meat are among the most potent mutagens and carcinogens known. The statement '*incinerators emit carcinogens*' is not scientific. It is also true that ovens emit carcinogens when we bake a cake, toasters emit carcinogens when we toast bread, pans emit carcinogens when we fry fish or meat (not to talk about barbecues), cars emit carcinogens when we drive and so on...

In the next chapter major neurological diseases are linked to pollutants. Again it is completely unclear what this has to do with modern MWIs. It is unacceptable that some doubtful correlations between levels of pollutants and major neurological diseases which are not more than speculation are taken as a basis for serious statements.

Even violence and crime (and other problems of modern times) is linked to pollutants in this report.

In the Chapter on *the foetus, the breast-fed infant and children* the issue of dose again is ignored. The authors focus on the mere presence of 'chemicals' claiming that chemicals made by humans (i.e. the chemical industry) are dangerous whereas toxicologists learn at the University that the most potent 'chemicals' have been made by nature.

These chapters are a mixture of correct statements, statements ignoring major findings mixed together with conclusions from inadequate studies such as the Sint Niklas study. The issue of dose, i.e. the quantitative issue, which is of central relevance in toxicology, is completely ignored. Likewise, the question on how much of a certain compound is really released from a modern MWI and to what percentage it contributes to background exposure is never discussed.

The issue of so-called *chemical sensitivity* discussed on pg. 29. is one of the most controversial issues in environmental medicine. It is unclear why it is discussed here. Its linkage to chemicals or contaminants is unlikely when considering the recent literature.

The so-called precautionary principle cannot be used and should not be applied to any environmental issue in the sense that precaution means 'stop the project'.

Many of the following chapters are completely unrelated to modern MWIs.

The issue of monitoring is discussed in an inappropriate way. The major toxicants emitted from MWIs are known. The chimera of '*highly toxic unknown substances*' is as old as it is

wrong. Our own experiments prove, e.g., that the acute toxicity of MWI fly ash can mainly if not exclusively be attributed to heavy metals.

The dioxin emissions from MWIs are so low that they can hardly be measured on-line. For this reason the dioxins have to be collected over several days. Such monitoring has been carried out e.g. by Hagenmaier in modern MWIs demonstrating that the emission levels are well below 0.1 ng TEQ/m³ emission gas.

The chapter on risk assessment shows that the authors do not trust scientific toxicology and epidemiology. Unfortunately, they do not tell the reader what they suggest to use instead to find out the truth except for their 'personal feelings or guess'. Their comments on risk assessment are biased. They accuse the method for their uncertainties. That the 'best guess' of the authors is hampered by enormous uncertainties and overwhelming inconsistencies is ignored.

The conclusions made by the authors are wrong for the following reasons.

- 1) The epidemiological studies claiming a relationship between incinerators and health problems are all hampered by small case numbers and/or lack of chemical analysis and/or biased by other sources in the same area and/or inadequate controls. A number of studies mentioned by the authors did not find significant relationships (A relative risk in the range of 1.1 or similar is meaningless).
- 2) Particulate matter (PM) in fact is suspected to be related to a number of diseases. Modern MWIs are not a major source for PM. The relative contribution of major sources of PM to human exposure is even not discussed in the report.
- 3) The issue of concentration/dose is a central issue in toxicology. It is permanently ignored in this report. The mere presence of a chemical is meaningless, the dose makes the poison.
- 4) Radioactive can easily be monitored. Modern MWIs are no relevant source of radioactivity.
- 5) The issue of fly ash is part of the environmental impact analysis. Fly ash can be treated and/or disposed safely.

6) The long term build up of toxicants is not real for most compounds. Some compounds in fact can accumulate in the human body. They can easily be measured. No accumulation of any chemical related to MWIs significantly higher than background was ever found in people in the vicinity of a modern plant. These plants have now been in operation for more than 15 years in many countries. There are no health problems or environmental impact documented which can be related to the MWIs.

7) Not a toxicological issue.

8) There is no toxic impact by modern MWIs. The prevention of any emission of harmful molecules (ignoring the dose issue) is not realistic. It would require the end of any civilization (including the use of fire). It is wrong to believe that this status (before civilization) would be chemically 'safe', since nature produces/bears the most effective toxicants known.

In summary this report is a compilation of facts and statements which are either wrong or used in a misleading way or are not related to the issue of modern MWIs. It cannot be considered as a serious and reliable source of scientific information. In contrast it reflects a strongly biased point of view probably with a political motivation. It ignores facts and, which is more concerning, ignores science.

3.2. Greenpeace Report on Incineration and Human Health

This report was published in 2001 by Greenpeace Research Laboratories, University of Exeter, UK. The authors are M. Allsopp, P. Costner and P. Johnston.

Related to '*Health impacts on populations living near to incinerators*' (Chapter 3) the authors claim *that a limited number of studies have been conducted to determine whether individuals residing near to incinerators have been exposed to pollutants. Studies are restricted to investigations of exposure to dioxins and heavy metals. Results of these studies are mixed. Some reported elevated exposure among nearby residents while others found no evidence of increased exposure.*

This introductory statement leaves the reader with the impression that the overall exposure situation for people living in the vicinity of a MWI is unclear, and therefore, needs further

investigation. This notion is highly misleading which becomes evident when the individual studies cited by the authors are analysed in detail:

The study by Gonzalez et al. (2000) found an increase in dioxin blood levels, two years after the MWI (in Spain) went into operation. However, the increase was not different in the residents living near to the MWI and those living further away which led Gonzalez et al. to the conclusion that *the increase in dioxin blood levels was unlikely to be attributable to the incinerator*.

The study by Miyata et al. (1998) was conducted in the vicinity of a traditional Japanese waste incinerator without any gas cleaning.

The study by Startin et al. (1994) was also carried out in the vicinity of a MWI which was not equipped with modern flue gas cleaning and was closed in 1991. The dioxin blood levels in seven residents in Derbyshire, UK, were 'higher' than in a 'comparison group' which was the German population. It is self-evident that such a comparison is worthless.

The study by Holdke et al. (1998) was never published in a journal but was only available as an abstract. No judgement can be made on the scientific quality of this study.

Deml et al. (1996) found no increase in dioxin blood levels in residents living in the vicinity of a modern MWI in Germany.

Van der Hazel and Frankfort (1996) did not see a difference in blood dioxin levels between residents living near to a modern Dutch MWI and a control group from the Dutch general population.

Kurtio et al. (1998) found higher levels of mercury in the hair of residents living near to a hazardous waste incinerator in Finland between 1984 and 1994. The incinerator was not equipped with modern flue gas cleaning.

In summary, this analysis shows that only two studies could demonstrate higher levels of dioxin or mercury in residents living close to an incinerator when compared to an apparently adequate control group. In both cases the incinerators were not equipped with any flue gas cleaning (Japan) or had insufficient flue gas cleaning (Finland). In all cases where modern

MWIs were in operation no indication for a relevant or measurable exposure of people due to the MWI was found. This fact is unfortunately ignored by Allsopp, Costner and Johnston.

In the following chapter on *biomarkers* the authors refer to a study on urinary excretion of thioethers. It is completely unacceptable from a scientific point of view to relate urinary thioethers to MWIs or any other putative source without identifying the chemical structure of the thioethers thus providing at least some scientific evidence for a possible relationship. Urinary thioethers can be derived from hundreds of compounds even including endogenous compounds. These include food constituents, food contaminants, occupational chemicals, cosmetics, household products, environmental agents etc.

In chapter 3.2 entitled *Health Effects – Epidemiological Studies* the authors claim that *the majority of epidemiological studies on the health of populations residing near to incinerators have focused either on incidence of cancer or respiratory symptoms. Additionally, some research has investigated other potential effects including congenital abnormalities and changes in the sex ratio. Considering the widespread use of incinerators on a global scale, the number of studies that have investigated health effects in residents near to these facilities is sparse.*

In subchapter 3.2.1 studies on cancer are discussed.

The study by Viel et al. (2000) analysed the incidence of soft tissue sarcoma and non-Hodgkin's lymphoma in the area of Besancon (France). It was found that the incidences of both diseases were increased in the vicinity of an MWI without modern flue gas cleaning. The dioxin emissions were reported to be in the range of 16.3 ng I-TEq/m³ which led the authors to the suggestion that dioxins were the causative agents. The study does not contain any data on the levels of dioxins in air, soil or in the blood or adipose tissue derived from residents of the various areas or from cancer patients. If a dioxin exposure was suspected to cause these disease, this hypothesis could have been easily tested by such analysis.

The authors of the study claim that confounders were unlikely. However, the issues of population density, local genetic clustering, heterogeneity of the population (racial confounders) and diagnostic bias (proximity to University hospital) were not adequately addressed.

Biggeri et al. (1996) analysed the spatial relationship between four sources of air contamination in Trieste, Italy, and lung cancer risk based on a case-control study. The risk of lung cancer was related to a location of residence close to the city centre and close to a MWI with insufficient gas-cleaning technology. It is mentioned by the authors, however, that the distances from the four sources were highly correlated. Furthermore, the emissions are not identified or analyzed which, from the authors' point of view, should be responsible for the effects of the incinerator on lung cancer risk. A number of probable confounding factors are discussed below.

The studies on laryngeal cancer appear to unreliable. In particular, the incidence of laryngeal cancer is highly modulated by widespread individual risk factors, i.e., consumption of alcoholic beverages containing more than 20% ethanol (calvados, whiskey, gin etc.) and smoking. Proximity to MWI has to be tested for the confounder 'urbanization'.

The studies by Elliott et al. (1996, 2000) carried out in the United Kingdom are discussed below. They are hampered by the probable confounders urbanization and socio-economic status. In all studies from this group no exposure data are provided.

The studies by Knox (2000) and Knox and Gilman (1998) have the same and other drawbacks. They are discussed below in more detail.

In subchapter 3.2.2 studies on respiratory effects are discussed.

In the introduction the authors claim that *Incinerators, in particular cement kilns, emit considerable quantities of SO₂ and NO₂. Long term exposure to theses substances is known to have negative impacts on respiratory health...* This statement is quite typical for the whole report. It uses inadequate generalizations e.g. from cases of cement kiln emissions to the general group of 'incinerators'. Furthermore, meaningless statements such as about '*considerable quantities*' are made.

An early study by Zmirou et al. (1984) is cited. The authors of that study mention that it was not possible to conclude a cause-effect relationship between the incinerator and respiratory effects.

It follows a list of publications which deal with respiratory diseases in the vicinity of a hazardous waste incinerator including reports about workers employed in the plant, studies on people living in the vicinity of a Taiwanese wire-reclamation incinerator without flue gas cleaning, a study on cement kilns in the United States and others about installations completely unrelated to modern MWIs. It remains unclear what the aim of such an unselected list of descriptions was.

The studies by Shy et al. (1995) and Lee and Shy (1999) on respiratory diseases in the vicinity of a modern MWI found no relationship between both and no impact of the MWI on the PM₁₀ levels. These publications are discussed in detail for their limitations. One example is that the authors did not see a relationship between PM₁₀ levels and respiratory function. Obviously, it appears hard to believe for the authors that a threshold for measurable PM₁₀ effects on respiratory function exists.

In a subchapter on sex ratios (3.2.3) the authors claim that Mocarelli et al. (2000) had reported changes in the sex ratio of births in Seveso after the TCDD incident in 1976. A study by Williams et al. (1992) found an excess of female births in an area 'identified as being most vulnerable to air pollution from incinerators'. The authors noted, however, that *it is not possible to attribute causality of increased female births to materials released by incinerators*.

In subchapter 3.2.4 studies on congenital abnormalities are discussed.

The studies were carried out in the vicinity of waste incinerators without modern flue gas cleaning (1961-1969). *The study by ten Tusscher et al. (2000) found an increase in the incidence of orofacial clefts in babies born after the incinerator began.* The authors relate cleft palate formation to TCDD exposure. However, no increases in cleft palate incidence were found in Seveso. Furthermore, no data on dioxin exposure (external or internal) were provided by ten Tusscher et al.

The second study on the Neerland neighbourhood in Belgium did not find statistically significant influences on chromosomal damage in children or on congenital malformations in the area. The report claims that the probability of giving birth to a baby with congenital malformation was 1.26 times greater for Neerland women than for Flemish women in general. For those familiar with the annual and spatial fluctuations of the incidences of malformations, such a figure must appear meaningless, however.

In subchapter 3.2.5 studies on multiple pregnancy are discussed.

The authors conclude that the findings on a relationship between multiple pregnancy and MWIs are inconsistent.

In subchapter 3.2.6 studies on hormonal effects are discussed.

A study carried out by Osius and Karmaus was published as an abstract in 1998.

3.3. Publications in peer-reviewed journals

Elliott et al. (1996) examined the cancer incidences of over 14 million people living near 72 MWIs in Great Britain between 1974 and 1987. The excess from 0 to 1 km distance ranged from 37% for liver cancer to 5 % for colorectal cancer. A major problem with this study is the 'urbanization factor', i.e., people living in industrialized, highly populated areas show higher incidences for various diseases including cancer. Reasons for this effect may be lifestyle (smoking, alcoholic beverages, lack of exercise, 'population stress') as well as air pollution from heating, traffic, dust etc. It appears not useful to publish 'correlations' to MWIs under these circumstances. The authors accuse TCDD and other 'dioxins' as probably causative for their findings without providing any data on the actual TCDD or dioxin levels in the populations or individuals investigated.

Biggeri et al. (1996) analysed the spatial relationship between four sources of air contamination in Trieste, Italy, and lung cancer risk based on a case-control study. The risk of lung cancer was related to a location of residence close to the city centre and close to a MWI with insufficient gas-cleaning technology. It is mentioned by the authors, however, that the distances from the four sources are highly correlated. Furthermore, the emissions are not identified or analyzed which, from the authors' point of view, should be responsible for the effects of the incinerator on lung cancer risk. Furthermore, the likelihood of exposure to occupational carcinogens was obtained from 'expert evaluation'. Smoking habits were investigated by the use of a questionnaire which, in particular in the case of lung cancer, can not be considered as reliable.

Knox (2000) studied the incidence of child cancer/leukaemia in a migration study in Great Britain. He found a highly significant excess of migrations away from birthplaces close to

MWIs. The relative risks calculated by Knox within 5.0.km of these sites were about 2:1. The author claims, however, that the specific effects of the MWIs could not be separated clearly from those of adjacent industrial sources on combustion effluents. The study does not take into account if the place of residence was located on the leeward or windward side of the MWI. It does also not consider other sources but was obviously designed to focus on MWIs. Data on the actual levels of air pollutants in the areas of migration are not provided.

In 2006, Knox and Gilman published another paper on a similar issue, i.e., the effects of migration towards or away from 'sources' of 'hazardous chemicals' in Great Britain on the incidence of death from childhood cancer. The authors found that the risk of childhood cancer death was related to proximity to several types of 'industrial sources' around the time of birth. The 'industrial sources' were identified by the use of 'map searches' or 'business directories', i.e. by best guess. In contrast to the paper by Knox (2000) MWIs are no longer listed among the types of 'toxic industrial sites'. It is also no longer claimed that migration towards a 'toxic industrial site' during childhood (before the age of 16) is the critical risk factor. Instead, the location of residency around the time of birth is now suggested as the critical parameter. For unknown reasons, the socio-economic background of the mothers was not evaluated. Furthermore, the incidence of cancer death but not that of cancer is considered. This may be particularly misleading since socio-economic factors may clearly influence the success of childhood cancer treatment. In addition, very critical confounders such as smoking habits of the parents are not investigated or discussed.

Viel et al. (2000) examined the spatial distribution of soft-tissue sarcomas and non-Hodgkin's lymphomas around a French MWI with relatively high levels of dioxin emission (16.3 ng I-TEQ/m³). They found identical clusters of increased standardized incidence ratios for both types of cancer 'around the MWI'. The authors discuss the possible confounding by urbanization since the highest incidence was found for the area of Besancon, the area with the highest population density among the areas investigated. The authors claim that the evidence for a relationship between urbanization and the incidence of non-Hodgkin's lymphoma is 'still controversial' and no similar findings were reported for the incidence of soft tissue sarcoma. Furthermore, no increases in incidences were found for other urbanized areas such as Montbeliard, Sochaux, and Audincourt. They do not mention, however, that the overall population of the area of Besancon is much higher than that of the next three densely populated areas, Montbeliard, Sochaux, and Audincourt. It is completely unclear, why they did not

chose a control area of the same degree of urbanization without MWI. Furthermore, it remains unclear why no blood levels of PCDD/PCDFs were measured in spite of the authors' suggestion that these compounds were responsible for the observed findings. The detection of PCDD/F blood levels is a well established procedure to analyse the exposure to these compounds because of their long elimination half-life in humans. In summary, this study leaves more questions open than it answers.

Elliott et al. (2000) reported an excess risk of 37% for liver cancer within 1 km of MWIs in the United Kingdom. They state that *'one difficulty in interpreting these numbers is the issue of socio-economic confounding.registered cases of primary liver cancer in Great Britain are strongly related to deprivation - ... showing more than twofold variation in risk between the most affluent areas and the most deprived.* Besides this obvious confounding factor which has much higher power than the 'effect' found for the distance from MWIs, the authors make no attempt to speculate on the possible causal factor which should be responsible for the increased liver cancer risk. This is a major drawback of most epidemiological studies dealing with this issue. In case of such hypotheses (which the authors avoid) a measurement of the levels of the accused contaminant would have been appropriate and necessary.

Hazucha et al. (2002) carried out a 3-year epidemiological study where they tested spirometric lung function once annually among residents in three communities in North Carolina surrounding a hazardous waste, biomedical, or municipal waste incinerator, and among residents in three comparison communities. The average monthly concentrations of particulate matter with diameters of 2.5 μm and less ($\text{PM}_{2.5}$), ranging from 14.6 – 31.5 $\mu\text{g}/\text{m}^3$ in ambient air, in all communities were similar during the 3 years of study supporting the notion that MWIs have no measurable influence on the $\text{PM}_{2.5}$ load of ambient air. There was no difference in percent predicted forced vital capacity, forced expiratory volume in 1 sec, or forced expiratory flow rate over the middle 50% of the forced vital capacity among members of the 'incinerator communities', compared with 'non-incinerator communities', and there were no significant differences in lung function within the three sets of communities. *There was no evidence from this study that an association exists between residence in the three waste incinerator areas, which met state and federal emissions regulations, and average spirometric pulmonary function of non-smoking community members.*

In a study by Floret et al. (2003) the vicinity of the MWI in Besancon (France) was also investigated (see above). The authors compared the pattern of non-Hodgkin's lymphoma diagnosed between 1980 and 1995 with a Gaussian-type dispersion model for 'dioxin'. This model had been applied as part of an EIS for a new combustion chamber. They found that *the risk of developing non-Hodgkin's lymphoma was 2.3 times higher (95% confidence interval = 1.4 – 3.8) among individuals living in the area with the highest dioxin concentration than among those living in the area with the lowest dioxin concentration.* Here, the authors tend to ignore that the 'dioxin levels' were based on a model. For unknown reasons, they did not measure the actual dioxin levels in ambient air or in blood of the individuals. All studies which have measured the dioxin levels in ambient air in the vicinity of modern MWIs did not find any measurable influence of the MWI (e.g. Deml et al., 1996). It appears highly likely that confounding factors have influenced the outcome, in spite of the notion made by the authors that the emission levels of the Besancon incinerator were (average?) 16.3 ng I-TEQ/m³, i.e., 163-fold higher than the EU regulation limit (part of the incinerator was shut down in 1998). Likewise, the racial background of the population was shown to influence the rate of non-Hodgkin's lymphomas being significantly higher among blacks than among whites in the United States (Wu et al., 2005).

Tango et al. (2004) analyzed the association of adverse reproductive outcomes in Japan with the proximity of the residence area of the mothers to MWIs with high dioxin emissions. None of the reproductive outcomes tested (male/female sex ratio, low birth weight, very low birth weight, infant deaths due to congenital malformations, neonatal deaths, neonatal deaths due to congenital malformations, spontaneous fetal deaths, and spontaneous fetal deaths with congenital malformations) showed statistically significant excess within 2 km distance from the incinerator. A statistically significant peak-decline in risk with distance from the incinerators up to 10 km was found for infant deaths and infant deaths with all congenital malformations combined. For this study no data on exposure or body burden of 'dioxinlike' contaminants, on socio-economic status, smoking and alcohol history were available.

For risk assessment purposes (Glorennec et al., 2005) estimated the emissions for major contaminants in cleaned flue gas by using the median value of measured levels in gas samples (usually taken once a year) and a Gaussian plume dispersion model to calculate the ambient air concentrations attributable to the incinerator. A multimedia model was used to calculate concentrations in the food chain. The authors conclude that after compliance of the emissions

following the upgrade of the incinerator in 2000, all hazard ratios and future individual lifetime excess risks appear minimal.

Cordier et al. (2006) studied the incidence of congenital malformations in communities surrounding 70 French MWIs that operated at least one year between 1988 and 1997. They found that the rate of congenital anomalies was not significantly higher in 'exposed' compared with 'unexposed' communities. Some subgroups of major anomalies, specifically facial clefts and renal dysplasia were more frequent in the 'exposed' communities. The risk of other types of anomalies increased with road traffic density. The authors conclude that although both incinerator emissions and road traffic may plausibly explain some of the excess risk observed, several alternative explanations, including exposure misclassifications, ascertainment bias, and residual confounding cannot be excluded. Some of the effects might, from the authors' point of view, be attributable to old-technology MWIs. They do not provide any data on external or internal exposure of the population or the mothers. The identity of the compounds possibly explaining the correlations seen is subject to speculation. Furthermore, the category 'other polluting sites' was restricted to 'smelting, metallurgy or industrial waste incinerator' giving the (wrong) impression that such facilities are the only sources (besides road traffic) of relevant environmental pollutants. Obviously, other sources such as conventional and nuclear power plants, chemical and petrochemical industry, emissions of organic solvents, use of agricultural chemicals etc. were not considered at all.

4. Summary and Conclusions

Studies on a possible impact of municipal waste incinerators on health can be divided into studies on exposure to hazardous compounds and studies on health effects.

This report concentrated on three main report types:

- Fourth Report of the British Society of Ecological Medicine on the 'Health Effects of Waste Incinerators'
- Greenpeace Report on Incineration and Human Health
- Publications in peer-reviewed journals

In peer-reviewed publications no increased levels of dioxins could be found in the vicinity of modern Municipal Waste Incinerators. However, there is good evidence that higher levels of internal and external dioxin exposure have existed and may still exist in the vicinity of Municipal Waste Incinerators with no flue gas treatment or insufficient flue gas treatment. Facilities without flue gas treatment are not found in Europe but do exist in countries such as Japan. Insufficient flue gas treatment did exist in Europe prior to 1990 in some facilities.

With respect to health effects a number of studies suggest a causal relationship between old Municipal Waste Incinerators and certain adverse health conditions/diseases such as cancer, respiratory diseases, congenital malformations and hormonal changes. Most of these studies were hampered by the lack of adequate measurements on internal or external exposure and by the likelihood of strong confounders. Such confounders are mainly urbanisation, socio-economic deprivation and related factors.

The reports published by Greenpeace and by the British Society of Ecological Medicine on this issue are relatively non-selective compilations of all kinds of reports on waste treatment and health. They comprise of and discuss studies on health effects at the workplace (workers at the plant) and in the vicinity of Municipal Waste Incinerators without any flue gas cleaning, with inadequate flue gas cleaning, and with modern flue gas cleaning facilities. Furthermore, findings from sewage sludge incinerators, hazardous waste incinerators, municipal waste incinerators and other types of incinerators etc. are presented and finally combined in an unscientific way.

In fact, there is not a single peer-reviewed study showing that modern Municipal Waste Incinerators release hazardous substances at a level causing any harm to the people in the vicinity. Monitoring studies have shown that emissions from modern facilities which are operating within the strict EU limit, have a negligible contribution to background levels. No study has shown any adverse health effects in the vicinity of a modern Municipal Waste Incinerator clearly related to the plant.

In summary modern Municipal Waste Incinerators can be regarded as safe facilities which have an imperceptible impact on the environmental and health situation in their neighbourhood.

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