The impact measure of solid waste management on health: the hazard index

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INTRODUCTION

In recent decades several studies have reported the effects of waste exposure on health. A wide range of toxic substances can be released into the environment from waste disposal sites, for example, methane, carbon dioxide, benzene and cadmium. Many of these pollutants have been shown to be toxic for human health. In addition if the waste disposals are illegal they are likely to contain highly hazardous compounds resulting from industrial activities (e.g. nuclear discharges, asbestos, lead).

Two main health outcomes have been found to be statistically associated with waste exposure: cancer...
and congenital malformations. Hazardous waste has been shown to influence the likelihood of developing lung, brain cancer, bladder and lung cancer \([1, 2]\) living close to a waste disposal site is also associated with a significant increase in congenital anomalies.

As of late, Campania, a Region of Southern Italy, has been a scene of controversy concerning waste disposal and treatment. Resident people and health authorities are more and more worried, while a heavy demand for new plants is in progress. Indeed, the regional administration is dealing with a rearrangement of the waste-disposal system following recent emergencies. Moreover, the regional territory houses some areas which have to be reclaimed as requested by a ministerial decree; precisely, in Agro Aversano and along Domitia-Flegrea seacoast various sites of uncontrolled waste-abandonment have been identified and assessed by the Campania Region’s Environmental Protection Agency (ARPA Campania) \([3, 4]\); many of them contain hazardous industrial substances. Here the spreading of unauthorized dumping has started in the ‘80s and goes on.

So one important issue in environmental matters is waste disposal. Accordingly it is desirable to start assessing possible consequences from population exposure to emissions from unauthorized dumping sites and plants for disposal and treatment of urban solid waste and hazardous substances.

A working group including World Health Organization (WHO), National Research Council (CNR), Istituto Superiore di Sanità (ISS), Department of Civil Protection (DCP), Campania Regional Epidemiologic Observatory (OER) and Campania Region’s Environmental Protection Agency (ARPA Campania) has been assigned the task of checking whether and how waste treatment in Campania could have adverse effects on environment and public health. Its work has partly dealt with epidemiological investigations on mortality and congenital anomalies in municipalities belonging to the Provinces of Naples and Caserta. At the same time, risk and exposure assessment relative to the presence of storage, treatment, illegal disposal and dumping sites of hazardous and urban waste has been worked out by implementing data dating back to the period 1997-2003 and coming from various administrations in a dedicated geo-database, so to extract “synthetical descriptive indexes” measuring position-variability of such sites and of their potential health impact.

The described approach has been used in many geographical-epidemiological studies on health effects deriving from the presence of waste; it consists in evaluating population exposure on the basis of their distance from landfills. Recent specialized literature suggests that the range of influence considered varies from 2 to 4 km \([2, 5, 6]\). But these studies are about dumping sites containing either hazardous or special large-sized waste. We rather aim to analyze an ensemble of sites, diversified in nature and dimensions, sometimes very close to each other, in an area characterized by either a high or very high population density. Therefore, our choice criterion was to select population living really close to the sites, according to a common epidemiological approach to high-risk groups. As a result, an area 1 km in range around each site has been chosen since it ensures an adequate statistical power.

Outcomes from the above analysis, performed on all 196 municipalities in the Provinces of Naples and Caserta, represented a basis for recent epidemiological studies \([7, 8]\) in order to assess adverse effects of the presence waste on the environment and resident population.

The impact chain starts when waste enters the landfill or is abandoned illegally in the soil or in the water. Depending on the intrinsic quality of the waste and on the density of the population in the surrounding area, hazardous emission will be released into the environment affecting human health. According to previous studies in Campania, the health risk due to environmental hazards arising from waste exposure is confined to the two provinces of Naples and Caserta, where most of the illegal dumping sites are located. The dumping sites in Naples and Caserta differ in dimension and composition. In addition, most of these waste disposals are illegal and not visible (sunken or buried) thus the toxic substances that the disposals contain are not known and are difficult to identify. In order to map the possible areas exposed to a higher waste related health risk, a synthetical hazard index (HI) was developed.

**METHODS**

The analysis of influence of polluting sources on the territory and people has been organized into the following steps.

**Characterization of waste disposal and abandonment sources and assignment of a hazard index (HI) to sites**

On the basis of the data regarding waste disposal plants and unauthorised dumping grounds (from 1997 to 2003) \([3, 4]\), and after a thorough validation of the georeferenciation process, 140 sites were chosen in the province of Caserta and 86 in the province of Naples.

Selected sites have been further classified according to their hazard level (HI hazard index) taking into account site nature (dumping and storage sites, slagheaps, submerged waste, uncontrolled waste abandonment, etc.), legal status (authorized or non-authorized sites), waste volume and nature, and pollutant emission-mode (Figure 1).

The assignment criterion rested mainly upon environmental impact on water, air and soil of storage-treatment-disposal-abandonment fashion concerning hazardous and urban waste.
According to the above-mentioned criteria, Table 1 shows the HI for various types of waste disposal/treatment and/or abandonment.

<table>
<thead>
<tr>
<th>TYPE</th>
<th>HI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Submerged waste (lakes)</td>
<td>4  A</td>
</tr>
<tr>
<td>Slagheaps</td>
<td>3  B</td>
</tr>
<tr>
<td>Hazardous waste storage and disposal</td>
<td>3  B</td>
</tr>
<tr>
<td>Abandonment of metal drums</td>
<td>3  B</td>
</tr>
<tr>
<td>Pit slagheaps containing hazardous waste</td>
<td>2  B</td>
</tr>
<tr>
<td>2nd class – type B dumping sites (special/industrial waste)</td>
<td>2  C</td>
</tr>
<tr>
<td>Car wrecking and scrapping plants</td>
<td>1  D</td>
</tr>
<tr>
<td>Plants for electric and electronic waste reclaim</td>
<td>1  D</td>
</tr>
<tr>
<td>Temporary storage of non-hazardous waste</td>
<td>1  D</td>
</tr>
<tr>
<td>Plants for chemical-physical treatment of waste</td>
<td>1  D</td>
</tr>
<tr>
<td>Non-hazardous waste reclaim</td>
<td>1  D</td>
</tr>
<tr>
<td>Plants for treatment (storage) of special waste</td>
<td>1  D</td>
</tr>
<tr>
<td>Special waste incineration and oil reclaim plants</td>
<td>1  D</td>
</tr>
<tr>
<td>Uncontrolled RSU dumping sites</td>
<td>1  E</td>
</tr>
<tr>
<td>Pit large-volume (&gt; 10 000 cc)</td>
<td>1  E</td>
</tr>
<tr>
<td>non-hazardous slagheaps</td>
<td></td>
</tr>
<tr>
<td>Large-volume (&gt; 10 000 cc)</td>
<td>1  E</td>
</tr>
<tr>
<td>non-hazardous slagheaps</td>
<td></td>
</tr>
<tr>
<td>Controlled RSU dumping sites – authorized inert-waste dumping sites</td>
<td>1  F</td>
</tr>
<tr>
<td>Composting plants</td>
<td>1  F</td>
</tr>
<tr>
<td>Plants for refuse-derived-fuel (RDF) selection and production</td>
<td>1  F</td>
</tr>
<tr>
<td>Refluent-water depuration plants</td>
<td>1  F</td>
</tr>
<tr>
<td>Industrial slagheaps</td>
<td>1  F</td>
</tr>
</tbody>
</table>

The grade consists of an alpha-numeric code where the number increases with hazard and the letter goes A to F at the decreasing of it (A = max hazard; F = min hazard). In a few words, the number identifies danger magnitude, while the letter is a multiplication factor related to waste intrinsic dangerousness.

Precisely:

- **A**: potential hazardous or very hazardous submerged waste
- **B**: hazardous waste
- **C**: potential hazardous emissions from industrial special waste
- **D**: potential hazardous emissions from non-hazardous waste
- **E**: uncontrolled non-hazardous waste
- **F**: controlled non-hazardous waste

### Identification and characterization of the environmental impact areas and assignment of a composite hazard index (CHI)

By means of ArcGIS software-platform [9, 10], customized through Python and Avenue programming languages, a territorial analysis has been performed in terms of sites and municipalities.

Site-analysis has identified and characterized sources, calculating their fallout “areas” (buffer strips of 1 km from sites). On the other hand, analysis on a municipality-scale needs an identification and characterization of areas influenced by more than one site, so as to avoid counting population living in one area more than one time; at the same time, a specific coefficient is needed to describe global danger to them. Therefore, a script has been worked out to pass from “fallout areas” to “environmental impact areas”.

Selecting a buffer strip 1 km in range around any potential polluting source, fallout areas have been identified. These latter have been assigned HIs from corresponding sites; then, each area influenced by more than one site has been attributed a multi-code (CHI) consisting in a series HIs from single sources lying in the examined area (Figure 2).

### Computation of a municipal hazard index (MHI)

A potential hazard index (PHI, numeric parameter) has been associated with each CHI (alpha-numeric parameter)\(^1\); this way a classification of hazard values was made. Consequently, if impact-area types and surfaces (S) are known for each municipality, then a municipal hazard index (MHI) can be derived.

As a result, the following function has been implemented:

\[
\text{MHI} = \sum_{i=1}^{n} S_i \times \text{PHI}_i
\]

n being the number of impact areas in the municipality under examination.

### Computation of population living in each impact area to assess risk from exposure

Then a further hazard index has been introduced, taking into account information about the distribution of potentially exposed population; at this aim, population falling in each impact area have been computed, extracting them from ISTAT 2001 census tracts.

Analysis steps follow:
- **computation of population density in census tracts**: population density in each tract has been obtained dividing resident people by tract surface;
- **intersection of census tracts and impact areas**: the two layers have been intersected, so deriving new

\(^1\)In each CHI, frequencies of numbers and letters have been assigned different statistical weights.
polygons. This way attributes associated with the two layers have been spatially combined as well:
- Computation of people living in polygons of the new layer: population falling in each new polygon has been computed by multiplying population density by polygon surface.

**Computation of a synthetical waste risk index (SWRI)**

A synthetical-waste risk index (SWRI) has been derived multiplying surfaces of impact areas falling in a specific municipality by their PHIs and population living in each area (E) and then summing over the number n of areas included in the municipality under examination:

$$SWRI = \sum_{i=1}^{n} S_i \times PHI_i \times EP_i$$

**RESULTS**

So far our approach has allowed us to describe geographical distribution of waste disposal sites in terms of their PHIs, in order to identify and characterize, by means of GIS, those areas apt to waste contamination, which gather between inshore mu-
nicipalities and those falling north-east of Naples. Mapping of impact areas (Figure 3) by means of their CHIs has enabled us to select those zones lying in the two Provinces, which are under waste pressure most [11].

A SWRI has been computed for each of the 196 municipalities under examination, thinking of resident population as a target of contamination. As shown by the geographical distribution of SWRIs, municipalities on the border between the Provinces of Caserta and Naples and those lying along the Tyrrhenian coast are exposed to risk most. According to epidemiological studies, high mortality by cancer and frequent congenital anomalies are typical of such areas as well [12]. A correlation study is in progress in order to assess connection among SWRI, mortality rates from specific causes and congenital anomalies.

CONCLUSIONS

The goal of this analysis was trying to give geographical-epidemiological studies a contribution, using waste-disposal data collected in Campania to derive an exposure index based not only on distance from dumping sites, but also on characterization of neighbouring areas depending on territorial significant elements, as allowed by GIS features.

As a first result, some municipalities along the coast and north of Naples have been shown to be characterized by high-risk impact areas, which represent top targets for reclamation procedures and further analytical epidemiological studies.

So far, only population living in impact areas around potential polluted sites (computed by means of population density of census tracts) have been taken into account as a possible target, but, as a second step, further environmental and territorial factors (hydrological data, soil exploitation, socioeconomic conditions, etc.) are going to be included into the computation of SWRI.

Geographical distribution of SWRIs is consistent with outcomes from epidemiological studies performed so far. Anyway, many other factors (extensive agriculture, industrial activities, socioeconomic conditions, high population density, health conditions) influence this territory from an environmental point of view and have to examined in the context of a multivariate analysis.

Conflict of interest statement

There are no potential conflicts of interest or any financial or personal relationships with other people or organizations that could inappropriately bias conduct and findings of this study.

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References


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