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Inequalities, inequities, environmental justice in waste management and health

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Background: The scientific evidence on the health effects of waste-related exposure is not conclusive. Differential exposure to waste by socio-economic status (SES) is often documented, but the interplay between environmental and social factors, crucial for policy making, is not well known. This review aims at investigating the role of health inequalities and inequities in waste management. **Methods:** Grey and peer-reviewed literature, published after 1983, was reviewed from Europe and the USA. **Results:** Available data provide consistent indications that waste facilities are often disproportionally more located in areas with more deprived residents, or from ethnical minorities. This applies to waste incinerators, landfills, hazardous waste sites, legal and illegal. In studies considering health effects (mainly from Europe), risks are estimated with standardization for SES. Such standardization almost always decreases risk estimates for several cancers and reproductive outcomes. However, effect modification is not investigated in these studies. **Conclusions:** The patterns of association between waste-related environmental pressures and SES suggest that some of the observed inequalities in exposure and health represent a case of environmental injustice as they are the result of social processes and may be prevented, at least partly. Disentangling the possible health effects remains difficult, due to limitations in the methodology. It seems important to investigate if disadvantaged people are more vulnerable, i.e. risks differ in different social groups living in the same area. Notwithstanding these open questions, public health officers and decision makers should identify waste management policies to minimize their potential health impacts and their unequal distribution.

Keywords: adverse effects, environmental exposure, hazardous waste, health effects, social class, socio-economic factors

Introduction

Waste and health: scientific evidence and knowledge gaps

Given the growing production of waste, policy-makers are increasingly confronted with the necessity of developing more capacity to safely dispose of waste. Despite the lack of univocal evidence on the health implications of waste-related environmental exposures, there are concerns over the health effects of different waste management options, including land filling, incineration, disposal of healthcare and other hazardous waste.[1]

Further insights on health effects of landfills and incinerators are needed; it is important to investigate these possible effects in conjunction with other environmental hazards, as concurrent exposures can result in synergistic health 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. It is urgent to clarify how population distribution of waste-related exposures (i.e. how uneven are such exposures among different subgroups) can inform the policy response, affect its effectiveness and acceptance, and how these aspects can be taken into account more systematically in policy-making. In particular, it is of great interest to clarify what proportion of health *inequalities* (i.e. general differences in health status and in exposure levels due for example to age or individual predisposition) can be regarded as *inequities* (i.e. avoidable differences, for example in access to healthcare service, preventing individuals from attaining their full health potential, and carrying an ethical negative judgement) and as such result in environmental injustice.

The present contribution is dedicated to the role of socio-economic differences and environmental justice on the potential health burden due to exposure to hazardous waste facilities.

Role of social health determinants

Social determinants of health have a strong influence on virtually all health endpoints considered in studies designed to assess the role of waste–related exposure. As in many other fields in environmental health, this realization has resulted in the adoption of methodology to formally take into account these effects in epidemiological studies. Typically, socio-economic factors have a strong potential for acting as *confounders* of the parameter of interest, i.e. the association between health and waste exposure. This is because exposed subjects often have socio-economic characteristics that can differ from those of unexposed subjects, and thus create differences in risk that could be erroneously attributed to waste. This is why effects of socio-economic factors are often regarded, in epidemiological studies, as *nuisance factors*, and standardization techniques are applied to remove their contribution and assess the waste–health association, net of the influence of socio-economic factors.

This routine standardization reflects the strong expectation that socio-economic factors are associated with environmental exposures—a prerequisite for a confounding effect. The systematic adoption of this practice relies on an important assumption, and suggests a certain attitude: the assumption is hazard *proportionality*, i.e. health risks from socio-economic conditions act as multipliers of an independent

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risk due to environmental factors. In other words, through standardization for socio-economic factors the environmental risk is assumed constant across different social strata, and the possibility of *modification of effect* (for example, different risks for different socio-economic groups) is seldom investigated. The attitude is the one of considering the multiple effects as independent of each other and attaching less importance to the contextual ones. Admittedly, full, holistic consideration of the mutual action of different risks is very challenging and is often not feasible; however, a fuller understanding of how environmental risk factors operate in the reality of the social environment would be very informative especially for designing effective policy responses.

In this paper we examine the evidence and the implications of the confounding effect of socio-economic factors. First of all then, we address the question of how strong is the evidence that more deprived communities are more exposed to waste-related contaminants; later, we examine how these gradients, where observed, can influence the risks for several health endpoints, considering how risks differ before and after adjustment for socio-economic factors. Finally, we discuss the implications of these inequalities.

Methods

Grey and peer-reviewed literature, published after 1983, when an influential paper appeared,[2] was reviewed from Europe and the USA.

Keywords or references in the titles to 'waste', 'health effects', 'socio-economic factors', 'inequities', 'environmental justice', 'congenital anomalies' and 'mortality' were used to search the Medline database. All European studies were selected. With regard to US studies, given the large amount of literature dealing with social differences on the residence near waste facilities, only the most s studies were chosen and commented. The grey literature was searched with the same criteria using Google Scholar and looking at the key references listed in the peer-reviewed articles to identify nongovernmental organization (NGO) reports and studies published by other agencies. A total of 47 studies were included in the review.

Results

Residence near waste facilities: unequal and inequitable

The characteristics and main findings of the identified studies are summarized in Supplementary Table 1.

The first studies on environmental justice, contaminated sites and waste were carried out in the USA and were prompted by the concerns of civil activists on the disproportionate location of landfills in predominantly black communities.[3] The correlation between race, income and residence influenced several outcomes such as a higher likelihood of being exposed to environmental hazards, the disproportionate impacts of environmental processes and policies, the targeting and siting of noxious facilities in more deprived communities and inequalities in the delivery of environmental services such as rubbish removal.[4–6]

Other studies found skewed distributions around waste sites, with less affluent population subgroups, and with more black people, living in the surroundings of the facilities.[2,7–9] In a US national assessment[10,11] (later updated[12]), a correlation was found between proportion of black residents and the presence of hazardous waste sites in the surroundings. Although these results were criticized,[13–16] ethnicity was considered to be a stronger predictor of the presence of toxic dumps than other variables, such as household income, the value of homes and the estimated amount of hazardous waste generated by local industry.

Brown[17] reviewed (i) exposure to toxic hazards, including the presence of hazardous waste sites and facilities (ii) regulations, ameliorations and cleanups, including record of decisions and cleanups at National Priority List (NPL) sites and (iii) regulatory actions, as measured by assessed fines for environmental pollution; he concluded that 'the overwhelming bulk of evidence supports the ''environmental justice'' belief that environmental hazards are inequitably distributed by class, and especially race'. These results were confirmed by the most recent study,[18] and the underlying social processes were analysed in different settings.[15,19,20]

Compared to US studies, European data are based on a different approach to measuring socio-economic status (SES), based on composite indices built combining information on several domains, such as social class, education, unemployment, housing, family structure, rather than variables such as income or ethnicity.

The association between social characteristics and residence in the vicinity of waste sites has been repeatedly documented in England and Wales. Several studies analysed the correlation between income and deprivation with localization of solid waste and other polluting facilities, finding that facilities were disproportionally located in the more deprived areas.[21–23] The correlation was not always observed for landfills at the subregional level.[24]

At the national level, a study by Elliott *et al.*[25] showed that 'the area within two km of the 9565 landfill sites tended to be more deprived than the reference area: 34% (versus 23%) of the population were in the most deprived tertile of Carstairs score (36% for special waste sites)'.

A national study on environmental inequalities in France on the distribution of environmental burden tested the hypothesis that poor and immigrant communities are disproportionately exposed to environmental risks. Eight types of hazardous sites (industrial and nuclear sites, incinerators, waste management facilities) and the socio-economic characteristics of populations were associated at the *commune*, or town, level for all 36 600 French towns. The results of the spatial regression analyses showed that towns with high proportions of immigrants hosted more hazardous sites, even controlling for population size, income, degree of industrialization of the town and region.[26]

In the European Union project Integrated Assessment of Health Risks of Environmental Stressors in Europe (INTARESE), an integrated approach for the health impact assessment of landfills and incinerators on the population living in the surroundings has been applied in Italy, UK and Slovakia, for a total 905 municipal urban solid waste landfills and 53 waste incinerators.[27] A direct relationship was found between social class and residence near waste facilities in Italy and UK, and an inverse relationship was found in Slovakia (Table 1). For incinerators, this may be due to the location of the two facilities in urban areas, where most affluent Slovakian people live.

The results of European Collaborative Study of Residence near Hazardous Waste Landfill Sites and Risk of Congenital Malformations (EUROHAZCON),[28] a multisite study that considered 21 landfills in several countries, suggested 'no overall evidence that socio-economically more deprived communities live near to landfill sites'.

An inverse relationship was also found in a study of a Welsh landfill, where most affluent people were found to be living closer the site.[29]

Cancer mortality and congenital anomalies of populations living in 196 municipalities of two provinces of Campania

Table 1 Characteristics of residents living close to waste facilities[a] in Italy[b], Slovakia and England, by quintiles of deprivation index, 2001

	Landfills			Incinerators		
	Italy	Slovakia	England and Wales	Italy	Slovakia	England and Wales
Number of sites	619	165	232	40	2	11
Population within 2 km	1350 852	328 869	1425 350	1060 569	16 409	1203 208
Most affluent population (I group, %)	13.3	24.2	2.5	12.6	55.6	30.
II group	15.0	24.7	17.9	15.1	2.4	6.3
III group	22.4	22.6	18.7	21.0	9.8	12.5
IV group	23.0	16.4	19.1	24.2	29.6	22.8
Most deprived population (V group, %)	26.1	12.1	20.1	24.9	2.5	55.4
Missing information (%)	0.0	0.0	21.7	2.2	0.2	0.0

Source: adapted from Forastiere *et al.*[27]
a: 2 km from municipal urban solid waste landfills; 3 km from waste incinerators
b: 118 landfills were geocoded, for population of 257 513. Socio-economic data were then extrapolated to 619 landfills

Region, southern Italy, were recently investigated.[30] The study area was characterized by more than 20 years of waste mismanagement (with the involvement of organized crime), including uncontrolled waste disposal, release of toxic substances and illegal waste burning. A positive correlation ($r = 0.30$) was found at municipality level between a waste exposure indicator (built using 227 waste facilities sites–138 of which illegal) and a deprivation index.[30]

Interest in environmental justice and in unequal distribution of environmental hazards and benefits has recently grown in countries of central and eastern Europe. It has been documented that hazardous sites and illegal waste disposal activities are disproportionally located in the working-class areas, as in Hungary with illegal asbestos disposal,[31] and in communities of ethnic or national minorities, predominantly the Roma populations,[32–34] whose camps are often settled on (or near) contaminated sites. The Hungarian National Public Health and Medical Officers' Service reported, for example, that 15% of the 767 Roma colonies identified in Hungary, for a total of three million persons, are within 1 km of illegal waste disposal sites, and 11% within one km of animal carcass disposal sites.[35]

In addition, minority groups in European countries are more at risk of environmentally based discrimination because they are more likely to be object of discrimination, and be segregated in enclaves or in deprived zones along the borders, or in refugee camps.[33,36,37]

Finally, besides differential levels of exposure to waste-related contaminants by socio-economic levels at local or national level, inequalities in exposure might take place at the international level, through the transfer of related hazards from one country to another.[38,39] In fact, illegal shipment and disposal of hazardous waste is of growing relevance in some countries of central and eastern Europe.[40,41]

Exposure to waste and socio-economic factors: compounded effects

Many of the studies above, especially from Europe, document a pattern where deprived people are overrepresented in the vicinity of waste treatment facilities. In some of these studies, in addition, it is observed that health effects—notably mortality, congenital anomalies, low birth weight—are associated with socio-economic factors.

Several studies were performed in UK on congenital anomalies,[25,42] Down syndrome[43] and cancer[44] in population living near landfills. In a recent study on congenital anomalies and landfill density, risks were standardized by SES, presence of a congenital anomalies registry and maternal age. On adjusting for these factors, risks decreased for all the anomalies under study, more markedly in areas with the highest special waste sites density.[25]

In a subsequent study[43] a decreasing risk of Down's syndrome with increasing levels of socio-economic deprivation was observed; however, adjustment for SES resulted in a marginal correction of the estimates of the risks from landfills, perhaps not surprising because of the strong effect of maternal age.

In another UK study on cancer and residence near landfill sites,[44] adjustment for SES decreased the risk estimate for bladder cancer, which however remained significantly in excess. The same was observed for hazardous sites, but the adjusted risk for bladder cancer lost statistical significance.

In the EUROHAZCON multi-site study a positive association was reported in the UK between SES and non-chromosomal congenital anomalies close to landfills.[28] The risk in the most deprived group was 40% higher than in the most affluent quintile; an impact measure was also estimated: if the rates observed in the most affluent group prevailed in the whole exposed population, the 18% fewer anomalies would have occurred.[45] This pattern was not observed in other European sites.

In a study carried out in Campania a positive association was observed between mortality for various cancer causes and both illegal waste exposure and socio-economic factors. For both sexes, mortality risk estimates unadjusted by socio-economic deprivation were much higher than adjusted ones, as shown in Table 2. Risk estimates were markedly corrected across the five levels of waste exposure, and so were estimates of linear trends. The only exception was stomach cancer in men.[46]

In a study in the New York state near PCB-contaminated (i) superfund sites, (ii) NPL sites and (iii) the six areas of concern,[47] the risk of giving birth to a low-birth-weight and to a very low-birth-weight baby was investigated. Positive associations were observed between having a low-birth-weight baby and (i) low levels of income and (ii) mother's educational level less than (or equal to) high school while only a low-income level was associated to having a very low-birth-weight baby.

Another US study[48] considered only ethnic minorities (Black/African American, Hispanic/Latino, American Indian/Alaska Native and Asian/Pacific Islander) and found a positive association between a range of anomalies and residence in the census tracts near the NPL hazardous waste sites. The largest association was found between potential exposure and neural tube defects [odds ratio (OR) = 1.54, 95% confidence

Table 2 Waste exposure, SES and mortality outcomes in Campania region[a]

	Mortality excess (%) risks by waste exposure group[b]										
	I	II		III		IV		V		*Trend*	
		Unadj	Adj[c]	Unadj	Adj	Unadj	Adj	Unadj	Adj	Unadj	Adj
Cause of death—men											
All causes	—	**9.2**	**5.4**	**6.9**	**7.9**	**7.1**	**3.9**	**13.6**	**9.2**	**2.2**	**1.7**
All cancers	—	**9.3**	**4.2**	3.2	**5.6**	**9.3**	**4.9**	**11.0**	4.1	**2.2**	**1.5**
Lung cancer	—	**11.4**	**5.5**	4.2	6.4	**11.1**	6.1	**14.0**	6.7	**2.7**	**1.9**
Liver cancer	—	−0.1	−9.2	12.7	**20.6**	7.0	0.7	35.5	**19.3**	**5.6**	**4.3**
Stomach cancer	—	−1.5	3.0	0.1	2.8	**17.0**	**19.4**	16.2	15.7	**5.0**	**5.2**
Bladder cancer	—	**17.3**	11.7	−11.0	−6.4	10.8	7.1	4.6	−4.1	0.8	−0.7
Kidney cancer	—	4.4	−2.8	−4.3	−0.6	−8.5	−14.9	−7.6	−16.7	−3.0	−4.0
Soft tissues sarcoma	—	10.6	−9.8	−7.2	−20.4	−23.6	−31.0	18.7	25.0	−3.1	−3.9
Non Hodgkin lymphoma	—	**24.2**	9.4	29.8	25.4	18.7	6.8	2.8	−3.7	2.3	1.3
Other cancers	—	**9.1**	**4.7**	2.4	4.3	**7.6**	3.3	6.2	0.3	1.4	0.7
Cause of death—women											
All causes	—	**3.1**	1.7	**7.2**	**8.1**	**5.6**	**4.8**	**14.4**	**12.4**	**2.6**	**2.4**
All cancers	—	**9.8**	**5.1**	2.3	2.4	**6.7**	3.6	**10.0**	**6.6**	**1.6**	**1.0**
Lung cancer	—	**63.8**	**45.4**	10.2	14.4	14.1	5.6	**22.7**	9.4	0.2	−2.3
Liver cancer	—	−3.5	−9.3	5.0	9.1	13.6	9.6	**39.5**	**29.1**	**7.3**	**6.6**
Stomach cancer	—	−8.1	−8.3	−2.3	−6.4	1.0	2.2	10.7	16.7	2.1	2.6
Bladder cancer	—	17.9	7.7	−6.5	−12.7	3.2	−2.8	−17.3	−16.7	−2.8	−3.3
Kidney cancer	—	19.2	6.9	2.4	11.2	8.7	3.4	36.2	19.1	3.8	1.7
Soft tissues sarcoma	—	4.3	7.7	76.0	84.1	35.2	33.6	4.2	−0.3	7.8	8.3
Non Hodgkin lymphoma	—	9.8	10.1	3.3	3.5	15.9	19.7	−2.1	−0.2	1.8	1.6
Other cancers	—	**7.4**	3.5	1.3	1	5.2	2.3	6.3	3.7	1.1	0.7

Source: Adapted from Martuzzi *et al*.[30]
a: In bold, statistically significant risks are reported (95% CI)
b: I group is used as reference, i.e. no waste-related exposure; V group has highest exposure
c: Mortality excess risks (%) = (relative risk −1) × 100. Risks adjusted by SES

interval (CI) = 0.93–2.55]. The strongest association between birth defects and potential exposure was among American Indians/Alaska Natives (OR = 1.19, 95% CI = 0.62–2.27). This study design, however, does not allow a comparison with the effects in the majority population.

Discussion

Waste and health: same risk for everyone?

The evidence summarized above indicates that there is a tendency in poorer, less educated, disadvantaged people or ethnical minorities to live closer to waste treatment facilities of any kind and, in addition, that when adverse health effects due to such proximity are detected, these are often compounded (usually multiplicatively) with the adverse effects of social disadvantage. This pattern may occur for other localized source of environmental pollutants, but is not systematically documented. On the whole, the evidence suggests marked inequalities in the health pressures and impacts due to the combination of environmental and social factors. Some of these inequalities are due to socially driven processes, for example residential segregation or differential access to health-promoting resources, amenable to mitigation.

Some questions arise from these observations.

- Are disadvantaged people, besides being disproportionally exposed to waste-related environmental risk, also more vulnerable to its impacts?
- Do risks differ in different social groups living in the same exposed place and, if so, to what extent?
- In other words, is there an interactive, synergistic relationship between the adverse health effects of waste exposure and of the disadvantaged social environment, or conversely does the proportionality assumption hold?
- How preventable are the observed inequalities?

The available information on the health effects of waste facilities by social groups, needed to address these questions, is limited. First, not all the studies carried out to evaluate the potential associations between exposure to waste facilities and health have considered SES; in some studies, socio-economic-adjusted risks are estimated but unadjusted risks are not published, or are indistinguishable from those due to other factors (for example, maternal age or the presence of a dedicated registry in studies of congenital anomalies). Secondly, and crucially, in no cases are interaction effects between socio-economic factors and waste exposure tested and reported. Some studies are designed with selected populations either highly exposed[47] or from socially disadvantaged,[48] making the assessment of the interaction impossible.

For waste and health as well as for many other cases in environment and health, these issues are central; together with better quality data on waste-related exposures, recognized as a prerequisite for more informative studies,[1] more detailed information on exposure and health by the socio-economic group would not only shed light on the nature of the interrelationship between the social and the physical environment but would also allow the identification of more effective strategies to prevent or reduce the impacts.

There are, however, substantial difficulties in estimating the joint effects of different risk factors, for example, low power to estimate interactive effects, given the high collinearity between environmental exposures and deprivation. This is one facet of environmental justice: different risk factors, such as environmental contamination, social disadvantage, unhealthy lifestyles, are often observed to insist on the same subgroups. This makes the assessment of the interplay between these different factors difficult and represents an important reason to consider inequalities

(in exposure and in health outcomes) as inequities. Other relevant considerations in terms of equity include the following.

- While a certain degree of inequalities are inevitable, at least a part (arguably a substantial one) of the observed inequalities is preventable. Exposure inequalities can and must be reduced by appropriate measures of mitigation and abatement of emissions from potential sources. This includes not only established noxious agents (for example, particulate matters, persistent organic pollutants, heavy metals) but also emissions interfering with residents' quality of life (for example, odours, noise). Inequalities can be further countered by primary prevention and health promotion initiatives undertaken in conjunction.
- It is possible that people who bear the most part of the adverse impacts from waste disposal activities (in terms of health and well-being) produce less waste. This might occur, for example, when residential exposures are disproportionately distributed towards population strata with lower income, lower purchasing power and lower rates of consumption of material goods. There are examples, in other domains, where this unfair, negative correlation between benefits and negative impacts is obvious (for instance, greenhouse gas emission at global level) and similar mechanisms may take place at more local level too.

Currently, both of these dimensions of environmental justice are, by and large, speculative. Data and evidence to assess the extent of these inequities would be highly informative.

Conclusions

Numerous studies in Europe and in the USA have documented that disadvantaged communities often suffer disproportionately from the impact of waste facilities. Several questions are unresolved that should be addressed with the collection of targeted data and research. Uncertainties include the presence and magnitude of environmental different waste-related risks, the possible synergistic effects with the social environment, the extent to which inequalities are preventable and the degree to which benefits and adverse impacts are differentially distributed in the population. However, while these knowledge gaps are being filled, public health professionals should contribute to the identification and development of waste management policies that minimize health impacts and inequalities. In the words of Mohan:[49]

> Health inequalities should be one of the key considerations when developing waste management strategies or when conducting HIAs of waste sites. If waste management installations are to be located in an area, every effort should be made to mitigate any potential adverse health effects. [...] Every effort should also be made to ensure that the local community enjoys any potential benefits from waste management.

For waste management as well as for other domains, a direct participation of the health sector in the decision-making process is desirable. Participatory processes are necessary to achieve fairer policies, where the interests of all stakeholders are taken into consideration. In view of the various limitations hampering our ability to characterize all risks, policy decisions on new facilities and remediation schemes should be inspired by a precautionary approach,[9] where health and equity are put at the centre of the debate.

Supplementary data

Supplementary data are available at *EURPUB* online.

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Key points

- The expectation that waste-related environmental exposure is stronger in disadvantaged population subgroups is confirmed by most studies available in Europe and the USA.
- The effects of socio-economic health determinants are often removed, through standardization, in epidemiological studies; the possible occurrence of modification of effect would be of great interest, but is not documented.
- Despite the limited understanding of the interplay between waste-related exposures and social health determinants, observed patterns raises a question of environmental justice, which require adequate policy responses.

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