COMMITTEE FOR PREVENTION AND PRECAUTION

MUNICIPAL SOLID WASTE INCINERATORS:

RISKS AND POLICIES

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Ministry of Ecology and Sustainable Development

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INTRODUCTION:

On 14 October 2003, Madame Roselyne BACHELOT, Minister of Ecology and Sustainable Development, asked the CPP to examine an article recently published by Floret et al. [1]. This epidemiologic study concluded that persons living near the municipal solid waste incinerator (MSWI) in Besançon had an elevated risk of developing non-Hodgkin lymphoma. The authors argued that their results supported the hypothesis of a causal link between this proximity and risk of non-Hodgkin lymphoma, due to exposure to airborne dioxins. The Minister also requested that at the conclusion of its examination the CPP make appropriate recommendations about the management of incineration plants currently in operation and, in particular, on the means of monitoring their environmental impact.

At the same time, the national institute for public health surveillance (InVS) and the French food safety agency (AFSSA) began work intended to confirm or rebut the results of the study by Floret et al. at several sites throughout France and to examine the possible excess burden of dioxins and dioxin-like compounds in persons living near MSWIs, especially its relation to their ingestion of locally produced food. Protocols for these studies were finalized, and they began at the same time as these recommendations were drafted.

The risks that MSWIs may cause for the health of their neighbors have received substantial media and public attention in recent years, at the time as waste in France has been increasingly managed by incineration. For a somewhat longer period, groups of scientists across the country have been studying the risks of incineration and all of the pollutants it emits, not only dioxins (for example [2]).

Other expert groups (for example [3]) have specifically examined the health risks of dioxin exposure, of which MSWIs are only one source among many. The CPP issued guidelines about the risks of dioxins in 1998 [4]. International expert assessments on this subject also abound (for example [5]-[6]-[7]-[8]).

The Minister's referral thus concerns a topic about which ample data exist: a large amount of basic data about the risks of incineration and more specific data about dioxin are available and have been interpreted divergently by different groups of experts. Dioxins have many toxic effects. Some are still debated, especially those observed experimentally in animals but not yet confirmed epidemiologically (for example, immune system effects and malformations). Population exposure to dioxins takes place almost entirely (at least 95%) through the dietary pathway, because of the persistence of these substances and their capacity to dissolve in fats (their capacity to vaporize or dissolve in water is very limited). On the other hand, they are strongly adsorbed by particles of organic matter that can subsequently be transported by air, water, or dust. The greatest uncertainties are those related to the risk level at a given dose, including the possibility, accepted by some US experts, that these carcinogenic effects have no dose threshold.

At the same time, incinerator emissions of pollutants are increasingly regulated. It is agreed [2] that if the hypothesis of a threshold dose level for the carcinogenic effect of dioxins is correct, compliance with current regulations should lead to a zero health risk. For the inverse hypothesis of no threshold, studies until now have concluded that the additional risk for those living near MWSIs is very low (labeled negligible). Before the current regulations went into effect, incinerator operations emitted relatively high quantities of pollutants into the environment. These emissions may have created much larger health risks for neighborhoods around incinerators, due to dioxins (especially under the hypothesis of a non-threshold model for carcinogenesis) and other pollutants (heavy

metals) [2]. It is important to note that many and various processes emit dioxins; only now are we beginning to characterize the nature and importance of some of them adequately.

Moreover, many diseases, including cancers, have relatively long latency periods and may continue to appear for several decades after exposure ends. Accordingly, the article that led to this referral by the Minister raises the question of the consequences of past emissions of relatively high levels of dioxins.

To respond to the Minister's questions, the CPP decided against a completely new assessment and focused on analyzing the existing data, interpreting them in the light of the Minister's request, and proposing recommendations based on a global public health approach. First, the CPP considers that the current and future impact of incineration appears to be contained but that uncertainties remain and must be resolved. It is essential to develop environmental monitoring of current sites and urgent to promote a policy to prevent further increases in waste volume. Second, implementation of current measures of prevention (regulations) must be accelerated. Finally, expert assessment practices must become credible to and accepted by the public: this necessitates a broad analysis of public participation and the promotion of an ambitious policy to that end.

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RECOMMENDATIONS of the CPP

The CPP recommends that the question of the incineration of household waste in France be analyzed as part of a comprehensive policy of waste management in France, structured around the following themes: prevention, reinforcement of the regulation and monitoring of plant operations, development of research, environmental and population monitoring, optimization of waste streams, and an ambitious participatory policy of information and awareness involving the public and participants in the decision-making processes.

Promote prevention policies

It is absolutely necessary that immediate steps be taken to establish an aggressive policy to **stop the increase in waste volume**, which has not stopped growing—fast—for the past 30 years. Major campaigns to provide information and raise public awareness are both essential and urgent, as is implementation of incentive mechanisms for various economic stakeholders (for example, packaging producers, direct marketers, and distributors of flyers). Nonetheless, more coercive mechanisms should be planned for follow-up, if these prove insufficient; Ireland and Germany, for example, now tax plastic packaging.

The CPP recommends the energetic development of incentives to **eliminate pollutants at the source** insofar as possible and to promote the production of biodegradable packaging made of biomass products. These measures must be implemented at two levels: 1) to limit emissions of toxic pollutants, recycling or disposal must be considered in the process of designing new materials; 2) **waste sorting and recycling must be promoted** in the collection of household waste to prevent insofar as possible contamination of the waste stream by substances that are or are likely to become hazardous during the waste treatment process. Despite undeniable efforts over the past ten years to introduce sorting of household waste, this process is still relatively undeveloped in France. These efforts must continue and increase. They should include, for example, regular public information campaigns, both **local and national**.

Apply, Enforce, and Improve Regulations

Upgrading MSWI units to compliance with local, national and European guidelines must continue, and the European directives concerning waste composed of electric and electronic equipment must be applied swiftly. Authorities in France became aware of the environmental impact of MSWI emissions very late, compared with several of our European neighbors. It would be wrong for us also to be late in applying these regulations, as we were for asbestos regulations.

Current emissions regulations must be improved. Information would be more accessible to the different participants concerned by the health effects if regulations covered not only concentrations in emissions but also instantaneous emission flow rates and if they specified concentrations not to be exceeded in the environment (air, water, and soil).

Training and licensing of MSWI workers must be strengthened, to match those in the chemical and nuclear industries. A specific collaboration between the Ministry of Labor and the regional offices of industry, research, and environment (DRIRE) could be developed for MSWIs, like those that already exist for some chemical plants.

Improve data collection and assessment

The CPP recommends that the public authorities make a significant effort—or create incentives—to develop both basic data collection and research in the area of waste management. Both are essential foundations of a policy to reduce waste volume and to develop materials whose environmental fate will be taken into account from its design.

Research is also essential to **improve our knowledge and understanding of the environmental and health consequences of emissions** and other waste from MSWIs (or from other waste management plants). The relevant bodies should thus launch a research program to:

- Advance our knowledge of the **toxic content of waste streams** and monitor their environmental fate
- Improve impact studies, which should include a **site climate assessment** that takes into account, for example, the thermal structure of the lower layer of the atmosphere, frequency of haze and fogs, and effects of topographic relief, as well as a **study of food production** by those living near MSWIs
- Improve the **use** of pollution transfer models, with as a special priority better characterization of the data and input parameters for models; impact studies must also make every effort to **validate modeling results locally**; moreover, tools for modeling the transport, diffusion, and deposition of pollutants on soils or vegetation require more consideration of micrometeorologic phenomena.
- Ameliorate knowledge of the type, and size, distribution of particles transported by gases and the nature of the residual gases after scrubbing, because the reliability of airborne transfer models depends in part on these input data
- Learn more about **pollutant transfer in soils and to groundwater**, their permanent binding, and remediation processes. Current data do not allow us to understand the possible natural *in situ* attenuation phenomena of these pollutants, which we may ultimately be able to use for managing contaminated sites. Research in this direction is also imperative for remediation of those former incineration sites that remain "hot spots".
- Develop knowledge about the possible health repercussions of MSWI emissions on neighboring populations, focusing especially on the consequences of exposure to dioxins, pollution mixes, and heavy metals; the studies of body burden currently underway are especially useful.
- Improve our understanding of the discordances sometimes noted between the results of epidemiologic observations and risk calculations
- Develop a comprehensive strategy of environmental monitoring that takes into account the background levels around MSWIs, including in food.

Develop monitoring of current MSWIs and of old incinerator sites

Identify the sites concerned — new and old

The sites concerned by pollution from old incinerators (or polluting incinerators still in operation) should be identified and mapped and this information made available to all, beginning with public authorities and the owners, users, and neighbors of the sites.

Strengthen monitoring of incinerator operations

The variability of MSWI operations must be enumerated and its consequences on emissions clarified. Semi-continuous measurements over relatively short periods should be combined with measurements over long periods for a better approach to the variability in the pollutant content of emissions. If dioxin measurements are not available for the incidental phases, knowledge of the variations of more standard indicators (temperature, NOx, CO_2, CO, SO_2, etc.) would make it possible to assess changes in the conditions of their production.

Studies about the human factors in MSWI operation and maintenance should also be encouraged, to improve our knowledge of the possible difficulties faced by the operating staff.

Strengthen environmental monitoring near incinerators

Environmental monitoring around MSWIs is imperative. The most useful methods involve measurements of the concentration of persistent pollutants at emission, in soils, on vegetation, and in animals. Analyses should consider the use of animals as pollution sentinels: cows (milk), chickens (eggs), and snails because they provide the closest match to human "biology". Measurement of soils and vegetation should not be limited to downwind areas, which are not always the most polluted. **Measurements** should be taken routinely **before the start-up** of an incinerator to determine the baseline background levels. This will also facilitate monitoring of changes in dioxin levels in France.

Similar surveillance must take place around old incineration sites no longer in use to monitor their long-term impact on the environment.

Routine surveillance of populations presents problems—both ethical (because of the large number of body fluid samples necessary for these assays) and methodological. The CPP considers routine testing of population body burdens without specific scientific research aims to be ethically and scientifically dubious.

Reinforce monitoring of incinerator personnel

Workers at MSWIs are exposed to multiple risks. Some of these come from their inhalation of dust and chemical and biological agents. Surveillance of indoor air in MSWIs should be reinforced, and where appropriate, measures should be taken to prevent workers' overexposure in normal and off-normal (e.g. fires) operations as well as during maintenance.

The general population is exposed to dioxins principally by ingestion. MSWI workers, on the other hand, are also exposed by the respiratory route (emission of particles in the building at different phases of incineration, including redispersion of dioxin-rich fly ash deposited on the floor and grounds). There are currently no data available about pulmonary retention of dioxin particles and lipophilic molecules (in the pulmonary parenchyma and intrathoracic lymphatic nodes) containing dioxins or its relation with plasma toxic equivalent (TEQ) concentrations. Animal studies are necessary.

Moreover, there is still no descriptive health information on the some 3000 MSWI workers in France. Because their status varies (public authorities, private companies, etc.), individual data of medical follow-ups has not been grouped by occupation. It would be desirable to organize at least one ongoing health study to monitor this population, or, even better, a longitudinal cohort (multicenter French or European study).

Promote optimization of waste management (storage, incineration, recycling and sorting)

All the current technical solutions have disadvantages. In recent years, the overwhelming choice in France has been to "incinerate almost everything". The CPP recommends instead that steps be taken to optimize the various channels of waste management, taking into account the different technical solutions available. Tools for decision analysis and support are available for this purpose. Local public authorities also need better information.

Promote an ambitious participatory policy to inform the public and other stakeholders, heighten their awareness, and to increase their involvement in decision-making processes

The CPP considers that behind the question of the "social acceptability " of incinerators lies a broader question of waste management generally. A public debate on the entire issue of waste management, rather than a consultation about a specific proposal, has very clear advantages. Participants in the public debate on waste management planning must pass judgment on the principal directions of collective action and thus indicate the modes of treatment that appear desirable to them. If this phase of the consultation is conducted correctly, it should produce a formal document of proposals, endorsed by the stakeholders. Selection of the sites for the management chosen should only take place afterwards. This extremely sensitive phase may benefit from an advance analysis of the economic compensation to be accorded the municipalities or neighborhoods where the sites will be located, before these sites are actually selected.

This comprehensive procedure would give public policy-makers a more complete vision of the issues, including the technical solutions and the specific interests of all the stakeholders.

The procedure of consultation that the CPP proposes to generalize may seem long, especially given that the Commissariat General of Planning deems this issue worrisome in the intermediate term. The CPP is aware of the lack of waste treatment facilities and the need to develop them. Nonetheless ramming projects through will not necessarily save time. Legal challenges can be used by local advocacy groups to block proposals for quite a while. Diverse studies show that local opposition to incinerator projects is rarely an absolute opposition to the technique, but more often results from governance errors. When the population is involved in the decision-making process, it generally demonstrates great responsibility afterwards. People understand that waste management must consider both environmental and economic criteria. Solutions reached through formal public debate procedures generally take account of the diverse constraints.

Chapter 1.

INPUT AND OUTPUT OF MUNICIPAL SOLID WASTE INCINERATORS

1. Incinerators in France[1]

Despite the progressive shutdown of highly polluting incinerators, France has many MSWIs: 292 in 1985, 213 in 2000, and 130 in 2004. MSWIs treat extremely heterogeneous kinds of waste, varying with the season.

In 2002, the total quantity of waste produced in France reached 625 million tons (Mt), 375 Mt of which came from agriculture and forestry, 105 Mt from businesses (including 11 Mt of "special", mainly hazardous, industrial waste), 100 Mt from mines and quarries (inert waste), 31 Mt from households, and 14 Mt from institutions. What is called household waste, in the broad sense of the term (that is, 26.4 Mt), is waste from households,[2] after subtracting bulky refuse and "green waste" (9.5 Mt) and includes some industrial waste (from small businesses and shops) collected with household wastes. The final category is waste from sewage and industrial treatment plants: sludge and industrial sanitation residue.

The mean quantity of household waste produced in France was approximately 552 kg per year per inhabitant in 2000 and has been rising constantly since 1985, when it was 289 kg per year per inhabitant.

Almost the entire population (99.5%) has its refuse picked up by a sanitation department. The last available statistics (1993) showed household waste to be composed (in percentage of wet mass) of putrescible waste (28.6%), paper (16.2%), cardboard (9.3%), plastic (11.1%), glass (13.1%), textiles (5.7%), metals (4.1%), and an unclassified noncombustible fraction. "Special" household waste (0.5%) is hazardous waste products, such as batteries, organic solvents, and used oils. To that must be added waste electric and electronic equipment (WEEE) (approximately 5%). Humidity levels vary considerably according to type of waste (35% on average). The mean heating-value is 7500 kJ/kg.

To apply Law n° 92-646 of 13 July 1992, **districts have developed plans for waste disposition**. The statute directs that by 2002 only "final" waste storage will be authorized, that is, "waste that cannot be treated given current technical and economic limitations, by extraction of a part that can be recycled or reduction of its pollutant or hazardous

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[1] Sources : - http://www.ademe.fr/Collectivites/Dechets-new/Mots-chiffres/chiffres-cles/dec01.htm - http://www.ademe.fr/collectivites/Dechets-new/Mots-chiffres/ITOM2002.asp - ADEME - Atlas des déchets en France Collection de données de références. ADEME éditions 1998. - Commissariat Général du Plan, Le service public des déchets ménagers, La Documentation Française ; février 2004. - Buclet N., Godard O. Municipal Waste Management in Europe. Kluiver Academic Publishers ; 2000, 234 p. - Dron R. Les Mâchefers d'Incinération d'Ordures Ménagères. Note du laboratoire central des Ponts et Chaussées ; 1996, 15 p. - Le Goux J., Le Douce C. L'incinération des déchets ménagers ; 1995 - Pineau J.L., Ranguis-Barale I., Massiani C., Prone A. La masse de l'échantillon d'ordures ménagères en vue d'une étude descriptive quantitative. TSM,12 ; 1995, p. 941- 944.

[2] The waste labeled "equivalent to household waste" is that whose collection and treatment does not require any particular technical treatment, so that it can be treated with household waste. It is contrasted to specific categories, such as medical waste (infectious risks), waste containing PCBs and PCTs, used oil waste, and radioactive waste, and to industrial waste, which is very diverse and can cause serious pollution or other hazards, in particular, "special (that is, possibly hazardous) industrial waste", which requires specific treatment techniques.

character". This statute led to the development of procedures for recycling waste: reuse, recycling or any other activity aimed at obtaining reusable materials or energy from waste.

France has more incinerators than any other country in the European Union. In principle, their feedstream includes only non-hazardous waste; hazardous waste is fed towards specialized treatment facilities.

It is hoped that **sorting and recycling** will reduce the waste requiring thermal treatment to 60% of the total current waste. Segregated waste collection has developed substantially in recent years and concerns in particular newspapers, cardboard, glass, plastic packaging, and vegetable waste. Traditional garbage collection (50-80% of the waste stream), that is, unsorted waste, is intended either for landfills or incineration. In 2002, the tonnage incinerated with energy recovery was equal to that sent to landfills. Incineration is either performed directly or after sorting by the incinerator operator. Hazardous objects (for example, batteries or electronic components) may thus reach MSWIs. The operator's management determines how well these items are identified. In any case, the separation of scattered quantities of toxic waste presents a problem. Incineration plants ought therefore have robust, complex systems with filters, precise measurement equipment, and diverse treatments. Development of such effective systems in France dates back only to 1995, and we have far to go to catch up with countries that began using such equipment 5 to 10 years earlier.

2. Toxic Elements in Waste Fed into MSWIs

Another way to look at the type of products to be treated is to examine their physicochemical composition. The figures listed below are for household waste (per kg dry weight): they include 59.2% organic matter, 33.4% carbon, and 4.4% hydrogen. Table 1 lists other elements (these are means; the percentages vary substantially according to geography and over time).

Table 1: Global physicochemical composition of household waste in 1993[3]

Nitrogen	7.3 g/kg
Chlorine	14 g/kg
Sulfur	2.8 g/kg
Fluoride	58 mg/kg
Arsenic	5 mg/kg
Boron	14 mg/kg
Cadmium	4 mg/kg
Cobalt	113 mg/kg
Chromium	183 mg/kg
Copper	1.05 g/kg
Manganese	412 mg/kg
Mercury	3 mg/kg
Lead	795 mg/kg
Zinc	1 g/kg

[3] Source: ADEME, Les déchets en France; 1993.

The sources for these elements are diverse (appendix 1). Cadmium comes principally from plastics (37%), mercury mainly (82%) from combustion of household waste (batteries, light bulbs, thermometers, dental fillings), lead from lead metal and lead crystal, arsenic from glass, and chlorine from plastics (50%) [1]. These statistics, like those for Table 1, are for 1993. They are changing swiftly, with waste sorting and the banning of some elements, such as mercury in batteries and thermometers.

Manufacture of PCBs has been forbidden since 1987, and exposure to them should be falling. The national plan for the elimination of PCBs calls for their processing only in approved incinerators. Special disposition is required at levels of 50 mg/kg or higher. There are no regulatory standards for PCB emissions from MSWIs.

In early 2004, **Europe adopted two directives on WEEE**. The first enlarged the concept of responsibility of its producers, who must participate in reducing this waste. The second mandated a diminution in the hazardous substances included in the composition of electronic goods. WEEE includes a wide variety of diverse products and the substances they contain are not always well known. These directives should reduce the content of heavy metals and other hazardous substances (halogenated compounds, etc) in waste streams toward incinerators and landfills.

A **detailed national inventory of waste treatment facilities** is taken every other year and kept up to date by the French environmental and energy agency (ADEME). More specific and usable information requires more reliable data from the local authorities managing these sites. The dispersion of responsibility does not facilitate this data collection: household waste is the responsibility of district councils, while the regions manage industrial waste. The development of **regional observatories** thus varies greatly by region. The Ministry of Ecology and Sustainable Development (MEDD) assesses dioxin and heavy metal emissions from MSWIs annually.

3. MSWI Output

MSWI emissions of toxic products have decreased considerably since the early 1990s. By 2001, for example, dioxin emissions decreased by nearly 80%. Another large diminution should occur in 2006, when new regulations go into effect.

Combustion of household waste takes place at high temperatures, with flue gases reaching 900-1000℃ but decreasing rapidly afterwards. Pollutant emissions are heterogeneous (by the very nature of household waste, its composition fluctuates enormously) and their characteristics are modified as they cool and are dispersed in the environment. A ton of unsorted waste is distributed as follows [2]:

- 700 kg of gas or particulate vapor
- 240 kg of bottom ash
- 20-40 kg scrap metal
- 20-30 kg ashes.

3.1 Gas and Particles

Incinerators classically produce pollution in the form of particles and gas [3]:

- 10-30 grams of particles are produced per ton of pre-treatment waste. Well-designed air pollution control devices in modern MSWIs can reduce particulate emissions by at least 99%. The particles most difficult to stop are those with a size from 0.1-1 µm

- before treatment, the gases produced per ton of waste include1.5-2 g SO_2, 2- 2.5 g NOx, and 6-7 g HCl. Most of these gaseous pollutants are also captured by pollution control systems. Emissions depend on the effectiveness of the pollution control.

Limit values for particulate emissions

The decree of 20 September 2002 set the maximum acceptable concentrations for particle emissions: 10 mg/m^3 as a daily (24-h) mean and 30 mg/m^3 as a half-hourly mean. Particles are classified in a category inappropriately labeled total dust (see Fontan [4] for particle terminology). It is in fact the total quantity emitted per unit of time that determines environmental concentrations (see below, transport and diffusion). The limit values for environment concentrations of PM10 are set by the decree dated 6 May 1998.

3.2. Metals and Organic Compounds

3.2.1. Cadmium

Incinerators are thought to be the source of 16% of all cadmium emissions; an unknown portion comes from electronic waste materials.[4] In 2001, total cadmium emissions were 11.1 tons, 1.8 of which came from incinerators. This figure is a minimum, because of the progress in cleaning systems.

3.2.2. Dioxins and furans

Incinerators contribute substantially to total dioxin emissions—65% in 2001, when total dioxins from all sources were estimated at 468 g, with 304 g estimated to have been emitted from MSWIs (212 g in 2002 and 115 g in 2003). Beginning 28 December 2005, emissions from all MSWIs must be less than 0.1 ng per m^3. The dioxin/cadmium ratio for incinerators is four times higher than for total atmospheric emissions (see section 3).

3.2.3. PCBs

In 2001, MSWIs emitted approximately 20% of total PCB emissions from all sources (43 kg). Upgrading incinerators to bring them into compliance with European directives should reduce the total quantity emitted.

3.2.4. Volatile organic compounds (VOC)

They include many species, with methane generally excluded. Emissions come in approximately equal proportions from transportation, residences, and industry. Incinerators account for only a small proportion of the latter. French regulations classify VOC emissions in the category of total organic carbons (TOC). The mean values are given as concentrations, 10 mg/m^3 for the mean daily (24-h) value and 20 mg/m^3 for the mean half-hourly value. Toxicity of VOC varies substantially according to compound.

Among VOC, the volatile or polyaromatic hydrocarbons (PAH) are considered separately, because of their persistence. They belong to the family of persistent organic products (POP), and some of them, such as benzo(a)pyrene, are carcinogenic. They are thought to form during the combustion of paperboard and the organic fraction of waste. According to the french CITEPA (interprofessional technical center for air pollution studies) inventory, PAH derived from industry and from energy transformation contributed approximately 20% of total emissions. This figure includes PAH from incinerators, but it is difficult to quantify their contribution further.

[4] According to CITEPA

Emissions of this particular type of VOC from incinerators remain unregulated. European directive n° 96/62/EC, dated 27 September 1996, is intended to take environmental PAH concentrations into consideration. The proposed follow-up directive sets a mean annual limit value for benzo(a)pyrene of 1 ng/m^3 and a long-term goal of 0.1 ng/m^3.

3.2.5. Mercury, lead

Mercury

Emissions from MSWIs accounted for 12% of the total mercury emissions in 2001 (13.8 tons), the lowest emissions since 1990, because of both the limitations on its use and improved waste sorting.

Lead

Lead emissions from MSWIs accounted for 9% of total lead emissions in 2001. Total emissions that year were the lowest since 1990: the use of lead-free fuels helped to reduce total emissions by a factor of 20, to only 175 tons. Between 1990 and 2001 lead emissions from incinerators were cut by approximately one third.

3.2.6. Copper, zinc

In 2001, MSWIs emitted the following quantities of copper and zinc:

- Copper: 6% of the national total, 5.2 tons
- Zinc:13% of the national total, 170 tons

3.2.7. Solid residues

Solid residues include bottom ash as well as the flue-gas purification residues that are collectively referred to in French as REFIOM.

Bottom ash accounts for 25-30% of the incinerated tonnage. Used either for highway construction or deposited in class 2 landfills,[5] bottom ash is composed mainly of silica (approximately 50%), with some calcium, iron, and aluminum, combined to produce silicate minerals, oxides resistant to high temperatures [5], or diverse metals, including heavy metals more or less bound to these silicates and oxides, incompletely-burned organic matter, and traces of PAH and dioxins (mean 9.2 ng/kg dry weight). In principle, these ashes should not release their components after treatment. Nonetheless, consideration of the reuse of bottom ash for road construction must take into account the risks associated with its pollutant levels and the risks of their transfer. Recent experiments show that particles containing dioxins can be transferred to subjacent soils; the type of soil plays an important role [6].

REFIOM include:

- fly ash from flue gas purification: 14-37 kg per ton of incinerated household waste; water may cause it to release its metals;
- filter-cake resulting from treatment of the gas wash water: 2-5 kg per ton of incinerated household waste;

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[5] There are 3 types of landfills in France:

Class 1: receive hazardous industrial waste (hazardous for the environment or living things); most of this waste should be stabilized before burial.

Class 2: receive urban residues and/or harmless industrial waste.

Class 3: site for inert residues, from construction, buildings, or public works, for example.

- compounds formed by neutralization of acid gases (such as HCl and HF).

All of these residues are deposited in class 1 landfills and made inert.

We also note the dust associated with waste handling.

3.2.8. Effluent

Effluent from incineration plants includes:

- waste water, sent to a treatment plant
- pluvial (??) water (treated first)
- used industrial water
- residual water from smoke purification.

The quantity of water used is approximately 0.5-1.6 m^3 per ton of waste. Water from drainage, floor-washing, ash extinction, and so on contributes relatively little. They undergo preliminary processing before transfer to a wastewater treatment plant. Water used in smoke treatment may contain ashes, heavy metals, acids, and salts. Chemical treatment produces solid cakes that are sent to landfills.

The pH of the wastewater is adjusted to an appropriate level. Purification of this water in treatment plants presents problems because of the sometimes high quantity of salts.

Directive 2000/76/EC includes measures for monitoring and control of effluent:

- measurement of temperature and discharge flow
- continuous pH measurements
- semiannual measurement of dioxins and furans
- monthly measurement of heavy metals.

3.2.9. Biologic pollutants: microorganisms

Microorganisms in waste are due both to the inherent nature of waste itself (which includes tissues, diapers, and feces) and to their proliferation in the favorable medium of waste. The microorganisms encountered are essentially:

- Gram-negative bacteria, which can produce dangerous endotoxins
- fungi, such as *Aspergillus fumigatus* and *penicillium*, which are allergenic and induce asthma
- yeasts, mainly *candida albicans*.

These microorganisms are easily destroyed by incineration: there is practically no probability of finding them living in either vapor or ashes, given the temperatures of 900-1000 ℃, standard in incineration.

On the other hand, workers in MSWIs and the neighboring populations may be contaminated during waste handling. Special surveillance of indoor air and the immediate vicinity of these systems is recommended.

3.3. Waste Electric and Electronic Equipment (WEEE)

This category of waste was mentioned above because it contains toxic substances likely to enter an incineration feedstream. It is the object of two European directives awaiting transcription into French law. Europe produces more than 6 million tons of waste electric and electronic equipment each year, with growth on the order of 3-5% a year. The composition of this waste is very complex, because beyond the plastic materials that

provide its casing and its metal components, there are also flame retardants (brominated or phosphorus compounds) likely to form very toxic products (e.g., dioxins and PCBs) during incineration. In view of the increasing importance of this waste, it is important to:

- · reuse and recycle it
- · design these goods to use recyclable materials.

Segregated collection of WEEE, made mandatory by European directive 2002/96/EC, dated 27 January 2003, should reduce emissions from these toxic compounds, although it is not currently possible to quantify the importance of this reduction. Industry is to manage these WEEE streams, which must still be defined and then implemented.

4. Determinants of Incineration Policies

Policy options for waste management vary according to objectives, which may favor recovery (recycling of materials), energy production (incineration), or the destruction or stabilization of pollutants. Consideration of the carbon cycle (and its "greenhouse effects") does not yet play an important role in this decision-making process. These objectives—the priority of which varies from one to another in European and French policies—face some constraints, including public acceptance, technological capacity, costs, environmental impact, and desired product quality. Priorities today are recycling and valorization and diminishing residues. Accordingly, segregated collection and recycling take precedence. Organic waste recovery is viable only if preceded by effective segregated collection. This necessarily requires the adhesion of citizens and institutions.

Recycling biological waste involves the fermentable portions—vegetable waste, paper and several other kinds of waste. There are two types of recycling:

- **Composting**: aerobic treatment that can be implemented on any scale
- **Methanation**: anaerobic treatment that produces a bio-gas that can be used for heat or electricity.

The aim of composting is to produce fertilizer. Here again, segregated waste collection is important, at least for the image and quality of the products. Some 40-odd French municipalities have set up systems for recovery of biological waste and aim to collect for it 50-70% of the fermentable fraction and 15-20% of household wastes. Other waste, including green waste, are also treated in these plants. France has made less progress in this area than countries such as Germany. Given the large quantities of animal excrement (275 Mt) and of waste from agriculture (55 Mt) and the food industry (43 Mt) in France, sources other than household waste might be more pertinent sources for recovery of biological material. These doubts have contributed to limiting the progress of composting.

Overall, recovery of biological material is inapplicable to 50-80% of the household waste stream, the portion that presents the principal issues for debate and decision. **The two major options are incineration or landfill**. The principal environmental issues thus concern their impact, compensated insofar as possible by energy recovery (methane from landfills and heat from MSWIs).

Research is needed on long-term stable and clean storage (mineralization of compounds, such as carbon).

5. Optimization of Incineration and Landfills

Incineration allows the recovery of significant energy and serves to mineralize, stabilize and reduce the quantity of waste to be landfilled (only 5% of incinerated waste if ash can be used for road construction). Nonetheless, incineration produces, as we have seen, flue

gas and byproducts that require further processing. How can we optimize use of incineration?

Reduce the quantity of waste to be incinerated

The first step is to cut back the quantity of waste to be incinerated. The primary objective is to stop the continuous increase in waste volume. Prevention begins first with consumers, who must become aware of the issues, as must manufacturers if they are to reduce packaging volume and produce biodegradable packaging. The second objective is to develop recycling (recovery or reutilization). Beyond the need to develop the technical capacity for recycling (viable only if there is a market or use for the recycled products), recovery of recyclable waste presents technical problems and costs money [7],[8]. Recycling rates depend on population participation rates. Even when citizens sort their waste, it is difficult to prevent errors.

Select the waste to be incinerated

It is also possible to select the waste to be incinerated to prepare fuel. What should the selection criteria be? Is energy capacity or exclusion of pollutants more important? If the products are clean, recycling should be favored. Excessive selectivity minimizes the energy that can be recovered. The other objective is to extract the problem items, that is, the hazardous household waste, but pollutants are distributed through the different fractions. The impact of removing some fractions is difficult to assess since some pollutants, such as dioxins, disappear during incineration and then reform.

Deposit in landfills

Landfills were long unregulated and thus unauthorized, disapproved by both public opinion and regulatory authorities. Technologies today, however, have advanced considerably. Accordingly, mechanical and biological processes make it possible to stabilize waste for its subsequent disposition (landfill or incineration). Because practices are so irregular, however, landfills can present long-term problems that are not always contained (e.g., atmospheric emissions and effluent). Nonetheless, although the bad reputation of landfills has improved with the technical progress, appropriate landfill sites remain rare: the difficulty is to open new sites.

Another option is pyrolysis or thermolysis (thermal reactions without oxygen). They permit energy recovery and the preparation of fuel substitutes usable in industrial processes such as cement manufacturing. In this way, some emissions can be delocated.

Improve recycling and valorization of mineral residues

Complete knowledge of the materials, their intrinsic characteristics, and their reactive pathways would make it possible to predict their fate in the short and intermediate term in specific scenarios. This improvement also involves assessment of innovative processes such as: 1) fly ash treatment to convert this raw material into a secondary material usable in public works, and 2) consideration of processes to extract metals, either because they are valuable or because they are hazardous to the environment (such as copper, lead, and zinc) and thus to produce usable materials, such as clinker for cement. Such operations may also reduce calcium use in cement manufacturing and thus the large quantities of the CO_2 (important in the greenhouse effect) it emits.

What criteria should be considered for optimization?

Of the criteria to be taken into account (greenhouse effects, social acceptability, energy, health risks, etc.), health risks are among the least documented. Studies about incinerators are beginning to appear, but there are few data about landfills.

In conclusion, there is not currently any method that is best from every point of view. The solutions are manifestly only partial and limited (among other things, by population acceptance, geological quality of sites, and operator's performance). **Waste management is a domain that requires interdisciplinary research and technological development involving the physical, chemical, geological, biological and medical sciences as well as human and social sciences.**

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Chapter 2

TECHNICAL PROCESSES, OCCUPATIONAL EXPOSURE, AND RISKS ASSOCIATED WITH INCINERATOR OPERATIONS

1. MSWI Technical Processes

MSWIs use industrial processes similar in many ways to those used in chemical and nuclear power plants. Thus, numerous studies have examined the operation of chemical and nuclear plants, looking at their workers' tasks, specific difficulties, and their consequences on the processes and emissions, but MSWI operations have not been studied in detail. The similarities justify an assumption that MSWI instantaneous emissions depend on the phase of operation and difficulties encountered. Measurements taken during normal operations in strict accordance with protocols provide no information about possible peaks during "off-normal" periods of malfunctioning.

MSWIs in France vary widely in their capacity, from less than 3 tons per hour for the smallest to more than 30 tons per hour for the newest plant designs. Nonetheless, their heterogeneity is diminishing: all plants currently in operation are continuous process plants equipped with control and monitoring instrumentation. MSWI technical processes can schematically be divided into three phases:

- waste storage and preparation, in the refuse bunker, or pit. The waste is deposited by dump-trucks and then moved by the grapple crane operator to the feed chute;
- combustion, with an approximately one-hour cycle
- flue-gas purification and sometimes treatment of its residues.

Depending on the plant, the following may be added to this basic process:

- equipment for recovery and use of heat (waste-to-energy plant)
- system for ash treatment.

Waste combustion is not the only source of air pollution. The heat recovery system may sometimes include an additional boiler, intended to make up for a temporary insufficiency of heat production in the waste treatment facility.

2. MSWI Workers

Different jobs are described according to the waste treatment phase in an incineration facility. Specifically, we distinguish (SPLF 1999)[1]:

- grapple crane operators (loading waste into the furnace from the refuse bunker)
- furnace operators (monitoring in control room and intervention during incidents or for maintenance)
- maintenance workers
- staff responsible for monitoring flue-gas and water treatment (intervention to take samples).

Overall, approximately 3600 persons worked in these jobs in more than 200 plants in 2000. Because of the relatively small number of employees at each plant, specialization is uncommon, and workers replace one another at different jobs as needed.

According to the available data and depending on incinerator size, each shift crew has 1-3 workers assigned to processing the feedstock and pit management while 2-6 monitor combustion control and effluent processing. In general, shift supervisors have completed two years of college, while control room workers have vocational or high school training. It should be stressed that operators qualified for chemical or energy plants prefer those to MSWIs, especially because of the overwhelming odor of garbage.

These crew sizes make it likely that an incident in any area will entail assistance from the entire crew to the operator responsible for the area. Attention to monitoring other parts of the process, including air pollution control, may diminish temporarily.

For example, fires break out spontaneously in the stockpit occasionally. If the grapple operator cannot extinguish it immediately, the spread of smoke will make other maneuvers difficult. Accordingly, the entire crew moves to this area to prevent a generalized fire. To prevent the release of pollutants, they avoid opening the smoke vents and are probably working in individual respiratory masks. Monitoring combustion and pollution indicators is temporarily abandoned while they deal with this incident.

MSWI maintenance varies according to the plant, and the most recent are generally programmed. Maintenance operations are conducted in part by in-house staff (3-50

persons), with the major work subcontracted to outside firms. Plants shut down twice a year, the newer models slightly less often. Shutdowns constitute a potential source of occupational exposure.

3. Variations in MSWI Emissions and Surveillance

The heterogeneity of waste in the feedstream can cause variations at each phase of the process, especially during combustion and waste processing. Bulky products (metal bars or concrete blocks that create problems for the bottom ash extractor) and explosives (such as solvents and gas bottles) are especially critical. Very acid fuel loads can cause peaks of hydrochloric acid (HCl) in effluent. Similarly, over or under-proportioning furnace loads may cause malfunctioning by failing to maintain the optimum saturation level, that is, the best ratio between effective load and capacity.

Some combustion variations may be associated with meteorologic conditions (humidity of waste in autumn, low air temperature and high pressure in winter). Training and occupational accreditation must guarantee that workers know how to take these indicators into account during plant operations.

In 1999 INERIS conducted an experiment at two plants to quantify the consequences of shutdowns on dioxin emissions at start-up (for ADEME [2]). At one plant, after a shutdown for 4 hours at a plant where the mean I-TEQ dioxin concentration leaving the stack was normally 1 ng/Nm^3, it increased to 13 in the immediate start-up period and was still 2.2 ng/Nm^3 after 30 days. At another plant, the effect of a 30-day shutdown was compared with that of a 4-hour shutdown. After a one-month shutdown, I-TEQ dioxin concentrations were still 18 ng/Nm^3 one week after start-up and 7.4 ng/Nm^3 one week after start-up after a short shutdown. The study concludes that for incinerators with fuel-oil burners, the annual mass flow rate of dioxins and furans increases by 15% due to a 4-hour shutdown and by 45% due to three shutdowns in a year. For incinerators without fuel-oil burners, the annual mass flow rate is thought to rise 18% from a one-month shutdown and 24% when both a one-month and 4-hour shutdowns take place the same year. Impact and epidemiologic studies should therefore increase the annual mass flow obtained from measurements taken in normal operations by 30-50% to take shutdowns into account.

Dioxin is not measured continuously in MSWI emissions; instead it is sampled at planned intervals. Given of the uncertainties and variability of real operating conditions, this type of measurement is unlikely to represent real variations accurately. Systems for semi-continuous dioxin measurement are available on the French market. They work by installing a sampling apparatus in the stack, letting it function for a given interval (several hours to several months), and then analyzing in the laboratory the dioxin content of the sample taken. Combining measurements for short and for long periods would improve our understanding of the variability of waste.

4. Occupational Risks Associated with MSWIs

The literature about the activities of these plants on the health of their employes varies widely in its focus. It can be analyzed under 3 headings.

4.1 Occupational Status and Medical Surveillance

Workers' status depends on the organization of incinerator plants in municipalities and districts; they may be either civil servants [FPT] (and therefore monitored by FPT prevention physicians) or private-sector employees (and therefore monitored by occupational physicians from the general national health insurance plan). The distinction is important because of the difference in the regulations concerning medical surveillance

and in the circuit of information collection. Moreover, regardless of their status, physicians providing preventive care for these employees usually also cover many other enterprises in different industries at the same time.

Because of the geographic dispersion and legal variability of the plants and their personnel, no complete collection of medical information about all these employees is available.

4.2 Occupational Exposure

It is clear that MSWI staff are potentially exposed to all of the hazards present onsite. Beyond the organizational problems associated with shift work and the quality of supervision in these units, the principal occupational exposure results from the nature of the materials (household waste, therefore microbiological hazards) and their processing (incineration, therefore chemical hazards from thermal breakdown of waste).

Several studies have documented the values of the toxic equivalent dioxin concentration (TEQ), measured mainly in blood lipids.

Studies before 2000 report mean dioxin concentrations (in blood lipids, expressed in TEQ) not significantly higher than that of reference populations (INSERM, 2000) [3].

Similarly, several more recent studies of blood dioxin concentrations in subjects working in MSWIs find that nearly all mean values differ little from those of the control populations. Congener profiles, on the other hand, appear more specific than those observed in general populations. At best, results for incinerator workers cover several dozen subjects whose working conditions and exposure are never well documented (for example, [4]-[11]).

Thus, although exposure levels are thought to be 100-1000 times greater among workers than in the general population [3], the TEQ differential between these populations is low.

Two hypotheses may explain these findings:

- Real occupational exposure is low, especially since ingestion is thought to be the principal exposure pathway. That is, even if air contamination is significant (as several studies measuring these levels inside incinerators show), oral contamination is modest, except for some cases related to hand-mouth contamination.
- The marker used (dioxins expressed in TEQ per gram of blood lipids) does not accurately reflect exposure by inhalation: the physicochemical form of dioxins near emissions sources (very stable absorption on carbonated aerosol particles) may lead to their intermediate storage in the respiratory tract and pulmonary lymph nodes (very slow exchange with blood).

Moreover, there are practically no usable collective data about exposure to other pollutants (such as respiratory allergens, endotoxins, asbestos and ceramic fibers, fine and ultrafine PAH particles, and metals).

In all cases, more information appears to be needed about the physicochemical characteristics of the aerosols in MSWIs and about the kinetics of particles and their dioxin loads after deposit in the respiratory tract (particle translocation, toxicokinetics of dioxins in the macrophagic bronchioloalveolar, pulmonary interstitial and lymphatic compartments).

4.3 Epidemiologic Studies

Very few interpretable studies are available.

4.3.1.Cancers

Retrospective analyses have looked at the causes of death in two small cohorts [12].

In Gustavsson's [study 13], the mortality rate among 176 employees of a Swedish municipal incinerator was compared with national and local rates. A significant excess of bronchopulmonary cancers was observed (SMR=355 [95% CI 162-675]) in comparison with the national population.

Rapiti's study [14] followed 532 employees of two Italian municipal incinerators and found no significant excess of cancer deaths.

These studies do not support any conclusion about the carcinogenic risk of this occupational exposure. Only a multicenter study can document this risk, which in any case concerns only past exposure at levels substantially above those in today's plants.

4.3.2. Other effects

This recent literature is also very sparse.

A Korean study [10] compared 13 exposed workers with 2 control groups of 26 subjects (exposed = 53.4 pgTEQ/g lipids; general population = 12.1 pgTEQ/g lipids). The authors found a significant increase in urinary excretion of 8 hydroxydeoxyguanosine (8OHdG) and malondialdehyde (MDA); there were no adjustments for confounding factors.

In a Japanese study [7], 94 workers underwent blood dioxin assays (range: 13-805 pgTEQ/g lipids; median 39.7). The authors found a significant correlation between blood dioxins and increased gamma GT (not significant after adjustment for age, smoking, and alcohol use), increased in NK activity, and response to PHA stimulation (after adjustment for age).

Finally, a French study [15] of 102 MSWI workers compared with 94 controls found a significant increase in cutaneous symptoms and respiratory abnormalities (questionnaire and spirometry).

In 1992, two related studies reported an augmentation in the mutagenic and pro-mutagenic activity in the urine of workers at several US MSWIs [16]. These results do not support an association between this biological response and any specific exposure. Moreover, the small sample sizes and the failure to reproduce the results make these data less than convincing.

4.4 Conclusion

It is currently impossible to assess accurately the impact of MSWIs on the health of the people who work in them. In view of the results in general populations and the uncertainties about the real exposure levels for workers, a multicenter study (France-Europe) of this population is desirable, as is improvement of our knowledge of the toxicokinetics of the principal pollutants inhaled (especially dioxins).

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Chapter 3.

TRANSPORT TO ENVIRONMENTAL COMPARTMENTS

1. Transport and Diffusion of Pollutants in the Atmosphere

1.1 Impact of Stack Height on Transfer Conditions

The pollutants produced by waste combustion in an incinerator are emitted through a chimneystack. Its height, regulated by the decree dated 2 February 1998, is an important characteristic affecting environmental transport, diffusion, and deposition of pollutants. A high stack limits the presence and deposition of pollutants in the immediate vicinity of the incinerator; it allows them to be transported over greater distances and thus causes the plume (emissions) to be more highly diluted when it touches ground. High stacks thus cause contamination of larger areas, but a lesser degree of contamination.

1.2 Modifications of Pollutant Characteristics in the Plume (Atmospheric Emission)

The **characteristics of pollutants** measured as they leave the stack are modified thereafter, in the plume. In the absence of condensed water, micronic or submicronic particles behave like gas. In the presence of mist, however, the particles are captured by droplets, as gas soluble in water is. Pollutants then behave differently. Hot gas emissions and high speed cause the water vapor present to condense, elevating the plume; this rise can be substantial when the wind is low and the atmosphere unstable. If the plume cools rapidly, vertical ascension stops. The pollutants are then transported by the wind and are scattered (or diffused) by atmospheric turbulence, which varies during the day with the vertical temperature changes (vertical temperature profile). During this transfer, pollutants may condense, move from a gaseous to a solid state, and settle on drops of water.

Pollutant concentrations in the environment depend on the emission flow (quantity emitted per unit of time). The decree dated 20 September 2002 regulates acceptable concentrations in emissions. It would be useful for one decree to state the maximum limit values for the quantity instantaneously emitted into the atmosphere and for environmental concentrations. The 1998 decree implementing the 1996 statute on clean air and rational energy use sets regulatory values for environmental concentrations of the most common pollutants (NO_2, SO_2, particles).

1.3 Influence of Atmospheric Conditions (Wind Speed and Direction, Vertical Temperature Variations)

The prevailing winds are well identified. Low winds, less than 1 m/s (calms) are generally not measured. From the point of view of the vertical temperature profile they correspond to stable meteorological situations (most frequent at night) and to unfavorable conditions for transport and diffusion, therefore to high pollutant concentrations in the plume. Deposition thus do not occur in the direction of prevailing winds. We note that the wind speed and direction at the stack are different from those measured by weather stations, at 10 meters from the ground.[6] Available instrumentation is unable to measure low winds easily;

[6] The wind direction turns by approximately 25° between the ground and the top of the boundary layer (1000 m on average), because of both air-ground friction and Coriolis acceleration. Wind rotation is more marked in the lower layers.

another problem is that the wind field[7] is very variable in space and time. The best method for characterizing them is therefore to use small-scale meteorologic models. The thermal structure of the lower atmospheric layers depends on the site; it is an essential characteristic governing plume diffusion. It should be included in the climate studies performed for impact studies but is not measured in standard meteorologic stations. Specific measurements can nonetheless be requested or modeling performed.

1.4 Dry Deposition, Damp Deposition

Dry deposition of pollutants, either gas or particles, on the ground and vegetation, take place under the effect of turbulence. The "deposition velocity "[8] depends on the chemical characteristics of the gaseous pollutant, particle dimensions, roughness of the soil or vegetation surfaces, wind speed, and intensity of turbulence (thermal or mechanical). These phenomena are all difficult to quantify. Physiological plant activity may be an important characteristic for gases. One example is ozone, which penetrates plants through the stomata, when they are open. Wet deposition most frequently involve mist droplets or dew. The plant area in contact with the atmosphere must also be taken into account. For vegetables like cabbage or some lettuces, deposits occur principally on the outer leaves. Relative to the total plant mass, the quantity of pollutant deposited is theoretically low.

1.5 Lack of Validated Models, Poor Representativeness of Measurements

The phenomena of transport, diffusion, and deposition are therefore complex and difficult to model or measure. Models and measurements can be considered realistic only for meteorological situations corresponding to well-known winds, for short periods of time (on the order of an hour), and for flat sites. They are more approximate when all of the site's meteorological situations are included, along with hilly terrain. The results of models or air concentration measurements (generally in a limited space) must therefore be used prudently to assess the concentration fields of pollutants emitted by a fixed source, here the incinerator stack, and the deposits from its plume. Several models are commercially available today but they have not been validated. The models may best be thought of as providing a qualitative assessment of contamination; its representativeness depends on the sophistication of the models used and the complexity of the relief and meteorological situations for each site.

1.6 Other Airborne Emissions

When waste is handled, before or during its feeding into the incinerator, gases and especially dust containing live material (bacteria, spores, viruses, etc.) may be emitted. The corresponding plume will be diffused differently than that emitted at high altitudes. These pollutants will be found in or very near the plant. They may also be transported further by strong winds or in a highly convective atmosphere. Little information is available about these emissions.

2. Transfer to soils

Although airborne emissions have clearly diminished over the past several years, with the implementation of better pollution control technologies in most industrial systems, this is

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[7]Wind field: the field corresponds in space to all of the wind values at a given moment. It is a very common term in physics: electric field, magnetic field, gravitational field, temperature field, etc.

[8] Relation between flow on the ground and concentration at a reference level near the ground.

unfortunately not the case for soil pollution, the principal reservoir of dioxins and heavy metals, because of their great persistence.

These compounds may accumulate in soils or in plants after atmospheric deposition or in plants through soil contamination (by transfer through the roots). The plants most heavily contaminated by dry deposition are those with the largest area, relative to their mass, in contact with the air. Animals whose food is in direct contact with the soil or that ingest polluted soil particles are most heavily exposed. Thus, chickens raised near industrial or incinerator sites lay dioxin-polluted eggs [1]-[2]-[3].

Nonetheless, much remains to be learned and we must stress that the transfer of MSWI pollutants in soils is a field in which there are few French publications.[9] Questions concerning the nature and properties of the pollutants emitted (dioxins and heavy metals), soil concentrations, changes in the site over time, the process of pollution degradation or binding, and more generally the factors that influence their concentration in soils remain to be answered. Finally, the modes of transfer of pollutants from soil to water, plant, and the food chain must be addressed.

Transfers from soil to other compartments

Research abroad shows that the course over time of soil pollutants may be associated with transfer to another compartment (soil volatilization towards air, erosion, or animal ingestion), or a process of abiotic (photolysis) or biotic degradation.[10] The establishment of an irreversible bond between dioxins and soil is an essential question and some authors have looked at it.

Site monitoring and pollutant persistence

Follow-up data for sites so far available shows no real reduction in soil concentrations in the short term (1-8 years). Several dozen years (from 13 years to more than a century) may be necessary to reduce dioxin concentrations by half [4]-[5].

Biodegradation of dioxins and furans

Laboratory studies of biodegradation are intensifying; for the moment they concern mainly the mono-, di- and tri-chlorinated PCDD/PCDFs, more easily biodegradable but not toxic, and their non-chlorinated equivalents. The principal microorganisms involved are fungi and aerobic (selective deoxygenation) and anaerobic (dechlorination or dehalogenation) bacteria. Some studies report encouraging results for the tetra-octachlorinated molecules.

Currently, almost no data help to identify bacterial strains or biological functions that might degrade dioxins into nontoxic molecules. Moreover, the yield and complexity of the factors controlling biodegradation do not allow us to foresee the development of *in situ* biological treatment processes in the reasonably near future. This essential topic nonetheless requires research.

Current needs

There may be natural phenomena that attenuate these pollutants *in situ*, which could be used in the management of contaminated sites. Current data are insufficient, and research in this direction is imperative to remediate former incineration sites.

More generally, the sites polluted by old incinerators (or polluting incinerators still in operation) should be identified and mapped and this information made available to all, beginning with public authorities and the owners, users, and neighbors of the sites.

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[9] ADEME has conducted several studies, especially around the Bourgoin incinerator.

[10] According to a BRGM study now underway (forthcoming).

The relevant research bodies (BRGM, INERIS, INRA, and INSERM) should initiate a program to improve our knowledge of the processes of transfer (especially towards groundwater), permanent fixation, and remediation.

Environmental monitoring around MSWIs is imperative. The most relevant surveillance would measure concentrations of persistent pollutants at emission, in soils, on plants, in animals or animal products, and possibly, the body burden of populations living around incinerators (with rigorous methods). Measurement of soils and vegetation should not be limited to downwind areas, which are not always the most highly polluted.

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TO LEARN MORE

Fontan J. Les pollutions de l'air "les connaître pour les combattre "Edit. Vuibert Sciences ; 2003. (Pour avoir plus d'information sur la dispersion des polluants en fonction des caractéristiques de l'atmosphère ainsi que sur les propriétés et caractéristiques des particules).

Chapter 4

EXPOSURE ESTIMATES

In most scientific assessments conducted either nationally or internationally, dietary exposure to pollutants from MSWIs is estimated to comprise 50-90% of total exposure (all sources) for heavy metals (lead and cadmium), for dioxins, and for PCBs. In the current state of knowledge, it is not possible to rebut or confirm these figures precisely but in any case the dietary pathway is a major vector of exposure to these contaminants.

A look at the global assessments of pollution emissions indicates that incinerators previously played a leading role in the body burden of dioxin but not of other pollutants. Moreover, a risk assessment of one site showed that dioxin was by far the major source of risk and that no other pollutants required study. Consequently, we have chosen to focus this section on dioxins.

1. Background Levels in Food in France

By definition, the result of dietary exposure to a chemical substance is obtained by combining, in more or less sophisticated ways, food contamination data (expressed in µg or mg per kg food) and data on human consumption of these foods (expressed in g per kg body weight and per day). Exposure may be quite elevated in two particular situations: When "normally"[11] contaminated food is consumed in especially large quantities and when heavily contaminated food is eaten in "normal"[12] quantities. The improbable case of heavy consumption of highly contaminated food will therefore not be examined.

As part of this CPP opinion, we focus on exposure of those living near incinerators and on consumption of food raised or produced near the incinerator, which may therefore be contaminated. Such food may cause high exposure of the populations living near incinerators if they grow their own food or shop in local markets that purchase locally. This point will be examined below in this text.

In the opposite case, that is, if these food products are consumed through (or transformed for subsequent) mass distribution, they become part of the general population exposure to background dioxin levels in food. The contribution of incinerators to this "background level" is not calculated here.

Figure 1 represents the distribution of dioxin-contaminated food from animals. The contamination of food products grown near MSWIs should correspond to the elevated percentiles in figure 1. Contamination at the 99th percentile (that is, the contamination level of the most contaminated 1% of the samples) is 3 to 4 times higher than the mean contamination level.

Useful complementary information comes from a detailed descriptive analysis of a national "food intake" survey: Dubeaux [1] found that 9% of households reported keeping chickens and 6% rabbits and that production from them accounted for 50% of the rabbit consumed, 17% of the eggs, and 16% of the poultry.

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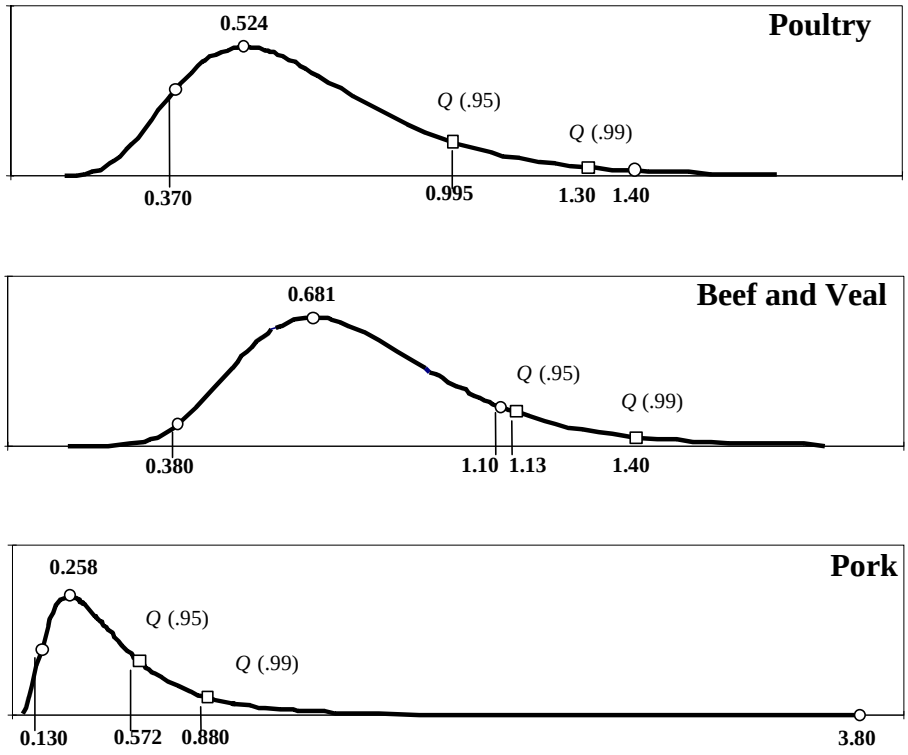
[11]In this case, the term "normally" means contaminated at a median level compared with the samples from the entire country or region.

[12]In this cases, the term "normal" means consumption at a median level compared with the distribution for the consumption measured throughout France or throughout the region.

References for defining background levels are therefore available. European exposure data, owed to scientific cooperation, show that a considerable portion of the European population is exposed beyond the threshold of 2 pg/kg body weight/day (tolerable daily dose according to the European Commission, that is, 14 pg/kg body weight/week). The safety factors established for particular situations have therefore been eroded by the considerable background level. Regulatory measures must be based on limiting the sources of dioxins in the environment and excluding the most contaminated food from the food chain.



Picogram Toxic Equivalent / gram lipid

(Frequency / Q (0.99): 99th percentile)

Figure 1: Distribution of dioxin contamination in food from animal sources[13]

[13]Source: European Commission. Opinion of the SCF on the Risk Assessment of Dioxins and Dioxin-like PCBs in Food. SCF/CS/CNTM/DIOXIN/8 Final/23 Nov. 2000, 141 p.

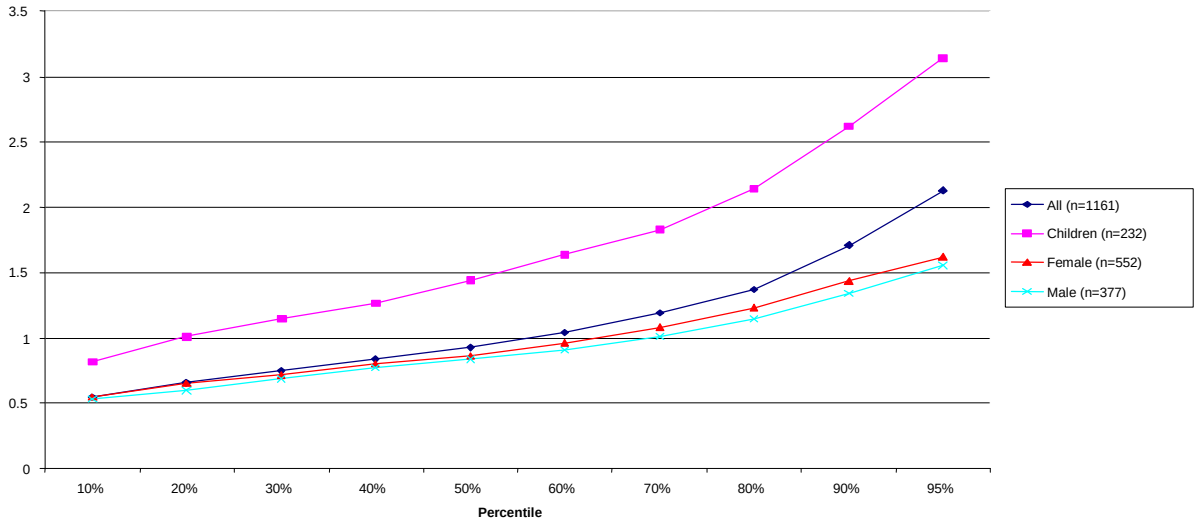


Figure 2: Distribution of dioxin exposure in the French population[14]

(Exposure in Picogram Toxic Equivalent / kg body weight / day)

2. Dietary Exposure and Other Exposure Pathways in Neighborhoods around Incinerators.

Dioxin exposure is due essentially to food. Numerous studies confirm that the proportion attributable to inhalation is negligible in nationwide analyses. This assertion is accurate when no incinerator is nearby.

On the other hand, the contributions of different exposure pathways are more variable for populations living near incinerators. A parametric analysis was thus conducted to shed light on this question. The results illuminate the issues but are not generically applicable; as this analysis shows, the reality of the local situation determines the exposure structure.

INERIS performed these calculations (Cf. note appendix and related bibliography). Exposure from inhalation, in an atmosphere considered highly loaded (1 picogram per m^3, value chosen from the upper limit of the values reported by InVS and SFSP, compared, for example, with 0.07 at Angers) represents an additional 15% (approximately) added to the exposure associated with ingestion of a mean French diet (general background concentration estimated by AFSSA[15] in 2000). We can draw two conclusions from this:

Even among those living near MSWIs, inhalation contributes little to total exposure; the predominant contribution comes from food. This proportion is overwhelming for families that grow much of their own food. It remains dominant even when they eat no home-grown food, because of the background levels in food. The choices of a higher value for airborne exposure strengthens this affirmation.

The result is different if we consider simply the exposure added by the incinerator. For an urban consumer eating no local food, exposure by inhalation accounts for one third

[14] Source: European Commission. Opinion of the SCF on the Risk Assesment of Dioxins and Dioxin-like PCBs in Food. SCF/CS/CNTM/DIOXIN/8 Final/23 Nov. 2000, 141 p.

[15] AFSSA. Dioxines: Données de contamination et d'exposition de la population française, 2000.

of the additional exposure. This proportion is probably higher because we assumed soil ingestion and cutaneous absorption here at fairly overestimated levels. On the other hand, for local residents who eat local products, the proportion of inhalation increases within the added exposure. These ratios do not depend on the level of additional exposure.

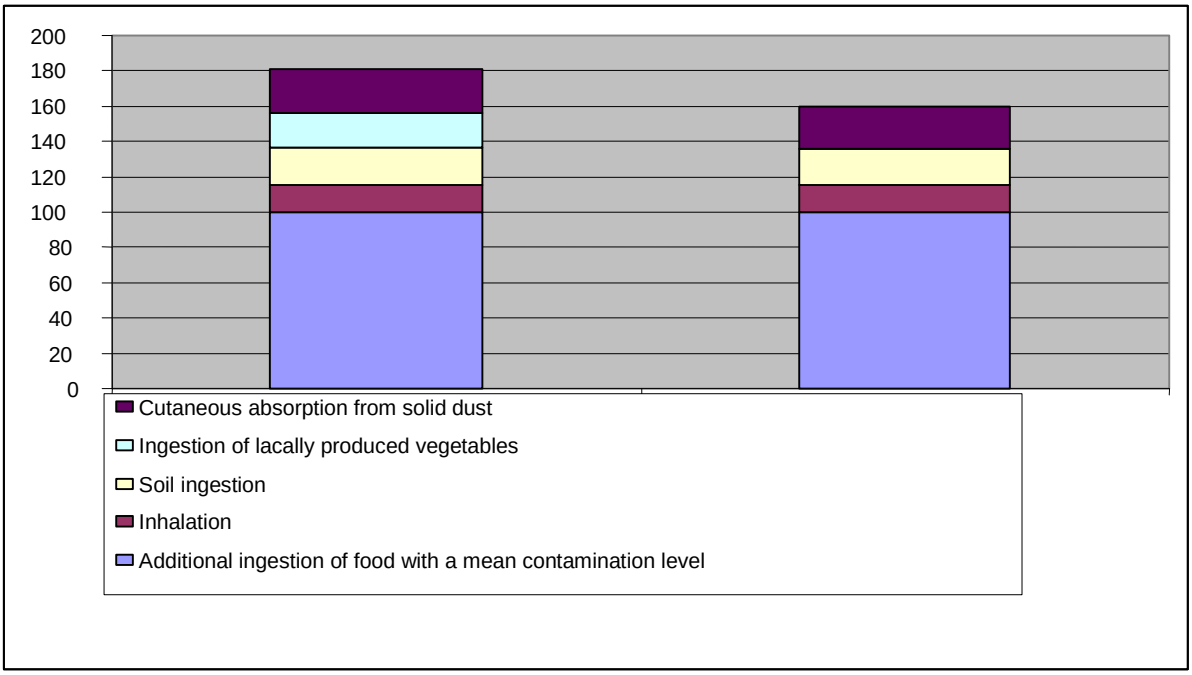


***Figure 3: Maximum exposure of local residents compared with exposure tobackground food contamination (base 100), with (left) and without (right) a vegetable garden*.**

Additional exposure increases substantially for people with vegetable gardens. It clearly exceeds exposure to the background level in food for those raising and eating rabbits and poultry and can be as much as 50 times greater.

In conclusion, exposure to food background levels is dominant even around incinerator sites, except for those who grow much of their own food.

The predominance of the food pathway has an important consequence for the risk analysis; lifestyle is more important for exposure than distance.

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Chapter 5

DO PEOPLE LIVING NEAR MUNICIPAL SOLID WASTE INCINERATORS HAVE A HIGHER RISK OF DEVELOPING CANCER?

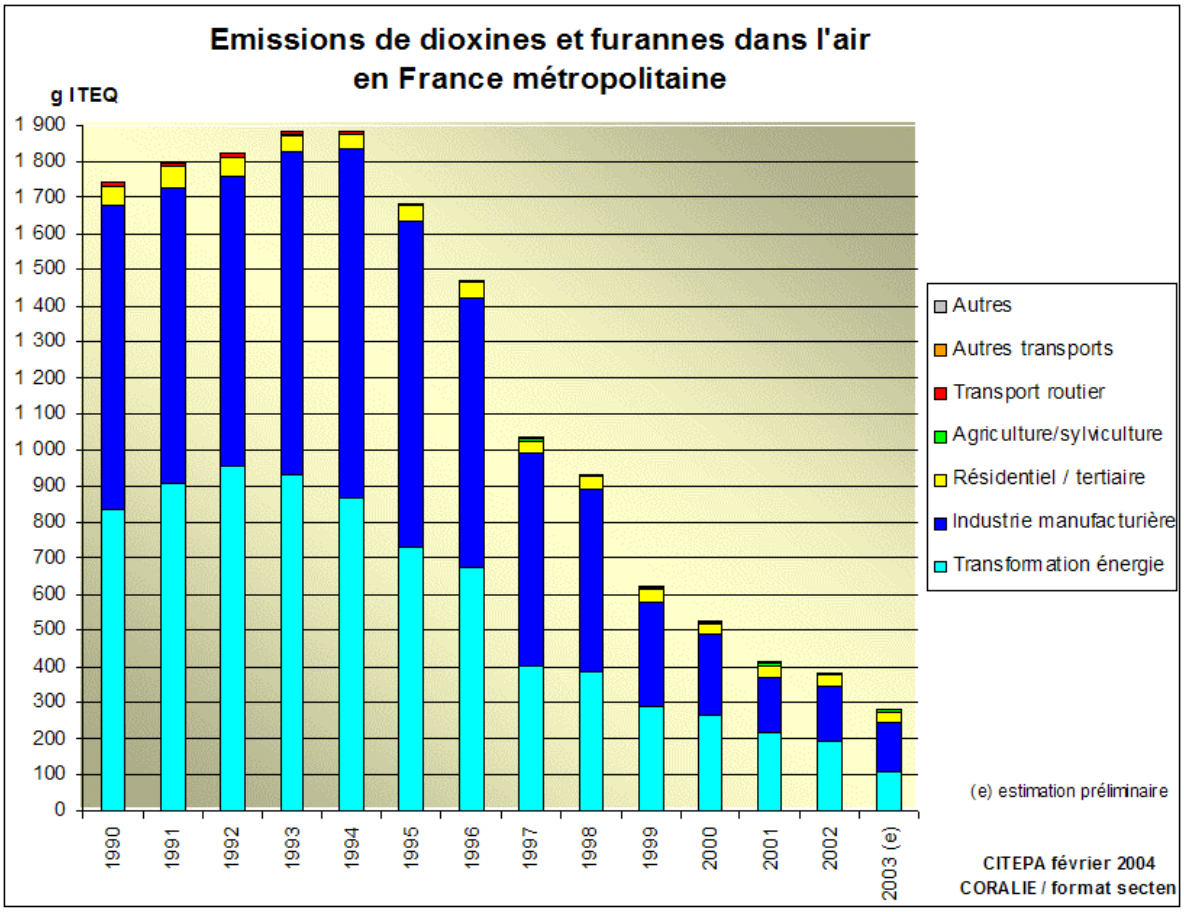
In recent years, populations living near French MSWIs have raised questions about the risks of cancer associated with the emissions, but few epidemiologic studies have attempted to verify the risks in these precise exposure conditions. An epidemiologic study in Besançon recently published in an international journal observed a significant excess of non-Hodgkin lymphoma in the population living near the incinerator. Do these findings show that those living near MSWIs have an increased risk of cancer? What do we know about the risks of cancer associated with different types of dioxin exposure in human populations? How important is this problem in France?

1. Population exposed to MSWI emissions in France

The large number of MSWIs in France implies that the size of the population now or formerly living near them is relatively substantial: it has been estimated at 2 million people [1]. To clarify the context, two preliminary remarks must be made:

- The possible health effects of MSWI emissions may correspond to exposure that took place long ago, at least 10 years for diseases with long latency periods, such as cancer.
- The relative importance of diffuse dioxin sources, domestic for example, remains little known despite ongoing efforts to characterize them (figure 4).

Figure 4: Emissions of dioxins and furans in the air in metropolitan France



2. Scientific Data about the Potential Risks of MSWI Emissions

The risks of cancer and of reproductive effects of exposure to MSWI emissions have been the object of epidemiologic studies in several countries. A group of French experts reviewed these studies in 2002 [3]. They found that the several reports of increased risk of disease (cancer or other) involved moderate increases that could not be attributed with certainty to incinerator emissions.

This conclusion is consistent with the scientific data about the carcinogenic effects of dioxins and furans (PCDD/PCDF), especially the observations of cohorts of chemical industry workers highly exposed (100-1000 times more so than the general population) to these products in the mid-20th century. Despite their intense exposure, the excess risk of death from cancer (all sites) does not exceed 40% in these populations. Under these circumstances, one would not expect to observe an excess risk in populations with much lower exposure levels [1]. Nonetheless, a recent meta-analysis [4] of three cohorts of subjects with occupational exposure to dioxins analyzed the relation between dioxin doses and cancer and concluded that dioxin exposure at least three times the background levels in the general population may be carcinogenic. Two particular types of rare cancers are associated, albeit inconsistently, with exposure to high doses of PCDD/PCDF: soft-tissue sarcoma and non-Hodgkin lymphoma [5].

3. Study in France by Floret et al.

A team of French epidemiologists recently published in a prestigious international journal the results of its epidemiologic survey about the risk of non-Hodgkin lymphoma in a population living near the MSWI in Besançon (Floret et al. 2003)[6]. This study followed a descriptive study by the same team that indicated an excess of cases of non-Hodgkin lymphoma and soft-tissue sarcoma in this area [7]. According to the authors, their results support the hypothesis that environmental dioxins increase the risk of non-Hodgkin lymphoma in populations living near MSWIs. In view of the context and the possible public health issues, this article merits careful attention.

The study by Floret et al. is a case-control study. Its protocol is original, combining an individual approach (the cases were individuals identified through the Doubs cancer registry, incidence data 1980-1995) with an ecological approach (the control subjects were the inhabitants, comparable in age and sex, of residential blocks, as defined by INSEE, and accordingly essentially virtual), with 10 controls for each case. The authors note that the 225 non-Hodgkin lymphoma cases counted over this 16-year period in their study area, the city of Besançon, correspond to a standardized incidence rate double that for France as a whole in 1995. The analysis covers the 222 cases for which it was possible to find an address.

Exposure for all pathways together was estimated from a gaussian model of the atmospheric dispersion of dioxin emissions from the MSWI stack. Modeling was performed with a widely used commercial software (APC3) and based on emission values measured in 1999. As the history of these emissions is not known (the MSWI began operations in 1971), airborne dioxin concentrations by zone were given on a relative basis. Four exposure zones were defined, from very low [reference, odds ratio (OR) set at 1] to the highest (at least 4 times higher than the reference zone). It was only in the zone of highest exposure that the authors found an elevated risk of non-Hodgkin lymphoma (OR = 2.3; 95% Confidence Interval: 1.4-3.8), based on 31 cases and 146 controls. The standardized incidence rate of 2 mentioned above indicates 111 excess non-Hodgkin

lymphoma cases; the study explains 15 of them ((2.3-1)/2.3=56.5% or 17 cases),[16] or approximately 16% of the total excess.

4. Comparison of the Results of the Study by Floret et al. with Those of Earlier Epidemiologic Studies

The epidemiologic studies mentioned above, which observed an inconsistent significant association between exposure (extremely elevated: 500-1000 times greater than exposure in the general population) to dioxins and non-Hodgkin lymphoma risk concluded for the most part that the risk doubled (at most, tripled) [5]. Floret et al. obtain the same result. If there is a causal link with MSWI activity, the people living in the maximum exposure zone should have been highly exposed.

This suggests two hypotheses: 1) extremely elevated dioxin emissions from the Besançon MSWI, or 2) massive consumption of food grown within the exposed zone (local and home-grown), since food is the principal pathway for dioxin exposure [5]. There are no data on which to base even a very rough estimate of past dioxin emissions from MSWIs in France, including Besançon. The literature (as cited by Floret et al.) shows no evident increase in the dioxin body burden of people living near MSWIs. A recent article [8], however, does report such an effect in a rural area near a highly polluting MSWI: the authors note an excess dioxin burden of 50% among the exposed subjects (longtime residents and consumers of local products) compared with controls. Body burden was highest in those who consumed large quantities of animal fat but remained very far from the burden observed in chemical industry worker cohorts [5] or even those observed at Seveso [9]. Neither of the two hypotheses mentioned above appears valid.

5. Comparison of the Results of the Study by Floret et al. with Those of a Risk Calculation

To assess the risks of non-Hodgkin lymphoma associated with emissions from the Besançon incinerator, the CPP conducted a risk calculation. It was based on the study by Nerrière and Zmirou [10] for the Bourgoin-Jallieu incinerator, which began operations in 1996 and whose levels of dioxin emissions are similar to those of the Besançon incinerator (see appendix 3 for details of the calculation). Our procedure adapted the calculation to estimate the number of non-Hodgkin lymphoma cases that might be expected during the period considered in the case-control study and compared the two estimates. Subject to the validity of the underlying hypotheses, the results show that the number of excess non-Hodgkin lymphoma cases calculated and attributed to the incinerator emissions is lower by 4 orders of magnitude than the number estimated in the case-control study. This result assumes, as Floret et al. suggest, that the inhalation is the sole exposure route for incinerator emissions. Consideration of the ingestion of contaminated food (according to the data collected for Bourgoin-Jallieu) led to the calculation of 1 excess non-Hodgkin lymphoma case, substantially lower than the 17 reported in the case-control study. The hypotheses for the calculation concerning ingestion are probably conservative, since the city of Besançon is part of a dense urban area where the proportion of home-grown food is probably low. The results of the epidemiologic observation thus differ from those of the risk calculations, which were based, it is true, on several hypotheses, especially concerning exposure levels.

[16] Attributable risk AR = (RR-1)/RR: relative risk (RR) is considered here equivalent to the central value of the estimated OR.

6. Possible Explanations of the Results of the Study by Floret et al.

The incidence of non-Hodgkin lymphoma is growing throughout the world (60% increase since the beginning of the 1970s in the United States, where incineration of household wastes is relatively uncommon) and is apparently not attributable only to better diagnosis [11]. Many causes are suggested; a role for some viruses (Epstein-Barr, HTLV I, HHV8, hepatitis C) is strongly suspected, and the influence of HIV [11] is nearly certain. Under these circumstances and, more specifically, for the cancer risk associated with incineration, the study by Floret et al., despite its overall quality, does not provide a definitive response to the question raised in the title of this chapter. One reason may be that its protocol, mixing individual and ecological approaches, increases the possibility and effect of confounding factors.

This publication presents the problem of the divergences, sometimes very large, between risk assessment and epidemiology. These have been observed as well in the domain of ionizing radiation [12] [13]. The number of excess cancers observed in epidemiology and attributed to environmental pollution at low or very low doses is sometimes much higher than the results of calculations from risk assessments based on exposure data and extrapolations from high to low doses, based on earlier epidemiologic knowledge. Several factors may explain these differences. Limitations of epidemiology include selection bias and observation bias (the second is more probable for reported data, for example in case-control studies, in which case subjects often remember past exposure better than control subjects), failure to consider confounding factors (which may not even be known), and erroneous exposure modeling. Risk assessments, on the other hand, may fail to take into account the many pollutants besides dioxins emitted by MSWIs, make errors in assessing the shape of the dose-effect relation at low doses (a linear relation may underestimate effects), or lack sufficient data about environmental emissions. The reasons for these discrepancies should be analyzed and the limitations of the application of epidemiology and risk assessment in these conditions should be described in more detail.

Overall, while the observation by Floret et al. shows an excess of non-Hodgkin lymphoma cases in the study zone and study period, the overall evidence reviewed does not justify the conclusion that the dioxins emitted by the Besançon MSWI are responsible for this excess; nor do they justify ruling out this possibility. A comprehensive explanation of this excess of cases remains difficult.

More generally, there is not yet any solid evidence to support a conclusion that people living near MSWIs have an increased risk of cancer, regardless of the type. But we must note the scarcity of historical data on incinerator emissions and exposure levels for the populations living near them. It is thus appropriate to remain prudent and not draw any definitive conclusion before the conclusion of complementary studies that should permit, insofar as possible, a better documentation of exposure levels and body burdens of individuals living near MSWIs.

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Chapter 6.
LEGAL ASPECTS OF OPERATING SOLID WASTE INCINERATORS

The waste qualified as "equivalent to household waste" is that whose collection and treatment does not require any particular technical treatment, so that it can be treated with household waste as mixed municipal waste. Municipalities, individually or in groups, are required to provide for the disposition of this waste in conditions that will avoid any harmful effects to human health or the environment (art. L 541-2, Environmental Code).

The disposition processes used are controlled landfilling, composting, and incineration. Since 1 July 2002, however, landfilling is authorized only for "final waste", that is, waste that cannot be further treated given current technical and economic limitations..." (art. L541-1 Code envt.), therefore, after sorting, recycling, or incineration.

Substantial plant construction followed the increased demand for incineration. This development, however, revealed its risks, linked to the emission of various pollutants. This chapter succinctly presents the legal framework intended to control them.

1. Law Applicable to Incinerators

Historically, the first technical directives about incineration of household waste date back to 16 June 1972. Two subsequent European directives, dated 8 and 21 June, 1989, relative to new and existing systems, respectively, were transcribed into French law by ministerial decree dated 25 January 1991.

In the future, the law applicable to incinerators in the European Union will be derived from the *directive of the European Parliament and of the Council, dated 4 December 2000, on waste incineration* (2000/76/CE). This text, which reduces the limit values for emission of various pollutants into the atmosphere (Appendix V) and imposes some limit values on discharges of waste water from cleaning exhaust gases (Appendix IV) enters into full effect on 28 December 2005, when it becomes applicable to existing systems (it was applied to new systems on 28 December 2002) and when the previous directives will be abrogated. A decree dated 20 September 2002 (J.O. 1 December, 2002) transposed the new directive into French law.

The limit values for emissions are stated as mass per unit of volume (mg/m^3, for example). There is no value for the total quantity emitted per unit of time (taking the flow rate into account), which is what determines the environmental concentration around the incinerator.

As indicated in chapter 1, the term *dust* is incorrectly used instead of *particles*. In general, in definitions of aerosols, dust designates those particles whose source is either a mechanical phenomenon or erosion.[17]

The decree dated 20 September 2002 regulates plants that incinerate and co-incinerate non-hazardous waste and those that incinerate medical waste (infectious risks). It covers waste that does not present serious risks—including household waste, ordinary industrial waste, and non-hazardous sludge, as they are treated by in-house or collective facilities providing incineration, co-incineration,[18] or vitrification.

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[17] See Fontan J. Les Pollutions de l'air, Vuibert 2003, chap 6, p37-38.

[18] According to section 2 of the decree:

The directive and the decree exclude some plants: on the one hand, those treating certain types of waste exclusively (such as vegetable waste from agriculture, forestry, or food processing, fibrous waste from virgin pulp products, papermaking pulp, wood or cork waste, radioactive waste, and animal carcasses), and on the other hand, some low-capacity experimental plants intended to improve the incineration process.[19] The decree dated 20 September 2002 includes two sections. First, it organizes the design and general facilities of the plants and defines the waste that can be treated there (which it bizarrely refers to as *incinerated* although it is *to be incinerated*, see § II) and the technical operating conditions. Second, it lists a series of provisions aimed at preserving the environment. Beyond the measures, modest, but very worthy of attention, concerning noise and vibrations (art.11 arr.), prevention of odors (art.12 arr.), and site cleanliness (art.13 arr.), three sections are devoted to prevention of risks, air pollution, and water pollution.[20]

2. Principal Legal Difficulties Created by the Implementation of Regulations concerning Incinerators

In 1997, appraisal of compliance found "clearly unsatisfactory"[21] results. This led to a reduction in the number of plants with a capacity of 6 tons/h or more that were not in compliance with the regulations: from 24 in 1998 to 2 in 2001. Of the 190 incinerators with a smaller capacity, 100 units were closed down. At the end of 2002, all French incinerators met regulatory standards. This delay in bringing its MSWIs into compliance resulted in a finding against France by the Court of Justice of the European Communities on 18 June 2002.

Other issues that led to litigation in France concerned the administrative deadlines for compliance and the unfortunate error in drafting that overlooked the legal order of administrative law sources (Conseil d'Etat, 16 Nov. 1998, syndicat national des industries des déchets et de l'environnement: a circular cannot modify the mandatory provisions of a ministerial decree).

Other problems involved the definition of ashes and slag in the classification of regulated plants and, especially, the operating conditions for small incinerators. The inability of the latter to comply with regulatory requirements[22] and the discrepancy between the "paper" requirements and their actual application led the authorities to discourage small

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Incineration plant: any stationary or mobile technical unit or equipment dedicated to the thermal treatment of waste, with or without recovery of the combustion heat generated. This includes the incineration by oxidation of waste as well as other thermal treatment processes, such as pyrolysis, gasification or plasma treatment.

Co-incineration plant: any stationary or mobile plant whose main purpose is the generation of energy or production of material products and which uses wastes as a regular or additional fuel or in which waste is thermally treated for the purpose of disposal.

Collective plant is one that incinerates waste from several producers; an in-house plant is operated by a producer to incinerate its own waste.

[19] Existing systems, that is, those authorized before 28 December 2002, except as specifically stated, are subject to this regulation as of 28 December 2005 (art. 34 arrêté).

[20] The decree dated 20 September 2002 replaces the decrees dated 23 August 1989 and 25 January 1991, which are abrogated as of 28 December 2005.

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incinerators; instead, transfer centers have been set up to ship waste to larger incinerators.[23]

[23] Tribunal Administratif de Montpellier, 30 November 1989, Doublet Id. loc. n°39 c, p.1615.

Chapter 7.
INCINERATORS AND SOCIAL ACCEPTABILITY: PUBLIC PARTICIPATION

Despite the evident progress, management of household (and equivalent) waste presents cost problems, associated with the ever-increasing flow and the growing strictness of environmental standards. Local governments must decide upon the investment needed, taking into account the environmental goals imposed on them by law as well as budgetary constraints (and the taxpayers' pockets).

In this context, numerous intermunicipal waste disposal authorities have chosen incineration with recovery energy (waste to energy plants), a type of waste treatment controversial, as we have seen, because of its possible health and environmental effects. Several incinerator projects have faced long delays, and some have even been abandoned because of local or national opposition. The multiplication of conflicts raises questions about whether France will have sufficient capacity to manage its household waste in several years. The French Planning Office has pointed to the cost explosion in waste management and—especially—the risk that three quarters of French districts will lack the capacity to treat their waste within the next several years. Here we analyze these problems essentially in terms of social acceptability.

1. Increased Opposition to Incineration

Let us summarize some points that may have affected this question:

> *Only with the circular dated 28 April 1998 from the ministry of land use planning and the environment did the French orientation, which had clearly favored incineration, shift. In 1997, an assessment of district plans for waste disposal showed that roughly 65% of household waste was supposed to be incinerated. National goals called for recycling half of all municipal waste in 1998 and afterwards. Prefects were directed to relaunch the planning process based on these new orientations. In early 2004, however, some district plans still presented problems, while intermunicipal authorities wanted to construct incinerators not included in the district plans and sought to extend their field of action to reach a size that would economically justify incineration. Proposals for new incineration plants nonetheless face tough going. The question of dioxins and the minimal effort devoted to recycling are only some of the arguments brandished by opponents who often have the impression that the government is seeking to impose on them projects that they do not want.*
>
> *Denmark and the Netherlands followed very different policies, assigning priority to reuse, recycling, and prevention of the waste flow. Because of that, these countries today use incineration serenely. Public opinion in Denmark and the Netherlands is aware that the authorities did not have recourse to incineration until after major efforts promoted modes of management considered environmentally preferable.*
>
> *At the beginning of the 1990s, the Netherlands dealt with and resolved the question of dioxins. In France, the association between dioxins and waste incineration was never mentioned. In 1996, the authorities and the media gingerly began to consider the issue, but not until 1997 were dioxins mentioned, and then very indirectly, in a statute concerning incineration of household and equivalent*

waste. Pending the European directive finally adopted in 2000, there were thus no legal standards for dioxin emissions by existing MSWIs.

Then came the French *dioxin controversy*, the principal points of which we mention briefly here.

Beginning in 1996, the media rapidly began to denounce what it called the authorities' minimization of the dioxins emitted by MSWIs. Many incinerators were challenged across the country. Closings and lawsuits multiplied but local governments only rarely upgraded their facilities. The monthly magazine "Science et Vie" reported in May 1998 that a large food-processing company opposed an incinerator proposed in Douai.

After a long battle by local advocacy groups, on 25 October 2001 the prefect of Savoie suspended operation of the incinerator at Gilly-sur-Isère, which emitted 750 times more dioxins than the limit value prescribed by the European directive. The spectacular aspects of this case made its impact felt far beyond Savoie, and Gilly-sur-Isère became a symbol of the damage caused by incineration: 7000 head of cattle slaughtered, a high incidence rate of cancer, a prefect talking of a "health catastrophe". While the questions about food safety were rapidly and effectively resolved, the massive cattle slaughter seriously harmed the image of incineration, reviving still recent memories of foot-and-mouth and "mad cow" diseases. The unhappy population was left with the feeling that little nothing or nothing was done about the impact on the health of the people living nearby. Charges for endangerment of life were filed against the president of the intermunicipal waste authority, the prefect of Savoie, and the director of the company operating the plant.

Other legal proceedings began elsewhere in France. More incinerators closed down, but there again, municipalities moved two steps forward and one back, as in Le Havre, despite the substantial dioxin emissions.

In January 2003, the Ministry of the Environment and Sustainable Development was finally able to report that there were no longer any substandard incinerators operating in France. The authorities thus appear to consider that the problem of the social acceptability of incineration is in the process of being resolved. Nonetheless, any waste authority wishing to begin incineration today must undertake an extremely long and uncertain process.

2. Local Strategies for Managing Municipal Solid Waste

Even if they are developing segregated collection, many local governments find incineration is a necessity and consider opposition to be essentially a technical problem: local residents' opposition to projects is considered the equivalent of *NIMBY*[24] and must therefore be circumvented. While what is called a *NIMBY* attitude is generally expressed

[24] The NIMBY (acronym for *Not In My Back Yard*) syndrome characterizes the opposition of some local associations and populations to any proposal that may generate various hazards and which nonetheless may meet a collective need. It is necessary to specify what we mean here by associations (or NGOs). On the one hand, some groups have a considerable degree of expertise and essentially demand the right to participate in the analysis of the environmental and health questions. Others, however, are established precisely in reaction to a specific proposal and are much less open to debate. When the approach of the local policy-makers is based from the very beginning on cooperation and dialogue, such associations emerge only rarely and then generally have little credibility in the public's eyes. The possible emergence of *NIMBY* groups is thus largely blocked.

by the rise of strong opposition to the proposal, it cannot always be reduced to a handful of neighbors or to that particular attitude.

> *On 29 September 2002 at Carhaix (Finistère), 2000 protesters from all over Brittany expressed their worries about the forty-odd incinerators planned for the region. The mayor of Carhaix, while sponsoring an incinerator proposal, stated his own concern: "Our plant has received all the approvals possible from the government. But I share the worries of the associations: we do not know if the reassurance the specialists give us today will still be valid tomorrow. I am glad that this challenge leaves from our city, in the heart of Brittany, to say that the region expects better information and alternative solutions."*[25]

Local governments, many of which have not the slightest intention of renouncing incineration, seek to reduce the occasions available for opponents to criticize the projects. The adoption of a proactive approach to the emissions standards to be met by the proposed plants is sometimes considered sufficient. Several plants have voluntarily committed themselves to meeting the most draconian standards in Europe, those of the Netherlands.

2.1. Opening Up the Decision-Making Process

Technical excellence appears to be a necessary but not sufficient condition to legitimate an incinerator proposal and to guarantee its sponsors that they will not be sued or face criminal charges for serious violations impairing public health. Despite repeated assurances, new environmental problems are often "discovered" to be associated with some apparently proven techniques. A second method used by some municipalities involves developing a sustainable public confidence by including the population and its representatives in the definition of a specific proposal. At the same time, they establish a program to follow-up any possible pollutant depositions associated with the plant and take precise measurements of local environmental condition before incinerator operations begin. These sponsors may also display a willing to promote composting and recycling, with incineration a back-up technique that should not slow the development of recycling. But cooperation limited to a proposed plant does not always suffice to calm opponents.

> *At Douarnenez, in view of the population's hostile reaction, after the case of Gilly-sur-Isère, the president of the intermunicipal waste authority decided to open a debate not simply on the single question of the proposed incinerator, but on the entire set of tools available and appropriate for waste management in the area. Diverse technical options were presented in detail, working groups were set up, and site inspections organized. Incineration was not abandoned, but a mixed solution was planned: sorting, accompanied either by composting or methanation for the fermentable waste and either landfilling or incineration for the residual waste.*
>
> *The Châtelets waste authority (Côte-d'Armor) organized a public debate to clarify the positions of the various participants, promote real dialogue in an constructive climate, and inform the various stakeholders of the nature of the issues. A number of persons questioned afterwards expressed a desire for other local questions to be treated in the same way. While the conclusions of the citizen panel are not binding on the authority, it would nonetheless appear difficult not to take it into account once a participatory approach has been adopted.*

[25] Aujourd'hui en France, " Les incinérateurs dans le collimateur ", 30 September 2002.

2.2. Two Possible Types of Dialogue

Two types of dialogue may be adopted. The first is essentially focused on a proposal, while the second involves the public in a detailed analysis of the overall issues. Which procedure is preferable depends on the local policy-makers' objectives. If they want above all to build an incinerator, the first type is probably better. Initiating an intensive debate on the future of waste management may entail a considerable risk that incineration will be ruled out. In this case, the partisans of incineration are unlikely to find broad public debate to their advantage. In the second type of approach, the local policy-makers do not start by considering incineration the only choice[26] but want to begin an analysis with the public about the solution best suited to the particular situation.

Many municipalities choose incineration today because it is the best known technical solution. Supported by commercial interests with a process for sale, it often appears easier to set up than segregated collection of green waste and construction of facilities for composting or methanation. Local governments are then tempted to choose incineration, because they lack the expertise to understand all of the available techniques. In this sense, the participation of the public and of associations (often ready to share their knowledge of the issues) and advocacy groups can be a means of widening the field of vision of the policy-makers about the options to study.

In the second place, presenting a proposal for an incinerator to the population assumes that the local government already has a waste management plan that includes and explains the incinerator.[27] In many cases, because the plan is not clearly presented to the public, local participants, including the associations, cannot have a global view of the question. As they admit, these associations then find themselves almost "condemned" to contest the proposal, because of their serious doubts about its usefulness, doubts due to their lack of knowledge of the policy-makers' intentions.

In ratifying the Aarhus Convention, France committed itself to promoting public information and participation—at the broadest levels possible and at as early a stage as possible—in decision-making about environmental issues. This Convention authorizes citizens to challenge in court decisions made without respecting these rights. While it seems difficult to imagine that the Convention will be strictly applied from one day until the next, it also appears wise for local authorities not to wait for lawsuits to modify their behavior. The Aarhus Convention is indubitably an additional legal weapon for stakeholders opposed to projects that government seeks to impose without constructive debate. It would be regrettable indeed if the deficiency in waste treatment capacity continues because of the multiplication of this legal impediment.

3. Conclusion

The logic of opposing public information and especially public participation as early as possible in the decision-making process for fear of inspiring opposition and NIMBY attitudes confuses causes and consequences. Opposition to proposals and systematic NIMBY attitudes are often the consequences of a lack of cooperation and transparency. A clash between private interests then replaces the necessary multipartite analysis of the collective interest. On the other hand, as proven by the attitude of numerous associations who have been offered the opportunity to participate in the process, public participation in

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[26] Even if it seems difficult to avoid for large urban areas.

[27] Because otherwise, it is a a confession that they want to build an incinerator at any cost for reasons that can only be perceived from the outside as "obscure".

the debate about collective choices frequently results in defusing temptations to defend private interests.

TO LEARN MORE ...

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APPENDICES

Appendix 1

Sources of Toxic Components in Household Waste

(1993 data; Source: ADEME)

CADMIUM

- · putrescible waste 12%
- · paper- cardboard:8%
- · plastics 37%
- · leather and rubber 13%

MERCURY:

- · putrescible waste 7%
- · paper cardboard 2%
- · plastics 5%
- · hazardous household waste 82%

LEAD:

- · lead metal and glass additives, mainly

COPPER:

- · metallic waste, mainly (copper pipes, soldering on tin cans...)

ZINC:

- · soldering of hazardous wastes

ARSENIC:

- · found widely in glass

CHLORINE:

- · 50-75% comes from plastics (PVC). Today, PVC has been widely replaced and plastics no longer contribute more than 50% of the chlorine content.
- · 8%, from putrescibles
- · 7%, from paper and cardboard
- · The largest proportion of chlorine is in the form of hydrochloric acid.

SULFUR:

- · 17%, from putrescible waste
- · 20%, from paper and cardboard
- · 9%, from plastic
- · the rest, from unclassified fuels (shellfish, etc)

FLUORIDE:

- · 50%, from paper and cardboard
- · 10% approximately, from plastics

Appendix 2

Cadmium/Dioxin Ratio in Emissions

(Source : CITEPA , 2001: Centre Interprofessionnel Technique d'Etudes de la Pollution Atmosphérique)

Emissions standards call for a ratio between cadmium and dioxins (that is, between 2 very toxic and carcinogenic compounds) of 500 000. For comparative purposes, the ratio of these concentrations in urban air is on the order of 50 000, with cadmium concentration on the order of 5 ng/m^3, a value that already corresponds to an excess risk of 1 case of lung cancer per 100 000 persons. The table below shows that incinerator emissions of dioxins compared with those of cadmium are approximately 4 times greater than for all sources of atmospheric emissions of these compounds. In relative terms, therefore, incinerators emit more dioxins than cadmium. That means that incinerators are the greatest source of dioxin emissions, but account for only a limited fraction (1/6) of cadmium emissions.

	Total	**Incinerators**
Dioxins	468 g	304 g
Cadmium	11.1 tons	1.8 tons
Cadmium/dioxin ratio	4000	6000

Appendix 3

Dioxins

The principal pathway for dioxin contamination in humans is food. Examination of the properties of dioxins explains this observation and their persistence.

Two families of molecules belong to this category:

- polychloro-dibenzo-para-dioxins (PCDD), of which 75 individual species are known
- polychloro-dibenzo-furans (PCDF), of which there are 135.

All possess some degree of toxicity, sometimes low. The reference for the concept of toxic equivalence (TEQ) is one of the most dangerous: 2,3,7,8-tetrachlorobenzo-dioxin (2,3,7,8-TCDD), which caused the pollution of Seveso. Assigned a coefficient 1, it dominates nearly all the other species.

This molecule serves as a model for a summary of their principal properties and consequences:

- It is a solid with a melting point of 305-306℃ and stable (like the other dioxins) up to 800℃. Only plasma torches can reach the tempera ture of 1300 ℃ necessary for its total destruction.
- It is only very slightly soluble in water, with a solubility of 4.93 x 10-5 mg/l at 25℃. Its elevated hydrophobicity (logP=6.80) allows it to cross cell membranes, concentrate in lipids, and accumulate in fat tissues.

We can thus understand that this compound is not only found along the entire length of the food chain, but also that the risk of exposure to it by water ingestion is very low.

- Its very low vapor pressure—2.0 x 10-7 Pa at 25℃—m akes it highly stable, so that exposure by direct inhalation is minimal.
- On the other hand, dioxins adsorb strongly onto particles in the air, soil, and water. Inhalation of these particles is thus one component of the risk, but a very limited one.

Adsorption nonetheless has a negative effect because it protects dioxins from the degradation process: this phenomenon aggravates soil pollution, for example.

- Their chemical stability is high, and only strong reagents (such as potash) in appropriate solvents induce reactions.
- Dioxins consist of aromatic nuclei that absorb ultraviolet wavelengths: their interesting and useful photochemical reactions are nonetheless very limited, because of the position of the absorption domain (relative to the solar spectrum), their photochemical stability, and molecular rearrangements that are likely to lead to compounds more toxic than those initially irradiated.
- Finally, even if several microorganisms and fungi are found that might degrade them biologically, these compounds have substantial biochemical stability.

In summary, the resistance of dioxins to all sorts of physical, chemical, and biological agents explains their persistence in the environment. The most important characteristic remains their solubility in lipids, which explains why they mainly concentrate in trophic chains and why exposure is due mainly to food of animal origin (90-95%).

TO LEARN MORE

Appendix 4

Population Exposure to Dioxins in Incinerator Emissions: Contribution of Different Pathways

As an illustration, we estimate the exposure of an adult exposed to dioxin emissions according to three different scenarios.

Scenarios studied

CASE 1: scenario: traditional rural lifestyle

The exposure routes considered are:

- inhalation of particulate and gaseous pollutants
- soil ingestion
- ingestion of local plant (root, leafy, and fruit vegetables, as well as fruits) and animal (meat, egg, milk, and dairy) products
- additional ingestion of food with mean background contamination levels
- cutaneous absorption from soil particles.

CASE 2: generic scenario with vegetable garden

The exposure routes considered are:

- inhalation of particulate and gaseous pollutants
- soil ingestion
- ingestion of local plant (root, leafy, and fruit vegetables, as well as fruit) products
- additional ingestion of food with mean background contamination levels
- cutaneous absorption from soil particles.

CASE 3: generic scenario urban consumer

The exposure routes considered are:

- inhalation of particulate and gaseous pollutants
- soil ingestion
- additional ingestion of food with the mean background contamination levels
- cutaneous absorption from soil particles.

Cases 1 and 2 correspond to the exposure scenarios classically studied in risk assessments for environmental impact and soil pollution studies. These scenarios make it possible to show the role of home-grown products in exposure to dioxin emissions from industrial plants. The additional consumption of food with the mean background dioxin concentrations found in food in France was added to the pathway of exposure associated with local emissions.

Case 3 aims to compare non-dietary exposure associated with a local emission source to the exposure of the general population through food.

Calculation Methods

Exposure is estimated from equations coded under EXCEL and presented in the study report drafted for the large combustion systems (GIC) working group at the Ministry of Ecology and Stainable Development, entitled *Assessment of the Health Impact of Atmospheric Emissions of Coal-burning Units of Large Combustion Systems - Part 2: indirect exposure* (INERIS -DRC[1]). This approach uses overestimation and does not consider any natural attenuation phenomena. The routes of inhalation, cutaneous absorption, and ingestion of food products contaminated at the mean background levels found in France were added to the calculation code used for the GIC working group.

For scenarios 1 and 2, percentages of home-grown food were calculated from INSEE survey data [2]. For scenario 1, data about the farming population of rural municipalities were taken into account. Scenario 2 used data from the Paris metropolitan area.

Exposure associated with the background level of food contamination is estimated from the exposure level of the general population estimated by AFSSA [3]. The contribution of home-grown food in scenarios 1 and 2 was subtracted from the exposure level given by AFSSA, to avoid counting food exposure twice.

Respiratory volume is defined from the *Exposure Factor Handbook* (US-EPA, 1997) [4]. Cutaneous absorption was also estimated based on values proposed by the US-EPA (1992)[5] (soil quantity deposited on skin: 1 mg/cm^2, exposed body surface in adults: 5800 cm^2, sum of the areas of the head, hands, leg, and forearms). Soil skin contact for eight hours daily was considered; for the first approach, the cutaneous absorption rate, defined for 24 hours, was estimated proportionally for 8 hours. The absorption rate for ingestion is assumed to equal 1.

Values of the other exposure indicators, as well as the values used to define the soil indicators, are the default values from the *Large Combustion Systems* study.

The physicochemical indicators used to estimate these exposures are those for 2,3,7,8 TCDD, as defined in the report entitled *Physicochemical and Transfer Coefficients of Dioxins for Risk Assessment* (INERIS -DRC[6]). The rate of particulate and gaseous deposit is assumed to equal 1 cm/s.

Adult exposure was estimated for this exercise. Exposure and emission are assumed to be concomitant. A 30-year period is considered.

Concentrations in environmental and exposure media were calculated from the atmospheric concentrations of the pollutant assumed to be generated by the incinerator.

Few measurements appear to be available for dioxin concentrations in air near incinerators. According to the InVS report [7] *Incinerators and Health, Dioxin Exposures of the Population Living near MSWIs*, concentrations up to 2000 fg I-TEQ/m^3 have been measured near emission sources. Domingo [8] reports concentrations of 350 and 71 fg I-TEQ/m^3 measured at 500 meters from a MSWI and of 286 and 58 fg I-TEQ /m^3 at 1000 meters. References for concentrations modeled from incinerator flow rates include:

- the SFSP study [9], which reports a maximum atmospheric concentration of 1000 fg/m^3, obtained from an incinerator producing a substantial dioxin flow (38.5 ng/m^3 at emission),
- the study of the Angers incinerator [10], models for which produced a mean concentration for the study area of 70 fg/m^3.

For this exercise, a concentration of 1000 fg I-TEQ/m^3 will be applied to illustrate the maximum proportion that non-dietary routes can represent in the total exposure of an individual living near a local source of dioxin emissions.

Results

Table 1: Doses and exposure pathway for scenario 1

Mean exposure for an adult during the exposure period

Exposure pathways	Means lifetime exposure doses (g/kg/d)	Proportion of different pathways in total exposure
Inhalation	2,0.10	0,4
Soil ingestion	2,7	0,5
Ingestion of locally produced vegetables	5,0	0,9
Ingestion of locally produced meat	3,4	63,4
Ingestion of locally produced milk	7,3	13,7
Ingestion of locally produced eggs	1,0	18,8
Additional ingestion of food with a mean contamination level	9,4	1,8
Cutaneous absorption from soil dust	3,1	0,6
Total	5,3	

Ingestion of food accounts for 98.5% of total exposure.

Table 2: Doses and exposure pathway for scenario 2

Mean exposure for an adult during the exposure period

Exposure pathways	Means lifetime exposure doses (g/kg/d)	Proportion of different pathways in total exposure
Inhalation	2,0	8,6
Soil ingestion	2,7	11,7
Ingestion of locally produced vegetables	2,5	10,8
Additional ingestion of food with a mean contamination level	1,3	55,2
Cutaneous absorption from soil dust	3,1	13,6
Total	2,3	

Ingestion of food accounts for 66% of total exposure.

Table 3: Doses and exposure pathway for scenario 3 - Exposure of an adult

Exposure pathways	Mean lifetime exposure doses (g/kg/d)	Proportion of different pathways in total exposure (%)
Inhalation	2,0	9,5
Soil ingestion	2,7	12,9
Cutaneous absorption from soil dust	3,1	15,0
Additional ingestion of food with a mean contamination level (AFSSA estimate)	1,3	62,6
Total	2,1	

Ingestion of food accounts for 63% of total exposure.

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Appendix 5

Risk Calculation for Non-Hodgkin Lymphoma Associated with Incinerator Emissions in Besançon

OBJECTIVE compare the non-Hodgkin lymphoma risk potentially associated with incinerator emissions and observed in the study by Floret et al [1] in Besançon with the risk calculated from an estimate of published exposure levels and coefficients of excess cancer risk (number of excess cases of non-Hodgkin lymphoma).

PRINCIPLE: use the risk calculation performed by Nerrière and Zmirou (MATE Report 24/2001) [2] for the incinerator at Bourgoin-Jallieu and adapt it to calculate the risk for the incinerator at Besançon.

CHARACTERISTICS OF ZONES

	Besançon	Bourgoin-Jallieu
Zone considered	canton of Besançon	Zone modeled = square, 21 km on each side
Number of inhabitants	114 000[a]	104 225 (estimation)
Area (km^2)	65	441
Population density ($inhab/km^2$)	1754	236
Calculation zone	Most exposed zone, in which excess was observed[b]	Zone of previous model, divided into grids (square with 30 grids on each side)
Number of inhabitants in the calculation zone	13 412[c] (estimated)	104 225
Incinerators		
Date of operations started	1971	1996
Incineration capacity Emissions	2 furnaces at 2.1 tons/hour and 1 furnace at 3 tons/hour 16.3 ng I-TEQ/m^3	2 furnaces of 5 and 6 tons/hour 8.95 ng/Nm^3
Tool for modeling atmospheric diffusion and deposits	APC3[d] (Aria Technologies)	
Hypotheses of exposure pathways	Inhalation Ingestion ?[f]	Inhalation and ingestion Consumption of locally-produced food [e]

a. Mean population for 1982-1999

b. This area corresponds to 6 of the 51 "block groups" identified by Floret et al.[1] from the 705 INSEE blocks in Besançon. Blocks had a mean population of 161 inhabitants.

c. The total number of inhabitants in this zone was not specified by Floret et al. and was estimated as follows; n= 114 000 * 6/51=13 412.

d. Gaussian dispersion model, second generation, allowing 3-dimensional modeling of the transport and diffusion of dioxin emissions and their deposits on soil; see chapter 3 for the limitations of these models.

e. Data from INSEE's food intake survey (Bertrand 2003) [3] providing regional data about the proportion of households with vegetable gardens near the incinerator site (51.2%) and the proportion of the area used for these gardens.

f. In view of the high population density of the area around the incinerator considered by Floret et al.[1], the hypothesis of dioxin ingestion from consumption of local products appears improbable; in any case, taking this hypothesis into account would probably result in overestimating the risk.

CALCULATION STRUCTURE

The risk coefficients for cancer for Bourgoin-Jallieu are those calculated in Nerrière and Zmirou's study (MATE Report 24/2001)[2] of dioxin inhalation and ingestion.

These are coefficients of **individual lifetime excess risk for all cancers**. A 70-year period is conventionally used for lifetimes.

The area in which excess non-Hodgkin lymphoma cases were observed in the study by Floret et al. [1] is the most exposed: therefore we retain the maximum values of coefficients of excess individual risk calculated by Nerrière and Zmirou. The ratio between the minimum and maximum values of surface deposits in this study, however, is a factor of 100, while it is lower in the study by Floret et al [1]. Therefore using the maximum values from the study by Nerrière and Zmirou [2] probably **overestimates the risk**.

For dioxin ingestion, the coefficient of excess individual risk in the study by Nerrière and Zmirou [1] was 2.38 E -2 lifetime, for an exposure of 70 years. This means that of 100 persons exposed by ingestion to the dioxin levels calculated by Nerrière and Zmirou [2] in the zone considered, between 2 and 3 excess cancers will occur during their lifetime.

For dioxin inhalation, the coefficient of excess individual risk in the study by Nerrière and Zmirou [2] was 8.92 E -5 lifetime, for an exposure of 70 years (exposure to dioxins only; note: Nerrière and Zmirou [2] also considered cadmium, nickel, arsenic, and chromium in their evaluation; they were not considered here, but their low value means that they would modify the results very little).

To calculate the all-cancer lifetime risk **in a population**, the preceding coefficients of excess risk individual are multiplied by the number of inhabitants in the zone considered.

Changes from the risk coefficients in the study by Nerrière and Zmirou [2] to those used for the study by Floret et al. [1]

The following table presents the differences between the two approaches.

	Nerrière and Zmirou [2]	Floret et al. [1]
Incinerator emissions	8.95 ng/Nm^3 [A]	16.3 ng I-TEQ/m^3
Coefficient of excess individual risk	All cancers [B] Lifetime (70 years) [C]	Non-Hodgkin lymphoma only For 16 years
Duration of exposure	70 years [D]	Mean duration of residence in a place in France

A. The dioxin emissions for the Besançon incinerator are approximately twice those of Bourgoin-Jallieu (16.3/8.95): we therefore apply a corrective coefficient to those used by Nerrière and Zmirou [2], corresponding to the ratio 16.3/8.95.

B. To transform the **all-cancer** risk (Nerrière and Zmirou) [2] into a **risk of non-Hodgkin lymphoma**, we weight the coefficient of excess individual risk in Nerrière and Zmirou [2] by the weight of non-Hodgkin lymphoma in all cancers, that is, 3.72% (EUCAN 1999), assuming that all cancer sites contribute proportionally to the all-cancer risk associated with dioxin; this is probably not exactly the case, and it is possible that non-Hodgkin lymphoma contributes more than other cancers to the cancer risk associated with dioxin: this weighting method may therefore **underestimate the non-Hodgkin lymphoma risk**.

C. The study by Floret et al. [1] used an observation period of 16 years (unlike the 70 years considered by Nerrière and Zmirou[2]): we therefore apply a correction to the individual risk coefficient of Nerrière and Zmirou [2]. Taking into account a latency period of 10 years, that amounts to multiplying the coefficients of excess individual risk by 16/(70 -10).

D. Finally, it is necessary to take into account the average time of residence in a study area and not a 70-year duration of exposure; the average duration of residence in a single place, calculated from electricity company data (Nedellec 1998)[4] can be estimated at approximately 11.5 years in the general population and on average for France as a whole; it is therefore necessary to further weight the individual risk coefficients of Nerrière and Zmirou [2] by (11.5/70).

RESULTS

Ingestion pathway: we find, in this calculation intended to overestimate for every assumption, 1 case of excess non-Hodgkin lymphoma compared with the 17.5 excess cases estimated by Floret et al. [1].

Inhalation pathway: we find 0.0035 cases of excess non-Hodgkin lymphoma compared with the 17.5 excess cases estimated by Floret et al.[1], for a difference of 4 orders of magnitude.

DISCUSSION

The risk calculations above for the Floret study [1] follow those used by Nerrière and Zmirou [2] for the incinerator at Bourgoin-Jallieu. The environmental characteristics of the latter are most probably not the same as those of the Besançon incinerator. : for the latter, population density is greater and consumption of home-grown food less probable than in the hypotheses by Nerrière and Zmirou [2] for Bourgoin-Jallieu. The excess risk calculation for dioxin ingestion in the area most exposed to the Besançon incinerator based on the estimates made by Nerrière and Zmirou [2] for Bourgoin Jallieu are therefore probably strongly overestimated.

These results must be interpreted with prudence because of the assumptions and uncertainties inherent in this type of calculation:

- Hypotheses about the shape of the dose-effect relation between cancers and dioxin exposure, the relation used here being linear with no threshold;
- Hypotheses made in the atmospheric diffusion and deposit models (see section 3);
- Uncertainties about the origin of the food eaten in the canton of Besançon.

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Appendix 6

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