

# WASTED HEALTH THE TRAGIC CASE OF DUMPSITES

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# A MESSAGE FROM ISWA PRESIDENT

## Foreword

Health of populations and then the environment were always driving forces behind waste management from the very earliest times as the nexus between clean urban metabolisms and waste became clear. Today, most economically advanced countries can boast that waste collection and treatment poses little or no health risk to their populations. This has taken us decades and billions in expenditure ( dollars, pounds, euros) to achieve , but is an achievement waste managers can be justifiably proud of.

The situation in less economically developed nations is often entirely the contrary, and this report highlights the disastrous position in which many nations and their populations today find themselves through uncontrolled dumping of waste. It really is not recommended reading for the faint hearted !

The recommendations of this report are clear: the international community has an urgent task ahead in closing waste dumps globally, for the sake of populations affected by them because they live in or near them, but also because all the world's people are breathing in the toxins released by burning on open dumps. And the greenhouse gas emissions involved are huge too, and unless we act, the growth of open dumping is inevitable.

ISWA and its experts are willing to take part in this global clean up and will, with other interested parties, collaborate on drawing attention to the damage caused to human health through poor waste management practices. There is no time to lose on this issue.

I thank the authors of this report for their detailed work on this report.



David Newman  
ISWA President

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# KEY-MESSAGES

Dumpsites are a global problem. They receive roughly 40% of the world's waste and they serve about 3.5-4 billion people. The 50 biggest dumpsites affect the daily lives of 64 million people, a population the size of France. As urbanization and population growth will continue, it is expected that at least several hundreds of millions more people will be served by dumpsites, mainly in the developing world.

Although there is a lack of systematic long-term epidemiological studies that fully document the health impacts from dumpsites, the existing scientific evidence demonstrates very important health risks.

The health problems associated with dumpsites are related to their emissions, which usually involve POPs (persistent organic pollutants), heavy metals and VOCs (volatile organic compounds). The actual health risks depend on the practices followed and on the type of the waste disposed of in each dumpsite, as well as on the environmental and social conditions of the area.

Open burning and animal feeding increase the health risks substantially, the first by direct emissions of dangerous pollutants and the second by transferring the pollutants to the food chain.

Uncontrolled disposal of hazardous and healthcare waste as well as manual on-site treatment and disposal of e-waste by informal workers result in important increases of all the health risks and the negative environmental impacts.

ISWA calls upon international organizations, governments and local authorities to develop emergency programs that will identify the riskiest dumpsites and proceed with their closure. ISWA considers the closure of the dumpsites as a global health emergency and it will work closely with all the involved stakeholders to accelerate programs, initiatives and investments that will result in a world free of dumpsites.



# INTRODUCTION

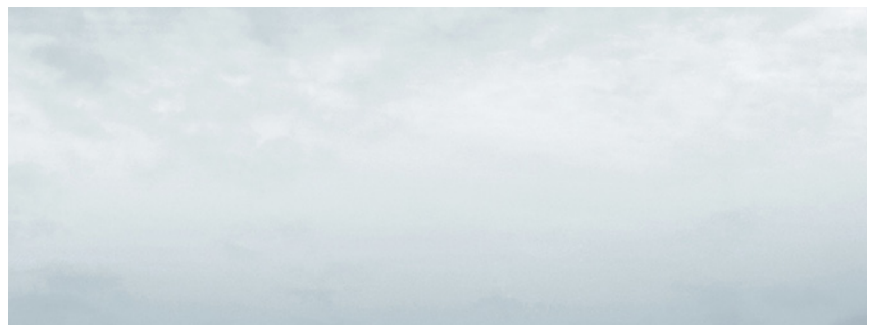
The purpose of this report is to highlight the severe health risks that are posed by dumpsites to tens of millions of people. Since people exposed to dumpsite risks will continue to grow, due to rapid urbanization and the lack of sound waste management systems in the developing world, the closure of dumpsites should be considered a global health emergency. International organizations, governments and local authorities should develop appropriate plans that will gradually substitute dumpsites by better-controlled and less impacting infrastructure.

The report starts with facts and figures regarding dumpsites in the modern world. Then a conceptual framework for dumpsites is presented and their main characteristics are discussed.

The main part of the report presents the scientific evidence for health risks from dumpsites, the impacts on workers, informal recyclers and nearby residents and the factors affecting the extent of those impacts. A note on the economic valuation of the health impacts is also included in order to highlight the importance and the difficulties involved in such an analysis.

Finally, the report closes with some conclusions and recommendations for further research.

The report is part of ISWA's Scientific and Technical Committee work-program 2014-2015.



# 1. AN OLD PROBLEM BECOMES A GLOBAL CHALLENGE

Disposal through open dumping with open burning was the norm in most developing countries until the turn of the 21<sup>st</sup> century. This practice has led to creation of dumpsites posing significant risks to neighboring communities and the environment. Open dumping practices are still being practiced, as the dominant method, in both low-income and upper middle-income countries. The practice tends to be eliminated in the developed world, although there are still reports of illegal dumpsites<sup>1,2</sup>. Recent reports indicate that roughly 3.5 - 4 billion people are served by dumpsites where 40% of the total waste generated is disposed of<sup>3,4</sup>. The geographical distribution of population without access to regular collection and sound disposal of waste is presented in Figure 1.

% of population in developing countries without access to minimum waste management service

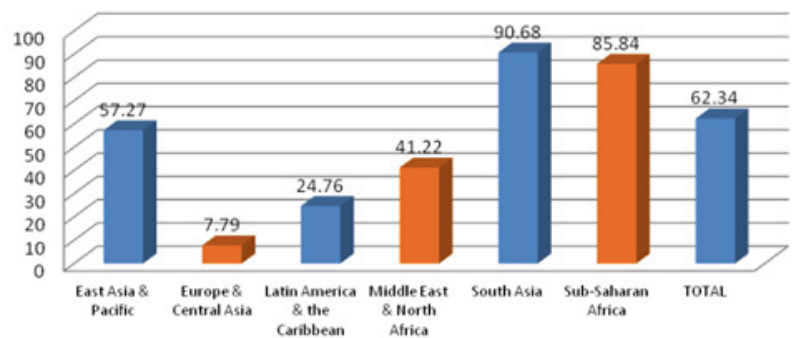


Figure 1: Percentage of population in developing countries without access to regular collection and sound disposal of solid waste -the term TOTAL refers to the percentage of population of all developing countries<sup>4</sup>

Waste Atlas 2014 report lists the world's 50 biggest dumpsites and highlights their environmental and health impacts<sup>5</sup>. According to the estimates provided, those 50 dumpsites affect the lives of 64 million people (a population the size of France) and they host on-site more than 50,000 informal sector recyclers.

Open dumping usually takes place close to the urban centers and in some cases residential areas are formed and expanded around the dumpsites. Almost all of the world's 50 biggest dumpsites<sup>5</sup> are located near or even within urban areas and close to natural resources. 42 out of the 50 dumpsites have settlements in a distance of less than 2 km, 44 dumpsites are close (less than 10 km) to natural resources and 38 dumpsites are close to water sources such as rivers, lakes, oceans, posing a threat to marine and coastal pollution. Obviously, although unquantified, the contribution of dumpsites to marine litter is substantial.

<sup>1</sup>European Court of Justice decisions for Italy and Greece available at <http://www.courthousenews.com/2014/12/02/eu-trashes-italy-and-greece-for-garbage-woes.htm>

<sup>2</sup>EUROPOL, Europol warns of increase in illegal waste dumping, 2011, available at <https://www.europol.europa.eu/content/press/europol-warns-increase-illegal-waste-dumping-1053>

<sup>3</sup>ISWA, Globalization and Waste Management, Phase 1, Concepts and Facts, 2012, available at <http://www.iswa.org/media/publications/knowledge-base/>

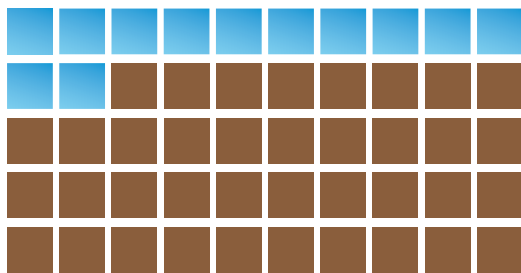
<sup>4</sup>D-WASTE, Waste management for everyone, 2013, available at <http://d-waste.com>

<sup>5</sup>WASTE ATLAS, The World's 50 Biggest Dumpsites, 2014 available at <http://www.atlas.d-waste.com>



Due to both the expected increase of population and the growing GNI/capita in the developing world, additional amounts of municipal, industrial and hazardous waste are entering into the waste streams every day. It has been estimated that globally, urban food waste is going to increase by 44% from 2005 to 2025<sup>6</sup>. If present waste management trends are maintained, dumped or landfilled food waste is predicted to increase the landfill share of global anthropogenic Greenhouse Gas emissions from 8 to 10%. Considering that there is a growing gap between progress in providing sanitation and the growth of urbanization<sup>7</sup>, it is almost certain that within the next 10-15 years much more waste will be driven to dumpsites and some additional hundreds of millions of people will be also served by dumpsites.

Dumpsites are receiving different waste streams including municipal waste, sewage sludge, hazardous waste, e-waste, healthcare waste etc. Many of them are the final destination of illegal hazardous waste shipping (waste-trafficking) which is estimated at a value of between \$10 and \$12 billion annually and generates very high revenues for the criminals involved in the trade<sup>8</sup>. As an example, the European Union, despite its legislation, is a major source of e-waste, which is illegally exported and dumped in developing countries, an estimated 75 per cent of e-waste generated in the EU<sup>9</sup>. Figure 2 summarizes the global dimensions of dumpsites.



38 out of the 50 biggest landfills pose a threat for marine and coastal pollution

With the business as usual scenario dumpsites will account for 8-10% of the global anthropogenic Greenhouse Gas emissions in 2025



\$10 - \$12 billion annually is the turnover of illegal waste shipping to dumpsites

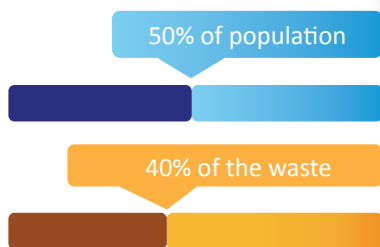


Figure 2: Dumpsites as a global challenge

<sup>6</sup>Adhikari, B. K. and Barrington, S. (2006) 'Predicted Growth of World Urban Food Waste and Methane Production', Waste Management & Research, vol.24, issue 5, pp. 421-433

<sup>7</sup>WHO & UNICEF, Progress on sanitation & Drinking Water, 2010 update

<sup>8</sup>ISWA, Globalization and Waste Management, Final report, available at <http://www.iswa.org/media/publications/knowledge-base/>

<sup>9</sup>UK Environmental Investigation Agency, System Failure, The UK's harmful trade in electronic waste, May 2011

## 2. DUMPSITES AND ENVIRONMENT

The term “open dump” is used to characterize a land disposal site where the indiscriminate deposit of solid waste takes place with either no - or at best - very limited measures to control the operation and to protect the surrounding environment<sup>10</sup>.

In addition, it is typical that no planning (such as location sensitivity) or engineering measures (such as a liner system) have been implemented prior to the delivery of waste. An open dump has nothing to do with a sanitary landfill. Sanitary landfill is an acceptable waste management method, with controlled emissions and limited health and environmental impacts, while open dumps are exactly the opposite. In between an open dump and a sanitary landfill there is a grey area usually named as “controlled dump” with varying levels of engineering and environmental controls. These vary from region to region and/or from nation to nation. In brief, the differences between open dumps, controlled dumps and sanitary landfills are presented below.

Table 1: Differences between open dumps, controlled dumps and sanitary landfills<sup>11</sup>

Criteria	Open Dump	Controlled Dump	Sanitary Landfill
Sitting Of Facility	Unplanned and often im-properly sited	Hydro geologic conditions considered	Site chosen is based on environmental, community and cost factors
Capacity	Site capacity is not known	Planned capacity	Planned capacity
Cell planning	There is no cell planning The waste is indiscriminately dumped The working face/area is not controlled	There is no cell planning, but the working face/area is minimized Disposal is only at designated areas	Designed cell by cell development The working face/area is confined to the smallest area practical Disposal is only at designated cells
Site preparation	Little or no site preparation	Grading of bottom of the disposal site Drainage and surface water control along periphery of the site	Extensive site preparation
Leachate management	No leachate management	Partial leachate management	Full leachate management
Gas management	No gas management	Partial or no gas management	Full gas management
Application of soil cover	Occasional or no covering of waste	Covering of waste implemented regularly but not necessary daily	Daily, intermediate and final soil cover applied
Compaction of waste	No compaction of waste	Compaction in some cases	Waste compaction
Access road maintenance	No proper maintenance of access road	Limited maintenance of access road	Full development and maintenance of access road
Fencing	No fence	With fencing	Secure fencing with gate
Waste inputs	No control over quantity and/or composition of incoming waste	Partial or no control of waste quantity, but Waste accepted for disposal is limited to MSW	Full control over quantity and composition of incoming waste Special provisions of special types of wastes
Record keeping	No record keeping	Basic record keeping	Complete record of waste volumes , types, sources and site activities/events
Waste picking	Waste picking by scavengers	Controlled waste picking and trading	No site waste picking and trading
Closure	No proper closure of site after cease of operations	Closure activities limited to covering with loose or partially compacted soil and replanting of vegetation	Full closure and post-closed management
Cost	Low initial cost, high long term cost	Low to moderate initial cost, high long term cost	Increased initial, operational and maintenance costs, moderate long term cost
Environmental and health impacts	High potential for fires and adverse environmental and health impacts	Lesser risk of adverse environmental and health impacts compared to an open dumpsite	Minimum risk of adverse environmental and health impacts

The health and environmental impacts of dumpsites are caused by the emissions from waste decomposition, namely leachate and biogas.

<sup>10</sup>ISWA, Sanitary Landfill Working Group, Key-Issue Paper on Closing of Open Dumps, 2006, available at <http://www.iswa.org/media/publications/knowledge-base/>

<sup>11</sup>UNEP, Training Module - Closing an Open Dumpsite and Shifting from Open Dumping to Controlled Dumping and to Sanitary Landfilling, 2005

Leachate is a liquid produced when wastes undergo decomposition, and when water (due to rainfall, surface drainage, groundwater, etc.) percolate through solid waste undergoing decomposition. As the water percolates downward, biological and chemical constituents of the waste leach into the solution. The percolating water may also mix with the liquid that is squeezed out of the waste due to the weight of the material. Thus, leachate is a liquid that contains dissolved and suspended materials that, if not properly controlled, may pass through the underlying soil and contaminate sources of drinking water, as well as surface water. The composition of leachate depends on the stage of degradation and the type of wastes within the disposal facility.

The decomposition of waste also brings about the generation of gases, mainly a mixture of methane and carbon dioxide (about 50-50% in anaerobic conditions), which is called biogas. As methane is formed, it builds up pressure and then begins to move through the soil, following the path of least resistance. Often it moves sideways for a time before breaking through to the surface. Methane is lighter than air and is highly flammable. If it enters a closed building and the concentration builds up to about 5 to 15% in the air, a spark or a flame is likely to cause a serious explosion. Aside from being a flammable gas, methane released to the atmosphere greatly contributes to the depletion of the ozone layer and to climate change since it has approximately 21 times the global warming potential of carbon dioxide, over a 100 year period<sup>12</sup>.

Soil pollution is another environmental problem caused by dumpsites. Waste carries different metals, which are then transferred to plants by different ways. Depending on the tendency of the contaminants, they end up either in water held in the soil or leached to the underground water. Contaminants like Cd, Cu, Ni, Pb and Zn can alter the soil chemistry and have an impact on the organisms and plants depending on the soil for nutrition<sup>13</sup>. Many studies show evidence of serious hazards caused by open waste dumping ultimately affecting the plants' life cycles<sup>14</sup>.



Waste in open dumps often becomes a breeding ground for vermin, flies, and other potential carriers of communicable diseases. Open dumpsites without daily soil cover can be also a source of odor, dust and litter.

When open burning of solid waste is practiced (a usual practice to reduce volume), it could result in the emission of toxic substances to the air from the burning of plastics and other materials. The toxic fumes usually increase the concentration of air pollutants such as nitrogen oxides (NOx), sulfur oxides (SOx), heavy metals (mercury, lead, chromium, cadmium, etc.), dioxins and furans, and particulate matter<sup>15</sup>.



<sup>12</sup>USA EPA, Overview of Greenhouse Gases, 2012 at <http://epa.gov/climatechange/ghgemissions/gases/ch4.html>

<sup>13</sup>D. Voutsas, A. Grimanis, C. Samara, Trace elements in vegetables grown in an industrial area in relation to soil and air particulate matter, *Environ. Pollut.*, 94 (1996), pp. 325–335

<sup>14</sup>Syeda Maria Ali et al, Open dumping of municipal solid waste and its hazardous impacts on soil and vegetation diversity at waste dumping sites of Islamabad city, *Journal of King Saud University - Science* Volume 26, Issue 1, January 2014, Pages 59–65

<sup>15</sup>Akpofure Rim-Rukeh, An Assessment of the Contribution of Municipal Solid Waste Dump Sites Fire to Atmospheric Pollution, *Open Journal of Air Pollution*, 2014, 3, 53-60

It is important to stress that the intensity of the environmental impacts posed by a dumpsite depends on a number of site-specific factors like the following:

- Location
- Geological / hydrogeological conditions
- Local climate
- Local flora and fauna
- Solid waste streams, composition and quantity
- Area covered by waste
- Years of operation
- Engineered controls in place

The different waste streams disposed of at dumpsites determine not only their environmental but their health impacts as well, as it will be discussed in the next chapter.

### Air pollution

Landfilled organic waste may contribute to the greenhouse effect via emissions of methane. Other types of gas emissions may contribute to the degrading of the ozone layer and/or may be toxic to scavengers or local populations.



### Uncontrolled burning

Open burning of solid waste (particularly certain types of plastics) releases smoke and gaseous contaminants into the air. The smoke commonly contains particulates, carbon monoxide and other contaminant gases including low levels of dioxins, all of which can be hazardous to health.

### Fauna

Fauna in and around dumpsites may be impacted either by direct consumption of the solid waste, or by consumption of contaminated plants and/or animals, or as a result of leachate effects on groundwater and surface water.



### Flora

Nearby plants can be impacted directly by the waste, dust or smoke from burning. The presence of dead vegetation is often associated with the zone of direct impact around dumpsites.



### Soil contamination

Many contaminants (especially heavy metals) are trapped in the soils beneath dumpsites, resulting in long term environmental contamination



### Surface and groundwater contamination

Contamination of water may occur when leachate from the dump, via flow paths (on or under the surface), reaches groundwater or surface water or via direct contact with water.



Figure 3: Interactions between a dumpsite and the environment

# 3. HEALTH RISKS BY DUMPSITES

## 3.1 Introduction

Several population studies document (scientifically) that dumpsites can have serious effects on the health and well-being of the population<sup>16</sup>. A wide range of toxic substances can be released into the environment from uncontrolled waste disposal, for example, methane, carbon dioxide, benzene and cadmium. Many of these pollutants have been shown to be toxic for human health. The International Agency for Research on Cancer<sup>17</sup> classifies exposure to cadmium and benzene as highly carcinogenic for humans. In addition, dumpsites are likely to contain highly hazardous compounds resulting from industrial production, for example asbestos and lead. Previous epidemiological studies have found that two main health outcomes – cancer and congenital malformations – are statistically associated with waste exposure in dumpsites.

But before going into the details, the conceptual framework that describes the health risks and impacts associated with dumpsites needs to be outlined. Understanding this conceptual framework is necessary in order to put all the other elements in their right place. The health impacts related to dumpsites are directly linked to the types of the different waste streams that are disposed of. Different waste streams involve different health and safety risks. Besides municipal waste, hazardous waste, health-care waste and e-waste are going to be discussed.

Dumpsites' on-site activities might increase or decrease the related health risks. Uncontrolled scavenging and open burning of waste, either for volume reduction or for metal recovery, are two of the most usual causes for increased health risks. Occupational health risks and impacts to workers and informal sector recyclers (ISR) within dumpsites will be addressed, as this is a key-issue for a big part of the world and an important component of the on-going research.



<sup>16</sup>Carla Guerriero and John Cairns, The potential monetary benefits of reclaiming hazardous waste sites in the Campania region: an economic evaluation, *Environmental Health* 2009, 8:28 doi:10.1186/1476-069X-8-28

<sup>17</sup>IARC: Monographs on the Evaluation of Carcinogen Risks to 29. Humans. Beryllium, Cadmium, Mercury and the Glass Manufacturing Industry. Volume 58. Lyon: International Agency for 30. Research on Cancer; 1993.

## 3.2 Conceptual framework

The health risks and impacts from dumpsites are associated with some of the pollutants (or hazardous substances) that are found in waste streams or with pollutants that are created at the dumpsite through physical-chemical interactions.

In general terms, pollutants can move through air, soil and water. They can also settle on or digested by plants or animals, and can get into the air, the food chain and the water. The different ways a person can come into contact with pollutants are called exposure pathways. There are three basic exposure pathways: inhalation, ingestion, and skin contact. Inhalation is breathing or inhaling into the lungs. Ingestion is taking something in by mouth. Skin contact occurs when something comes in direct contact with the skin. Ingestion can be a secondary exposure pathway after skin contact has occurred.

Exposures can be either acute or chronic. An acute exposure is a single exposure to a hazardous substance (pollutant) for a short time. Health symptoms may appear immediately after exposure; for example, a burn when exposed to a strong acid such as from a leaking battery.

Chronic exposure occurs over a much longer period of time, usually with repeated exposure in smaller amounts. For example, people who lived near Love Canal<sup>18</sup>, a leaking hazardous waste dump, did not notice the health effects of their chronic exposure for several years. Chronic health effects are typically illnesses or injuries that take a long time to develop, such as cancer, liver failure, or stunted growth and development. One reason chronic exposure to even tiny amounts of hazardous substances can lead to harm is bioaccumulation. Some substances are absorbed and stay in human bodies rather than being excreted. They accumulate and cause harm over time.

Adverse health effects depend upon the factors of exposure. Factors that play a part in whether or not adverse health effects may result from an exposure are:

- The type of pollutant;
- The amount or dosage (the amount or level of a pollutant a person was exposed to);
- The duration (how long did exposure occur);
- The frequency (how many times the person was exposed).


Consequently, any effort to associate dumpsites with health risks and impacts will certainly involve evaluation of the following parameters<sup>19</sup>:

- Mass rate of release of both waterborne and airborne pollutants.
- Areal extent of contamination, and persistence and transformation of the pollutants and their transformation consequent products.
- Concentrations and gradients of those pollutants that adversely impact air, water and land resources.
- Number of people and especially sensitive populations that could be influenced by the release of pollutants from the site.
- Total period of time over which pollutant release occurs.
- Duration of exposure.
- Synergistic and antagonistic impacts of other pollutant releases or adverse health conditions that might cause an exposed population to be more susceptible to pollutants derived from the site.
- Characteristics of the site such as the depth of solid waste and degree of compaction.
- Characteristics of the wastes accepted by the site owner/operator during the dumpsites' active life.
- Size of the site as defined by the total amount of solid waste disposed of and the areal coverage.



<sup>18</sup>Goldman LR et al. (1985). Low birth weight, prematurity and birth defects in children living near the hazardous waste site, Love Canal. *Hazardous Waste and Hazardous Materials*, 2:209-223.

<sup>19</sup> Kurian Joseph et al, A decision making tool for dumpsite rehabilitation in developing countries, Proc. Sardinia, Tenth International Waste Management and Landfill Symposium. Cagliari, Italy, October 2005



The whole process of assessing the health risks and impacts of a dumpsite is really difficult and requires high expertise, time and financial resources in order to be completed. Its successful implementation requires us to manage the non-availability of specific data on the dose response relationship for some of the chemicals of concern and to make a number of informed assumptions and interpretations.

For a better understanding of what is more or less required, it is useful to outline the study that UNEP implemented regarding the public health impacts of the Dandora dumpsite in Nairobi, Kenya<sup>20</sup>.

For the implementation of the study, environmental samples (soil and water) were analyzed to determine the content and concentrations of various pollutants (heavy metals, polychlorinated biphenyls and pesticides) that are known to affect human health. Soil samples from the dumpsite were compared to samples taken from another site, which is a peri-urban residential area on the outskirts of Nairobi. A medical camp, located next to the dumpsite, was also set up. A total of 328 children and adolescents living and schooling adjacent to the dumpsite were examined and treated for various ailments. Of these, 40 were referred for further laboratory tests that entailed blood and urine sampling to assess the impact of exposure to environmental pollutants from the dumpsite on human health.

Below, the flow chart of the study shows the link between the environmental pollutants from the dumpsite and public health impacts on the adjacent communities. This flow chart is characteristic for any similar analysis and describes the conceptual framework between health and dumpsites.

The waste streams disposed of at a dumpsite are one of the most important factors that determine its health risks. Besides municipal waste, healthcare waste, hazardous and e-waste are common streams found in dumpsites. The problem is that in most dumpsites all the previous waste streams are usually present in unknown quantities and with roughly unknown interactions.



<sup>20</sup> UNEP, Environmental Pollution and Impacts on Public Health: Implications of the Dandora Municipal Dumping Site in Nairobi, Kenya, 2007

Flow Chart of the Public Health Effects brought about by Environmental Pollution emanating from Dandora Waste Dumping Site<sup>21</sup>

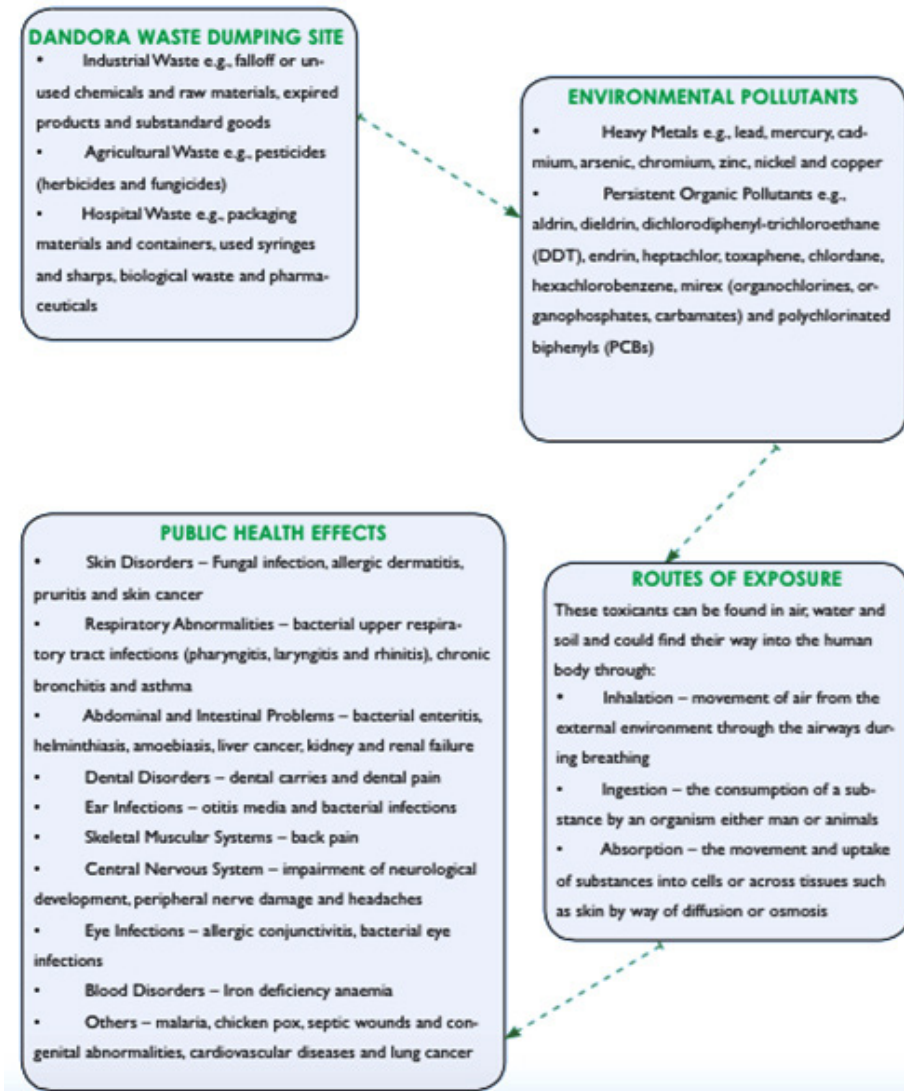


Figure 4: The flow chart of the Dandora study<sup>21</sup> shows the conceptual framework for health & dumpsites

<sup>21</sup> UNEP, Environmental Pollution and Impacts on Public Health: Implications of the Dandora Municipal Dumping Site in Nairobi, Kenya, Summary Report, 2007



### 3.3 Municipal waste

Organic wastes in dumpsites are biodegraded and thus they create conditions favorable for the survival and growth of microbial pathogens. These conditions can be further enhanced if the waste is disposed of with pathogens from human body fluids such as faeces, urine, blood and sputum. All are present in typical municipal waste through nappies, sanitary pads and the general discards from vomiting and human secretions. Organic wastes also provide a food source for carriers of enteric pathogens such as rodents, insects, birds and larger wild mammals. Subsequently, the diffuse airborne emissions from biologically and chemically decomposing municipal solid wastes at dumpsites are clearly a health risk. Decomposition of organic fraction in dumpsites results in the generation of gases and contributes to leachate formation. Thus the main sources of pollutant emissions from a dumpsite are as follows:

- a. The wastes as they are brought onto site, normally in heavy vehicles,
- b. Emissions from transport and bulldozers, compactors etc.
- c. Waste blown by the wind as it is tipped or deposited at the dumpsite,
- d. Dust generated from the surface of the dumpsite and when waste is tipped or unloaded,
- e. Historical waste that have been already disposed off,
- f. Any gas generated as the waste decomposes (if not collected and treated),
- g. Any leachate produced as the waste decomposes
- h. The discharges from any processes used to treat the leachate (if any at all).

While in modern sanitary landfills all those emissions are eliminated or under complete control (due to the use of advanced environmental protection measures like liners, top covers, biogas and leachate management system, continuous monitoring), in dumpsites those emissions are uncontrolled and they are actually associated with serious health hazards.

The main pollutants associated with health risks in dumpsites are the following .:

#### Persistent Organic Pollutants

POPs, such as dioxins and furans (PCDDs and PCDFs) are persistent non-biodegradable organic compounds produced through uncontrolled burning of waste, natural generation of methane gas and low temperature burning of waste to recover metals. POPs trigger a biological response in humans that results in neurological, immunologic and reproductive problems<sup>22</sup>. POPs have been also considered responsible for respiratory disorders<sup>23</sup>, and elevated cancer risk<sup>24</sup>.



<sup>22</sup> S.S. White and L.S. Birnbaum, An Overview of the Effects of Dioxins and Dioxin-Like Compounds on Vertebrates, as Documented in Human and Ecological Epidemiology, Journal of Environmental Science and Health, Part C., 2009, 27(4), 197-211p

<sup>23</sup> K.O. Boadi and M. Kuitunen, Environmental and health impacts of household solid waste handling and disposal practices in third world cities: the case of the Accra Metropolitan Area, Ghana, Journal of environmental health, 2005, 68(4), 32-36p

<sup>24</sup> J. Krajcovicova and A.Q. Eschenroeder, Comparative Health Risks of Domestic Waste Combustion in Urban and Rural Slovakia. Environmental Science & Technology, 2007, 41(19), 6847-6853p

## Heavy Metals

Heavy metals can be found in dumpsite leachate, air and soil produced either from plastic burning or smelting of scrap metals and e-waste. Lead, mercury, cadmium and arsenic are the main heavy metals causing neurological impairments, anemia, kidney failure, immunosuppression, gastrointestinal and respiratory irritation, abnormalities of skeletal system, inflammation of liver, cancer of liver, cardiovascular diseases after chronic exposure<sup>25</sup>.

## Volatile organic compounds (VOCs)

Volatile organic compounds are harmful to humans and also contribute to ground-level ozone pollution, also known as smog. Inhaling certain VOCs can lead to eye, nose, and throat irritation, headache, loss of coordination, nausea, and damage to liver, kidney, and central nervous system<sup>26</sup>.

## Polynuclear Aromatic Hydrocarbons (PAHs)

The PAHs are a class of compounds composed of two or more aromatic rings and they are present in dumpsites<sup>27</sup>. Hundreds of them have been identified and found as complex mixtures. They are generated by incomplete combustion, forest fire and volcanic eruptions or by other anthropogenic sources such as industrial production, transportation and waste incineration. They are classified as environmentally hazardous organic compounds by European Community (EC) and United States Environmental Protection Agency (US EPA), and are included in the priority pollutant list<sup>28</sup>. Several PAHs are known to be potential human carcinogens, some examples include benz[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[a]pyrene and benzo[g,h,i]perylene<sup>29</sup>.

## Hydrogen Sulfide (H<sub>2</sub>S)

Hydrogen sulphide is a colorless, flammable gas with a characteristic odor of rotten eggs. It is produced in dumpsites when sulphate-bearing materials (such as gypsum and plasterboard) with high concentrations, are mixed with biodegradable waste. The composition of the waste material and the practices followed on site will determine the amount of H<sub>2</sub>S produced. At low concentrations, H<sub>2</sub>S may result in irritation to the mucous membranes of the eye and respiratory tract. Exposure to high concentrations results in depression of the central nervous system, loss of consciousness and respiratory paralysis<sup>30</sup>. Other health effects have been reported, although data on the effects in humans following repeated exposure are limited and difficult to interpret because of co-exposure to other chemicals.



<sup>25</sup> United Nations Environment Programme, Environmental Pollution and Impacts on Public Health: Implications of the Dandora Municipal Dumping Site in Nairobi, Kenya, 2007

<sup>26</sup> EPA, Human Health, 25 June 2014, Available at <http://www.epa.gov/osw/nonhaz/municipal/backyard/health.htm>, access on 22 January 2015

<sup>27</sup> J. K. Nduka et al, Polyaromatic Hydrocarbons (PAHs) and Inorganic Chemical Contaminants at Refuse Dumpsites in Awka, South Eastern Nigeria: A Public Health Implication, Journal of Scientific Research and Reports, ISSN: 2320-0227, Vol.: 2, Issue.: 1 (January-June). P. 173-189, 2013

<sup>28</sup> Guillen MD, Sopelana P, Partearroyo MA. Determination of polycyclic aromatic hydrocarbons in commercial liquid flavouring of different composition by gas chromatography-mass spectrometry. Journal of Agricultural and Food Chemistry. 2000;48:126-131.

<sup>29</sup> Nieva-Cano MJ, Rubio-Barroso S, Santos-Delgado MJ. Determination of PAH in food samples by HPLC with fluorimetric detection following sonication extraction without sample clean-up. The Analyst. 2001;126:1326-1331.

<sup>30</sup> HPA (Health Protection Agency), Compendium of Chemical Hazards. Hydrogen Sulphide. Available at [http://www.hpa.org.uk/web/HPAwebFile/HPAweb\\_C/1246260029655](http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1246260029655), 2009

## Particulates

Dumpsite activities produce both fine and coarse particulates, the make-up of which will depend on the activities undertaken on-site and the types of waste being handled<sup>31</sup>. Exposure to particles that can enter the respiratory system is known to be associated with a range of adverse effects on health. Particles of greater than 10 µm in diameter (particulate matter, PM10) are unlikely to penetrate beyond the nose and larynx but, as the diameter of particles falls, the likelihood of their entering the lungs and being deposited in the airways increases.

Particles of less than about 2.5 µm diameter (PM2.5) are referred to as Black Carbon or 'fine' particles and are deposited relatively efficiently in the deeper parts of the lung – for example, in the alveolar spaces. Black Carbon consists of pure carbon in several linked forms. It is formed through the incomplete combustion of dumpsites bio-components. According WHO<sup>32</sup>, the systematic review of the available time-series studies, as well as information from panel studies, provides sufficient evidence of an association of short-term (daily) variations in Black Carbon concentrations with short-term changes in health (all-cause and cardiovascular mortality, and cardiopulmonary hospital admissions). Cohort studies provide sufficient evidence of associations of all-cause and cardiopulmonary mortality with long-term average BC exposure.

Particles between 2.5 and 10 µm in diameter are referred as comprising the 'coarse' fraction of PM10. These particles may also have effects on health. Dust emitted from dumpsites will include particles, which fall into both the PM10 and PM2.5 categories. People with pre-existing lung and heart disease, the elderly and children are particularly sensitive to particulate air pollution.

Dusts from dumpsites can become airborne and move off site through a number of mechanisms. The amount of dust lifted from the surface of the dumpsite is dependent upon the speed of the wind, the condition of the surface and the size of the dust particles. The distance travelled by dust emissions will depend on the particle size and on the wind speed and turbulence. Smaller dust particles will stay airborne for longer and disperse over a wider area. Strong and turbulent winds will also keep larger particles airborne for longer.

## Odors

Odors are frequently a key issue for dumpsites, especially those receiving biodegradable waste. Odors are typically associated with activities such as the handling of odorous wastes and the covering of biodegradable wastes or with the presence of trace components in gas or leachates. Odorous emissions are often accompanied by reports of ill-health from communities<sup>33</sup>. Individuals may report a wide range of non-specific health symptoms, attributing these to odor exposure, including nausea, headaches, drowsiness, fatigue and respiratory problems. Health symptoms reported in association with odorous emissions can arise at olfactory detectable concentrations well below the levels associated with toxic effects or thresholds for mucous membrane irritation. Individual responses to odors are highly variable and are influenced by many factors including sensitivity, age and prior exposure to the odor. Psychological and social factors, in addition to an individual's level of concern about the potential harm to their health, will also play an important role in an individual's response. There are published studies that show strong correlation between perceived odor annoyance and subjective symptoms<sup>34</sup>.

<sup>31</sup> HPA (Health Protection Agency), Impact on health of emissions of landfill sites, 2011

<sup>32</sup> WHO Europe, Health effects by Black carbon, 2012, available at [http://www.euro.who.int/\\_\\_data/assets/pdf\\_file/0004/162535/e96541.pdf](http://www.euro.who.int/__data/assets/pdf_file/0004/162535/e96541.pdf)

<sup>33</sup> Steinheider B, Environmental odours and somatic complaints. Zentralblatt für Hygiene und Umweltmedizin [International Journal of Hygiene and Environmental Medicine], 202, 101–19, 1999

<sup>34</sup> Dalton P., Upper airway irritation, odour perception and health risk due to airborne chemicals. Toxicol Lett, 140–141, 239–48, 2003

## Leachate

The nature of landfill leachate is a function of waste types, solubility, the state of decomposition and degradation. Rainfall input can serve to dilute and flush contaminants in addition to assisting in the degradation process by wetting the wastes. A wide range of substances may potentially be present in leachate, some of which are potentially harmful to human health. Table 2 shows the most important leachate substances that can be associated with health risks.

Table 2: Leachate substances associated with health risks

Priority substances in landfill leachate		
Aniline	Fluoride	Organotin compounds
Arsenic	Mecoprop	Pentachlorophenol
Biphenyl	Methyl chlorophenoxy acetic acid	Phenols
Cyanide	Methyl tertiary butyl ether	Phosphorus
Di(2-ethyl hexyl)phthalate	Naphthalene	Polycyclic aromatic hydrocarbons
Dichloromethane	Nitrogen	Toluene
Ethylbenzene	Nonylphenol	Xylenes

In fact, the health risks posed by leachate demonstrate the huge difference between a dumpsite and a modern landfill. Any modern landfill is located through a proper site allocation and Environmental Impact Assessment procedure that takes into account environmental vulnerability. Leachate in a modern landfill is discharged following treatment in an on-site process, and/or at an off-site sewage works. Modern landfill liners are also very effective in containing leachate and only a tiny amount of leachate might be released via the landfill lining system to land or groundwater. Modern landfills also impose continuous monitoring procedures, which identify leakages as soon as they happen. For all those reasons, it can be documented that leachate releases from modern landfills to surface or groundwater are unlikely to pose a significant risk of adverse effects on health<sup>35</sup>.

In contrast, leachate releases by dumpsites are uncontrolled and surface and groundwater pollution should be considered as an almost certain consequence of the dumpsites operation. Taking into account that dumpsites are located without any proper procedures that take into consideration environmental vulnerability, it is not a surprise that serious surface and groundwater pollution is the rule in dumpsites<sup>36,37</sup>.

<sup>35</sup>EA (Environment Agency), Updating the Landfill Leachate Pollution Inventory Tool. R&D Technical Report No. PI-496/TR(2). Shrewsbury, Enviro Consulting Ltd. , 2003

<sup>36</sup>David, O. M., & Oluyeye, A. O , Effect of Open Refuse Dumpsite on the Quality of Underground Water Used for Domestic Purposes in Ado-Ekiti, Nigeria - A Public Health Awareness Study, Journal of Environment and Ecology, Vol. 5, No. 2, ISSN 2157-6092 2014

<sup>37</sup>Glenn Sia Su, Water-borne illness from contaminated drinking water sources in close proximity to a dumpsite in Payatas, The Philippines, Journal of Rural and Tropical Public Health 4: 43-48, 2005

## Biogas

Biogas formation at dumpsites can result in explosion risks and several similar accidents have been reported, some of them with lethal consequences (see relevant paragraph). Carbon dioxide and methane are the two major components of biogas. The health effects of exposure to methane and carbon dioxide are well known.

Both are colorless, odorless gases which act as asphyxiants. Carbon dioxide is non-flammable and, at low concentrations or low levels of exposure, it increases the depth and rate of respiration, blood pressure and pulse<sup>38</sup>. At increasing concentrations, a depressive phase develops which can culminate in cardiorespiratory failure. Concentrations above 6% by volume can give rise to headache, dizziness, mental confusion, palpitations, increased blood pressure, difficulty breathing and central nervous system depression. Humans cannot breathe air containing more than 10% carbon dioxide without losing consciousness.

In contrast to carbon dioxide, methane is a flammable gas, which is explosive in air at concentrations between 5 and 15% by volume. Inhalation can cause nausea, vomiting, headache and loss of coordination. At very high concentrations it may cause coma and death due to respiratory arrest<sup>39</sup>.

In addition, municipal waste usually includes limited quantities of harmful substances like:

- Chemicals (pesticides, garden products, batteries, bleach, paint, varnishes, cleaning products)
- Biologicals (human waste, green waste, animal infestations, dead animal carcasses, animal waste, used needles/syringes, drugs etc.)

In a dumpsite, health risks from those harmful substances can occur via the following routes (for both workers and informal recyclers)<sup>40</sup>:

- Skin contact, especially through cuts and abrasions or contact with the eye's mucus membrane;
- Skin penetration through sharps injuries; sharp items, such as broken glass and tin cans, may increase the risk of exposure
- Ingestion through hand-to-mouth contact (usually when eating, drinking or smoking);
- Breathing in infectious aerosols/droplets from the air.



<sup>38</sup>HPA (Health Protection Agency), Carbon Dioxide. Incident Management. Available at [http://www.hpa.org.uk/web/HPAwebFile/HPAweb\\_C/1279889001588](http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1279889001588) , 2010

<sup>39</sup>HPA (Health Protection Agency), Compendium of Chemical Hazards. Methane. Available at [http://www.hpa.org.uk/web/HPAwebFile/HPAweb\\_C/1287147970726](http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1287147970726) , 2009

<sup>40</sup>HSE, Health and hazardous substances in waste and recycling, UK, 2014

## 3.4 Hazardous waste

Hazardous wastes in dumpsites are a real threat for the lives of the workers and the nearby residents. WHO has estimated that environmental exposure contributes to 19% of cancer incidence worldwide<sup>41</sup>. Additionally, a WHO Global Health Risks report looked at five environmental exposures, (unsafe water, sanitation and hygiene, urban outdoor air pollution, indoor smoke from solid fuels, lead exposure and climate change), and estimated they account for nearly 10% of deaths and disease burden globally and around one quarter of deaths and disease burden in children under the age of five<sup>42</sup>. Hazardous wastes are by-products of human activities that could cause substantial harm to human health or the environment if improperly managed. As an example, the United States Environmental Protection Agency (EPA) classifies liquid, solid, and gaseous discarded materials and emissions as hazardous if they are poisonous (toxic), flammable, corrosive, or chemically reactive at levels above specified safety thresholds. The term hazardous waste generally refers to potentially dangerous or polluting chemical compounds, other potentially hazardous industrial, military, agricultural, and municipal byproducts, including biological contaminants. Chemical manufacturing, primary metal production, metal fabrication, and petroleum processing are some of the most usual industrial hazardous waste generators. However, businesses of all sizes generate dangerous chemicals; as an example, USA EPA currently lists more than 250,000 facilities as “small-quantity generators” of hazardous waste. These diverse, smaller producers account for about 10% of the potentially harmful substances produced each year.

Obsolete pesticides, stored in leaking drums or torn bags, can directly or indirectly affect the health of anyone who comes into contact with them. During heavy rains, leaked pesticides can seep into the ground and contaminate the groundwater. Poisoning can occur through direct contact with the product, inhalation of vapors, drinking of contaminated water, or eating of contaminated food. Other hazards may include the possibility of fire and contamination as a result of inadequate disposal such as burning or burying. Chemical residues discharged into the sewerage system may have adverse effects on the operation of biological sewage treatment plants or toxic effects on the natural ecosystems of receiving waters.

Asbestos is another common hazardous waste, directly linked with serious health impacts. Asbestos refers to a family of fibrous minerals found all over world. When the fibers break off and become airborne, they can create a health risk if inhaled. Asbestos exposure is associated with certain types of lung cancer, and long-term occupational exposure can also cause the lung disease asbestosis. In the past, asbestos was used in many household products and building materials because of its heat-resistant and structural properties. As a result, building renovation and demolition projects produce much of the asbestos waste found today.

A recent report published by Blacksmith Institute<sup>43</sup> estimates that hazardous industrial / municipal waste dumpsites rank fifth in the Top-Ten Industrial Pollution sources, while the first and second are lead battery recycling and lead smelting. There are almost 150 industrial or municipal dumpsites in the Blacksmith Institute’s database that are polluting local communities, potentially putting almost 3.5 million people at risk. The largest shares of these dumpsites are in Africa and in Eastern European and Northern Asian countries. Combined, these regions make up more than half of the total at risk population in the Blacksmith investigations of dumpsites. However, industrial and municipal dumpsites are prevalent throughout the developing world including in South and Central America and South and Southeast Asia.

At properly run municipal solid waste landfills, hazardous materials considered carcinogenic, corrosive, toxic, or flammable are not accepted and are directed to special treatment or disposal sites<sup>44</sup>. At informal or improperly run sites, all these items are disposed together, creating a toxic stew of waste exposed to heat, rain and air, causing the materials to break down and easily enter the environment. Industrial waste is one of the most toxic wastes at dumpsites and makes up a large portion of the pollution problem at the dumpsites investigated by Blacksmith. The main sources of pollutants from dumpsites are either leachate (contaminated liquids leaching into the groundwater), dust from poorly covered dumpsites and gases. Leachate can contain heavy metals, VOCs



<sup>41</sup> Vineis, P. and W. Xun. “The emerging epidemic of environmental cancers in developing countries.” *Annals of Oncology* 20: 205–212, 2009.

<sup>42</sup> WHO, *Global health risks: mortality and burden of disease attributable to selected major risks.*, 2009.

<sup>43</sup> BLACKSMITH INSTITUTE, *The World’s Worst Pollution Problems: Assessing Health Risks at Hazardous Waste Sites*, 2012

<sup>44</sup> Allen, A.R., Taylor, R. ‘Waste disposal and landfill: Control and protection.’ *Protecting Groundwater for Health: Managing the Quality of Drinking- water Sources*, WHO Drinking Water Quality Series Monograph, IWA Publishing. 2006.

or hazardous organic compounds. These pollutants are carried into aquifers or surface waters. Dust from dumpsites may contain metals and human pathogens that come into contact with this pollution through contaminated groundwater and soil, or direct contact with the waste site.

Children often are seen playing in and around dumpsites, introducing direct exposure with hazardous waste through dermal contact, inhalation of dust or accidental ingestion. Informal neighborhoods are often built on top of previous dumpsites where the soil, groundwater and nearby surface waters are contaminated, indirectly exposing the local population to leached pollutants. A notable issue with dumpsites in the developing world is the presence of scavengers - workers and their families at dumpsites who make their living by recovering economically valuable materials in the waste. In such situations, people come into direct contact with the hazardous waste.

In the Blacksmith Institute’s database of industrial or municipal dumpsites the most pervasive and harmful pollutants are lead and chromium. Combined they are the key pollutants in a third of the sites, potentially affecting almost 1.2 million people. The health impacts of these pollutants include lung cancer, neurological problems and cardiovascular disease. Other pollutants in the database of dumpsites include cadmium, multiple types of pesticides, and arsenic and VOCs. Researchers analyzed 373 toxic waste sites in India, Indonesia and the Philippines, where an estimated 8.6 million people are at risk of exposure to lead, asbestos, hexavalent chromium and other hazardous materials. Among those people at risk, the exposures could cause a loss of around 829,000 years of good health as a result of disease, disability or early death<sup>45</sup>. In comparison, malaria in these countries, whose combined population is nearly 1.6 billion, causes the loss of 725,000 healthy years while outdoor air pollution claims almost 1.5 million healthy years, according to the World Health Organization. In fact this is a shocking finding: it seems that dumpsites are a more serious health risk than malaria at least for the 1.6 billion people of India, Indonesia and Philippines.

## TOXIC DUMPSITES Vs MALARIA

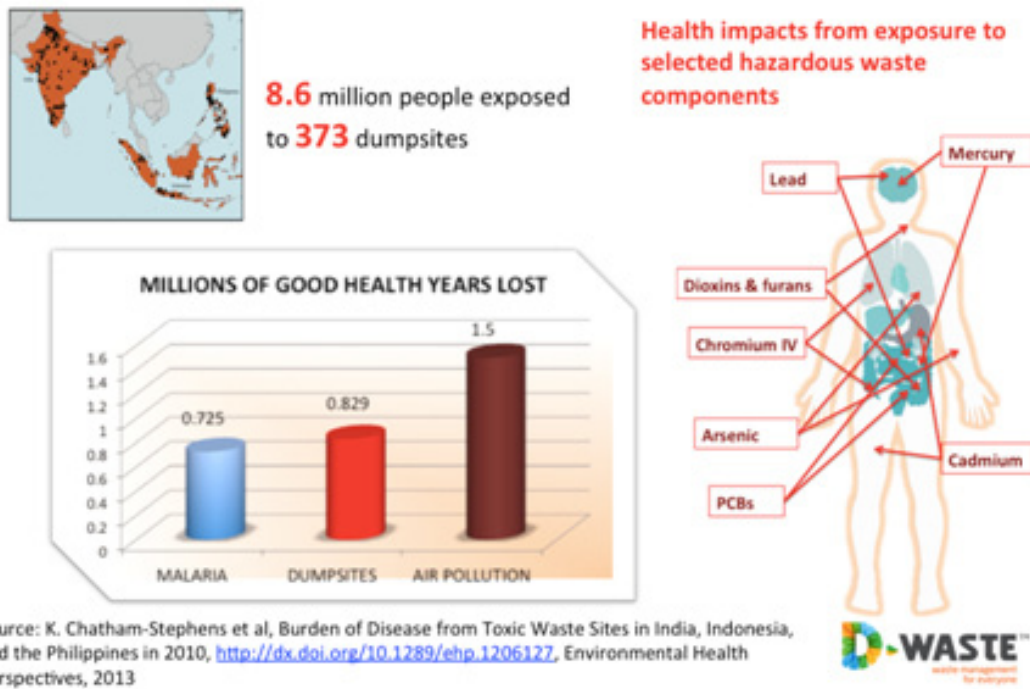


Figure 5: Dumpsites Vs Malaria as a health risk in India, Indonesia and Philippines<sup>44</sup>

<sup>45</sup> K. Chatham-Stephens et al, Burden of Disease from Toxic Waste Sites in India, Indonesia, and the Philippines in 2010, <http://dx.doi.org/10.1289/ehp.1206127>, Environmental Health Perspectives, 2013



## 3.5 Health-care waste

Health-care waste (HCW) are usually found in almost all the dumpsites in the developing world. Health-care facilities, microbiological research laboratories, diagnostic laboratories, pharmaceutical firms and funeral homes have always generated a wide variety of waste components that have the potential of transmitting infectious agents to humans. These include discarded materials or equipment from the diagnosis, treatment and prevention of disease, assessment of health status or identification purposes, that have been in contact with blood and its derivatives, tissues, tissue fluids or excreta, or wastes from infection wards.

Typical elements of the HCW are the following:

- Cultures and stocks of infectious agents and associated biologicals, including: cultures and stocks of infectious agents generated in research or clinical laboratories; wastes from the production of biologicals including vaccines, antigens and antitoxins, and sera.
- Pathological waste, including tissues, organs, and body parts; body fluids that are removed during surgery, autopsy, or other medical procedures; specimens of body fluids.
- Blood and blood products including discarded liquid human blood; discarded blood components (e.g., serum and plasma); containers with free flowing blood or blood components.
- Items or materials contaminated with blood or blood products.
- Sharps from health care, research, clinical laboratories and blood banks, including but not limited to: needles and syringes, scalpel blades, and broken or unbroken glassware, which were in contact with blood or blood derivatives.
- Animal waste including carcasses, body parts, body fluids, blood originating from animals from veterinary clinics or research institutes.

The hazardous components of HCW pose physical, chemical, radiological and/or microbiological risks to the public and those involved in their handling, treatment and disposal. In most cases, the concentration of hazardous chemicals present in HCW is generally too low to be considered an occupational problem or a danger to the public.

Physical injuries caused by discarded sharps are a more significant risk associated with HCW and may directly contribute to the transmission of microbial infectious agents. In addition, health risks may be generated through the release of toxic pollutants during dumpsite open burning or accidental fires<sup>46</sup>.

The most common and most investigated cause of the microbiological risks associated with HCW are injuries due to needles. Other sharps wastes presenting similar risks include glass and plastic ware employed in clinical and anatomic laboratories, blood collection systems for obtaining specimens, and scalpel blades from surgical procedures. These sharps may all have been in contact with microbial pathogens. More importantly, sharps can cause percutaneous injuries and thereby create an opening for infectious agents to enter the body. The latter is one of the five essential elements in the acquisition of microbial infections.

Most exposures to biological hazards from health-care wastes occur when workers or informal recyclers are trying to recover useful elements like metals. Workers may be exposed to blood and body fluids from leaking containers as well as airborne pathogens as the waste enters the dumpsite.



<sup>46</sup> WHO, Review of Health Impacts from Microbiological Hazards in Health-Care Wastes, 2004





Health-care waste components may also create microbiological risks as a source of infectious aerosols, i.e. droplets of less than 1- 3 microns in diameter, which contain etiologic agents of human and animal diseases. Cultures and stocks from the clinical laboratory contain high concentrations<sup>47</sup> of many infectious agents, e.g. *Mycobacterium tuberculosis*, which is naturally transmitted to their hosts through inhalation, although generally all infectious laboratory waste is treated at the source. Human and animal tissues, organs, and body parts have also been reported in scientific literature as sources of infectious aerosols. Finally, animal bedding materials, which have been saturated with body fluids, blood and excrement, can generate aerosols, which are a potential microbiological risk.

Blood and blood products, as well as various types of body fluids may be capable of transmitting pathogens<sup>48</sup> when brought into direct contact with the mucosal lining of the mouth and nose, the eyes, and areas of the skin containing cuts and abrasions.

It should be also noted that many of the chemicals and pharmaceuticals used in health-care establishments are hazardous<sup>49</sup> (e.g. toxic, genotoxic, corrosive, flammable, reactive, explosive, shock-sensitive). These substances are commonly present in small quantities in health-care waste; larger quantities may be found when unwanted or outdated chemicals and pharmaceuticals are disposed of. They may cause intoxication, either by acute or by chronic exposure, and injuries, including burns. Intoxication can result from absorption of a chemical or pharmaceutical through the skin or the mucous membranes, or from inhalation or ingestion. Injuries to the skin, the eyes, or the mucous membranes of the airways can be caused by contact with flammable, corrosive, or reactive chemicals (e.g. formaldehyde and other volatile substances). The most common injuries are burns. Disinfectants are particularly important members of this group: they are used in large quantities and are often corrosive. It should also be noted that reactive chemicals might form highly toxic secondary compounds.



<sup>47</sup> Weber, AM, Boudreau, Y, Mortimer VD. Health hazard evaluation report 98-0027-2709, Stericycle, Inc, Morton, Washington. Cincinnati, National Institute for Occupational Safety and Health, 1999.

<sup>48</sup> Leese KE et al, Assessment of blood-splash exposures of medical-waste treatment workers. *Enviro Health*, January/February 1999, 8-11.

<sup>49</sup> WHO, Safe management of wastes from health-care activities, Chapter 3 - Health impacts of health-care waste

## 3.6 E-waste

The term E-waste describes waste electronic goods, such as computers, televisions and cell phones, while WEEE also includes traditionally non-electronic goods such as washing machines, dishwashers, refrigerators and ovens. Computers and mobile telephones are disproportionately abundant because of their short lifespan. Components of electrical and electronic equipment such as batteries, circuit boards, plastic casings, cathode-ray tubes, activated glass, and lead capacitors are also classified as e-waste.

According to the most recent statistics by STEP (Solving The E-waste Problem) initiative (<http://www.step-initiative.org/overview-world.html>), in 2014 roughly 42 million tonnes of e-waste were generated.

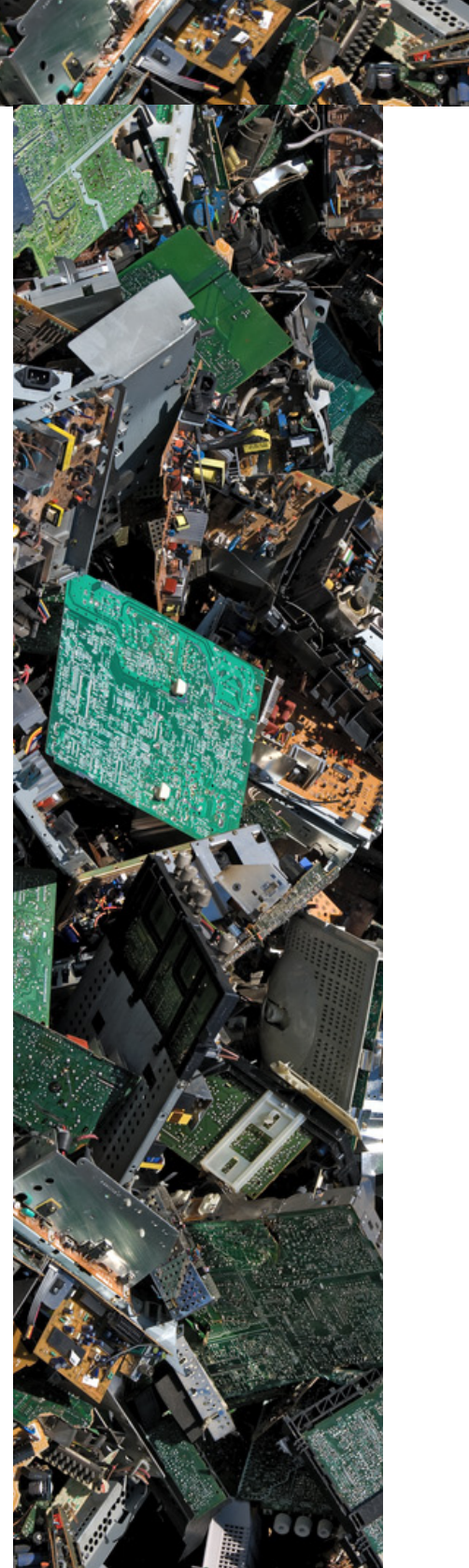
E-Waste is chemically and physically distinct from other forms of municipal or industrial waste; it contains both valuable and hazardous materials that require special handling and recycling methods to avoid environmental contamination and detrimental effects on human health. Recycling can recover reusable components and base materials, especially Cu and precious metals. However, due to lack of facilities, high labor costs, and tough environmental regulations, rich countries have only recently begun to recycle E-waste as EPR systems have been implemented in Europe and elsewhere. Instead, E-Waste has been either landfilled, or exported from rich countries to poor countries, where it may be recycled using primitive techniques and little regard for worker safety or environmental protection.

The chemical composition of E-waste varies depending on the age and type of the discarded item. However, most E-waste is composed of a mixture of metals, particularly Cu, Al, and Fe, attached to, covered with, or mixed with various types of plastics and ceramics.

Heavy WEEE items, such as washing machines and refrigerators, which are mostly composed of steel, may contain fewer potential environmental contaminants than lighter E-waste items, such as laptop computers, which may contain high concentrations of flame-retardants and heavy metals.

Virtually all E-waste contains some valuable components or base materials, especially Cu. These are environmentally important, because they provide an incentive for recycling, which occurs predominantly in poor countries, and may result in a human health risk or environmental pollution. Platinum group metals are included in electrical contact materials due to their high chemical stability and conductivity of electricity. The precious metal concentrations in printed circuit boards are more than tenfold higher than commercially mined minerals<sup>50</sup>.

The concentrations of environmental contaminants found in E-waste depend on the type of item that is discarded and the time when that item was produced. The potential environmental contaminants associated with E-waste and their typical concentrations are presented in Table 3<sup>51</sup>. Some contaminants, such as heavy metals, are used in the manufacture of electronic goods, while others, such as polycyclic aromatic hydrocarbons (PAHs) are generated by the low-temperature combustion of E-waste. The burning of insulated wire, which typically occurs in open iron barrels, generates 100 times more dioxins than burning domestic waste<sup>52</sup>.



<sup>50</sup> Betts K., Producing usable materials from e-waste. *Environ Sci Technol* 2008a; 42:6782–3.

<sup>51</sup> Brett H. Robinson, E-waste: An assessment of global production and environmental impacts, *Science of the Total Environment* 408 (2009) 183–191

<sup>52</sup> Gullett BK, Linak WP, Touati A, Wasson SJ, Gatica S, King CJ. Characterization of air emissions and residual ash from open burning of electronic wastes during simulated rudimentary recycling operations. *J Mater Cycl Waste Manag* 2007;9:69–79



Table 3: Environmental contaminants and their typical concentrations in E-Waste<sup>51</sup>

Contaminant	Relationship with E-Waste	Typical E-Waste concentration (mg/kg)
Polybrominated diphenyl ethers (PBDEs) polybrominated biphenyls (PBBs)tetrabromobisphenol-A(TBBPA)	Flame retardants	
Polychlorinated biphenyls(PCB)	Condensers, transformers	14
Chlorofluorocarbon (CFC)	Cooling units, insulation foam	
Polycyclic aromatic hydrocarbons (PAHs)	Product of combustion	
Polyhalogenated aromatic hydrocarbons (PHAHs)	Product of low-temperature combustion	
Polychlorinated dibenzo -p-dioxins (PCDDs),polychlorinated dibenzofurans(PCDFs)	Product of low-temperature combustion of PVCs and other plastics	
Americium (Am)	Smoke detectors	
Antimony	Flame retardants, plastics (Ernst et al.,(2003))	1700
Arsenic(As)	Doping material for Si	
Barium(Ba)	Getters in cathode ray tubes (CRTs)	
Beryllium (Be)	Silicon-controlled rectifiers	
Cadmium (Cd)	Batteries, tonners, plastics	180
Chromium (Cr)	Data tapes and floppy disks	9900
Copper (Cu)	Wiring	41,000
Gallium (Ga)	Semiconductors	
Indium (In)	LCD displays	
Lead (Pb)	Solder (Kang and Schoenung, (2005))	2900
Lithium(Li)	Batteries	
Mercury (Hg)	Fluorescent lamps, batteries, switches	0.68
Nickel (Ni)	Batteries	10,300
Selenium (Se)	Rectifiers	
Silver (Ag)	Wiring, switches	
Tin(Sn)	Solder (Kang and Schoenung, (2005))LCD screens	2400
Zinc (Zn)		5100
Rare earth elements	CRT screens	

Although recycling may remove some contaminants, large amounts may still end up concentrated in landfills or E-waste recycling centers, where they may adversely affect human health or the environment.

Polybrominated diphenyl ethers (PBDEs) are flame-retardants that are mixed into plastics and components. There are no chemical bonds between the PBDEs and the plastics and therefore they may leach from the surface of E-waste components into the environment<sup>53</sup>. PBDEs are lipophilic, resulting in their bioaccumulation in organisms and biomagnification in food chains. PBDEs have endocrine disrupting properties<sup>54</sup>.

<sup>53</sup>Deng WJ, Zheng JS, Bi XH, Fu JM, Wong MH. Distribution of PBDEs in air particles from an electronic waste-recycling site compared with Guangzhou and Hong Kong, South China. *Environ Int* 2007;33:1063–9.

<sup>54</sup>Tseng LH, Li MH, Tsai SS, Lee CW, Pan MH, Yao WJ, et al. Developmental exposure to decabromodiphenyl ether (PBDE 209): Effects on thyroid hormone and hepatic enzyme activity in male mouse offspring. *Chemosphere* 2008;70:640–7.

Obsolete refrigerators, freezers and air conditioning units contain ozone-depleting Chlorofluorocarbons (CFCs). These gases may escape from items disposed in landfills.

Dust is a significant environmental media that can provide information about the level, distribution, and fate of contaminants present in the surface environment. As an example, recent studies have demonstrated elevated body loadings of heavy metals and persistent toxic substances in children<sup>56</sup> and e-waste workers, respectively, at Guiyu, China.

E-waste pollutants are released as a mixture, and the effects of exposure to a specific compound or element cannot be considered in isolation. However, a more complex understanding of the interactions between the chemical components of e-waste is needed. Exposure to e-waste is a complex process in which many routes and sources of exposure, different lengths of exposure time, and possible inhibitory, synergistic, or additive effects of many chemical exposures are all important variables. Exposure to e-waste is a unique variable in itself and the exposures implicated should be considered as a whole. Sources of exposure to e-waste can be classified into three sectors: informal recycling, formal recycling, and exposure to hazardous e-waste compounds remaining in the environment (ie, environmental exposure).

Exposure routes can vary dependent on the substance and the informal recycling process. Table 4<sup>57</sup> provides the routes of exposure according to the pollutants and the e-waste components. Generally, exposure to the hazardous components of e-waste is most likely to arise through inhalation, ingestion, and dermal contact. In addition to direct occupational (formal or informal) exposure, people can come into contact with e-waste materials, and associated pollutants, through contact with contaminated soil, dust, air, water, and through food sources, including meat. Children, fetuses, pregnant women, elderly people, people with disabilities, workers in the informal e-waste recycling sector, and other vulnerable populations face additional exposure risks. Children are a particularly sensitive group because of additional routes of exposure (eg, breastfeeding and placental exposures), high-risk behaviors (eg, hand-to-mouth activities in early years and high risk-taking behaviors in adolescence), and their changing physiology (e.g. high intakes of air, water, and food, and low rates of toxin elimination). The children of e-waste recycling workers also face take-home contamination from their parents' clothes and skin and direct high-level exposure if recycling is taking place in their homes.

In a recent study of health risks posed by e-waste, 23 published epidemiological studies were reviewed, all from southeast China<sup>54</sup>. The project recorded plausible outcomes associated with exposure to e-waste including change in thyroid function, changes in cellular expression and function, adverse neonatal outcomes, changes in temperament and behavior, and decreased lung function. Boys aged 8–9 years living in an e-waste recycling town had a lower forced vital capacity than did those living in a control town. Significant negative correlations between blood chromium concentrations and forced vital capacity in children aged 11 and 13 years were also reported. Findings from most studies showed increases in spontaneous abortions, stillbirths, and premature births, and reduced birth weights and birth lengths associated with exposure to e-waste. People living in e-waste recycling towns or working in e-waste recycling had evidence of greater DNA damage than did those living in control towns.

In other studies<sup>58</sup>, researchers have linked e-waste to adverse effects on human health, such as inflammation and oxidative stress – precursors to cardiovascular disease, DNA damage and possibly cancer.

Although the toxicology of many e-waste components is well characterized, some newer materials, such as gallium and indium arsenides found in newer semiconductors, are less well understood. Their incorporation into nanomaterials may increase bioavailability in unanticipated ways. Developing children and fetuses may be particularly vulnerable to toxins found in e-waste, and early epidemiological studies near informal e-waste recycling sites indicate potential developmental neurotoxicity. Understanding the hazards of e-waste, the impacts of its disposal, and the dangers of informal or careless recycling will help reduce or prevent disease outcomes associated with exposure to e-waste components.

<sup>56</sup>Bi, X. H.; Thomas, G. O.; Jones, K. C.; Qu, W. Y.; Sheng, G. Y.; Martin, F. L.; Fu, J. M. Exposure of electronics dismantling workers to polybrominated diphenyl ethers, polychlorinated biphenyls, and organochlorine pesticides in South China. *Environ. Sci. Technol.* 2007, 41, 5647–5653

<sup>57</sup>Kristen Grant, Fiona C Goldizen, Peter D Sly, Marie-Noel Brune, Maria Neira, Martin van den Berg, Rosana E Norman, Health consequences of exposure to e-waste: a systematic review, *LancetGlobHealth* 2013; 1: e350–61, Published Online October 30, 2013 [http://dx.doi.org/10.1016/S2214-109X\(13\)70101-3](http://dx.doi.org/10.1016/S2214-109X(13)70101-3)

<sup>58</sup>Fangxing Yang et al, Comparisons of IL-8, ROS and p53 responses in human lung epithelial cells exposed to two extracts of PM2.5 collected from an e-waste recycling area, China 2011, *Environ. Res. Lett.* 6 024013 doi:10.1088/1748-9326/6/2/024013

Table 4: Routes of exposure for e-waste<sup>57</sup>

	Component of electrical and electronic equipment	Ecological source of exposure	Route of exposure
Persistent organic pollutants			
Brominated flame retardants	Fire retardants for electronic equipment	Air, dust, food, water, and soil	Ingestion, inhalation, and transplacental
Polybrominated diphenyl ethers			
Polychlorinated biphenyls	Dielectric fluids, lubricants and coolants in generators, capacitors and transformers, fluorescent lighting, Ceiling fans, dishwashers, and electric motors.	Air, dust, soil, and food (bioaccumulative in fish and seafood)	Ingestion, inhalation or dermal contact, and transplacental
Dioxins			
Polychlorinated dibenzodioxins and dibenzofurans	Released as combustion byproduct	Air, dust, soil, food, water, and vapor	Ingestion, inhalation, dermal contact, and transplacental
Dioxin-like polychlorinated biphenyls	Released as a combustion byproduct but also found in dielectric fluids, lubricants and coolants in generators, capacitors and transformers, fluorescent lighting, ceiling fans, dishwashers, and electric motors	Released as combustion byproduct, air, dust, soil, and food (bioaccumulative in fish and seafood)	Ingestion, inhalation, and dermal absorption
Perfluoroalkyls	Fluoropolymers in electronics	Water, food, soil, dust, and air	Ingestion, dermal contact, inhalation, and transplacental
Polyaromatic hydrocarbons			
Acenaphthene, acenaphthylene, anthracene, benz[a]anthracene, benzo[a]pyrene, benzo[e]pyrene, benzo[b]fluoranthene, benzo[g,h,i]perylene, benzo[j]fluoranthene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, fluoranthene, fluorene, indeno[1,2,3-c,d]pyrene, phenanthrene, and pyrene	Released as combustion byproduct	Released as combustion byproduct, air, dust, soil, and food	Ingestion, inhalation, and dermal contact
Elements			
Lead	Printed circuit boards, cathode ray tubes, light bulbs, televisions (1.5–2.0 kg per monitor), and batteries	Air, dust, water, and soil	Inhalation, ingestion, and dermal contact
Chromium or hexavalent chromium	Anticorrosion coatings, data tapes, and floppy disks	Air, dust, water, and soil	Inhalation and ingestion
Cadmium	Switches, springs, connectors, printed circuit boards, batteries, infrared detectors, semi-conductor chips, ink or toner photocopying machines, cathode ray tubes, and mobile phones	Air, dust, soil, water, and food (especially rice and vegetables)	Ingestion and inhalation
Mercury	Thermostats, sensors, monitors, cells, printed circuit boards, and cold cathode fluorescent lamps (1–2 g per device)	Air, vapor, water, soil, and	Inhalation, ingestion, and dermal contact
Zinc	Cathode ray tubes, and metal coatings	Air, water, and soil	Ingestion and inhalation
Nickel	Batteries	Air, soil, water, and food (plants)	Inhalation, ingestion, dermal contact, and transplacental
Lithium	Batteries	Air, soil, water, and food (plants)	Inhalation, ingestion, and dermal contact
Barium	Cathode ray tubes, and fluorescent lamps	Air, water, soil, and food	Ingestion, inhalation and dermal contact
Beryllium	Power supply boxes, computers, x-ray machines, ceramic components of electronics	Air, food, and water	Inhalation, ingestion, and transplacental

## 3.7 Open burning

“Open burning” of waste is a usual practice in many dumpsites, as a means to reduce the waste volume. The practice of open burning results in many harmful public health and environmental effects.

Worldwide scientific research has conclusively demonstrated that burning of waste at dumpsites produces air toxins. Typically, burning occurs at low temperatures (250 oC to 700 oC) in oxygen-starved conditions. Hydrocarbons, chlorinated materials and pesticide compounds under these conditions produce a wide range of toxic gases harmful to the environment and public health. These gases contain dioxins / furans, volatile organic compounds, particulate matter (PM), hydrogen chloride (HCl), carbon monoxide (CO) and oxides of sulfur and nitrogen and liberate metals including antimony, arsenic, barium, beryllium, cadmium, chromium, lead, manganese, mercury, phosphorus and titanium<sup>59</sup>.

The United States Environmental Protection Agency estimates<sup>60</sup> that uncontrolled mixed garbage burning is a larger source of dioxins than coal combustion, ferrous metal smelting, hazardous waste incineration or bleached pulp mill operations.

The burning of waste produces two types of ash, bottom and fly ash. Fly ash is made of light particles which is carried out by combustion gas and is laden with toxic metals, dioxin / furan and other products of incomplete combustion which can travel thousands of kilometers before they drop out where they enter into the human food chain. Open burning emissions are troubling from a public health perspective because of several reasons:

- Open burning emissions are typically released at or near ground level instead of through tall stacks, which aid dispersion;
- Open burning emissions are not spread evenly throughout the year; rather, they are typically episodic in time or season and localized/regionalized;
- Open burning sources are non-point sources and are spread out over large areas;
- Compliance to any bans on open burning are difficult to enforce.
- Open burning is a transient combustion phenomenon, frequently with heterogeneous fuels; it is difficult to attribute emissions to a single component of the fuel.

One of the most harmful pollutants released during open burning is dioxin. Dioxin is a known carcinogen and is associated with birth defects. Dioxin can be inhaled directly or deposited on soil, water and crops where it becomes part of the food chain.

Burning MSW can release hexachlorobenzene (HCB) to the environment. This compound is a highly persistent toxin that degrades slowly in the air. Therefore, it can travel long distances in the atmosphere. It bioaccumulates in fish, marine animals, birds, lichens, and animals that feed on fish and lichens. HCB is a probable human carcinogen, and based on animal studies, long-term, low-level exposures to HCB can damage a developing fetus, lead to kidney and liver damage, and cause fatigue and skin irritation.

Formaldehyde is released when pressed wood products, paints, coatings, siding, urea-formaldehyde foam, and fiberglass insulation are burned. Exposure to formaldehyde can result in watery eyes, a burning sensation in the eyes and throat, nausea, difficulty in breathing (i.e., coughing, chest tightness, wheezing), and skin rashes. Prolonged exposure to formaldehyde may cause cancer.

Burning of plastics, or polyvinyl chloride (PVCs), can produce hydrogen chloride gas, or hydrochloric acid, which can cause fluid buildup in the lungs and possible ulceration of the respiratory tract.

The visible smoke from burning is composed of tiny particles (particulates), which contain toxic pollutants. If inhaled, these microscopic particles can reach deep into the lungs and remain there for months or even years. Breathing particulates increases the chances of respiratory infection, can trigger asthma attacks, and causes other problems such as coughing, wheezing, chest pain, and shortness of breath.

<sup>59</sup> Nammari, D.R., Hog-land, W., Marques, M., Nimmermark, S. and Moutavtchi, V. (2004) Emissions from a Controlled Fire in Municipal Solid Waste Bales. *Waste Management*, 24, 9-18

<sup>60</sup> United States Fire Administration (USFA), “Landfill fires, their magnitude, characteristics and mitigation,” TriData Corporation, Arlington, Virginia, USFA Tech. Rep. FA-225, 2002.

Black Carbon is a very usual output of open burning practices. Besides being the second-greatest contributor to global warming after carbon dioxide, Black Carbon also poses risks to human health, including cardiovascular disease, respiratory disease and premature death<sup>61</sup>.

Carbon monoxide is generated from the incomplete combustion of waste. Carbon monoxide is a colorless, odorless gas that prevents oxygen from being absorbed by the blood and lungs. It is especially dangerous when inhaled by young children with immature lungs, the elderly, and people with chronic heart conditions or lung diseases.

Of particular health concern are tyre fires. Tyres are composed of natural rubber from rubber trees, synthetic rubber made from petrochemical feedstock, carbon black, extender oils, steel wire, up to 17 heavy metals, other petrochemicals and chlorine. A coal and tyre chlorine content comparison showed that tyres might contain as much as 2 to 5 times the chlorine level of typical western coal. Tyre fires burn for a long time allowing the build up of the by-products of combustion around surrounding areas. Burning tyres are known to emit dioxins and benzene derivatives, which have been linked with reproductive impairment and cancer in humans<sup>62</sup>. Tyre fires releases a dark, thick smoke that contains carbon monoxide, sulphur dioxide and products of butadiene and styrene. Further, tyre fires can be extremely difficult to contain and extinguish and therefore burn and smolder for a long period of time. Even after they are extinguished, tyre fires can flare up again weeks, even months later. This can cause a build-up of the by-products of combustion in confined areas such as surrounding homes, which creates an additional health hazard. Table 5 presents typical open burning emissions of pollutants included in the plumes emitted.

Table 5: Emissions from burning dumps and landfill fires (ng/m3)<sup>63</sup>

Compound	Controlled landfill fire	Uncontrolled landfill fire
Acenaphthylene	90	60
Acenaphthene	50	30
Fluoranthene	100	50
Phenanthrene	520	30
Anthracene	160	85
Fluorene	120	180
Pyrene	120	170
Benzo [a] anthracene	60	60
Chrysene	80	70
Benzo [b&k] fluoranthene	50	20
Benzo [a] pyrene	20	15
Indeno [1,2,3-cd]pyrene	10	10
Dibenz [a,h] anthracene	10	10
Benzo [g,h,i]perylene	10	10
Total PAHs	1480	810
Total PCBs	15.5	590

<sup>61</sup>PNAS, "Highway Proximity and Black Carbon from Cookstoves as a Risk Factor for Higher Blood Pressure in Rural China," 2014, available at <http://www.pnas.org/content/111/36/13229>

<sup>62</sup>Adeolu O. Aderemi, Adebayo A. Otitoloju An Assessment of Landfill Fires and Their Potential Health Effects- A Case Study of a Municipal Solid Waste Landfill in Lagos, Nigeria # IJEP Vol. 2 No. 2 February 2012 PP.22-26 [www.ij-ep.org](http://www.ij-ep.org)

<sup>63</sup>Paul M. Lemieux, Christopher C. Lutes, Dawn A. Santoianni, Emissions of organic air toxics from open burning: a comprehensive review, Progress in Energy and Combustion Science 30 (2004) 1–32

## 3.8 Occupational health risks

Occupational health risks in dumpsites concern both workers and informal recyclers. In solid waste management, occupational health risks can be minimized by making waste technologies more contained, reducing contaminant emissions, changing working methods, use of protective clothing, and keeping the public and residents a safe distance away from operations. For example, risk of respiratory infection or allergic response to organic dust can be greatly reduced if transfer stations, composting and recycling process systems are enclosed or ventilated and if workers wear respiratory masks<sup>64</sup>.

A study carried out in the USA on increased coronary disease events showed that solid waste workers had two times more risk than the country's general laborers. Because of inadequate understanding of the magnitude of the problem and poor financial resources, the risks are still largely unmanaged in most developing countries<sup>65</sup>.

In principle, workers and informal recyclers are exposed to the following health and safety risks<sup>66</sup>:

- They risk being killed or severely injured by moving equipment, such as bulldozers or trucks carrying waste, particularly when the vehicles are reversing.
- They are vulnerable to respiratory disorders due to prolonged and frequent exposure to smoke from the fires common at the dumpsites.
- Individuals risk being temporarily injured by the sharp and heavy waste materials that they handle.
- They may be damaged permanently by exposure to fecal matter or to chemically hazardous, toxic, or otherwise contaminated waste.
- They risk infection with HIV or hepatitis C, particularly from hazardous healthcare waste (HHCW).

Table 6 summarizes the health and safety risks for workers and informal recyclers.

Exposure to waste dumpsites is likely to give rise to significantly increased risks of chronic respiratory illness. Small quantities of biological material are present in most wastes, giving rise to a potential for exposure to bioaerosols<sup>67</sup>. Disposal of organic-rich wastes, including untreated MSW, greatly increases the potential for bioaerosol emissions.

Table 6: Health and safety risks for workers and informal recyclers in dumpsites<sup>68</sup>

Prevalence	Seriousness
Joint pain	Infectious diseases
Injuries / cuts	Respiratory issues
Respiratory issues	Skin infection
Gastrointestinal disorders	Gastrointestinal disorders
Fatigue	Injuries / cuts
Skin infection	Joint pain
Infectious diseases	Fatigue



<sup>64</sup>United Nations Environment Program Agency (UNEP), "Informal Solid Waste Management," 2006. <http://www.unep.org/PDF/Kenyawastemngntsector/chapter1.pdf>

<sup>65</sup>K. O. Boardi and M. Kuitunen, "Environmental and Health Impacts of Household Solid Waste Handling and Disposal Practices in the Third World Cities: The Case of Accra Metropolitan Area, Ghana," *Journal of Environmental Health*, Vol. 68, No. 4, 2005, pp. 34-36

<sup>66</sup>UNEP & Republic of South Sudan, 2013, *Health and Safety Guidelines for Waste Pickers*

<sup>67</sup>Mugo K.K, Gichanga J.M, Gatebe E. and Njogu P.M., *Assessment of the Safety and Health Hazards in Existing Dumpsites in Kenya*, Proceedings of the Sustainable Research and Innovation (SRI) Conference 6 - 8 May, 2015

<sup>68</sup>South Sudanese Development Organization (SSDO). 2013. *Survey Report on Health and Safety of Waste Pickers at Lagoon Dump Site, Juba*. Project No. AE/30200902. UNEP/SSFA/DEPI/2012/PCDMB/075. Juba: SSDO and UNEP.



Several studies have examined the health impacts to workers<sup>69</sup>. All of them have indicated a higher prevalence of work-related dermatological, neuromuscular, respiratory, hearing, gastrointestinal symptoms, and injuries among landfill workers than among the control group participants. Furthermore, specific symptoms like nasal stuffiness were positively correlated with the handling of wood products, machine oil, greases, and lubricants; job tasks that required the use of manual or power tools also were positively correlated with backaches and aching joints. Finally, hygienic surveys indicated a high amount of airborne dust, bacteria, and fungi within the breathing zone of the dumpsite employees<sup>70</sup>.

The occupational safety of waste scavengers, particularly at dumpsites, is very poor and unfortunately in many cases they concern children too<sup>71</sup>. Waste scavenging commences already during the unloading of lorries. The sight is not uncommon of young men climbing on the waste being unloaded from the lorry with the trailer still raised in the tipping position. Often, there are machines present at the site to spread (and compact) the waste. Waste scavengers search through high piles of waste in the close proximity of machines. There is a constant potential for injury from slips, trips and falls. As scavengers hardly ever use any protective clothing such as boots, gloves and masks, they often get cut by sharp objects like needles and broken glass, as well as bitten by dogs and rats. In addition to the safety issues mentioned, there are frequent incidents of violence as well.

GIZ completed an important study regarding the health issues of informal recyclers<sup>72</sup>- the fieldwork was carried out in Nicaragua, Costa Rica and Colombia with a total of 118 respondents. The main health problems mentioned were kidney problems, blood pressure and diabetes, which are general population problems not directly associated with the occupational type. Dizziness, asthma, coughing, skin diseases, arthritis and urinary tract and kidney infections, on the other hand, could be occupational illnesses, linked to the conditions in which the work is carried out, where there is smoke from the burning of waste, there are no sanitary facilities, and water consumption is low, despite direct exposure to solar radiation and high temperatures. The most common types of risks and accidents are related to injuries caused by some material, blows and getting hit by trucks, as well as skin infections. There are many more risks associated with the work than the interviewed people mentioned. It seems that because they work in such extreme conditions, they only manage to recognize the most common and visible risks and accidents. Another recent study<sup>73</sup> regarding the health impacts of dumpsites on informal recyclers concluded, “...(informal recyclers)... with higher years of experiences have higher chances of getting skin disease and respiratory disease such as shortness of breath. The results also showed that the risk of injured by sharp object decreased with the increase in education level of garbage collectors”.



<sup>69</sup>CDC Policy Working Paper Health & Social Conditions of Sanitation Workers in Nagpur, 2010

<sup>70</sup>Kitsantas P, Kitsantas A, Travis HR. Occupational exposures and associated health effects among sanitation landfill employees. *J Environ Health*. 2000; 63 (5):17-24.

<sup>71</sup>ISWA Landfill Working Group, Key issue paper on Landfill Working Group Key Issue Waste Scavenging at Dumpsites in Economically Developing Countries, written by Ljiljana Rodic-Wiersma, David C. Wilson and Derek Greedy

<sup>72</sup>GIZ, 2011, Report on health related issues of informal sector involvement in solid waste management

<sup>73</sup>Aweng, E.R., and Fatt, C.C., Survey of Potential Health Risk of Rubbish Collectors from the Garbage Dumpsites in Kelantan, Malaysia, *Asian Journal of Applied Sciences* (ISSN: 2321 – 0893) Volume 02 – Issue 01, February 2014

## 4. UNCERTAINTIES INVOLVED

This report aims to outline the health impacts posed by dumpsites. For that purpose, a long list of case studies and papers have been studied. The adverse health impacts posed by dumpsites are in no doubt, but still, going into the details of the studied materials, a number of limitations and uncertainties have to be considered, as they are presented below.

A wide variety of exposures, exposure pathways and exposure scenarios can be associated with dumpsites, entailing a large complexity and difficulty in estimating the health risks possibly involved. Only few epidemiological studies have evaluated sites with respect to the types of chemicals they contain and release; most studies on the health effects of waste dumpsites in fact lack direct exposure measurement, and rely on residential distance from the site or sometimes on exposure modeling. Many health endpoints have been considered in epidemiological studies, including cancer incidence and mortality and reproductive outcomes such as birth defects and low birth weight<sup>74</sup>.

If a waste dumpsite presents a risk to health, those affected may be diverse or numerous. The emphasis is on the word 'may', since the link to health may seem intuitive and realistic but demonstrating that waste causes ill-health is neither simple nor straightforward<sup>75</sup>.

Most research into health effects has been undertaken for chemical wastes deposited on to land in large quantities between the 1940s and 1970s and the most intensive investigations were conducted in America during the 1980s and 1990s. In spite of the many and extensive studies conducted a plausible link between a chemical pollutant and measurable illness has only been found at a minority of locations. The results of these epidemiological studies are seriously affected by many 'confounding' factors making it difficult to prove a link between the dumpsites and poor health when one takes into account for example, different lifestyles, smoking, diet, alcohol consumption, housing quality, susceptibility of ethnic, gender or age-specific groups to particular medical conditions and the list goes on.

Thus, it is important to investigate the health impacts of a dumpsite in conjunction with other environmental hazards, as concurrent exposures can result in synergic effects. In particular, it is of interest to consider how possible health effects of waste may take place in combination with other powerful health determinants depending on lifestyle and the social environment<sup>76</sup>.

The scientific evidence on the health effects of waste-related exposure is not 100% conclusive. Differential exposure to waste by socio-economic status is often documented, but the interplay between environmental and social factors is not well known and documented.

There are specific uncertainties that should be taken into consideration when the relation between health and dumpsites is discussed<sup>77</sup>:

- Specific characteristics of the dumpsites (age, waste streams disposed of, conditions at the bottom layer etc.) are not known and relevant data sets are simply not available
- The level of exposure is not clearly defined simply by the distance between the dumpsites and the affected populations. Other elements like groundwater flow or wind direction should be taken into consideration. This creates important consequences to the definition of a suitable population sample for the health studies involved.
- Many studies do not identify the specific route of exposure, which might create the health risks (air, water).
- Direct links between specific chemicals within the dumpsites and health risks are difficult to establish without appropriate epidemiological studies that study the same population sample for a sufficient time.
- An uncontrolled confounding by exposures to other environmental factors (e.g. industry) is still possible in many of the studies implemented.

Despite those methodological limitations, the scientific literature on the health effects of dumpsites provides strong indications of the existing linkages between dumpsites and adverse health effects<sup>78</sup> for workers, informal recyclers and nearby residents.

<sup>74</sup> WHO, Population health and waste management: scientific data and policy options, Rome, Italy, March 2007

<sup>75</sup> Philip Rushbrook, The Health Effects from Wastes - Overplayed or Underestimated? Workshop: Health Impact of Waste Management Activities IWM Annual Conference, Paignton, UK. June 2001

<sup>76</sup> Marco Martuzzi et al, Inequalities, inequities, environmental justice in waste management and health, European Journal of Public Health, Vol. 20, No. 1, 21–26, 2010

<sup>77</sup> WHO, Health effects from landfills – Impacts from the latest research, Report on a WHO meeting, Bilthoven, Netherlands, 1998

<sup>78</sup> Daniela Porta et al, Systematic review of epidemiological studies on health effects associated with management of solid waste, Environmental Health 2009, 8:60 doi:10.1186/1476-069X-8-60

# 5. ABOUT THE ECONOMIC COST OF HEALTH IMPACTS

One of the most important challenges is to assess the economic burden posed to national and local health systems by dumpsites. Environmental pollutants can have direct and indirect effects on human health. Moreover there are economic effects, e.g. on health care, productivity, recreation and intrinsic losses through disruption of ecosystems. National and international organizations increasingly request monetization of such effects for cost-effectiveness or cost-benefit evaluations. While some environmental health professionals regard the valuation of human health as unethical, it seems that the majority considers it a natural (though utilitarian) extension of burden of disease assessments.

Although the scientific and technical challenges involved in such an effort are really high, the relevant concepts are under development and some key concepts should be taken into consideration. The following paragraphs provide the key-concepts and some major reference documents.

The World Health Organization (WHO) has developed the conceptual framework for identifying the economic consequences of diseases and injuries<sup>79</sup>. A key conclusion was that if undertaken in a defined manner with reference to a coherent set of conceptual foundations, economic impact studies in health can usefully contribute to health policy dialogue. However, there have been several studies that were not founded within a clear, logical framework, meaning that they produce results that can be misleading or spurious. Much greater attention is therefore called for when considering or planning an analysis of the economic impact of disease or injury.

According to WHO, there are certain questions that must be answered before the decision for an economic valuation of health impacts will be taken. Is an economic impact study needed in the first place (what will it bring in addition to clinical or epidemiological indicators of disease burden)? What is the policy decision that it addresses or bears upon? What is the explicit purpose, scope and perspective of the study? What are the key channels through which economic impacts are expected to be felt, and what are the data (or other) constraints to their appropriate measurement and valuation? Dealing with these questions at the outset will encourage a more rigorous approach and a more meaningful assessment to economic impact studies in the future. It will also help to identify which of a number of specific measurement approaches or models might be appropriate to use in a given context. Figure 6 presents a simple algorithm that can be used in order to identify the economic costs related to certain diseases and injuries.

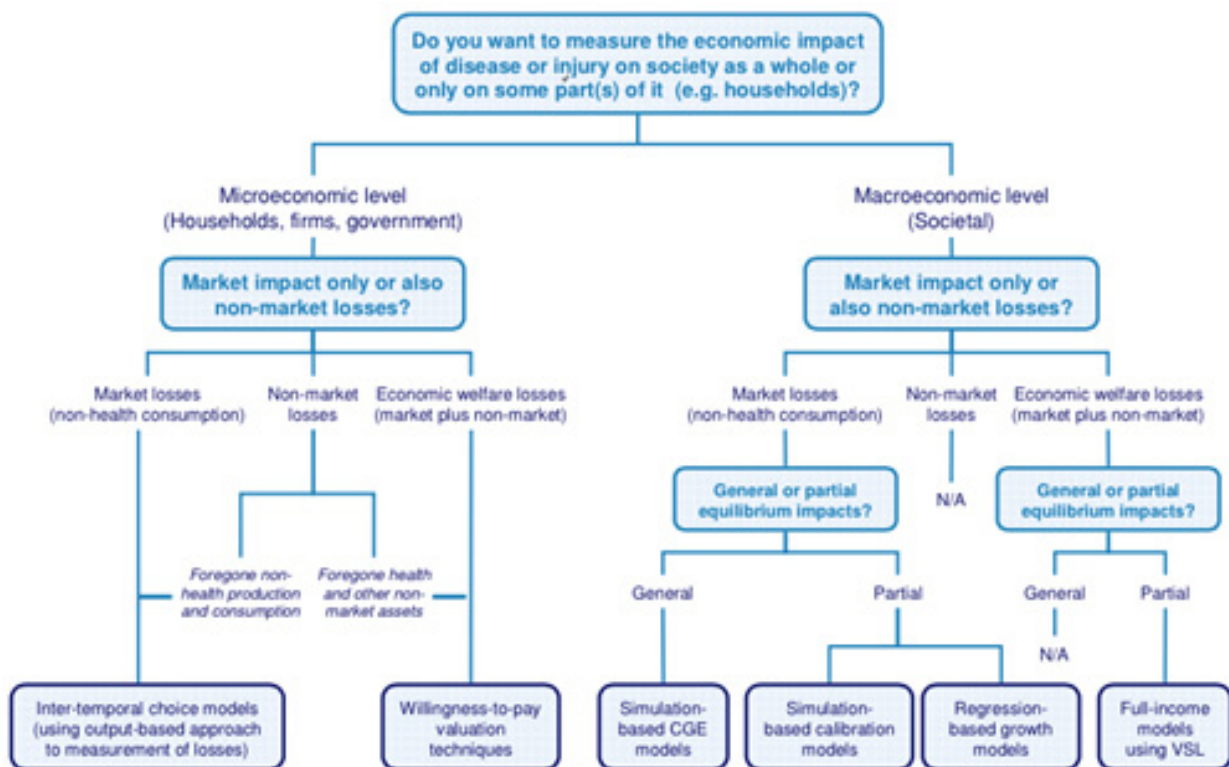


Figure 6: Algorithm for determining what methodological approach to use for economic impact studies in health<sup>79</sup>

<sup>79</sup> WHO, WHO GUIDE TO IDENTIFYING THE ECONOMIC CONSEQUENCES OF DISEASE AND INJURY, 2009

OECD has done a remarkable update by reviewing the recent empirical literature relating to the human health impacts of negative environmental externalities from air pollution, hazardous chemicals, and unsafe water and sanitation, and their use in cost-benefit analysis<sup>80</sup>. The study includes valuation of health impacts related to exposure to Particular Matter (PM) & Ozone, Hazardous Chemicals and Unsafe Water & Sanitation. The following table presents some key-figures for diseases associated with such an exposure, as a wide range of Willingness to Pay (WTP) studies has concluded them.

Table 7: Range of costs for selected diseases associated with dumpsites emissions<sup>80</sup>

EXPOSURE TO	HEALTH IMPACT	RANGE OF COSTS (USD 2010,ppp)
	Chronic bronchitis	170,000-500,000
PM & Ozone	Respiratory hospital admissions	2,000-24,000
	Cardiac hospital admissions	200-29,000
	Cancer (lung)	481,000
Hazardous Chemicals	Skin cancer	9,300
	Leukemia	2,658
	Neuro-devt. Disorders	10,000
Unsafe Sanitation	Gastrointestinal illness	40-170

Another issue of importance regards the valuation of health impacts to children. There is increasing concern that the health of children is particularly affected by environmental conditions. Important examples include the aggravation of respiratory diseases (such as asthma), lung development, water-borne diseases (such as gastro- enteritis) and increased cases of premature deaths among children<sup>81</sup>. In many respects, the valuation of health benefits to children is associated with issues that may have serious policy implications. An important issue relates to the special vulnerability of children to environmental degradation. A focus on the epidemiological differences between adults and children underlines how important it is in policy- making not to consider children simply as little adults. Additional differences between adults and children in terms of the valuation of such impacts also highlight the need for children-specific values when designing environmental policies.

A very important case study has been developed for Campania, Italy<sup>82</sup>. The study aimed to reduce the uncertainty about health damage due to waste exposure by providing for the first time a monetary valuation of health benefits arising from the reclamation of hazardous waste dumps in Campania. The results were really astonishing.

There were estimated 848 cases of premature mortality and 403 cases of fatal cancer per year considered to be a consequence of exposure to dumpsites with hazardous waste. The present value of the benefit of reducing the number of waste associated deaths after adjusting for a cancer premium was estimated at €11.6 billion. This value ranges from €5.4 to €20.0 billion assuming a time frame for benefits of 10 and 50 years respectively.

The study concluded that there is a strong economic argument for both reclaiming the land contaminated with hazardous waste in the two provinces of Naples and Caserta and increasing the control of the territory in order to avoid the creation of new illegal dump sites.

It is clear that the valuation of the health impacts related to dumpsites is a strong policy intervention tool that can help decision makers to upgrade the closure of dumpsites in the local and national agendas.

The range of costs presented above as well as the results from the case in Campania, demonstrate that the worldwide health impacts of dumpsites should be the in the order of magnitude of tens or hundreds of USD billions.

However, a more accurate assessment is rather impossible since a. the scientific context required for concrete results is still under development and b. there are significant data gaps and methodological difficulties that need to be managed.

<sup>80</sup>OECD Environment Working Paper Nr. 35 Policy Interventions to Address Health Impacts Associated with Air Pollution, Unsafe Water Supply and Sanitation, and Hazardous Chemicals, written by Prof. Alistair Hunt of the University of Bath, 2011

<sup>81</sup>OECD, Economic Valuation of Environmental Health Risks to Children, 2006

<sup>82</sup>Carla Guerriero, John Cairns, The potential monetary benefits of reclaiming hazardous waste sites in the Campania region: an economic evaluation, Environmental Health 2009, 8:28 doi:10.1186/1476-069X-8-28

## 6. CONCLUSIONS

Dumpsites are a global problem that threatens the health and the quality of life of 3.5 - 4 billion people that are served by dumpsites. Due to both the expected increase of population and the growing income/capita in the developing world, significant additional amounts of municipal, industrial and hazardous waste are expected to enter into dumpsites within next 15-20 years. Despite those methodological limitations, the scientific literature on the health effects of dumpsites provides strong indications of the existing linkages between dumpsites and adverse health effects for workers, informal recyclers and nearby residents. The different waste streams disposed of as well as the practices that are followed (open burning, informal recycling) determine both the health and the environmental impacts of dumpsites. Besides municipal waste, healthcare waste, hazardous and e-waste are common streams found in dumpsites. The problem is that in most dumpsites all the previous waste streams are usually present in unknown quantities and with roughly unknown interactions. This results in both increased health risks and increased difficulties in assessing the health risks in detail.

The health problems associated with dumpsites are related to their emissions, which usually involve POPs (persistent organic pollutants), heavy metals and VOCs (volatile organic compounds), soot. The actual health risks depend on the practices followed and on the type of the waste disposed of in each dumpsite, as well as on the environmental and social conditions of the area.

Open burning and animal feeding increase the health risks substantially, the first by direct emissions of dangerous pollutants and the second by transferring the pollutants to the food chain.

Several studies document that dumpsites can have serious effects on the health and well being of the population. A wide range of toxic substances can be released into the environment from uncontrolled waste disposal, for example, methane, carbon dioxide, benzene and cadmium. Many of these pollutants have been shown to be toxic for human health. In addition, dumpsites are likely to contain highly hazardous compounds resulting from industrial production, for example asbestos and lead. Previous epidemiological studies have found that two main health outcomes – cancer and congenital malformations – are statistically associated with waste exposure in dumpsites.

Dumpsites are becoming a widespread and alarming problem. According to recent research, the health risks posed by toxic dumpsites in India, Indonesia and Philippines are more important than the risks related to malaria. E-waste dumpsites are related to changes in thyroid function, changes in cellular expression and function, adverse neonatal outcomes, changes in temperament and behavior, and decreased lung function.

One of the most important challenges is to assess the economic burden posed to national and local health systems by dumpsites including all their economic effects, e.g. on health care, productivity, recreation and intrinsic losses through disruption of ecosystems. National and international organizations increasingly request monetization of such effects for cost-effectiveness or cost-benefit evaluations. It seems that the worldwide health impacts of dumpsites should be in the order of magnitude of tens or hundreds of USD billions, although no specific study with this particular scope has been implemented yet.





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