

Waste and human health: Evidence and needs

WHO Meeting Report

5–6 November 2015
Bonn, Germany



Abstract

Management of waste is a demanding and challenging undertaking in all European countries, with important implications for human health and well-being, environmental preservation, sustainability and economy. Comprehensive legal frameworks, mainly developed on the basis of environmental criteria, exist that regulate waste management. Compliance with these regulations has resulted in significant progress; however concerns remain as to the possible health impacts of waste circulation, management and disposal, especially in connection with informal practices and obsolete technologies. The available scientific evidence on the waste-related health effects is not conclusive, but suggests the possible occurrence of serious adverse effects, including mortality, cancer, reproductive health, and milder effects affecting well-being. This evidence, combined with the growing importance of sustainability considerations, should allow Member States of the WHO Regional Office for Europe to formulate health-friendly policy orientations.

Keywords

WASTE MANAGEMENT - methods
HAZARDOUS WASTE - adverse effects
ENVIRONMENTAL HEALTH
HEALTH
EUROPE

Address requests about publications of the WHO Regional Office for Europe to:

Publications
WHO Regional Office for Europe
UN City, Marmorvej 51
DK-2100 Copenhagen Ø, Denmark

Alternatively, complete an online request form for documentation, health information, or for permission to quote or translate, on the Regional Office web site (<http://www.euro.who.int/pubrequest>).

© World Health Organization 2016

All rights reserved. The Regional Office for Europe of the World Health Organization welcomes requests for permission to reproduce or translate its publications, in part or in full.

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement.

The mention of specific companies or of certain manufacturers' products does not imply that they are endorsed or recommended by the World Health Organization in preference to others of a similar nature that are not mentioned. Errors and omissions excepted, the names of proprietary products are distinguished by initial capital letters.

All reasonable precautions have been taken by the World Health Organization to verify the information contained in this publication. However, the published material is being distributed without warranty of any kind, either express or implied. The responsibility for the interpretation and use of the material lies with the reader. In no event shall the World Health Organization be liable for damages arising from its use. The views expressed by authors, editors, or expert groups do not necessarily represent the decisions or the stated policy of the World Health Organization.

CONTENTS

Acknowledgements	2
Abbreviations	3
Introduction.....	4
Waste management in Europe: the framework for the production and management	5
EU legislation on waste	5
The Basel Convention and waste movements	6
Separate collection	7
Green growth.....	8
Circular economy.....	8
The informal sector	9
Production of waste	9
Waste management	11
Health effects of waste management.....	14
Population exposed to pollution from waste management	14
Municipal solid waste – landfills.....	15
Exposure assessment.....	15
Health effects.....	15
Municipal solid waste – incinerators.....	16
Exposure assessment.....	16
Health effects.....	17
Towards a European assessment of the health impact of landfilling	18
Hazardous and toxic waste.....	19
Emerging priorities: E-waste	20
Discussion points.....	20
Knowledge gaps.....	21
References.....	23
Annex 1.....	28
Guidance documents and other support actions for implementation of EU waste legislation.....	28
Waste Framework Directive (WFD)	28
Mining Waste.....	28
WEEE/RoHS.....	28
ELV Directive	29
The Waste Shipment Regulation	29
BREFs on best available techniques.....	29
More information on EU waste policy and legislation	29
Annex 2: Meeting programme	30
Annex 3: List of participants.....	32

Acknowledgements

This report reflects the discussion and conclusions of the WHO meeting *Waste and human health: evidence and needs*, held in Bonn, Germany, on 5-6 November 2015. Programme and participants in the meeting are reported in the Annexes. WHO is most grateful to all participating experts who shared their knowledge, experiences and views.

The report was compiled by the meeting rapporteur Andrea Ranzi, Regional Environmental Protection Agency of Emilia-Romagna, Italy, on the basis of oral and written contributions from participants. Maria Dunbar, University of Copenhagen, provided invaluable support to the drafting and finalization.

The meeting was chaired by Pietro Comba, National Health Institute of Italy.

The meeting was financially supported by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, whose contribution is gratefully acknowledged.

Abbreviations

AC	attributable cases
AFexp	attributable fraction in exposed people
BAT	best available technique
DALYs	disability adjusted life years
DW	disability weight
EC	European Commission
EEA	European Environment Agency
EHP	European Environment and Health Process
EPR	extended producer responsibility
EU	European Union
EU-15	EU member countries until 30 April 2004
EU-27	EU member countries from 1 January 2007 until 30 June 2013
EU-28	EU member countries since 1 July 2013
HIA	health impact assessment
H2S	hydrogen sulphide
ICI	institutional, commercial and industrial
L	disease duration
MBT	mechanical biological treatment
NGO	nongovernmental organization
NIMBY	not in my backyard
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzo-p-dioxins
PCDF	polychlorinated dibenzofurans
PCT	polychlorinated terphenyl
PIC	prior informed consent
POP	persistent organic pollutant
PPP	polluter pays principle
RR	relative risk
SDG	Sustainable Development Goal
WEEE	waste electrical and electronic equipment

Introduction

Management of waste is a demanding and challenging undertaking in all European countries, with important implications for human health and well-being, environmental preservation, sustainability and economy. WHO and many other health agencies worldwide have addressed the health implications of waste in the past (WHO Regional Office for Europe, 2007).

Waste is part of the agenda of the European Environment and Health Process (EHP), initiated in the late 1980s by European countries to eliminate the most significant environmental threats to human health. Progress has been marked by a series of ministerial conferences held every five years and coordinated by WHO. The fifth and latest conference was held in Parma, Italy, in 2010. The 53 Member States of the WHO European Region set clear-cut targets to reduce the adverse health impact of environmental threats in the next decade. As the process is heading to its Sixth Ministerial Conference on Environment and Health in 2017, Member States have included waste among the topics to be addressed in the Conference.

In order to support the EHP and prepare for 2017, the WHO Regional Office for Europe decided to hold an expert consultation to review the evidence on the health effects of urban and hazardous waste and to explore practices, needs, knowledge gaps, and resources in Member States. The main areas of discussion were: current epidemiological evidence, relevant legal and normative frameworks, feasibility of policy options and their economic implications. The expert meeting was attended by 26 participants, from 10 countries and 5 International Organizations. This report presents the main findings of the exercise, which confirm that health impacts of waste disposal can be substantial. While modern technology for waste management can dramatically reduce noxious emissions and human exposure to hazardous agents, many cases persist where old generation facilities are in use, or worse where informal uncontrolled disposal such as casual dumping or open-air burning of waste occurs, typically affecting marginalized groups. It appears urgent to address the most acute occurrence of waste-related human exposure to toxic agents, and to accelerate the process of adoption of modern waste treatment technology.

Sustainability is also of growing prominence and there is increasing interest in further promoting circular economy, in line with the European Union (EU) waste hierarchy, which gives priority to reduced production and re-use or recycling of waste over incineration and landfilling. The latter, in particular, has been phased out in several countries due to its environmental implications.

On the basis of the available evidence on the health impacts of waste, further consultation will be held with Member States in 2016 in order to identify priorities, goals and policy action that can reduce detrimental health effects and their inequality, improve human well-being and promote long-term sustainability across Europe and beyond.

The following summarises the main outcomes of the meeting.

Waste management in Europe: the framework for the production and management

EU legislation on waste

The EU legislation and policy on waste addresses negative implications for environment and health. EU waste legislation has been developed and continuously modernized since the 1970s. The Directive 2008/98/EC on waste, the so-called Waste Framework Directive, (Council of the European Union and European Parliament, 2008) introduces the basic concepts and definitions relating to waste management, such as types of waste, recycling and recovery. It establishes when waste ceases to be waste and becomes a secondary raw material (so-called end-of-waste criteria), and distinguishes between waste and by-products. The Directive lays down some basic waste management principles: it requires that waste be managed without endangering human health and harming the environment, in particular without risk to water, air, soil, plants or animals, without causing a nuisance through noise or odours, and without adversely affecting the landscape or places of special interest. Waste legislation and policy of the EU Member States is based on the waste management hierarchy seen below in Figure 1, prioritized from top to bottom:

Figure 1. EU waste management hierarchy



The Directive provides for the polluter pays principle (PPP) and the extended producer responsibility (EPR, a strategy promoting the integration of environmental costs associated with goods throughout their life cycles into the market price of products). It also incorporates provisions on hazardous waste and waste oils (old directives on hazardous waste and waste oils were repealed with effect from 12 December 2010), and includes two recycling and recovery targets to be achieved by 2020:

- 50% preparing for re-use and recycling of certain waste materials from households and other origins similar to households; and
- 70% preparing for re-use, recycling and other recovery of construction and demolition waste.

The Directive requires that Member States develop and adopt waste management plans and waste prevention programmes.

Another piece of legislation which is of paramount importance is the Landfill Directive 1999/31/EC (Council of the European Union, 1999). This Directive aims at significantly reducing landfilling. Landfilling is the worst option from an environmental and resource efficiency perspective. Since biodegradable waste is of a particular concern, the current Directive has targets for diverting such wastes from landfills, which should be fully implemented by 2020. Where waste needs to be landfilled, it must be sent to landfills which comply with the requirements of the Landfill Directive. The objective is to prevent or reduce negative effects on the environment as much as possible, in particular on surface water, groundwater, soil, air, and on human health by introducing stringent technical requirements for landfills.

Standard procedures for the acceptance of waste in a landfill are prescribed to reduce risks, including that waste must be treated before being landfilled; hazardous waste must be placed in a hazardous waste landfill, and landfills for non-hazardous waste must be used for municipal waste and for other non-hazardous waste. Certain categories of waste may not be accepted in a landfill, i.e. liquid waste; flammable waste; explosive or oxidising waste; hospital and other infectious clinical waste; used tyres (with certain exceptions); and any other type of waste which does not meet the acceptance criteria (Annex II of the Landfill Directive). The Directive also sets up a system of operating permits for landfill sites.

The Basel Convention and waste movements

Another piece of legislation that is important in this context is the Waste Shipment Regulation (Regulation 1013/2006/EC) which implements the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, including the Basel Ban Amendment regulating transboundary movements for reuse, recycling or recovery operations (Council of the European Union and European Parliament, 2006). Under the Regulation, certain waste shipments are prohibited, including shipments of hazardous waste from the EU to developing countries. For other shipments, the regulation prescribes either a notification procedure (the “Prior Informed Consent (PIC) procedure”) or information requirements. Illegal waste shipments have been identified as a serious problem existing at a significant scale. Through inspections in recent years at sea-ports, on roads and in companies, it has been discovered that around 25% of shipments containing waste in the EU do not comply with the Waste Shipment Regulation. Numerous reports by nongovernmental organizations (NGOs), media and studies have shown that large amounts of waste originating in the EU are illegally exported to developing countries in Africa and Asia (EC, 2013). In order to improve Member States’ inspection systems, ensure proper controls and effectively prevent illegal shipments, the Waste Shipment Regulation was strengthened in May 2014 (Council of the European Union, 2014). Member States will have to establish risk-based inspection plans and provide new powers to national inspectors. These changes to the Regulation have to be applied by Member States in 2016/2017. The reinforced inspections should help to reduce illegal exports of waste.

The European Commission (EC) is currently preparing the ground for an electronic data exchange for waste shipment notifications and an implementing act on this topic is scheduled for 2016/2017. The goal is to replace the current system of paper documents on waste shipments with electronic exchange of relevant data. Today, some documents, such as notification and movement documents, create a very large administrative burden and paperwork between industry and the different authorities involved. The authorities in some Member States must handle more than 100 000 pages of waste shipment documents per year.

Besides saving on paperwork, an efficient electronic system will improve transparency and better traceability of waste flows, including better control of illegal waste trafficking.

EU directives also cover the environmentally sound management of certain waste streams, including:

- electrical and electronic equipment waste;
- packaging and packaging waste;
- batteries and accumulators;
- end-of-life vehicles;
- sewage sludge;
- mining waste; and
- polychlorinated biphenyl (PCB) and polychlorinated terphenyl (PCT) waste (EC, 2016b).

These directives share the same principle in terms of substance restrictions, extended producer responsibility as well as collection, recovery and recycling targets. In addition to the above-mentioned recycling and recovery targets for household waste and construction/demolition waste, a number of specific targets have been laid down for Member States to recycle specific waste streams. The waste stream directives have been key in improving waste management, stimulating innovation and changing consumer behaviour.

Separate collection

Separate collection of waste will further help increase recycling yields and is among the main facilitating factors of increased recycling. Separate collection of paper, metal, plastic and glass has been gaining popularity and has been obligatory since 2015 in several European countries. Institutional, Commercial and Industrial (ICI) waste is generally homogenous and therefore more often separately collected than household waste. However, there is still room for improvement in effectiveness and efficiency (Council of the European Union and European Parliament, 2008).

In countries where separate collection of waste from households has already been introduced and where it has been common practice for years, there is a wide variety of collection schemes. In some Member States, multiple approaches to separate collection exist, ranging from the existence of different types of separate collection in some regions, through no separate collection in others, and mixed collection in yet other regions.

The EC is currently carrying out a study which investigates the existence and structure of separate waste collection schemes in the 28 Member States. The study will provide a comprehensive understanding of the functioning, effectiveness and efficiency of such separate collection schemes, whether public or privately organized. It is expected that the study will provide an overview of the most characteristic and prevalent systems in the capital cities of EU Member States (EC, 2016b).

Green growth

In the EU, each inhabitant uses 16 tonnes of materials per year, 6 tonnes of which become waste. Although the management of this waste continues to improve, the European economy currently still loses a significant amount of potential “secondary raw materials” such as metals, wood, glass, paper and plastics in present waste streams. In 2010, the total waste production in the EU amounted to 2.5 billion tonnes. From this total, only a limited (albeit increasing) share was recycled (36%), while the remainder was sent to landfill or incinerated, some 600 million tonnes of which could be recycled or reused. In terms of household waste alone, each inhabitant in Europe is currently producing, on average, half a tonne of waste every year. Only 40% of it is reused or recycled and in some countries more than 80% still goes to landfill (Eurostat, 2016).

Waste can make a big contribution to economic growth and job creation. A study published by the EC in 2012 showed that full implementation of EU waste legislation would save €72 billion a year, increase the annual turnover of the EU waste management and recycling sector by €42 billion and create over 400 000 jobs by 2020. The study concluded that illegal waste operations are causing missed opportunities for economic growth, which was backed up by several case studies (BIO Intelligence Service, 2011; EC, 2012).

Regarding waste as a resource, current legislation marks a shift away from seeing waste as an unwanted burden only. The underlying long-term goal is to turn the EU into a recycling society based on so-called circular economy, avoiding waste production and using unavoidable waste as a resource wherever possible. The aim is to achieve the highest possible recycling rates and minimize the extraction of natural resources. If waste is to become a resource that is fed back into the economy as a raw material, a high priority must be given to reuse and recycling. Currently some EU Member States recycle more than 80% of their waste, which indicates the possibility to use waste as one of the key resources. In Germany, more than 200 000 people work in the waste management industry, which represents a profitable economic activity. This required substantial investments in technology and facilities, which may represent a burden in countries willing to adopt a similar approach.

Circular economy

The EC has adopted its proposal “Closing the loop – An EU action plan for the circular economy” (2nd December 2015), which includes legislative proposals to amend current EU waste legislation, including the Waste Framework Directive, the Landfill Directive and the Directives on packaging and packaging waste and electrical and electronic waste (EC, 2016a). The objective is to stimulate a transition towards a circular economy which can contribute to improving global competitiveness, fostering sustainable economic growth and generating new jobs.

The circular economy package consists of an EU Action Plan that establishes a concrete and ambitious programme of action, with measures covering the whole cycle: from production and consumption to waste management and the market for secondary raw materials. The annex to the action plan sets out the timeline when the actions will be completed. The proposed actions will contribute to “closing the loop” of product lifecycles through greater recycling and re-use, and provide benefits for both the environment and the economy.

The revised legislative proposals on waste set clear targets for the reduction of waste and establish an ambitious and credible long-term path for waste management and recycling. To ensure effective implementation, the waste reduction targets in the new proposal are accompanied by concrete measures to address obstacles on the ground and the different situations across Member States. Key elements of the revised waste proposal include:

- A common EU target for recycling 65% of municipal waste by 2030;
- A common EU target for recycling 75% of packaging waste by 2030;
- A binding landfill target to reduce landfill to a maximum of 10% of all waste by 2030;
- A ban on landfilling of separately collected waste;
- Promotion of economic instruments to discourage landfilling;
- Simplified and improved definitions and harmonised calculation methods for recycling rates throughout the EU;
- Concrete measures to promote re-use and stimulate “industrial symbiosis”, thereby turning one industry’s by-product or unwanted output into another industry’s material input; and
- Economic incentives for producers to put greener products on the market and support recovery and recycling schemes (e.g. for packaging, batteries, electric and electronic equipment, vehicles).

The informal sector

The informal activities around waste collection, sorting, treatment and disposal, as well as the illegal flows and trafficking of hazardous waste represent a serious challenge. While the extent of the problem is largely unknown, some data and anecdotal evidence suggest that such activities are not uncommon. Clearly, informal waste management activities can provide income and support the livelihoods of families and local communities, but the price in terms of direct health impact for those involved is likely to be very high. Implementation and enforcement of national and international legislation and conventions, such as the Basel Convention, is key to tackling this worrying phenomenon. Severe questions of health inequality and environmental justice arise, as the people engaged in informal waste management are socially disadvantaged in other respects, like it is the case for Roma people, who have been repeatedly reported to be involved.

Lack of complete data and information on the problem should be addressed urgently, not so much because more evidence is needed to respond with decisive policy action, but rather to create a stronger political case, by highlighting the extreme exposures and inequities, so as to urgently remediate this state of affairs.

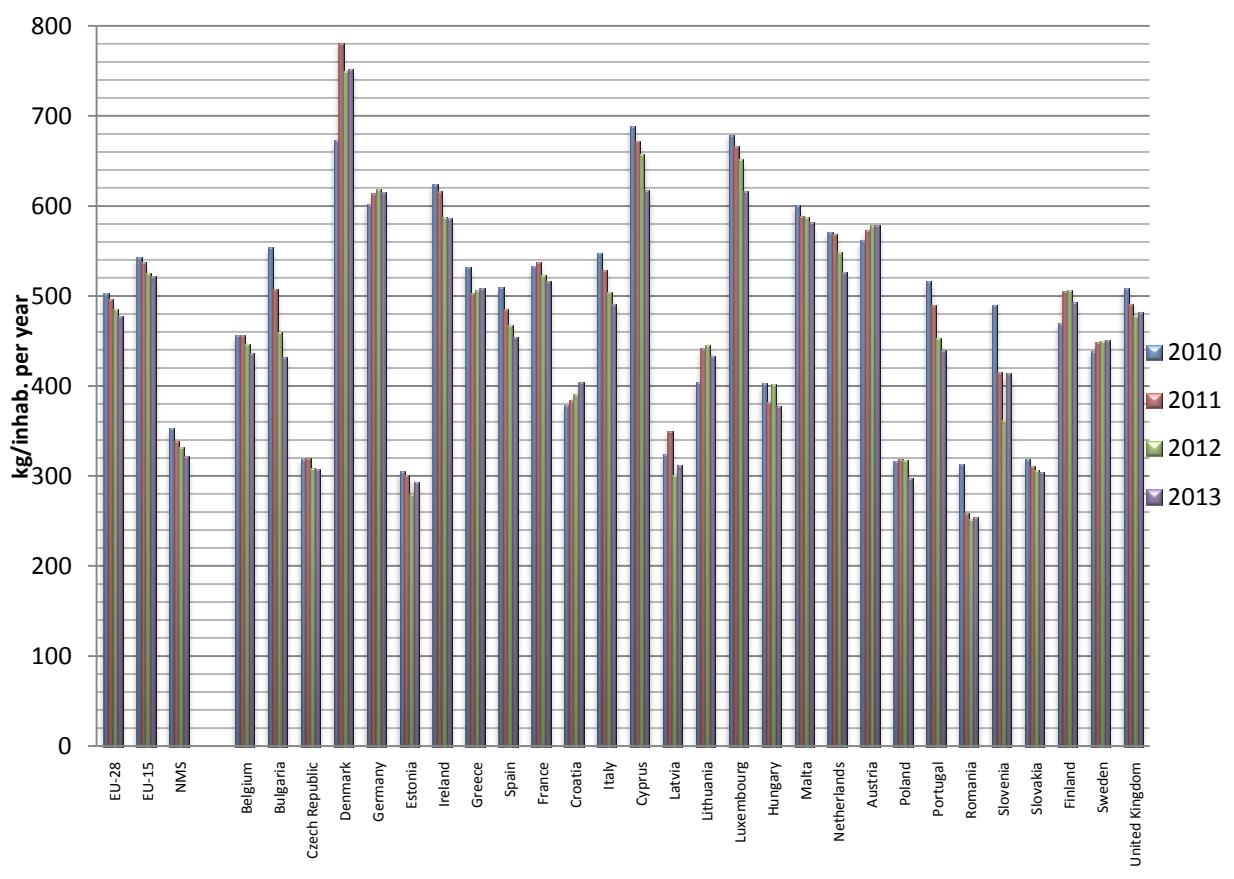
Production of waste

As mentioned above, the Waste Framework Directive (Council of the European Union and European Parliament, 2008) is the main document guiding the EU policy on waste. It defines the waste hierarchy, which prioritizes waste prevention, followed by preparation for reuse; recycling; recovery; and finally disposal as the least desirable option.

Production and management of waste in Europe is heterogeneous, and data gaps and differences in national methodologies for describing waste flows make it difficult to draw a full picture, however it is clear that waste generation has declined since early 2000s in EU, with a consolidated trend to the reduction of total production and per capita municipal waste in recent years. While it is difficult to distinguish between the role of the economic downturn and virtuous practices in the reduction of waste production, a trend of diminishing overall production of waste is confirmed by long-term analyses over the crisis period. Despite missing data, uncertainties on available data and differences in waste calculation methods between European countries, overall waste generation has declined in EU in the period 2004–2013, with an estimated decrease of 7% in production per capita (1,943 kg/person to 1,817 kg/person). Limited to municipal waste only, a decrease of 4% has been observed in the same period.

In 2013 (year with the latest available data), the negative trend that began in the production of urban waste in previous years was confirmed at EU level. Between 2012 and 2013, a decrease from 488 to 481 kg/inhabitant/year (-1.4%) in the per capita production of municipal waste occurred. There is considerable variability across Europe (see Figure 2 below), with values between 272 kg/inhabitant/year in Romania and 747kg/inhabitant/year in Denmark.

Figure 2. Production of urban waste in EU (kg/inhab. per year) - years 2010-2013

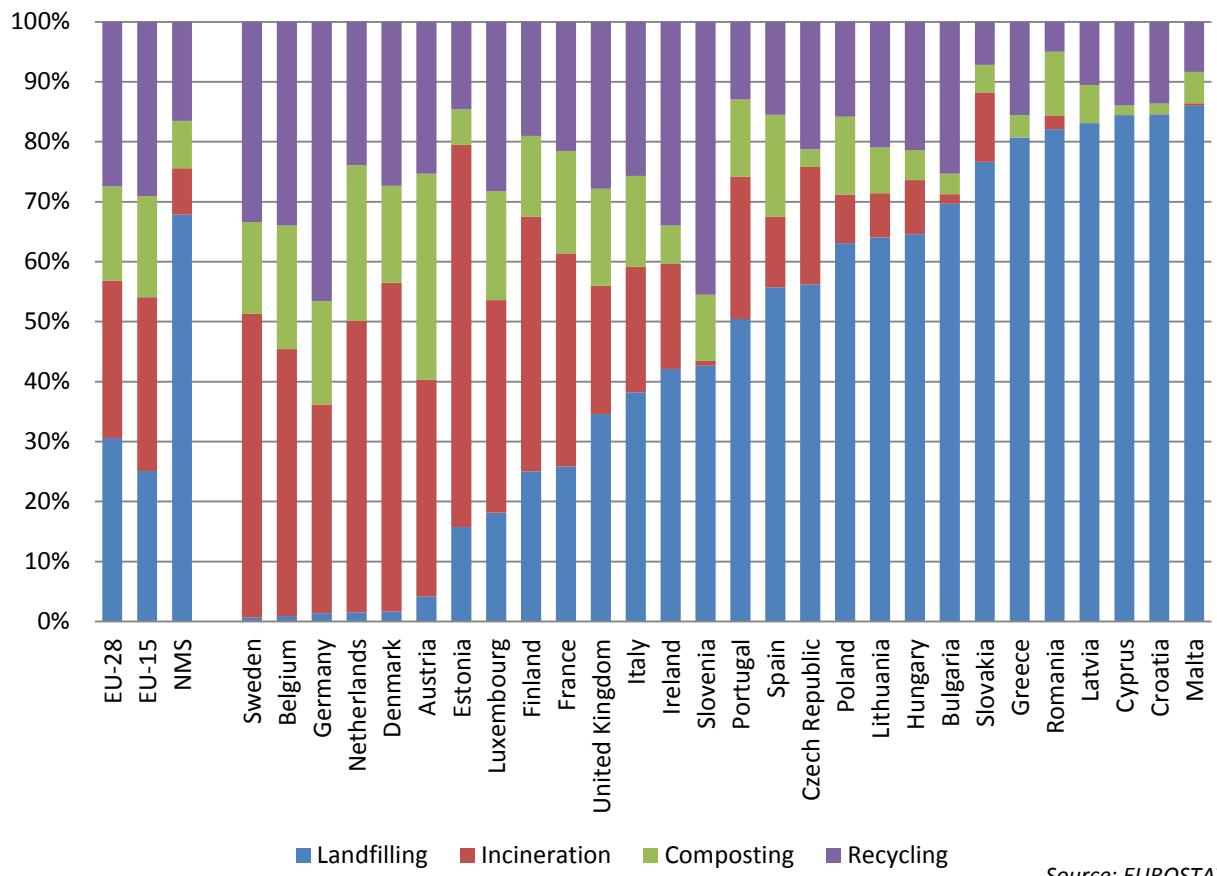


Data show a difference between the old and more recent EU Member States, with production values per capita in the latter lower than the former, reflecting economy sizes: in EU-15 waste production is 521 kg/inhabitant/year (-1.3% compared to 2012), against 325 kg/inhabitant/year for the other EU Member States.

Waste management

Beyond overall waste generation, there are also signals of progress in waste management in Europe. Figure 3 below shows the percentage of the main forms of waste treatment (recycling, composting, incineration, and landfill) in 2013 for each EU Member State, the EU-28, the EU-15. In the 28 Member States 28% of municipal waste was recycled, 15% composted (through aerobic and anaerobic processes), while 26% and 31% were, respectively, incinerated and disposed of in landfill. The figure confirms the large variability in approaching waste management of municipal waste between the different Member States. With the exception of Greece, a significant use of landfills as main waste disposal (over 65% of total waste) is confined to countries which recently joined the EU.

Figure 3. Management of urban waste in EU, year 2013 (data ordered by increasing percentage of landfilling)



Source: EUROSTAT

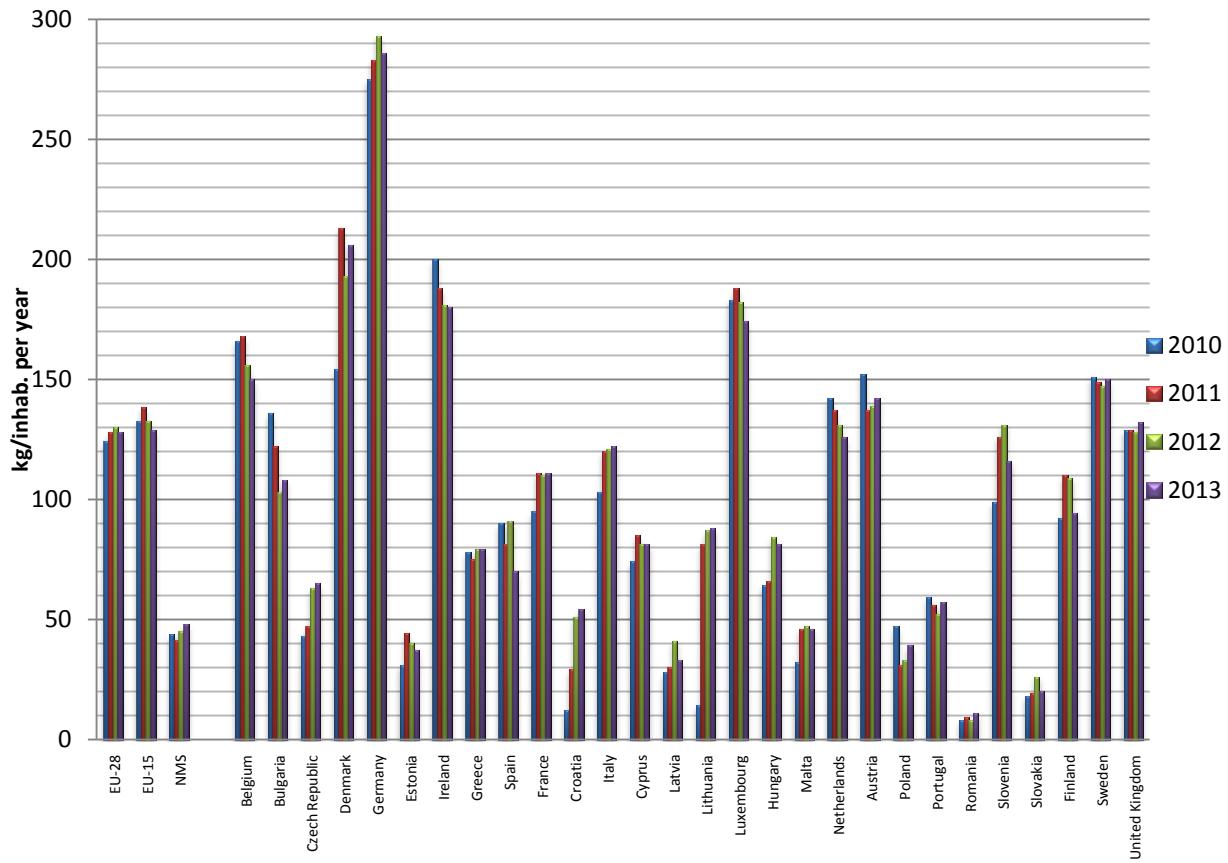
In 2013, the per capita value (calculated as the ratio between the quantity of waste treated and the average population of the reference year) of the disposal in landfills in the EU-28 amounted on average to 147 kg/inhabitant/year, a reduction of 6.4% from the previous year. Lower values are recorded in the EU-15 (on average 133 kg/inhabitant/year), while in more recent EU Member States, in which the implementation of EU legislation was started later, values are higher (on average 204 kg/inhabitant/year). In both groups there was a reduction compared to 2012 (-5% in EU-15 and -8.1% in the others).

With regard to incineration, about 61.6 million tonnes of municipal waste were sent to incineration in EU in 2013. The average per capita amount of municipal waste incinerated in the EU-28 amounted to 122 kg/inhabitant/ year in 2013. Here, the relationship between EU-15 and

other EU Member States is inverted, with 96.3% of the total incinerated in the EU-15 (an increase of 4.4% with respect to 2012). The use of incineration is particularly widespread in central and northern Europe.

In 2013, 66.1 million tonnes of municipal waste were recycled in EU-28; 92.5% (about 61.1 million tonnes) of which occurred in the EU-15 countries. Large differences in recycling rates across Europe are again notable, as shown in Figure 4.

Figure 4. Recycling of urban waste in UE (kg/inhab. per year) - years 2010-2013



Source: EUROSTAT

Improving waste management practices have reduced pressures associated with waste disposal, such as pollution from incineration or landfilling and has also mitigated pressures associated with extracting and processing new resources. The European Environment Agency (EEA) estimates that improved municipal waste management in the EU-27, Switzerland and Norway prevented annual net greenhouse gas emissions of 57 million tonnes of CO₂-equivalent in the period 1990–2012, with most of the reduction achieved since 2000. The two main factors responsible for this were reduced methane emissions from landfill and avoided emissions through recycling (EEA, 2015).

There are still significant opportunities for increased recycling in many countries. Better recycling technologies, infrastructure, and collection rates could further reduce environmental pressures and European reliance on resource imports, including some critical materials (EEA, 2011).

On the other hand, large capacity for incineration in some countries presents a competitive challenge for recycling, making it harder to shift waste management up the waste hierarchy (ETC/SCP, 2014).

Health effects of waste management

Improper waste management and illegal waste shipments can have negative impacts on both environment and public health. Negative impacts can be due to different handling and disposal activities resulting in soil, water and air pollution. Inadequately disposed of or untreated waste may cause serious health problems for populations surrounding the area of disposal. Leaks from the waste may contaminate soils and water streams, and produce air pollution through emissions of e.g. heavy metals and persistent organic pollutants (POPs), ultimately creating health hazards. Other nuisances caused by uncontrolled or mismanaged waste disposal which may affect citizens negatively include impacts at local level, such as landscape deterioration, local water and air pollution, as well as littering. Managing waste properly and in an environmentally sound way is therefore important for health reasons.

Despite the increasing recycling activities, landfills and incinerators are widely used to manage the final phase of waste disposal. As a consequence, existing literature provides evidence mainly for these plants. Recently information on less severe diseases is available also in relation to waste treatment activities, such as mechanical biological treatment (MBT) plants. A number of reviews are already available (Vrijheid, 2000; Hu and Shy, 2001; Rushton, 2003; Dolk and Vrijheid, 2003; Franchini et al., 2004; WHO Regional Office for Europe, 2007; Russi, Borak, and Cullen, 2008; Giusti, 2009; Porta et al., 2009; Mattiello et al., 2013; Ashworth, Elliott and Toledano, 2014); DEFRA, 2004). The conclusion of these reviews is not definitive, with some difficulties in interpreting data from primary studies due to non-homogeneous design, and lack of accurate exposure information and control of potential confounders.

Population exposed to pollution from waste management

A relevant factor concerning health effects of waste management is how much and which population is involved in such risks. Unlike what happens for urban ambient air pollution, exposure to pollution from waste management facilities does not involve all the residents of an urban area, but only a small part of the population living in the vicinity of the plants. Different studies in Europe, such as SESPIR and INTARESE (Ranzi et al. 2014, Forastiere et al. 2011), estimated that about 2 to 6% of resident population are affected. Moreover, the population living in proximity of waste disposal plants is often more deprived than general population, which involves environmental health inequalities. It is no coincidence that the so-called NIMBY (not in my back yard) attitude often occurs within social conflicts related to pollution by waste premises.

A direct relationship between small area deprivation and residence near incinerators and landfills was often found in different studies (Martuzzi, Mitis and Forastiere, 2010; Forastiere et al., 2011). Data on social inequalities in exposures due to residence near landfills, however, are less reliable than those for incinerators, due to the lack of accurate information about the geographical location of landfills. The findings of these assessments, combined with information on connected activities such as waste transport, allow an evaluation of the overall health impact of these facilities.

Municipal solid waste – landfills

Living in the vicinity of a landfill can represent a risk for health of residents because they may be exposed to pollutants from landfill through different pathways: the inhalation of substances emitted by the site, the contact with water or polluted soil, directly or through the consumption of products or contaminated water. The biggest concerns regard illegal, uncontrolled landfills, receiving waste without any selection at the origin; however also the health effects of authorized landfills have been investigated by several studies.

Exposure assessment

Some studies have provided evidence of an association between residence near legal landfills and different health risks, but overall such evidence is not conclusive. The weakness of the observations is related, among other factors, to the quality of the exposure assessment. In most of the available studies, the distance from the landfill is used as proxy of exposure. It has been noted that this measure may reflect and integrate different routes of exposure (not only air, but also the contamination of soil or groundwater in the vicinity of the plant). This aspect, in addition to the ease of calculation, makes distance a still widely used metric. However, distance at best can only provide a first order approximation of the real exposure to pollutants emitted from this type of plant.

Recent work carried out in Italy as part of the ERAS project has proposed the combined use of the geographical distance and the estimated concentrations through a model chain (LandGEM Model as per US EPA, 2005) and Lagrangian model dispersion. This approach can provide a more complete picture of the impact of landfills on environment and human health, while keeping things simple. The concentrations of hydrogen sulphide (H₂S) emitted from waste is used as an indicator of the air contamination, while distance can be used as an indicator of pollution of water and soil matrices, under the assumption that the contamination occurs mainly in the area adjacent to the landfill.

Health effects

The possible health effects related to residential proximity to landfills have been studied in several papers and summarized in systematic reviews. They mainly concern cancer and births outcomes; more recently respiratory diseases and annoyance were also investigated¹. Excess for cancer has been found for different sites (e.g., pancreas, larynx, liver, kidney) and non-Hodgkin lymphoma, but the overall evidence is not sufficient for drawing firm conclusions: the most recent reviews (Porta et al., 2009; Mattiello et al., 2013) reached this same conclusion, mainly drawn by a large study conducted in England (Jarup et al., 2002).

¹ More recent data from Spain and Italy, in part published after the meeting, (Gouveia and do Prado, 2010a, 2010b; Mataloni et al., 2016) confirm this pattern, with the absence of evidence for the first study and an association with lung cancer for the latter. The Italian study founded also an association between exposure to landfills and respiratory diseases. A retrospective cohort of residents within 5 Km from 9 municipal solid waste landfills were considered, with a fine characterization of exposure, based on a dispersion model of hydrogen sulphide (H₂S) emitted by the landfills. This result is consistent with others previous works (Heaney et al, 2011, Correa et al. 2011), and is suggestive of a relationship between residential exposure to landfill pollution and respiratory diseases, as already indicated in a recent systematic review (Mattiello et al. 2013).

Several studies addressed birth outcomes. Adverse effects were observed for toxic waste, as described by both older and more recent papers, but this is less clear when only urban solid wastes are considered. The evaluation of 9,565 landfills in the United Kingdom, in which Elliott et al. distinguished between non-special and special or unknown waste disposal sites, confirmed an effect of the latter and no evidence of harm from the former (Elliott et al., 2009). This difference does not hold for congenital malformations and low birth weight, for which limited evidence exists of an increased risk for infants born to mothers living near landfill sites. The most informative results are those of the European EUROHAZCON Study (Dolk et al., 1998) and the United Kingdom investigation by Elliott et al. (Elliott et al., 2009). In the United Kingdom, statistically significant elevated risks were found for all congenital malformations, neural tube defects, abdominal wall defects, surgical correction of gastroschisis and exomphalos, and low and very low birth weight for births to people living within 2 km of the sites, both of hazardous and non-hazardous waste. Although several alternative explanations, including ascertainment bias, and residual confounding cannot be excluded, estimates effects and their level of confidence suggest an increase in risk of congenital anomalies due to the landfills.

In the most recent literature, health outcomes have been analysed that are less severe, but of a greater overall impact as more frequent in the exposed population. Several papers reported associations between exposure to odorous disposal facilities such as landfills, and respiratory symptoms and other non-specific symptoms in the population, such as noise and other problems due to annoyance. (Aatamila et al., 2011; Heaney et al., 2011; De Feo, De Gisi and Williams, 2013).

Municipal solid waste – incinerators

Exposure assessment

Emissions from incinerators have been improving over the years, as increasingly restrictive regulations came into force, and consequently better techniques for emission abatements were developed, the so-called best available techniques (BATs). Starting from the late 1970s, a continuous reduction of emissions (up to 3–4 orders of magnitude) from incinerators has taken place, with a consequent reduction of expected risks for human health. This aspect makes applying estimates and evidences from studies related to high levels of emissions (i.e. the French study on Besançon related to the 1970s and 1980s) to new-generation plants difficult. Some studies provide interesting analyses comparing emissions over time: the ratios of concentrations of released substances in the late 2000s compared with the 1990s ranges from one order of magnitude for total suspended particulate or some metals (e.g. mercury and cadmium) to four orders of magnitude for dioxins (polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF)).

Within the INTARESE project, which considered the health impact of incinerators, a calculation of how to recalibrate Elliott estimates (referring to emissions in the 1980s) for new generation incinerators confirmed the above indications (Forastiere et al., 2011).

A recent review on exposure assessment methods applied in epidemiological studies on incinerators has classified the quality of exposure methods in 41 studies from 1984 to 2013,

ranking the papers considering 3 crucial aspects of this assessment, namely the *proxy* measure adopted for intensity of exposure (qualitative or quantitative measure or model), the scale at which the spatial distribution of the exposed population was accounted for (municipality, small area, residential address), and whether temporal variability in exposure was considered or not (Cordioli et al. 2013). Exposure assessment methods were found to have improved, with reduction in misclassification of exposure when all three aspects were considered with the best approach of analyses.

Recent studies addressed the use of the human biomonitoring for exposure assessment of pollution due to incinerators. Biomarkers seems to be a less biasing surrogate of real exposure than environmental monitoring (Lin et al, 2005), for example with levels of polycyclic aromatic hydrocarbon (PAH) in urine associated to increasing levels of emissions from incinerators (Ranzi et al. 2014). As already stated in previous documents (WHO Regional Office for Europe, 2007), these findings suggest a promising way forward in the use of human biomonitoring to improve the assessment of low exposures to environmental stressors, as those from incinerators.

Health effects

As stated above, emissions from incinerators have been much changing over time. This entails changing health impacts, and it is difficult to formulate overall considerations on the health effects. Available evidence is therefore specific to the period of investigation and to the different types of incinerator analysed (old generation versus new generation plants). On the other hand, the improvement in exposure assessment methods mentioned above can help summarize the health risks.

Papers dealing with the health effects of incinerators active in the years 1969–1996 consistently report a detectable risk of some cancers in the populations living nearby, through high quality studies, as reported in different reviews. Quantitative estimates of excess risks of specific cancers in populations living near solid waste incinerator plants were provided (Elliott et al., 1996) for all cancers, stomach, colon, liver, and lung cancer. Other studies performed in Italy, France and the United Kingdom indicate some suggestive but not consistent results for non-Hodgkin lymphomas and soft tissue sarcomas (Elliott et al., 1996; Viel et al., 2000, 2008; Comba et al., 2003; Floret et al., 2004; Zambon et al., 2007; Ranzi et al., 2011).

The majority of these studies concerned old generation incinerators, characterized by high emission levels. The emissions of modern incinerators which have been investigated are different in quantity and composition, as a result of modern abatements techniques. For this reason the results of all available studies cannot be compared, and consistency across studies is not expected.

Congenital anomalies were also investigated by several studies. Particular attention has been given to the excess risk for urinary tract defects by a well-designed study in France (Cordier et al., 2010), which confirmed previous observations on an increased risk from exposure to solid waste incinerator emissions in early pregnancy. Results from other studies on the same outcomes are inconsistent.

Recent work in Italy found associations between birth outcomes (preterm birth and spontaneous abortion) in relation to increased level of exposure to incinerators (Candela et al., 2013). These findings are in line with work done in Taiwan (Lin, Li and Mao, 2006).

Results on chronic or acute respiratory effects in children or adults, were inconclusive, although recent literature reports new evidence on this outcome (Golini et al., 2014).

Towards a European assessment of the health impact of landfilling

Notwithstanding numerous uncertainties, the available knowledge makes it possible to develop a framework for assessing the health impact of waste management facilities in residential areas. Based on the evidence outlined above, a two-step process can be applied to select health outcomes to be considered in a health impact assessment (HIA) exercise of waste management.

1. First, consider diseases with at least “limited evidence”, as indicated by recent reviews, as cancer for incinerators, congenital anomalies and low-birth weight for landfills. Regarding cancer for incinerators, following considerations mentioned above on the reduction of emissions of these plants since the 1980s, a temporal correction coefficient has to be applied (following Forastiere et al., 2011).
2. Next, based on more recent findings, consider preterm births for incinerators, respiratory diseases and annoyance for landfills, based on multisite cohort studies with at least one similar positive result in the literature.

Table 1 below shows the outcomes that can be considered in the assessment for landfills:

Exposure buffer	Exposure index	Health outcome	Health risk	Metrics*	Ref.
2 km	Distance	- congenital anomalies	Relative risk (RR) = 1.02 (99%CI = 1.01-1.03)	I.C.	Elliott et al. 2001
		- annoyance from odour	5.4%**	P.	Herr et al. 2003
		- low birth weight	RR = 1.06 (99%CI=1.052-1.062)	I.C.	Elliott et al. 2001
5 km	H ₂ S (disp.model)	- respiratory diseases	RR = 1.09 (95%CI 1.00-1.19)	P.	Golini et al. 2016

* I.C. = cumulative incidence on the simulation period (2004-2020); P. = annual prevalence

** Confidence intervals are not available, because this value refers to data from questionnaires

Table 1. Exposure and health outcome metrics used for health impact assessments for landfills

The general formula of attributable cases (AC) can then be applied:

$$AC = AFexp \cdot Ratepopgen \cdot Popexp$$

where $AFexp = (RR - 1)/RR$ is the attributable fraction in exposed people, $Rategenpop$ is the background population incidence rate (proxy of rate in unexposed people) and $Popexp$ is the exposed population.

AC can also be converted to Disability Adjusted Life Years (DALYs), using the formula:

$$DALY = AC \cdot DW \cdot L$$

where AC is attributable cases, DW is the disability weight and L is the disease duration.

Despite the underlying assumptions, the methodology is suitable for a first order approach to assess the order of magnitude of health impacts under alternative scenarios in waste management.

Hazardous and toxic waste

The evidence reported above is related to studies on regulated management of urban waste. However, poor, outdated and illegal practices of urban and hazardous waste disposal still affect some local communities in industrialized countries and represent an increasing problem in middle-low income countries (Landrigan et al, 2015), the latter also due to illegal transboundary trade from industrialized countries (Marsili et al, 2009). Several investigations report a wider spectrum of risks for health of populations living in the surroundings of these areas.

The previously mentioned systematic review on health effects of residence near hazardous waste sites, published in 2000, reported that the evidence for a causal relationship with cancers "is still weak", highlighting specific cancers, as reported in more than one study: leukaemia, bladder, lung and stomach cancers. The review, considering also the above-mentioned EUROHAZCON studies, suggested a relationship with adverse pregnancy outcomes: low birth weights, total birth defects and cardiac, musculoskeletal and central nervous system defects. However, the authors stated that the studies were still few to draw conclusions regarding causality (Vrijheid et al, 2000).

A subsequent review of 2008 concluded that the studies could not determine whether residence near toxic waste sites causes an increased cancer risk (Russi et al, 2008).

Focusing on epidemiological studies published in 1999-2014 period (those not considered in the review by Vrijheid, 2000) concerning populations residing near toxic waste dumping sites, without considering e-waste and radio-active wastes that deserve specific evaluation on possible health effects, because of their specific characteristics, the following main findings can be abstracted.

Several diseases were reported in excess in single-site studies, but the study design and, in particular, the exposure evaluation, does not allow causal inference. However, excesses have been reported in more than one study for neoplasms (all sites, Pukkala, et al, 2001; Martuzzi et al, 2009; Fantini et al, 2012; Garcia-Perez et al, 2013; Pasetto et al, 2013; Pukkala et al, 2014), liver (Martuzzi et al, 2009; Garcia-Perez et al, 2013; Pasetto et al, 2013; Chatman-Stephens et al, 2014; Fazzo et al, 2014), lung (Martuzzi et al, 2009; Fantini et al, 2012; Pasetto et al, 2013; Chatman-Stephens et al, 2014; Fazzo et al, 2014), stomach (Martuzzi et al, 2009; Fantini et al, 2012; Garcia-Perez et al, 2013), bladder (Gensburg et al, 2009; Garcia-Perez et al, 2013; Fazzo et al, 2014), leukaemia (Boberg et al, 2011; Garcia-Perez et al, 2013), non-neoplastic diseases (respiratory (Pukkala et al, 2001; Kudyakov et al, 2004; Ma et al, 2004; Carpenter et al, 2008; Fantini et al, 2012; Mattiello et al, 2013), circulatory (Sergeev et al, 2005; Gensburg et al, 2009; Huang et al, 2006) and digestive systems (Kouznetsova et al, 2007; Fantini et al, 2012; Ala et al, 2006; Fazzo et al, 2012), and adverse reproductive outcomes (congenital anomalies, low birth weight, preterm births); the latter previously mentioned in the paragraph on landfills.

Recently, severe acute health effects have been reported in low income countries, near sites where hazardous wastes from industrialized countries were illegally dumped (Tiembre, 2009). Furthermore, occurrence of neurological disorders caused by exposure to lead has been foreseen in children resident close to hazardous wastes in Asian countries (Caravanos et al, 2012; Chatman-Stephens et al, 2014).

The main problems in reviewing these studies concern availability of data, differences in study design and different types of waste analysed. Data and studies of acute and long-term effects

of illegal disposal and uncontrolled waste burning in low income countries are limited, and suitable methods for assessing population exposure through different pathways of exposure on the basis of types of waste and types of contaminants are not yet available.

Emerging priorities: E-waste

Electrical and electronic waste is a fast growing solid waste stream, with more than 40 million tonnes of e-waste created globally each year. The management and disposal of these kind of waste is complex and sometimes related to illegal e-waste trade towards developing countries. E-waste comprises discarded electronic appliances, of which computers and mobile telephones are disproportionately abundant because of their short lifespan. Multiple definitions of e-waste have been used, as “any appliance using an electric power supply that has reached its end-of-life” (OECD, 2001), or “Waste Electrical and Electronic Equipment (WEEE) including all components, subassemblies and consumables, which are part of the product at the time of discarding” (Council of European Union, 2003)

E-waste comprises a source of a variety of materials that can be recovered and brought back into the production cycle. Over 1,000 different chemicals (as heavy metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and brominated flame retardants) are identified in the e-waste streams. The population exposed to potentially hazardous substances through inappropriate and unsafe management practices related to e-waste is increasing.

Given the pollutants involved, health effects from treatment of e-waste may include neurodevelopmental outcomes. A recent review recorded plausible outcomes related to alterations in thyroid function, associations of exposure to chromium, manganese and nickel with lung function, adverse birth outcomes (preterm birth, low birth weight, stillbirth, and congenital malformations), behavioural alterations, as well as DNA damage and chromosomal aberrations in lymphocytes. This relatively recent and growing problem needs to be addressed by suitable epidemiological studies in vulnerable populations (such as pregnant women and children).

Discussion points

As illustrated above, waste production, management and disposal involve a variety of complex activities, with a great potential to affect health directly and indirectly, through many pathways and mechanisms, only partly understood. The health effects include an increased risk of cancer and mortality, respiratory disease, congenital malformation and low birthweight; also, well-being is affected, through annoyance due to odour. Overall, however, the evidence is not conclusive, and more research is needed to strengthen the evidence base necessary for developing sound policy advice. In particular, it seems important to undertake studies on little investigated, but potentially relevant health outcomes, such as neurological disorders; “soft” health endpoints linked to well-being, like annoyance due to odour, deserve more systematic investigations, also in consideration of their large leverage in the policy debate. More comprehensive studies are also needed that consider multiple sources and mixes of agents, which are invariably involved. In general, better methodology for exposure assessment is needed in order to carry out more informative epidemiological studies. Human biomonitoring, especially of persistent substances, is a mature and powerful tool in this respect.

Further to these knowledge gaps, available evidence is becoming less relevant for some countries of the WHO European Region, as the waste industry evolves. Health impacts of different types of waste management have been documented in several instances, mainly in relatively controlled situations where old generation facilities, especially landfills and incinerators, were in operation. Modern technology has greatly reduced noxious emissions and measurable health impacts have in many cases become smaller. All in all, analyses carried out over time, ideally on population cohorts, would be the best option in order to clarify these temporal trends.

Old generation facilities are still in operation in many countries, however, and health impacts comparable with those described in the literature are likely to occur; in addition, the nature of the waste flows is changing, for example with e-waste, often informally treated with consequent exposures to hazardous substances. This is but one of the deep differences between countries of the WHO European Region in terms of waste management. In some cases, informal activities of waste collection, treatment and disposal, despite the patchy anecdotal evidence, are known to entail very high exposures to noxious agents, for example through open-air waste burning. More systematic data are needed to understand the extent of these practices in Europe and evaluate the likely health impacts, however these extreme exposures, typically suffered by disadvantaged groups, must be urgently prevented.

Following the adoption of the Sustainable Development Goals (SDGs), growing attention is being paid to sustainability in many domains, including waste. Sustainability introduces further elements of complexity, but it can also be regarded as a guiding principle that can help make policy progress even in the absence of conclusive evidence on specific health effects. Generally speaking, SDGs provide additional support to the EU waste hierarchy, and they can also be of help at the practical level, for example when local authorities are faced with decisions on waste management policies.

Circular economy is also an increasingly prominent pursuit, fully aligned with SDGs. By reducing, or ideally eliminating waste production, by using unwanted outputs from certain production cycles as input for others, circular economy has indeed the potential to contribute greatly to long term-sustainability, as well as profitability. Health considerations should be central to the debate, however, given the possibility that adverse effects are inadvertently introduced, for example by “recycling” toxic substances, compounds or materials, thereby introducing a process of toxification of certain waste streams.

Also, experiences in some Member States shows that a profitable industry can be run on waste collection and treatment, provided considerable investments are made.

Knowledge gaps

The health effects of waste management and disposal activities are only partly understood, and updated evidence would be needed for better informing the policy debate, especially in consideration of the fast-evolving technology. Multisite cohort studies, for example, would refine current risk estimates and would allow the consideration of health outcomes of increasing interest, such as neurological disorders.

At the same time, estimates on the severity and frequency of acute exposures deriving from old generation facilities would be important, so as to estimate the extent of local health impacts. Similarly, much better and more complete data are needed on informal waste management activities and illegal operations, given the likely substantial magnitude of the health burden suffered by the people involved. Data on hospital admissions, including for emergencies and acute cases, should be considered as a potential source of valuable information in this respect. In general, methods and resources for cost-efficient health surveillance should be developed, as this might help remediate and prevent further instances of such situations.

References

- Aatamila M, Verkasalo PK, Korhonen MJ, Suominen AL, Hirvonen MR, Viluksela MK et al. (2011). Odour annoyance and physical symptoms among residents living near waste treatment centres. *Environ Res*; 111(1): 164–70. doi:10.1016/j.envres.2010.11.008.
- Ala A, Stanca CM, Bu-Ghanim M, Ahmad I, Branch AD, Schiano T, Odin JO, Bach N (2006). Increased Prevalence of Primary Biliary Cirrhosis Near Superfund Toxic Waste Sites. *Hepatology*; 43:525-531. doi: 10.1002/hep.21076.
- Ashworth DC, Elliott P, Toledano MB (2014). Waste incineration and adverse birth and neonatal outcomes: a systematic review. *Environ Int*; 69(August):120–32. doi:10.1016/j.envint.2014.04.003.
- BIO Intelligence Service (2011). Implementing EU Waste Legislation for Green Growth, Final Report prepared for European Commission DG ENV Paris: BIO Intelligence Service (http://ec.europa.eu/environment/waste/studies/pdf/study_12_FINAL_REPORT.pdf, accessed 2 May 2016).
- Boberg E, Lessner L, Carpenter DO (2011). The role of residence near hazardous waste sites containing benzene in the development of hematologic cancers in upstate New York. *Int J Occup Med Environ Health*; 24(4):327-338. doi: 10.2478/s13382-011-0037-8.
- Caravanos J, Chatman-Stephens K, Bret E, Landrigan PJ, Fuller R (2013). The burden of disease from pediatric lead exposure at hazardous waste sites in 7 Asian countries. *Environ Research*; 120:119-125. doi: 10.1016/j.envres.2012.06.006.
- Carpenter DO, Ma J, Lessner L (2008). Asthma and Infectious Respiratory Disease in Relation to Residence near Hazardous Waste Sites. *Ann. N.Y. Acad. Sci.* 1140: 201–208. doi: 10.1196/annals.1454.000.
- Chatman-Stephens K, Caravanos J, Ericson B, Landrigan P, Fuller R. The pediatric burden of disease from lead exposure at toxic waste sites in low and middle income countries (2014). *Environ Research*; 132:379-383. doi: 10.1016/j.envres.2014.04.018
- Comba P, Ascoli V, Belli S, Benedetti M, Gatti L, Ricci P, et al. (2003). Risk of soft tissue sarcomas and residence in the neighbourhood of an incinerator of industrial wastes. *Occup Environ Med*; 60(9):680–83. doi: 10.1136/oem.60.9.680.
- Cordier S, Lehébel A, Amar E, Anzivino-Viricel L, Hours M, Monfort C et al. (2010). Maternal residence near municipal waste incinerators and the risk of urinary tract birth defects. *Occup Environ Med*; 67(7):493–99. doi:10.1136/oem.2009.052456.
- Cordioli M, Ranzi A, De Leo GA, Lauriola P. (2013). A review of exposure assessment methods in epidemiological studies on incinerators. *J Environ Public Health*. 2013:129470. doi: 10.1155/2013/129470.
- Corrêa CR, Abrahão CE, Carpintero Mdo C, Anaruma Filho F. (2011). Landfills as risk factors for respiratory disease in children. *J Pediatr (Rio J)*;87(4):319-324. doi:10.2223/JPED.2098.
- Council of the European Union (1999). Council Directive 1999/31/EC of 26 April 1999 on the Landfill of Waste. *Official Journal of the European Union*; L(182):1–19 (<http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31999L0031>, accessed 2 May 2016).
- Council of European Union (2003). DIRECTIVE 2002/96/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 January 2003 on waste electrical and electronic equipment (WEEE) (http://eur-lex.europa.eu/resource.html?uri=cellar:ac89e64f-a4a5-4c13-8d96-1fd1d6bcaa49.0004.02/DOC_1&format=PDF, accessed 10 June 2016).
- Council of the European Union (2014). *Official Journal of the European Union*; L(189):1–268 (<http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L:2014:189:TOC>, accessed 2 May 2016).
- Council of the European Union and European Parliament (2006). Regulation (EC) No 1013/2006

- of the European Parliament and of the Council of 14 June 2006 on Shipments of Waste." *Official Journal of the European Union*; L(190):1–98 (<http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32006R1013>, accessed 2 May 2016).
- Council of the European Union and European Parliament (2008). Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on Waste and Repealing Certain Directives. *Official Journal of the European Union*; L(312):3–30 (<http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0098>, accessed 2 May 2016).
- De Feo G, De Gisi S, Williams ID (2013). Public perception of odour and environmental pollution attributed to MSW treatment and disposal facilities: a case study. *Waste Management*; 33(4):974–87. doi:10.1016/j.wasman.2012.12.016.
- Dolk H, Vrijheid M, Armstrong B, Abramsky L, Bianchi F, Garne E et al. (1998). Risk of congenital anomalies near hazardous-waste landfill sites in Europe: the EUROHAZCON study. *Lancet*; 352(9126):423–27 (<http://www.sciencedirect.com/science/article/pii/S014067369801352X>, accessed 2 May 2016).
- Dolk H, Vrijheid M (2003). The impact of environmental pollution on congenital anomalies. *Br Med Bull*; 68(January):25–45.
- DEFRA (2004). Review of Environmental and Health Effects of Waste Management: Municipal Solid Waste and Similar Wastes. Department for Environment, Food and Rural Affairs, London United Kingdom. (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69391/pb9052a-health-report-040325.pdf, accessed 10 June 2016).
- Elliott P, Richardson S, Abellan JJ, Thomson A, de Hoogh C, Jarup L et al. (2009). Geographic density of landfill sites and risk of congenital anomalies in England. *Occup Environ Med*; 66(2):81–89. doi:10.1136/oem.2007.038497.
- Elliott P, Shaddick G, Kleinschmidt, Jolley D, Walls P, Beresford J et al. (1996). Cancer incidence near municipal solid waste incinerators in Great Britain. *Br J Cancer*; 73(5):702–10 (<http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2074344/?tool=pmcentrez>, accessed 2 May 2016).
- Eurostat (2016). Environmental Data Centre on Waste. [web site] (<http://ec.europa.eu/eurostat/web/waste/data>, accessed 10 June 2016).
- EC (2016a). Circular Economy Strategy. In: European Commission/Environment. [web site]. Brussels: European Union (http://ec.europa.eu/environment/circular-economy/index_en.htm, accessed 2 May 2016).
- EC (2016b). Waste. In: European Commission/Environment. Brussels: European Union (<http://ec.europa.eu/environment/waste/index.htm>; accessed 2 May 2016).
- EC (2012). Waste – a short cut to job creation and lower costs. In: European Commission/Press Release Database. Brussels: European Union (http://ec.europa.eu/rapid/press-release_IP-12-18_en.htm, accessed 2 May 2016).
- EC (2013). Commission Staff Working Paper: Impact Assessment: Accompanying document to a legislative proposal and additional non-legislative measures strengthening the inspections and enforcement of Regulation (EC) No 1013/2006 of the European Parliament and of the Council of 14 June 2006 on Shipments of Waste. Brussels: European Commission (SWD(2013) 268 final; <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52013SC0268>, accessed 2 May 2016).
- EEA (2011). Earnings, jobs and innovation: the role of recycling in a green economy, EEA Report No 8/2011 (<http://www.eea.europa.eu/publications/earnings-jobs-and-innovation-the>, accessed 10 June 2016).
- EEA (2015). European Environment Agency. The European environment — state and outlook

- 2015 (SOER 2015) [web site]. (<http://www.eea.europa.eu/soer>; accessed 10 June 2016).
- ETC/SCP (2014). Municipal solid waste management capacities in Europe, ETC/SCP Working Paper No 8/2014, European Topic Center on Sustainable Consumption and Production. (http://scp.eionet.europa.eu/publications/wp2014_8/wp/wp2014_8, accessed 10 June 2016).
- Fantini F, Porta D, Fano V, De Felip E, Senofonte O, Abballe A, D'Ilio S, Ingelido AM, Mataloni F, Narduzzi S, Blasetti F, Forastiere F (2012). [Epidemiologic studies on the health status of the population living in the Sacco River Valley]. *Epidemiol Prev* 36 (5) suppl 4: 44-52. Italian
- Fazzo L, Minichilli F, Pirastu R, Bellino M, Falleni F, Comba P, Bianchi F (2014). A meta-analysis of mortality data in Italian contaminated sites with industrial waste landfills or illegal dumps. *Ann Ist Super Sanita*; 50(3):278-285. doi: 10.4415/ANN_14_03_10.
- Floret N, Mauny F, Challier B, Cahn YJ, Tourneux F, Viel JF (2004). [Dioxin emissions and soft-tissue sarcoma: results of a population-based case-control study]. *Rev Epidemiol Sante Publique*; 52(3):213-20 (<http://www.ncbi.nlm.nih.gov/pubmed/15356435>, accessed 2 May 2016). French
- Forastiere F, Badaloni C, de Hoogh K von Kraus MK, Martuzzi M, Mitis F et al. (2011). Health impact assessment of waste management facilities in three European countries. *Environ Health*; 10:53. doi:10.1186/1476-069X-10-53.
- Franchini M, Rial R, Buiatti E, Bianchi F (2004). Health effects of exposure to waste incinerator emissions:a review of epidemiological studies. *Ann Ist Super Sanita*; 40(1):101-15 (<http://www.ncbi.nlm.nih.gov/pubmed/15269458>, accessed 2 May 2016).
- Garcia-Perez J, Fernandez-Navarro P, Castello A, Lòpez-Cima MF, Ramis R, Boldo E, Lòpez-Abente G (2013). Cancer mortality in towns in the vicinity of incinerators and installations for the recovery or disposal of hazardous waste. *Environ Int*; 51:31-44. doi: 10.1016/j.envint.2012.10.003.
- Gensburg LJ, Pantea C, Kielb C, Fitzgerald E, Stark A, Kim N (2009). Cancer Incidence among Former Love Canal Residents. *Environ Health Perspect*; 117:1265-1271. doi:10.1289/ehp.0800153.
- Gensburg LJ, Pantes C, Fitzgerald E, Stark A, Hwang SA, Kim N (2009). Mortality among former Love Canal Residents. *Environ Health Perspect*; 117 (2):209-216. doi: 10.1289/ehp.11350
- Giusti L (2009). A review of waste management practices and their impact on human health. *Waste Manag*; 29(8):2227-39. doi:10.1016/j.wasman.2009.03.028.
- Golini MN, Ancona C, Badaloni C, Bolignano A, Bucci S, Sozzi R et al. (2014). Stato di salute della popolazione residente nei pressi dei termovalorizzatori del Lazio: uno studio di coorte retrospettivo con approccio pre-post [Morbidity in a population living close to urban waste incinerator plants in Lazio Region (Central Italy): a retrospective cohort study using a before-after design]. *Epidemiol Prev*; 38(5):323-34 (<http://www.ncbi.nlm.nih.gov/pubmed/25387747>, accessed 2 May 2016).
- Gouveia N, do Prado RR (2010a). Health risks in areas close to urban solid waste landfill sites. *Rev Saude Publica*; 44(5):859-66.
- Gouveia N, do Prado RR (2010b). Análise espacial dos riscos à saúde associados à incineração de resíduos sólidos: avaliação preliminar [Spatial analysis of the health risks associated with solid waste incineration: a preliminary analysis]. *Rev Bras Epidemiol*; 13(1). <http://dx.doi.org/10.1590/S1415-790X2010000100001>. Portuguese.
- Heaney CD, Wing S, Campbell RL, Caldwell D, Hopkins B, Richardson D et al. (2011). Relation between malodor, ambient hydrogen sulfide, and health in a community bordering a landfill. *Environ Res*; 111(6):847-52. doi:10.1016/j.envres.2011.05.021.
- Huang X, Lessner L, Carpenter DO (2006). Exposure to persistent organic pollutants and hypertensive disease. *Environ Res*; 102(1):101-106. DOI: 10.1016/j.envres.2005.12.011.

- Hu SW, Shy (2001). Health effects of waste incineration: a review of epidemiologic studies. *J Air Waste Manag Assoc*; 51(7):1100–1109 (<http://www.ncbi.nlm.nih.gov/pubmed/15658227>, accessed 2 May 2016).
- Jarup L, Briggs D, de Hoogh C, Morris S, Hurt C, Lewin A et al. (2002). Cancer risks in populations living near landfill sites in Great Britain. *Br J Cancer*; 86(11):1732–36. doi:10.1038/sj.bjc.6600311.
- Kouznetsova M, Huang X, Ma J, Lessner L, Carpenter DO (2007). Increased Rate of Hospitalization for Diabetes and Residential Proximity of Hazardous Waste Sites. *Environ Health Perspect*; 115:75–79. doi:10.1289/ehp.9223.
- Kudyakov R, Baibergenova A, Zdeb M, Carpenter DO (2004). Respiratory disease in relation to patient residence near to hazardous waste sites. *Environ Toxicol Pharmacol.*;18(3):249-57. doi: 10.1016/j.etap.2004.06.005.
- Landrigan PJ, Wright RO, Cordero JF, Eaton DL, Goldstein BD, Henning B, Maier RM, Ozonoff DM, Smith MT, Tukey RH (2015). The NIEHS Superfund research Program: 25 years of translational research for public health. *Environ Health Perspect*; 123(10):909—918. doi: 10.1289/ehp.1409247.
- Lin YS, Kupper LL, Rappaport SM (2005). Air samples versus biomarkers for epidemiology. *Occup Environ Med*;62:750–60. doi: 10.1136/oem.2004.013102
- Lin CM, Li CY, Mao IF (2006). Birth outcomes of infants born in areas with elevated ambient exposure to incinerator generated PCDD/Fs. *Environ Int*; 32(5):624–29. doi:10.1016/j.envint.2006.02.003.
- Ma J, Kouznetsova M, Lessner L, Carpenter DO (2007). Asthma and infectious respiratory disease in children – correlation to residence near hazardous waste sites. *Paed Resp Review*;8:292-298. doi: 10.1016/j.prrv.2007.07.009.
- Marsili D, Fazzo L, Comba P (2009). Health risk from hazardous waste disposal: the need for international scientific cooperation. *Eur J Oncol*; 14(3):151-159.
- Martuzzi M, Mitis F, Bianchi F, Minichilli F, Comba P, Fazzo L (2009). Cancer mortality and congenital anomalies in a region of Italy with intense environmental pressure due to waste. *Occup. Environ. Med.*;66;725-732; doi:10.1136/oem.2008.044115.
- Martuzzi M, Mitis F, Forastiere F (2010). Inequalities, inequities, environmental justice in waste management and health. *Eur J Public Health*; 20(1):21–26. doi:10.1093/eurpub/ckp216.
- Mataloni F, Badaloni C, Golini MN, Bolignano A, Bucci S, Sozzi R et al. (2016). Morbidity and mortality of people who live close to municipal waste landfills: a multisite cohort study. *Int J Epidemiol.* 2016 May 24. doi: 10.1093/ije/dyw052
- Mattiello A, Chiodini P, Bianco E, Forgione N, Flammia I, Gallo C et al. (2013). Health effects associated with the disposal of solid waste in landfills and incinerators in populations living in surrounding areas: a systematic review. *International Journal of Public Health*; 58(5):725–35. doi:10.1007/s00038-013-0496-8.
- OECD (2001), Extended Producer Responsibility: A Guidance Manual for Governments, OECD (http://www.oecd-ilibrary.org/environment/extended-producer-responsibility_9789264189867-en, last update 10 June 2016)
- Pasetto R, Ranzi A, De Togni A, Ferretti S, Pasetti P, Angelini P, Comba P (2013). Cohort study of residents of a district with soil and groundwater industrial waste contamination. *Ann Ist Super Sanita*; 49(4):354-357. doi 10.4415/ANN_13_04_06.
- Porta D, Milani S, Lazzarino AI, Perucci CA, Forastiere F (2009). Systematic review of epidemiological studies on health effects associated with management of solid waste. *Environ Health*; 8:60. doi:10.1186/1476-069X-8-60.
- Pukkala E, Ponka A (2001). Increased Incidence of Cancer and Asthma in Houses Built on a Former Dump Area. *Environ Health Perspect*; 109:1121–1125.

- Pukkala E (2014). A follow-up of cancer incidence among former Finnish dump site residents: 1999-2011. *Int J Occup Environ Health*; 20(4): 313-318. doi: 10.1179/2049396714Y.0000000080.
- Ranzi A, Fano V, Ersamer L, Lauriola P, Perucci CA, Forastiere F (2011). Mortality and morbidity among people living close to incinerators: a cohort study based on dispersion modeling for exposure assessment. *Environ Health*; 10:22. doi:10.1186/1476-069X-10-22.
- Ranzi A, Ancona C, Angelini P, Badaloni C, Cernigliaro A, Chiusolo M et al. (2014) [Health impact assessment of policies for municipal solid waste management: findings of the SESPIR Project] *Epidemiol Prev*;38(5):313-322; Italian
- Rushton L (2003). Health hazards and waste management. *Br Med Bull*; 68(1):183-97. doi:10.1093/bmb/ldg034.
- Russi MB, Borak JB, Cullen MR (2008). An examination of cancer epidemiology studies among populations living close to toxic waste sites. *Environ Health*; 7:32. doi:10.1186/1476-069X-7-32.
- Sergeev AV, Carpenter DO (2005): Hospitalization rates for coronary heart disease in relation to residence near areas contaminated with persistent organic pollutants and other pollutants. *Environ Health Perspect*; 113(6):756-761.
- Tiembre I, Koné BA, Dongo K, Tanner M, Zinsstag J, Cissé G. [Epidemiologic and clinical aspects of toxic waste poisoning in Abidjan] (2009) *Santé*;19(4):189-94. doi: 10.1684/san.2009.0163. French.
- US EPA (2005). Landfill Gas Emissions Model (LandGEM) Version 3.02 User's Guide. Research Triangle Park, NC: United States Environmental Protection Agency (<https://www3.epa.gov/ttncatc1/dir1/landgem-v302-guide.pdf>, accessed 2 May 2016).
- Viel JF, Arveux P, Baverel J, Cahn JY (2000). Soft-tissue sarcoma and non-Hodgkin's lymphoma clusters around a municipal solid waste incinerator with high dioxin emission levels. *Am J Epidemiol*; 152(1):13-19. (<http://www.ncbi.nlm.nih.gov/pubmed/10901325>, accessed 2 May 2016).
- Viel JF, Clément MC, Hägi M, Grandjean S, Challier B, Danzon A (2008). Dioxin emissions from a municipal solid waste incinerator and risk of invasive breast cancer: a population-based case-control study with GIS-derived exposure. *Int J Health Geogr*; 7: 4. doi:10.1186/1476-072X-7-4.
- Vrijheid M (2000). Health effects of residence near hazardous waste landfill sites: a review of epidemiologic literature. *Environ Health Perspect*; 108(Suppl 1):101-12 (<http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1637771/?tool=pmcentrez>; accessed 2 May 2016).
- WHO Regional Office for Europe (2007). Population health and waste management: scientific data and policy options. Copenhagen: WHO Regional Office for Europe (http://www.euro.who.int/__data/assets/pdf_file/0012/91101/E91021.pdf, accessed 2 May 2016).
- Zambon P, Ricci P, Bovo E, Casula A, Gattolin M, Fiore AR et al. (2007). Sarcoma risk and dioxin emissions from incinerators and industrial plants: a population-based case-control study (Italy). *Environ Health*; 6:19. doi:10.1186/1476-069X-6-19.

Annex 1

Guidance documents and other support actions for implementation of EU waste legislation

Waste Framework Directive (WFD)

Guidance document on the interpretation of key provisions of the Waste Framework Directive: http://ec.europa.eu/environment/waste/framework/pdf/guidance_doc.pdf.

Guidelines on the practical application of the R1 energy efficiency formula: <http://ec.europa.eu/environment/waste/framework/energy.htm>

Guidance document on permitting and inspections, accompanied by a practical manual with best practice examples: <http://ec.europa.eu/environment/waste/framework/inspections.htm>

Guidelines on how to prepare a waste management plans: <http://ec.europa.eu/environment/waste/plans/index.htm>

Guidelines on how to prepare waste prevention programmes: <http://ec.europa.eu/environment/waste/prevention/index.htm>

Guidance on the issue of waste and by-products: <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52007DC0059>

Mining Waste

In accordance with Article 22(1) of the Directive, the Commission has adopted by Comitology the following implementing measures:

1. [Commission Decision 2009/337/EC on the Criteria for the classification of waste facilities in accordance with Annex III](#), adopted on 20/04/09, published on 22/04/09 (L 102, page 7)
2. [Commission Decision 2009/335/EC on the Technical guidelines for the establishment of the financial guarantee](#), adopted on 20/04/09, published on 21/04/09 (L 101, page 25)
3. [Commission Decision 2009/360/EC completing the technical requirements for waste characterization](#), adopted on 30/04/09, published on 1/05/09 (L 110, page 48)

The Commission has also adopted the [reference document on the best available techniques on the management of waste from extractive industries](#)

WEEE/RoHS

FAQ document on the WEEE Directive:

<http://ec.europa.eu/environment/waste/weee/pdf/faq.pdf>

FAQ document on the main provisions of the new RoHS Directive (RoHS 2):

http://ec.europa.eu/environment/waste/rohs_eee/pdf/faq.pdf

ELV Directive

Guidance Document on Directive 2000/53/EC on end-of life vehicles:
http://ec.europa.eu/environment/waste/pdf/guidance_doc.pdf

The Waste Shipment Regulation

The Waste Shipment Correspondents established pursuant to Article 54 of Regulation (EC) No 1013/2006 on shipments of waste have agreed on a number of non-legally binding guidelines which represent their common understanding of how the Regulation should be interpreted. These guidelines are listed on DG Environment's web site, see
<http://ec.europa.eu/environment/waste/shipments/guidance.htm>
Frequently asked questions, <http://ec.europa.eu/environment/waste/shipments/pdf/faq.pdf>.

BREFs on best available techniques

<http://eippcb.jrc.ec.europa.eu/reference/>

More information on EU waste policy and legislation

<http://ec.europa.eu/environment/waste/index.htm>,
<http://ec.europa.eu/environment/waste/pdf/WASTE%20BROCHURE.pdf>

Annex 2: Meeting programme

Thursday, 5 November 2015

09:00 – 09:30	<i>Registration and welcome coffee</i>
09:30 – 10:00	Welcome, introduction to the meeting and “tour de table” (E Paunovic) Appointment of chairperson and rapporteur Update on the European Environment and Health Process (S Matic) (Agenda items 1–2)
10:00 – 11:00	Goals of the meeting (M Martuzzi) Trends and policies in waste management in Europe (Agenda items 3, 4, 7) EU Policy and legislation on waste: developments and reflections for the future (P Wessman) Non-EU and global perspectives (A Mihajlov) Waste policies and trends I (A Jaron)
11:30 – 13:00	The Basel Convention (M Kern) Waste policies and trends II (I Déportes) Health care waste– One seventh of the journey to a circular economy (L Owen) The sustainable development agenda (B Menne) Discussion points: <ul style="list-style-type: none">- What are the main current trends in waste management policies?- What are the most likely needs and challenges in the short- and long-term?- What types of waste are of higher priority (urban, hazardous, e-waste, etc.)?- What policy actions are available to different Member States?- What are the equity implications?
14:00 – 15:30	Health effects and health impacts of waste: evidence and case studies (Agenda items 5, 6, 10) Introduction (P Comba) Health effects of municipal waste (A Ranzi) Health effects of hazardous waste (L Fazzo) Case study (C Ancona)

16:00 – 17:30	Case studies, views from REC (E Csobod) Case study (D Sarigiannis) Case study (J Dubnov) Case studies, views from the United States, wrapping up the evidence (D Carpenter) Discussion points: <ul style="list-style-type: none"> - What is the overall strength of the evidence? - What are the most important knowledge gaps? - What kind of studies/assessments are likely to be most informative, with reference with available policy options?
---------------	---

Friday, 6 November 2015

09:00 – 09:30	Sum-up and conclusions of 1 st day
09:30 – 10:45	Assessing health effects and impacts: methods and strategies (Agenda items 8, 9, 11) Ecological public health – application to waste (G Morris) Waste and cancer (K Straif) Exposome (D Sarigiannis)
11:15 – 13:00	Small area studies (D Fecht) Burden of disease (A Ranzi) The economic dimension (tbi) Participatory HIA (A Buroni) Discussion points: <ul style="list-style-type: none"> - How to best frame the question of waste and health? - What are the most promising approaches? - Is an overall European assessment feasible? - What data flows exist that can be used?
14:00 – 16:00	The way forward: needs, opportunities, partnerships (Agenda items 11, 12, 13) Collaboration with COST Action (I Iavarone) Discussion points: <ul style="list-style-type: none"> - Opportunities for partnerships and fundraising - Preparation of meeting report - Way forward Close of meeting

Annex 3: List of participants

Temporary advisers

Carla Ancona
Senior Epidemiologist
Lazio Regional Health Service
Rome, Italy

Andrew Buroni
Associate
Health and Social Impact Assessment Practice
Lead
RPS Planning & Development
Brighton, United Kingdom of Great
Britain and Northern Ireland

David O. Carpenter
Director, Institute for Health and the
Environment
University at Albany
Rensselaer, NY, United States of
America

Pietro Comba
Head, Environmental Epidemiology Unit
Environment and Primary Prevention Dept.
National Institute of Health (ISS)
Rome, Italy

Eva Csobod
Topic area leader, Health and Environment
Regional Environmental Center
for Central and Eastern Europe (REC)
Szentendre, Hungary

Isabelle Déportes
Sanitary and environmental impacts
assessment
Waste mobilization and valorization
department
The French Environment and Energy
Management
Agency (ADEME)
Angers, France

Jonathan Dubnov
Deputy District Health Officer
Haifa District Health Office
Ministry of Health
Haifa, Israel

Lucia Fazzo
Researcher, Environmental Epidemiology Unit
Environment and Primary Prevention Dept.
National Institute of Health (ISS)
Rome, Italy

Daniela Fecht
Research Associate
Department of Epidemiology and Biostatistics
Imperial College London
London, United Kingdom of Great Britain and
Northern Ireland

Ivano Iavarone
Head, WHO Collaborating Centre for
Environmental Health in Contaminated Sites
National Institute of Health (ISS)
Rome, Italy

Andreas Jaron
Head of Division
WR II 1 "General, Principal and International
Matters of Circular Economy, Transboundary
Movement of Waste"
Federal Ministry for the Environment, Nature
Conservation, Building and Nuclear Safety
(BMUB)
Bonn, Germany

Andjelka Mihajlov
Researcher/Professor
Environmental Ambassadors for Sustainable
Development
University of Novi Sad
Belgrade, Serbia

George Morris
Honorary Visiting Professor
University of Exeter, School of Medicine
European Centre for Environment and Human
Health
Truro, United Kingdom of Great Britain and
Northern Ireland

Laura Owen
Manager, Sustainable Resource
Head of Sustainability
Policy Connect
London, United Kingdom of Great Britain and
Northern Ireland

Andrea Ranzi
Project Manager
Regional Centre for Environment and health
Regional Agency for Prevention, Environment
and Energy of Emilia-Romagna region
Modena, Italy

Dimosthenis Sarigiannis
Associate Professor, Director
Environmental Engineering Laboratory
Aristotle University of Thessaloniki
Thessaloniki, Greece

Representatives of other organizations

European Commission

Peter Wessman
Legal Officer/Team leader
International coordination
A2 – Waste Management & Recycling
Directorate-General for Environment
Brussels, Belgium

United Nations Environment Programme

Matthias Kern
Senior Programme Officer
Technical Assistance Branch
Secretariat of the Basel, Rotterdam and
Stockholm Conventions
Geneva, Switzerland

World Health Organization

Regional Office for Europe

Maria Dunbar
Intern, Environment and Health Intelligence
and Forecasting
WHO European Centre for Environment and
Health
Bonn, Germany

Shinee Enkhtsetseg
Technical Officer, Water and Sanitation
WHO European Centre for Environment and
Health
Bonn, Germany

Marco Martuzzi
Programme Manager, Environment and
Health Intelligence and Forecasting
WHO European Centre for Environment and
Health
Bonn, Germany

Srđan Matić
Coordinator, Environment and Health
WHO Regional Office for Europe
Copenhagen, Denmark

Bettina Menne
Programme Manager, Climate Change, Green
Health Services and Sustainable Environment
WHO European Centre for Environment and
Health
Bonn, Germany

Julia Nowacki
Technical Officer, Environment and Health
Intelligence and Forecasting
WHO European Centre for Environment and
Health
Bonn, Germany

Elizabet Paunović
Head of Office
WHO European Centre for Environment and
Health
Bonn, Germany

International Agency for Research on Cancer (IARC)

Kurt Straif
Head, IARC Monographs
Lyon, France