Certainties and uncertainties in the evaluation of health impact from waste management options

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Issue framing

• Sources of waste: households, small manfactures, commerce, construction, demolition (hazardous waste) (sludge)

• Waste management: recycling, composting, gasification, incinerators, landfills,

• Emissions: lechates, gases, particulates, metals (mercury), dioxins, furans, HCL, HF, microbial agents

• Exposures route: inhalation, ingestion, dermal contact.

• Context: deprived areas, other industries, high community concern

• Health effects: birth defects, reproductive outcomes, cancer, respiratory disorders, psychosocial well-being
Reasons for concern

• “waste management” complex: generation, collection, processing, transport and disposal of waste

• large population groups and workers involved

• chemicals by way of inhalation of contaminated air, consumption of contaminated foods, water or dermal contact with contaminated soil

• many chemicals are known to be persistent, bioaccumulative, carcinogenic or endocrine disruptors

• Different stakeholders with competing interests
EU policy: The waste hierarchy

Changes in package design → Backyard composting grasscycling
Changes in purchasing habits → Increased reuse
Changes in industrial practices → Other changes in use patterns

Generation of waste for management → Recovery for recycling (including composting)

Landfill disposal → Combustion disposal

SOURCE REDUCTION

WASTE REDUCTION
Rotmans and van Asselts, 2001

Social dimension
Human behaviour

Economic dimension
Resources
Capital
Labour

Institutional dimension
Policy options and measures

Environmental dimension
Physical, chemical and biological changes
Typical characteristics of complex - uncertain - risks

• Decisions will need to be made before conclusive scientific evidence is available
• Potential impacts of ‘wrong’ decisions can be large
• Values are in dispute
• Knowledge base is characterized by large (partly irreducible, largely unquantifiable) uncertainties, multi-causality, knowledge gaps, and imperfect understanding;
• More research ≠ less uncertainty; unforeseen complexities!
• Assessment dominated by models, scenarios, assumptions, extrapolations

(Funtowicz & Ravetz)
Uncertainties

• Identify, assess, consider the consequences (dealing with uncertainties)
• Create, introduce, induce (fabricating uncertainties)
• Hide, negate (wiping out uncertainties)
An Epidemiologic Study in the Area of Coriano (Forli’)

Working Group:

ASL di Forlì,
ARPA Struttura di Epidemiologia Ambientale,
Registro Tumori della Romagna,
Dipartimento di Epidemiologia ASL Roma E
area within the circle of 3.5 km radius from two incinerators located in the industrial area
cohort study

cohort of residents in Coriano on Jan 1, 1990 and those subsequently entered in the area until Dec 31, 2003
data base

methods

residence history

mortality follow-up

cohort enrollment

(registry office of the municipality of Forlì)

cancer incidence

hospital admissions

 bertinoro, 23 novembre 2006
<table>
<thead>
<tr>
<th>outcome</th>
<th>period</th>
<th>source</th>
</tr>
</thead>
<tbody>
<tr>
<td>hospital adm.</td>
<td>1998 – 2003</td>
<td>HDR</td>
</tr>
</tbody>
</table>
Cohort of residents with 5 rings and Hg
## Results

### % Distribution by Heavy Metals

<table>
<thead>
<tr>
<th>Socioeconomic Level*</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>8.0</td>
<td>7.4</td>
<td>14.3</td>
<td>19.5</td>
</tr>
<tr>
<td>Medium low</td>
<td>21.3</td>
<td>12.8</td>
<td>41.4</td>
<td>35.1</td>
</tr>
<tr>
<td>Medium</td>
<td>27.1</td>
<td>23.1</td>
<td>30.6</td>
<td>28.5</td>
</tr>
<tr>
<td>Medium high</td>
<td>31.7</td>
<td>31.0</td>
<td>13.0</td>
<td>16.9</td>
</tr>
<tr>
<td>High</td>
<td>11.9</td>
<td>25.7</td>
<td>0.7</td>
<td>0.0</td>
</tr>
<tr>
<td>Total individuals (men)</td>
<td>6693</td>
<td>4833</td>
<td>5767</td>
<td>2114</td>
</tr>
</tbody>
</table>

* Quintiles of total distribution (municipality of Forli)
main results

- we observed an increase of soft tissue sarcoma among exposed to high levels of heavy metals, both for men and women

- moreover, only for women we observed:
  - an increase in all cause and all cancer mortality;
  - an increase in stomach and colon cancer incidence;
  - an increase in breast cancer mortality (but not incidence)
study design

→ retrospective cohort with individual data collection

→ complete follow-up

→ use of dispersion models allowed the evaluation of air pollution exposure (multiple sources)
limits

→ residential history <1990 not available

→ exposure data refer to a specific point in time (static measure)

→ lack of information on confounding factors (occupational history, smoking habit...)

Dipartimento di Epidemiologia ASL RME

bertinoro, 23 novembre 2006
Exposure and health impact assessment from waste management options

WP 3.6 Waste
The INTARESE Partnership

• 33 partners, in 14 countries, including:
  – Universities
  – National research institutions/centres
  – National governmental agencies
  – IGO
  – Industry

• Co-ordinated by Imperial College London and ICON

• Advisory board including users from:
  – Research/science (other EU projects)
  – EU institutions (EEA, JRC)
  – Industry
For More Information

Visit the INTARESE Web Site

www.intarese.org
INTARESE WP 3.6 Waste

To assess potential exposures and health effects from solid wastes throughout their lifecycle

Key objectives

1. To review the established and suspected health effects of exposures deriving from the waste management cycle

2. To identify gaps in knowledge and methodology for effective characterisation of the health impact of waste disposal in Europe

3. To develop tools and methods for exposure and health risk assessment
The full chain approach - from waste production to health effects
Incinerators in Italy, 2001
Relevant issues for risk assessment

• Estimate the impact from past exposure conditions
  – what is the impact (today and tomorrow) of incinerators operating during the ‘70 and the ’80?

• Estimate the impact from current exposure conditions
  – what is the impact (today and tomorrow) of incinerators operating today?

• Estimate the impact from future exposure conditions
  – what will be the impact (tomorrow) of new incinerators operating in the future?
## Approaches to risk assessment

<table>
<thead>
<tr>
<th>Time of exposure</th>
<th>Exposure data</th>
<th>Health data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yesterday</td>
<td>no quantitative data, only distance from the source (retrospective dispersion modelling?)</td>
<td>health data available but no dose response functions, only relative risks</td>
</tr>
<tr>
<td>Today</td>
<td>Exposure distribution for air pollutants from modelling, population data available</td>
<td>dose response functions available for some pollutants, time dimension uncertain</td>
</tr>
<tr>
<td>Tomorrow</td>
<td>Exposure distribution for air pollutants from modelling, population data uncertain</td>
<td>Uncertainties for some dose-response functions, time dimension uncertain</td>
</tr>
</tbody>
</table>
Step 1: yesterday

- **Estimate the impact from past exposure conditions**
  - e.g. what is the impact (today) of incinerators operating during the ‘70 and the ’80?
  - **Easy!!!:**
    - estimate population size (GIS)
    - derive relative risks (RRs) from the literature
    - apply RRs to the population and get expected cases
Incinerator located near Modena
Estimate of the population
All census blocks within 3 km from the plants

Modena incinerator
Systematic review of epidemiological studies on health effects associated with waste management
AIM

To assess potential exposures and health effects arising from municipal solid waste:
- cancers (stomach, colorectal, liver and lung cancer, soft tissue sarcoma, kidney and bladder cancer, non Hodgkin’s lymphoma, childhood cancer)

- birth outcomes (congenital malformations, low birth weight, multiple births, abnormal sex ratio of newborns)

- respiratory, skin and gastrointestinal symptoms or diseases
METHODS (1)

Relevant papers were found through:

- Computerized literature searches on the MEDLINE e PUBMED databases, using the MeSH terms “waste management”, “waste products”, “health effects” 427 papers

- FREE SEARCH, with several combinations of relevant key words “waste incinerator or landfill or composting or recycling”, “cancer or respiratory effects or birth outcome or health effects” 224 papers

- references listed in 8 previous REVIEWS from 01/01/1983 through 31/12/2006
METHODS (2)

Were not included

- Articles in languages other than English
- Studies on industrial, toxic or hazardous waste
- On sewage treatment
- On biological monitoring
- Studies conducted at municipality level

Total papers reviewed: 42
**METHODS** (3)

Papers have been grouped according to the following criteria:

- Waste management technologies (recycling, composting, incinerating, landfill)
- Study population (general population or workers employed in waste management plants)
- Health outcomes (e.g. cancers, birth outcomes, etc.)
METHODS (4)

For each paper:
- results with respect to the quantification of the health effects studied
- the potential sources of uncertainty in the results due to design issue have been reported
SOURCES OF UNCERTAINTY

The possibility that selection bias, information bias, confounding could artificially increase or decrease the relative risk estimate has been noted using the plus/minus scale.

PLUS/MINUS SCALE

- - - - - + ++ +++

% 50 20 0 20 50
Final evaluation

OVERALL EVALUATION OF EVIDENCE (IARC, 1999):

**Inadequate:** available studies of insufficient quality, consistency, or statistical power to decide the presence or absence of a causal association

**Limited:** a positive association has been observed between exposure and cancer, but chance, bias, or confounding could not be ruled out with reasonable confidence.

RELATIVE RISKS:

Only when the evidence is at least “limited”, extract the relative risks from the relevant studies

ASSESS THE DEGREE OF UNCERTAINTY OF THE RELATIVE RISKS:

use of a scale “degree of uncertainty” (very high, high, moderate, low, very low).
RESULTS: environmental exposure

Communities living near LANDFILLS:

- limited evidence of an increased risk of congenital malformations (moderate level of uncertainty)
- limited evidence of an increased risk of low birth weight (low level uncertainty)
RESULTS: environmental exposure

Communities living near INCINERATORS:

- limited evidence of an increased risk of liver cancer, non Hodgkin’s lymphoma and soft tissue sarcoma (low level of uncertainty)
- limited evidence of an increased risk of stomach, colorectal and lung cancer (moderate level of uncertainty)
- limited evidence of an increased risk of some subgroups of congenital anomalies (moderate level of uncertainty)
## Evaluation

<table>
<thead>
<tr>
<th>HEALTH EFFECT</th>
<th>LEVEL OF EVIDENCE</th>
<th>Landfills</th>
<th>Incinerators</th>
</tr>
</thead>
<tbody>
<tr>
<td>All cancer</td>
<td>Inadequate</td>
<td>Limited</td>
<td>Limited</td>
</tr>
<tr>
<td>Stomach cancer</td>
<td>Inadequate</td>
<td>Limited</td>
<td>Limited</td>
</tr>
<tr>
<td>Colorectal cancer</td>
<td>Inadequate</td>
<td>Limited</td>
<td>Limited</td>
</tr>
<tr>
<td>Liver cancer</td>
<td>Inadequate</td>
<td>Limited</td>
<td>Limited</td>
</tr>
<tr>
<td>Larynx cancer</td>
<td>Inadequate</td>
<td>Limited</td>
<td>Inadequate</td>
</tr>
<tr>
<td>Lung cancer</td>
<td>Inadequate</td>
<td>Limited</td>
<td>Limited</td>
</tr>
<tr>
<td>Soft tissue sarcoma</td>
<td>Inadequate</td>
<td>Limited</td>
<td>Limited</td>
</tr>
<tr>
<td>Kidney cancer</td>
<td>Inadequate</td>
<td>Adequate</td>
<td>Limited</td>
</tr>
<tr>
<td>Bladder cancer</td>
<td>Inadequate</td>
<td>Limited</td>
<td>Limited</td>
</tr>
<tr>
<td>Non Hodgkin’s lymphoma</td>
<td>Inadequate</td>
<td>Limited</td>
<td>Limited</td>
</tr>
<tr>
<td>Childhood cancer</td>
<td>Inadequate</td>
<td>Limited</td>
<td>Limited</td>
</tr>
<tr>
<td>Total birth defects</td>
<td>Inadequate</td>
<td>Limited</td>
<td>Limited</td>
</tr>
<tr>
<td>Neural tube defects</td>
<td>Inadequate</td>
<td>Limited</td>
<td>Inadequate</td>
</tr>
<tr>
<td>Orofacial birth defects</td>
<td>Inadequate</td>
<td>Limited</td>
<td>Limited</td>
</tr>
<tr>
<td>Genitourinary birth defects</td>
<td>Inadequate</td>
<td>Limited</td>
<td>Limited</td>
</tr>
<tr>
<td>Abdominal wall defects</td>
<td>Inadequate</td>
<td>Limited</td>
<td>Inadequate</td>
</tr>
<tr>
<td>Gastrointestinal birth defects</td>
<td>Inadequate</td>
<td>Limited</td>
<td>Inadequate</td>
</tr>
<tr>
<td>Low birth weight</td>
<td>Inadequate</td>
<td>Limited</td>
<td>Limited</td>
</tr>
<tr>
<td>Respiratory diseases or symptoms</td>
<td>Inadequate</td>
<td>Limited</td>
<td>Inadequate</td>
</tr>
</tbody>
</table>

**Health Effects**
- All cancer
- Stomach cancer
- Colorectal cancer
- Liver cancer
- Larynx cancer
- Lung cancer
- Soft tissue sarcoma
- Kidney cancer
- Bladder cancer
- Non Hodgkin’s lymphoma
- Childhood cancer
- Total birth defects
- Neural tube defects
- Orofacial birth defects
- Genitourinary birth defects
- Abdominal wall defects
- Gastrointestinal birth defects
- Low birth weight
- Respiratory diseases or symptoms
## Relative Risks

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Distance from the source</th>
<th>Relative Risk (Confidence Interval)</th>
<th>Level of uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Landfills</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Congenital malformations (Elliott et al, 2001)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All congenital malformations</td>
<td>Within 2 km</td>
<td>1.02 (99% CI = 1.01-1.03)</td>
<td>Moderate</td>
</tr>
<tr>
<td>Neural tube defects</td>
<td>Within 2 km</td>
<td>1.06 (99% CI = 1.01-1.12)</td>
<td>Moderate</td>
</tr>
<tr>
<td>Hypospadias and epispadias</td>
<td>Within 2 km</td>
<td>1.07 (99% CI = 1.04-1.11)</td>
<td>Moderate</td>
</tr>
<tr>
<td>Abdominal wall defects</td>
<td>Within 2 km</td>
<td>1.05 (99% CI = 0.94-1.16)</td>
<td>Moderate</td>
</tr>
<tr>
<td>Gastroesophageal reflux disease</td>
<td>Within 2 km</td>
<td>1.18 (99% CI = 1.03-1.34)</td>
<td>Moderate</td>
</tr>
<tr>
<td><strong>Low birth weight (Elliott et al, 2001)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very Low birth weight</td>
<td>Within 2 km</td>
<td>1.02 (99% CI = 1.052-1.062)</td>
<td>Low</td>
</tr>
</tbody>
</table>

| **Incinerators** | | | |
| **Congenital malformations (Cordier et al, 2004)** | | | |
| Facial cleft | Within 10 km | 1.30 (99% CI = 1.06-1.59) | Moderate |
| Renal dysplasia | Within 10 km | 1.55 (99% CI = 1.10-2.20) | Moderate |
| **Cancer (Elliott et al, 1996)** | | | |
| All cancer | Within 3 km | 1.035 (99% CI = 1.03-1.04) | Moderate |
| Stomach cancer | Within 3 km | 1.07 (99% CI = 1.02-1.13) | Moderate |
| Colorectal cancer | Within 3 km | 1.11 (99% CI = 1.07-1.15) | Moderate |
| Liver cancer | Within 3 km | 1.29 (99% CI = 1.10-1.51) | Low |
| Lung cancer | Within 3 km | 1.14 (99% CI = 1.11-1.17) | Moderate |
| Soft tissue sarcoma | Within 3 km | 1.16 (99% CI = 0.96-1.41) | Low |
| Non Hodgkin’s lymphoma | Within 3 km | 1.11 (99% CI = 1.04-1.19) | Low |
Step 1

- Estimate the impact from past exposure conditions
  - e.g. what is the impact (today and tomorrow) of incinerators operating during the ‘70 and the ‘80?
  - Easy, but consider duration/latency dimension. E.g. for cancer
    - 0-10 years: RR\*0
    - 11-20 years: RR\*0.5
    - 21-30 years: RR\*1.0
    - 31-40 years: RR\*0.5
Step 2: today

- Estimate the impact from current exposure conditions
  - e.g. what is the impact (today and tomorrow) of incinerators operating today?
- Easy!!!:
  - run dispersion model and estimate population distribution of exposure (GIS)
  - derive dose-response functions from the literature
  - apply dose-response functions and get expected cases
Exposure modelling and dose-response for classical pollutants

- Meteorology
- Sources
- Topography

Population → Pollution map → Exposure map → Health risk

Air pollution dispersion model

Geographical Information System

Dose-response relationship
Exposure map: PM10
Step 2

- Estimate the impact from **current** exposure conditions
  - e.g. what is the impact (today and tomorrow) of incinerators operating today?
  - Easy, but consider time dimension.
    - When the 3-4% increase in mortality per 10 ug/m3 PM10 will start to operate? Constant with time? When a decline of the effect is estimated?
Time, intervention and diseases burden (Murray et al, 2003)
Conclusions

- New epidemiological studies based on individual data, good exposure assessment, control of confounding, multisite protocols (e.g. Moniter)
- Integrated risk assessment should consider the time dimension of exposure and of the health effects
- GIS (distance, old) and Dispersion modelling (new) methods should be combined
- More research tends to increase uncertainty: reveals unforeseen complexities
Aknowledgements

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