

A systematic critical review of epidemiological studies on public health concerns of municipal solid waste handling

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Abstract

Aims:

The ultimate aim of this review was to summarise the epidemiological evidence on the association between municipal solid waste management operations and health risks to populations residing near landfills and incinerators, waste workers and recyclers. To accomplish this, the sub-aims of this review article were to (1) examine the health risks posed by municipal solid waste management activities, (2) determine the strengths and gaps of available literature on health risks from municipal waste management operations and (3) suggest possible research needs for future studies.

Methods:

The article reviewed epidemiological literature on public health concerns of municipal solid waste handling published in the period 1995–2014. The PubMed and MEDLINE computerised literature searches were employed to identify the relevant papers using the keywords solid waste, waste management, health risks, recycling, landfills and incinerators. Additionally, all references of potential papers were examined to determine more articles that met the inclusion criteria.

Results:

A total of 379 papers were identified, but after intensive screening only 72 met the inclusion criteria and were reviewed. Of these studies, 33 were on adverse health effects in communities living near waste dumpsites or incinerators, 24 on municipal solid waste workers and 15 on informal waste recyclers. Reviewed studies were unable to demonstrate a causal or non-causal relationship due to various limitations.

Conclusion:

In light of the above findings, our review concludes that overall epidemiological evidence in reviewed articles is inadequate mainly due to methodological limitations and future research needs to develop tools capable of demonstrating causal or non-causal relationships between specific waste management operations and adverse health endpoints.

Keywords: municipal solid waste, epidemiological studies, risk

Introduction

Several epidemiological studies conducted in both developed and developing countries have suggested that municipal solid waste management is a risky and life-threatening activity for populations residing near landfills and waste incinerators, for municipal waste workers and for informal waste recyclers.

A central theme in literature reviewed in this article is that the major health problems of populations residing near landfills and incinerators are cancer, low birth weight, congenital anomalies and Down's syndrome and for municipal waste workers and recyclers the health problems are musculoskeletal disorders, injuries, respiratory, gastro-intestinal and skin conditions. Unfortunately, these epidemiological studies have essentially neglected several critical aspects on the human health risks of municipal solid waste handling.

Noteworthy, all the studies reviewed in this article on cancer risks on populations residing near landfill sites or former sites merely suggest either elevated or no risk, but none has conclusively identified a causal or non-causal relationship between cancers and landfills for such populations.

Equally important, a major limitation of some studies on cancer, low birth weight and congenital anomalies in populations near municipal landfills is their failure to account for potential sources of error like misclassification of waste sites, operating dates of landfills and non-examination of possible effects of multiple or differential exposures from different sites.¹⁻³ However, on the positive, it is noteworthy that, despite these shortcomings, some of these studies were very large and had high power.^{1,2,4}

Some studies of residents potentially exposed to landfills reported an elevated risk of cancers of the pancreas and liver², kidneys^{2,5} and bladder.⁵ Additionally, Gensburg *et al.*⁵ reported higher bladder cancers in exposed children. With regard to the popular Love Canal landfill, Gensburg *et al.*⁵ concur that the role of exposure to the landfill is unclear, given limitations such as a relatively small and incomplete study cohort, imprecise measurements and the exclusion of cancers diagnosed before 1979.

Noteworthy, most studies on municipal waste workers have regrettably negated performing exposure assessments for waste handlers. Epidemiological studies with exposure classification based on field measurement are needed, both to further identify high-risk work conditions and to provide a detailed basis for establishment of occupational exposure limits for mechanical and energetic load particularly in relation to pulling and tilting of containers.⁶ Evidently, non-conduction of exposure assessments in this body of research does not allow for strong evidence-based conclusions to be drawn regarding exposure levels and associated health effects of municipal solid waste handling. There is need for an appropriate risk assessment that informs local government structures and relevant sectors on the health risks associated with different waste management technologies.

Finally, while most studies on waste handling have revealed abundant evidence on respiratory complaints among waste handlers, a lot of research needs to be done on other associated health problems of waste handling. While moderate evidence is available to support that waste collection increases the risk of respiratory complaints, there is limited evidence on gastro-intestinal complaints and hearing loss.⁷ This suggests that research on occupational health risks of waste handlers has not been exhaustive but is rather limited in its coverage of occupational health risks of municipal solid waste handling. There is therefore a paucity of information on other occupational health problems of waste handling.

Review

Method

The PubMed and MEDLINE computerised literature searches were employed to identify the relevant papers using the keywords solid waste, waste management, health risks, recycling, landfills and incinerators. We also examined the references of all potential papers and found more articles that met the inclusion criteria. A total of 379 papers were identified, but after intensive screening only 72 met the inclusion criteria. Of these studies, 33 were on adverse health effects in communities living near dumpsites or incinerators, 24 on municipal solid waste workers and 15 on informal waste recyclers. The inclusion criteria required that the papers reviewed (1) be journal articles published in the period 1995–2014; (2) focus on municipal solid waste management risks to nearby populations, municipal waste workers and informal recyclers; and (3) be articles written in English language. Articles on sewage were excluded from the review since sewage is not part of municipal solid waste. Also articles published prior to 1995 were considered less recent and consequently excluded from this review. Notably, various parameters were employed to assess the epidemiological evidence of human health risks from municipal solid waste management. First, on cancer studies we weighed epidemiological evidence in reviewed cancer studies guided by the criteria set by the International Agency for Research on Cancer (IARC) of 1999, pages 14–25. Notably, the criteria allow for ranking of epidemiological evidence provided by cancer studies in terms of being sufficient, inadequate and limited. Good quality studies revealing a causal or non-causal relationship between exposures and adverse health endpoints were classified as ‘sufficient’, while ‘inadequate’ studies were of poor quality to reliably support the presence or absence of a causal association. On the other hand, ‘limited’ scientific evidence denotes a scenario where a positive causal relationship between exposure and adverse health outcomes has been noted but no provision exists to significantly rule out confounding factors and chance. Second, for studies on other health endpoints other than cancer, we assessed their quality by examining the strengths and limitations in the study methods used. In particular, we noted whether the study used a study type capable of proving causality, a large sample size, a large reference group and controlled for possible confounders, and whether it was a single-centre or multi-centre study. Data extraction tables are also provided so that readers can assess the systematic review process used.

Results and Discussions

Cancer

Cancer risks associated with residence near landfill sites have been extensively researched and entail cancers of the stomach, liver, intrahepatic bile ducts, cervix, skin and pancreas. While high incidence of cancers for populations residing near landfills has been reported,^{2,3,5,8–13} Jarup *et al.*¹ did not find any excess cancer risks for such populations. Clearly, there appears to be no complete congruence among researchers on the cancer risk to communities living near landfill sites or waste incinerators. The majority of ecological study designs used had no capacity to prove causal or non-causal relationships between residence near landfills or incinerators and investigated adverse health effects. This can mainly be attributed to non-performance of individual-level exposure assessments and failure to control for confounding variables.

In Great Britain, Jarup *et al.*¹ conducted an ecological study in which they defined the exposed population group as people living within 2 km of 9,565 landfill sites that were operational at some time from 1982 to 1997 and the reference group as populations living more than 2 km from a landfill. Notably, Jarup *et al.*¹ did not find any excess risks for bladder cancer, brain cancer, hepatobiliary cancer, adult leukaemia and child leukaemia even after adjusting for age, sex, region, year and deprivation. A remarkable strength of Jarup *et al.*'s¹ study is that it was large and had high power. In light of the following limitations which grossly impinge on the capacity of Jarup *et al.*¹ to conclusively demonstrate causality, our review considers evidence of non-causal relationship in Jarup

*et al.*¹ 'inadequate'. First, with regard to their own study, Jarup *et al.*¹ concur that potential sources of error like misclassification of waste sites, operating dates of landfills, non-examination of possible effects of multiple or differential exposures from different sites could have dwarfed their study's ability to detect any adverse health effects. Additionally, misclassification of exposure could not be ruled out since the study did not account for potential bias in scenarios where pregnant mothers migrated away from their usual residence in the concerned study period. Moreover, the study was not immune to ecological fallacy since group level rather than individual exposure level assessments were done. Also, Jarup *et al.*¹ used a rather small reference group in relation to the exposed group.

Goldberg *et al.*² conducted a case-control study on municipal solid waste landfills using geographic zone and distance from the landfill site as exposure estimates and found excess risk of cancer of the pancreas (2.2), prostate (1.5) and non-Hodgkin lymphomas (2.0). Arguably, while the study by Goldberg *et al.*² was remarkably very large and had high power, unfortunately the weight of this study's findings can also be classified as inadequate since a very small control group which was over seven times less than the study subjects' was used and this may have impaired the study's results. Also, case-control designs have difficulties in proving causality due to their retrospective direction of enquiry, inability to stringently manipulate and control study variables and their excessive reliance on available secondary data that may be often incomplete and gathered for a different purpose. However, Goldberg *et al.*² need to be credited for their use of unconditional regression models to estimate odds ratios.

In Helsinki, Pukkala and Pönkä³ found the relative cancer risk for inhabitants of houses built in a former dumpsite to increase slightly with the number of years lived in the area. Noteworthy, evidence of cancer risk on inhabitants of houses built in a former dumpsite in Pukkala and Pönkä's³ study seems inadequate for the following reasons. The study only adjusted for demographic characteristics like age and sex and noted an excess of skin and pancreatic cancers but unfortunately negated adjustment for vital confounding variables like lifestyle risk factors such as smoking and alcoholism. Arguably, this is a major loophole of this study since for pancreatic cancer the World Health Organization classifies smoking as a sufficient human carcinogen and alcoholism as a carcinogen with limited evidence. Additionally, like many other ecological designs, the study succumbs to ecological fallacy since it did not measure or model individual-level exposures but rather performed group-level environmental measurements for landfill soil and air pollutants. Nevertheless, the study had a large sample size with a bigger reference group.

Gensburg *et al.*⁵ observed elevations of bladder cancers for children and elevations of both bladder and kidney cancers for residents exposed to the Love Canal landfill. However, in explaining these excess risks in Gensburg's study, the role of exposure to the landfill is unclear, given limitations such as a relatively small and incomplete study cohort, imprecise measurements and the exclusion of cancers diagnosed before 1979.⁵ Consequently, epidemiological evidence in this study is inadequate to support causality.

Comba *et al.*⁸ investigated the association between occurrence of soft tissue sarcomas (STS) in Mantua and residence near an incinerator of industrial wastes using 37 STS cases and 171 controls matched for sex and age and reported a significant increase in risk of STS associated with residence within 2 km of an industrial waste incinerator. Notably, the strength of this study was the attempt to have about five randomly selected controls for each case. However, the evidence of causality is limited in this study. The category for limited is justified on the basis that matching controls and cases was done, but case-control designs cannot demonstrate causality as already discussed earlier. Nevertheless, a small sample size was used and the study did not account for potential confounders like socio-economic factors and other sources of exposures like landfills. According to Portia *et al.*,¹⁴ a major limitation of Comba *et al.*'s⁸ study is the possibility that increased attention to the diagnosis of STS in the vicinity of the Mantua incinerator plant could have introduced bias in the risk estimate.

In Italy, Zambon *et al.*⁹ conducted a population-based case–control study on the risk of sarcoma from incinerator and industrial plants on dioxin emissions and found a statistically significant increase in sarcoma risk to both the level and the length of environmentally modelled exposure to dioxin-like substances and their results were more significant for women than for men. Zambon *et al.*⁹ tried to minimise the effect of confounding factors by matching three controls for age and sex with each of the 205 sarcoma cases, thus producing a comparable reference group. Consequently, epidemiological evidence on sarcoma risk from incinerators is limited. Notably, a small sample size was used and historical data used could have been incomplete for their study purposes and the study did not measure the effect of potential confounders like socio-economic factors and occupational exposures.

In Italy, Biggeri and Catelan¹¹ investigated the relationship between various sources of pollution and lung cancer using a case–control study and reported higher relative risk towards the source and radical decrease away from it. Epidemiological evidence linking incinerators with lung cancer is limited in this study. First, residual confounders from unmeasured confounders cannot be excluded,¹¹ and a small sample size is used. Additionally, very little information can be obtained from the study regarding the types of chemical pollutants and levels from the incinerators studied. In addition, the purely distance-based surrogate of exposure assessment used further limits the demonstration of causality issues.

In Great Britain, an ecological study by Elliott *et al.*¹⁰ investigating cancer incidence in over 14 million people living near 72 municipal solid waste incinerators between 1974 and 1987 found statistically significant ($p < 0.05$) decline in risk with distance for all cancers, stomach, colorectal, liver and lung cancers. This study was large and had more power, thus its epidemiological evidence can be classified as limited. Regrettably, their study findings need to be considered with caution since even the authors admitted that residual confounding bias and misdiagnosis might have increased their risk estimates. Additionally, an ecological study design can only provide association but cannot prove causality. Thus, it is difficult to classify Elliott *et al.*'s¹⁰ study findings under the sufficient category. However, a further study by Elliott *et al.*¹⁵ on histopathological and case note review of primary liver cancers reported as low as 0.53–0.78 excess cases compared to the prior 0.95 cases per 10^5 per year within 1 km from the landfill. Noteworthy, the findings from the improved study of Elliott *et al.*¹⁵ need to be treated with caution due to non-availability of histopathological material or case notes for half of the 235 cases in their study.

Birth weight

Increased incidence of low birth weight in populations living near landfill sites has been observed.^{4,16–18} Noteworthy, none of these studies^{16–18} examined the contribution of exposures at individual level for the pregnant mothers studied particularly in terms of exposure doses and duration. Additionally, these studies did not control for possible vital confounders like occupational exposures and migration out of the 1- to 2-km residence from the landfill for the pregnant mothers in the study period. The purely distance-based surrogate of exposure assessment is not enough to support causality issues. Nevertheless, some studies were large and had more power.⁴ Based on these loopholes, it is not possible to conclude with certainty that maternal residence near landfills during pregnancy has teratogenic effects culminating in increased risk of giving birth to a baby with a low or very low birth weight.

Congenital malformations

Congenital anomalies in relation to residence near landfill sites are discussed in this article. Two of these studies reported increased risk of congenital anomalies^{19,20} and the remainder found little or no excess risk for such populations.^{15,21–23} On the positive, all of these studies^{15,19–23} were multi-centre studies and some used a larger reference group.^{19,20} Notably, results from multi-centre studies unlike those from single-centre studies have wider application. Regrettably, none of the studies^{15,19–23} had mechanisms to address biases arising from possible exposure misclassification. Additionally, a few

studies adjusted for age as a potential confounder^{19,20} but regrettably negated measuring effect of potential confounders like socio-economic factors. Also, none of these studies pushes back our boundaries of ignorance with regard to the types and quantities of toxic chemicals in the various hazardous landfills studied. Conclusively, this review argues that very little capacity, if any, is available in these studies with regard to demonstrating causal or non-causal relationships between residence closer to hazardous landfills or incinerators and adverse health effects on such populations.

Respiratory and other diseases

In Finland, Pukkala and Pönkä³ evaluated the prevalence of cancer and asthma in relation to residence in houses built on a former dumping area containing industrial and household wastes. Their study revealed that prevalence of asthma was significantly higher in the dump cohort than those living nearby but outside the landfill site. While this study provides some crucial insights, its worthiness is questionable given the fact that it unfortunately has not been replicated and the overall evidence may be inadequate.¹⁴ Additionally, in Swaziland, Abul²⁴ found that residents with houses built less than 200 m from the dumpsite were victims of malaria, chest pains, cholera and diarrhoea. However, findings from this study need to be treated with caution since a small sample size of 39 exposed participants and 39 participants in the reference group was used. Furthermore, health effects of dumpsites on residents in Abul's²⁴ study are only based on self-reported complaints of research participants which could have introduced recall bias and inflated risk estimates.

Heavy metals in waste disposal sites

Several studies conducted in developing countries have reported high levels of heavy metals in municipal waste disposal sites.²⁵⁻²⁸ Most waste disposal sites in developing countries are poorly sited,^{29,30} constructed and managed³¹⁻³³ despite handling hazardous waste from industries and medical facilities. Arguably, at the heart of the problems of solid waste management are the absence of adequate policies, enabling legislation and an environmentally stimulated and enlightened public.³³⁻³⁵ However, none of these studies went a step further to demonstrate causality between the heavy metals found and human health risks for populations residing near such sites (see online supplementary material, Table 1).

Studies on municipal waste workers

Municipal solid waste management has been associated with various adverse health problems for waste workers which entail respiratory problems,³⁶⁻⁴³ musculoskeletal disorders,^{36,44-51} injuries,^{36,52-55} nail infection⁴² and inflammation of biomarkers.⁵⁶ Noteworthy, most of the studies employed a descriptive cross-sectional design and were single-centre studies. This suggests that they had no capacity to definitively demonstrate a causal or non-causal relationship between municipal solid waste handling and adverse occupational health endpoints. Additionally, most studies used a small sample size,^{38-41,43,44,49-51,54-56} thus dwarfing the applicability of their findings to a wider population of waste workers. Furthermore, several of these studies negated enrolling a comparison group.^{50,51,54,55,57} Notably, most of the few studies that enrolled a reference group tended to use a smaller group than the waste workers cohort.^{36,37,44,56,57} Some studies did not control for possible confounders like selection bias and smoking.^{38-41,56} One study was longitudinal⁴³ but regrettably used a small sample size with a very small reference group, thus dwarfing its value to the wider scientific community. Another study consisting of a larger sample size and reference was conducted in Denmark,⁵⁸ but unfortunately it was cross-sectional and had limitations with regard to proving causality. Overall, these various limitations of epidemiological studies for waste workers suggest that their findings need to be interpreted with caution and that more carefully designed studies are needed to yield more reliable insights on health risks of waste workers.

Studies of informal municipal waste recyclers

A central theme in these studies is the fact that waste recyclers are prone to health problems like injuries,^{59–62} respiratory problems,^{60,63–65} diarrhoea,^{64,66} infections,⁶⁴ psychological disorders,⁶² chemical hazards^{61,67–69} and musculoskeletal complaints.^{62,64,67–70} Most studies on waste recyclers had more or less similar limitations discussed on studies on waste workers. Notably, most studies used the cross-sectional design, thus dwarfing their capacity to prove causality issues. Equally important, several of these studies^{31,60–65,67–69,71} did not enrol a reference group. Consequently, it is unclear whether it is safe to associate their reported adverse health effects strongly with municipal solid waste management exposures. Still some studies purely relied only on qualitative data in the form of verbal reports from research participants^{59,72} which may have introduced recall bias in their results. Probably, triangulating respondents' verbal reports using additional techniques like lung function tests and environmental exposure assessments could have added value to such studies (see online supplementary material, Table 2).

Conclusion

In the final analysis, studies reviewed in this article have suggested that municipal solid waste management presents adverse health endpoints not just to formal municipal waste workers but also to informal recyclers and populations residing near waste landfills and incinerators. Noteworthy, a major limitation of the studies reviewed in this article is their failure to provide a causal relationship between waste management processes and adverse health effects. Based on the major findings from this review, it is recommended that future studies focus on the development of tools capable of providing causal relationships between adverse health endpoints and specific waste management operations.

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Conflict of Interest The author(s) declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Ethical Issues The article only critically summarises published articles and does not have any images, videos or voice recordings of participants. The study does not contain any trials of health-care interventions or pilot or preliminary studies of trials.

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