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WASTE RECOVERY

Strategies, techniques and applications in Europe

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STRATEGIES, TECHNIQUES AND APPLICATIONS IN EUROPE

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On the front cover: Luciano Morselli, *Le rane blu* (*The Bue Frogs*), 1989
acrylic on paperboard, cm 70x100 (detail)

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1. Integrated Waste Management: Towards a European Recycling Society

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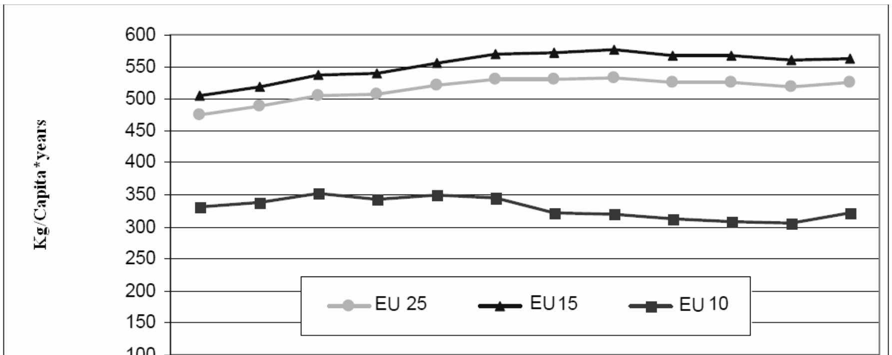
Every year about 2 billion tonnes of waste are produced in the EU. Even if the waste production is generally linked to socio-economics drivers, among the Member States there are several differences in municipal waste generation, especially between EU15 and New Member States (Fig. 1).

Fig. 1 - Waste generation in Europe, in EU15 (i.e.: A, B, DK, SF, F, D, GR, IRL, I, L, NL, P, E, S, GB) and in EU10 new Member States (i.e.: CY, CZ, H, LV, LT, M, PL, R, SK, SLO) – (ISPRA, 2007).



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
EU25	476	490	506	507	521	531	531	534	527	525	519	525
EU15	505	520	537	540	555	569	572	576	568	567	560	563
EU10	331	339	352	342	349	345	322	320	313	309	307	322

Different waste treatments and management strategies are adopted by the Member States (Fig. 2). It can be observed that the 40% of waste is landfill disposed, on average. In particular (but not only) for new EU

Countries, that is the principal waste treatment option. However, the use of landfill is decreasing everywhere in EU, year by year (Fig. 3).

Fig. 2 - Treatment and disposal of urban waste in Europe (ISPRA, 2007).

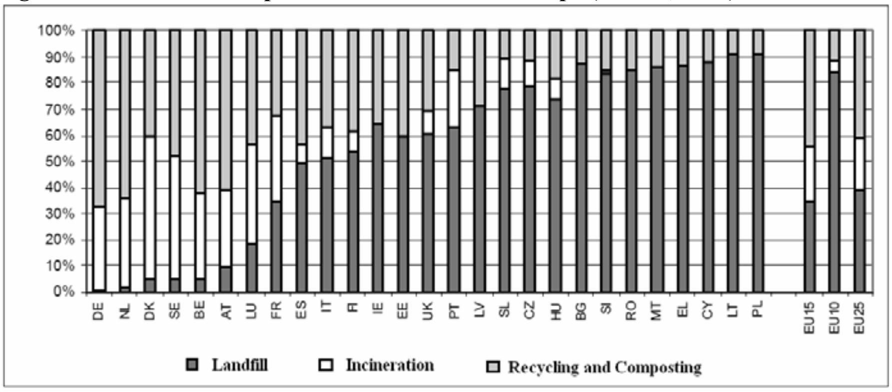
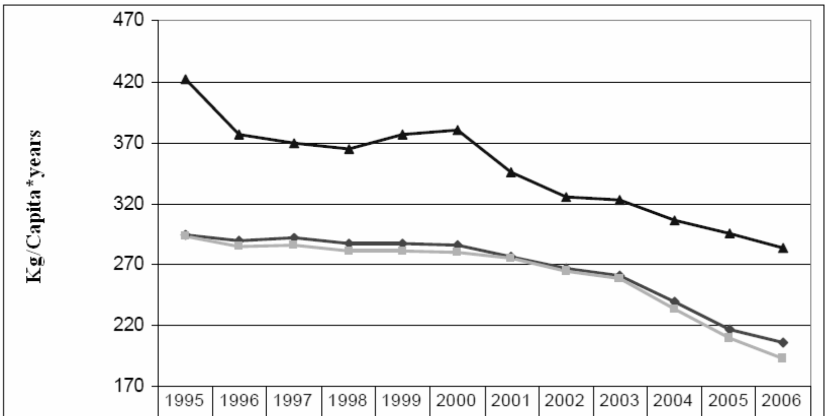


Fig. 3 - Waste landfill disposal of urban waste in Europe (ISPRA, 2007).



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
EU 25	294	289	292	287	287	286	276	267	261	239	217	206
EU 15	293	285	286	281	281	280	275	264	259	233	209	193
Italia	422	377	370	365	377	380	346	325	323	306	295	284

1.1. Waste Management Strategies

The Sixth Environmental Action Programme of EU: “Environment 2010: Our future, Our choice” defines the principles to which the whole environmental policy of European Countries would be referred. Some of these principles, concerning waste production and management are here reminded:

- Pollution caused by transport, agricultural activities, industrial processes and municipal and industrial waste management contributes to determine a poor environmental quality, which in turn has a negative impact on human health.
- The capacity of the planet to absorb resource demand and wastes deriving from their use is under pressure and negative effects are registered connected to metal, mineral and hydrocarbon consumption.
- In EU waste volume grows constantly with a consequent loss of land and resources and a pollution increase.
- A significant part of waste is hazardous.

Thus, many aims have been stated, in order to improve European situation concerning this issue. First of all, it is necessary to guarantee that renewable and non-renewable resources consumption and their impacts do not exceed the “bearing capacity” of the environment; then, the amount of waste destined to final disposal and the volume of hazardous waste produced must be significantly reduced; different prevention initiatives must be implemented to achieve a considerable overall reduction of waste amounts produced, a greater efficiency and a transition to more sustainable development models, decoupling in this way waste production from economical growth; wastes which will be still produced would not be hazardous or would present a minimum potential risk; it is necessary to favour recovery, and more specifically recycling; the amount of waste destined to final disposal must be reduced to a minimum and must be destroyed or safely disposed; and finally, wastes would be treated as near as possible to the place in which they are produced, provided that this is compatible with the European legislation and do not implies a reduction in the economical and technical efficiency in waste treatment operations.

These principles inspired the strategic approach to the waste management described by EU guidelines (DIRECTIVE 2008/98/EC). The few data reported above are however sufficient to understand that the EU approach, based on the “*hierarchy of waste treatments*” (prevention; preparing for re-use; recycling; other recovery, e.g. energy recovery; and disposal) is still far from being achieved for most States.

This hierarchy would be applied as a priority order in waste prevention and management legislation and policy. Furthermore, Member States would take measures to encourage the options that reach the best overall environmental outcome. This may require specific waste streams diverting from the hierarchy where this is justified by life-cycle thinking on the overall impacts (Article 4).

The EU legislation highlights the importance to prevent the production of waste, reintroducing it into the product cycle by recycling its components where there are ecologically and economically viable methods of doing so. The variations in the market and in social consumption could result in an improvement in product, technological and management quality. According to the principles of a sustainable development, a waste management strategy devoted to recycling can be described in different steps, as reported in Tab. 1.

Tab. 1 - Waste management strategies devoted to recycling.

<table>
<tr><td rowspan="7">Environmental Sustainability; Social Acceptability; Economic Sustainability; Recycling Culture; Education; Information</td><td>WASTE MANAGEMENT
devoted to Recycling</td><td>Reference tools</td></tr>
<tr><td>Environmental Policy and Strategies – Sustainable Development
European and national sector rules</td><td>Documents (VI Action Program 2000-2010);
Communications (COM-667)2005. European Directives</td></tr>
<tr><td>Flow Analysis
Integrated Waste Management System</td><td>National & European Reports;
Reports of
National Consortia</td></tr>
<tr><td>Waste Collection
Management Technologies
Mixed Waste: Treatment & pre-selection → material separation → treatment & technologies → material to be directed to the same or to other production cycles
Separate collection: Separated materials → Treatment & technologies → material to be directed to the same or to other production cycles</td><td>Planning (National, regional e provincial)
Information
Education
Fiscal benefits (rate system)

BAT
IPPC and guidelines
LCA</td></tr>
<tr><td>Waste material selection and physico-chemical analysis</td><td>Methodologies APAT, ASTM, ISO-UNI</td></tr>
<tr><td>Enhancement and recovery technologies:
Material recycling and energy recovery</td><td>Legislation Case studies
Environmental controls
Risk analysis</td></tr>
<tr><td>RE-PRODUCTS
and possible market</td><td>Certification, Eco-design, Eco-Label, EPD, GPP</td></tr>
</table>

Indeed, Integrated Solid Waste Management involves the selection and application of appropriate technologies, techniques, and management practices, to design a program to achieve business goals, minimizing operating costs and environmental hazardousness.

This system must consider the product features and the chemical-physical properties of waste. Furthermore, it is essential to determine the total waste flux and the flux of each commodity class. This approach allows an optimisation in the recovery of materials (by recycling), of electric and thermal energy (by incineration or anaerobic digestion), and a waste disposal with reduced environmental impacts.

This EU waste management legislation integrates well with the principles of European environmental policy and reduction of environmental impacts which could be summarised in these few points:

- All the subjects involved must give their contribution: the criterion of "shared responsibility".
- Reduction of environmental impacts and introduction of Life Cycle concept in waste policies.
- From management to prevention: IPP (Integrated Product Policy).
- Use of renewable raw materials and energy.
- Minimum waste production and maximum recycling.
- Eco-efficiency and dematerialization.
- Economy of closed cycles, i.e. extend product life cycle.
- ECODESIGN (Project strategy aimed to the supply of "products", "processes" or "services" with an environmental design).
- Reduction of obstacles in recyclable material markets.

1.2. Tools for the Assessment of Environmental Impact Relevant to Waste Treatment Activities

Every type of activity in the framework of an Integrated Waste Management Systems (reuse, recycling, recovery and landfill disposal) produces environmental impacts, at a global or more local scale. The identification of significant pollutants emitted from the contamination source is the first step in evaluation of impact associated to an anthropic activity.

The technological progress performed in recent years allowed a high improvement in pollution control associated to industrial processes. However, waste treatment facilities still create much concern in public opinion and in the public agencies involved in the safeguarding of human health. A general evaluation of the environmental impacts that derive from these processes is therefore necessary both in qualitative and quantitative terms, looking at the same time at the advantages and the negative aspects.

Below, some important tools which can support the assessment of environmental impacts are described (Morselli et al., 2005).

1.2.1. Integrated Environmental Monitoring System

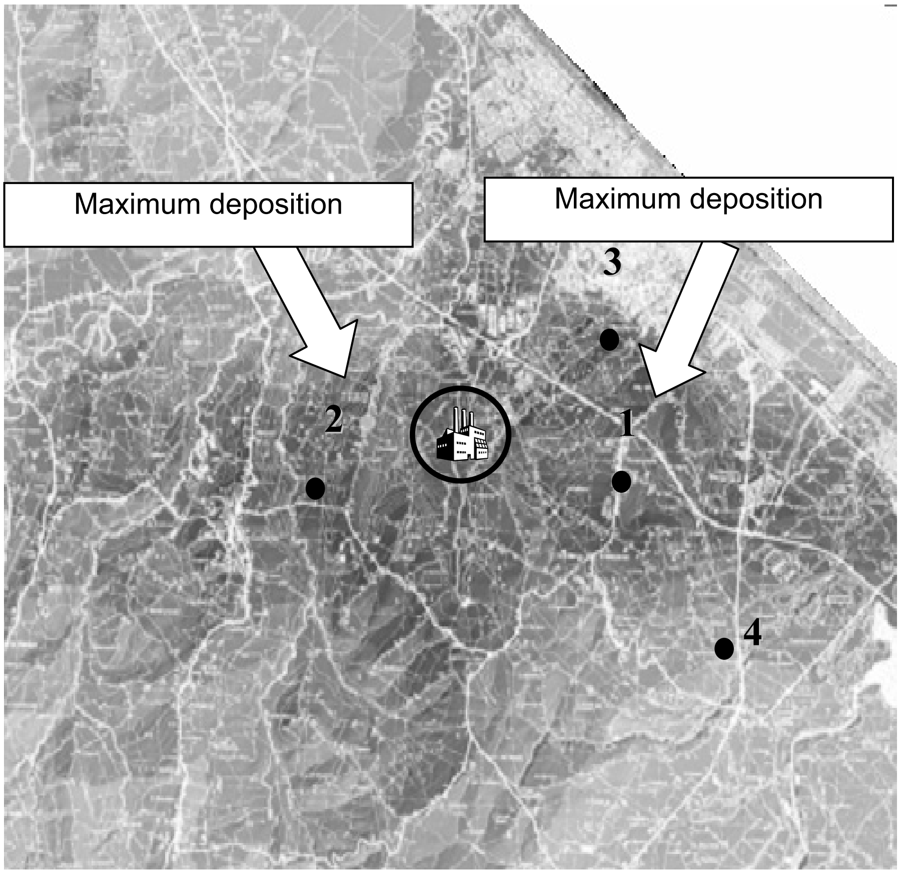
Since the more remarkable environmental impact is often produced at a local level and since the major pollutants dispersion is limited to a confined zone in the vicinity the plant, it becomes appropriate to investigate the environmental matrixes in the most invested areas. The Integrated Environmental Monitoring System (Morselli et al., 2002) is an important approach that could allows a remarkable understanding of relative impacts due to a contamination source. The first step of this procedure concerns the characterisation of the contamination sources and the application of a mathematical dispersion model to predict the area of higher dispersion of the contaminant emitted. A map representing different deposition loads of particulate emitted from a pollution source in the vicinity is shown in Fig. 4.

The sampling sites were chosen on the base of the dispersion model, in zones affected by different deposition extents, to assess pollutant diffusion. Then, some suitable indicators, that can be well linked to the source emission, are selected, such as the main ions, heavy metals, dioxins or a mix of polycyclic aromatic hydrocarbons (PAH); after, the most important environmental receptors as soil, wet and dry deposition, and particulate matter are analysed. The use of ordinary chemical monitoring instruments, together with biomonitoring methodologies, can give an interesting understanding of the interaction of the various pollutants with the biological matrices and the potentiality of their use in environmental studies.

Finally, the relationship of cause-effect between emissions and environmental concentration is investigated. Statistic tools of multivariate analysis can be very useful. An example of data elaboration is reported in Fig. 5a-b: loading and score plots related to the first two principal components of atmospheric deposition samples are reported, described by their content in the main ions (a) and in heavy metals (b).

As can be seen in Fig. 6a, the similarity between the sampling sites is in line with the choice of the areas at different deposition of pollutants from the plant, according to the distribution of the main ions. However (Fig. 6b), from the analysis of metal distribution, *site 1* is more similar to *4*, rather than the others; this could suggest that not only the plant, but other contamination sources affect the same zone, resulting in a similar heavy metals deposition for adjacent sites.

Fig. 4 - Annual deposition pattern of particulate from a pollutant source. The four different sampling sites identified for monitoring campaigns are indicated.

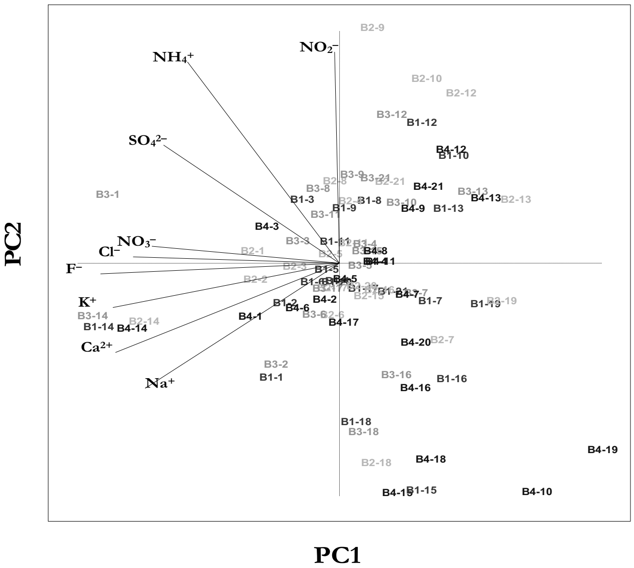


Furthermore, the resulting distribution, compared to the temporal variation of emissions and to the correlation of the same pollutants in the gas flows from the source, can suggest possible cause-effect relationships.

1.2.2. Environment and Human Health Risk Assessment (EHHRA)

Another useful tool is the Risk Assessment approach, which can be applied in order to assess the hazard represented by a waste treatment facility for the environment and for the health of the most affected population.

Fig. 5a,b - Loading (a) and score (b) plots calculated for main ions and heavy metals in deposition samples collected in the vicinity of an incineration plant.



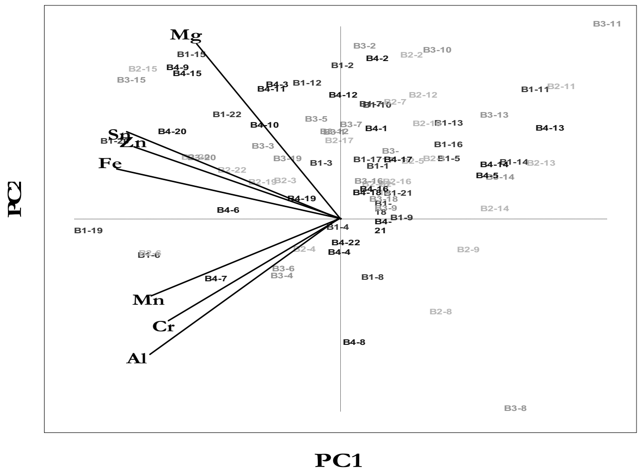
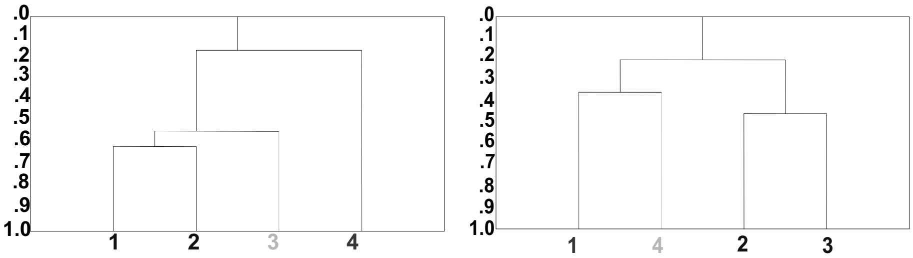


Fig. 6a,b - Cluster analysis (centroid classification) of the sampling sites calculated according to main ions (a) and heavy metals (b) concentration in deposition samples.



This is a powerful methodology, standardised by different environmental agencies (US EPA, 2005; DEFRA, 2004), to understand the fate of pollutants and their interaction with people. Its definition given by US NAS (1983) is: "the characterization of the potential adverse health effects of human exposures to environmental hazards".

This approach can be well integrated with the other used as control tools for the environmental impact of industrial processes or facilities.

Administrations, decision makers and public institution for the protection of health and environment can use it in order to oversee and monitor the possible impacts, and to implement a Strategic Environmental Assessment.

Companies can employ it to verify different industrial strategies; to trace the most convenient plant location; to perform the assessment of alternative scenarios; to compile a company certification; to take sustainable and transparent decisions; to communicate their efforts in environmental and health directions.

The methodology of application of HHRA is the following:

1. Hazard identification
2. Exposure assessment
3. Dose-response relationship assessment
4. Risk characterization

Once the pollution source is identified, the exposure assessment is performed by investigating all possible pathways of exposition to people living in the vicinity.

A scheme which summarises this approach is reported in Fig. 7.

According to the observation that almost all heavy metal content is in the fine fraction of particulate from the plant, atmospheric distribution around the plant has been calculated, as represented in Fig. 8.

Fig. 7 - Scheme of exposure assessment applied to the pollution from an incineration plant.

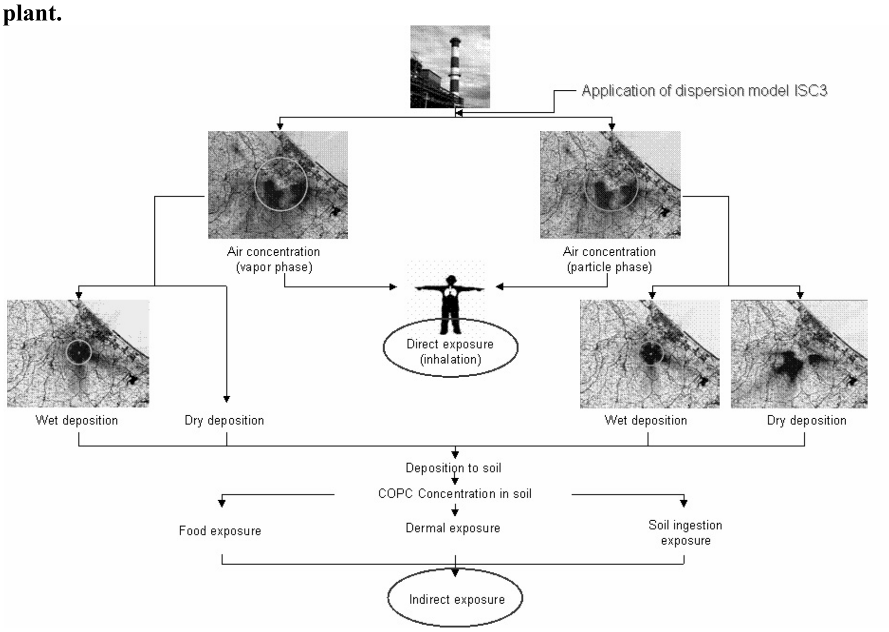
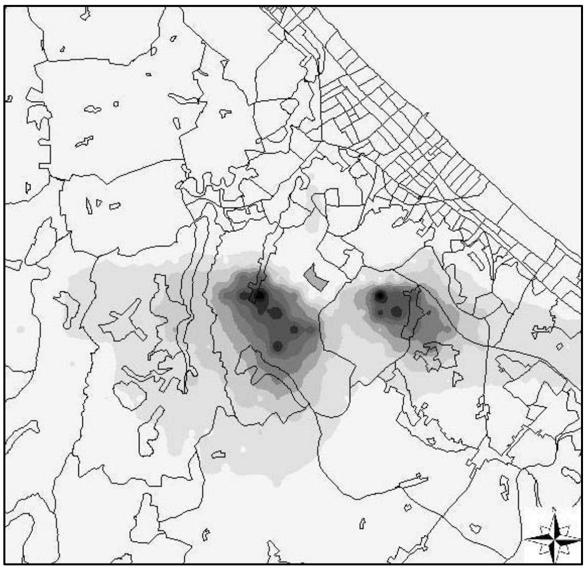
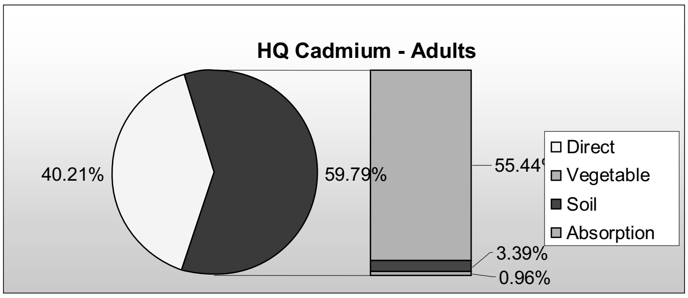


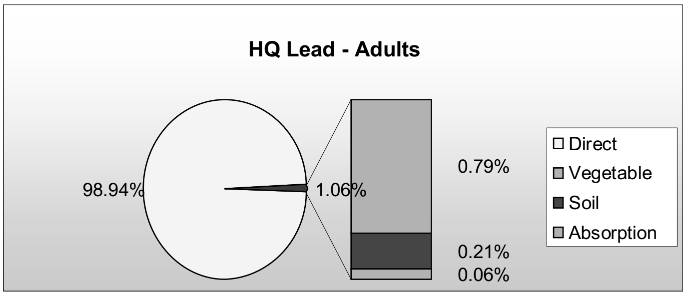
Fig. 8 - Atmospheric dispersion of fine particulate (PM_{10}) from an incineration plant.



For the toxicity of different heavy metals, a Hazard Quotient can be calculated, defined as the ratio of the exposure estimate to an effects concentration considered to represent a "safe" environmental concentration or dose. The quantification of different exposure pathways for adult people related to Cd and Pb emitted from the plant is reported (in %) in Fig. 9a-b.

Fig. 9a-b - Exposure pathways for adult people related to Cd and Pb toxicity (expressed in percentage of Hazard Quotient).





1.2.3. Life Cycle Assessment

Life cycle assessment (LCA) is a proven methodological tool, based on a global vision of the production system, in which all of the processes and the operations that occur, from the extraction of raw materials to the end of life, are analysed in terms of input and output, including the burdens associated with resource depletion and the releases on the environment.

The LCA applied to integrated MSW management constitutes a relatively new field of application of the methodology, and has a great potential of development, especially in support of the decisions of planners and companies that manage waste collection, transport and