INTERNATIONAL JOURNAL OF OCCUPATIONAL AND ENVIRONMENTAL HEALTH
2017, VOL. 23, NO. 4, 299–310
https://doi.org/10.1080/10773525.2018.1484996

Taylor & Francis
Taylor & Francis Group

Household waste and health risks affecting waste pickers and the environment in low- and middle-income countries

Jutta Gutberlet and Sayed Mohammad Nazim Uddin

Department of Geography, University of Victoria, Victoria, Canada

ABSTRACT

Household waste has evolved into a core urban challenge, with increased quantities of waste being generated and with more complex material compositions, often containing toxic and hazardous elements. Critical systems theory understands cities as urban metabolisms, with different material and energy flows, highlighting the circularity in production, consumption, and discard. Waste pickers in low- and medium-income countries work on dumps and landfills, sifting through highly contaminated household waste and are exposed to health hazards. This paper discusses the risk factors, hazards, and vulnerabilities waste pickers are exposed to during collection and separation of recyclables, based on the review of literature on waste and environmental health and on findings from participatory research with waste pickers conducted in Brazil. We take a social and environmental justice perspective and identify the vulnerabilities and waste-borne hazards of household waste, associated with these workers, their communities, watersheds, and the environment. Household waste, although not always per se toxic or hazardous, can become a hazard if not collected or inadequately managed. Those communities where household waste is not collected or waste collection is insufficient are the most critical places. Informal and organized waste pickers, municipal or private waste collectors/workers, small waste traders and sometimes residents, particularly small children, may be considered vulnerable if exposed to waste-borne hazards. The results include recommendations to address household waste-borne hazards and vulnerabilities, according to waste workers involved in this research.

ARTICLE HISTORY
Received 27 January 2017
Accepted 1 June 2018

KEYWORDS
Household waste; health risks; vulnerability; waste pickers; informal sector; waste management; recycling; low- and middle-income countries

Introduction

Worldwide, municipal solid waste generation has increased significantly over recent decades and so has the range of toxic and hazardous materials within the waste stream [1–3]. If household waste is not adequately collected, separated, and treated, as is often the case in low- and medium-income countries, not only the toxic components but also all waste can potentially become hazardous, generating long term and cumulative environmental and human health

CONTACT Jutta Gutberlet gutber@uvic.ca Department of Geography, University of Victoria, PO BOX 3060 STN CSC, Victoria, B.C. V8W 3R4, Canada

impacts. The health of local communities, particularly low-income neighbourhoods, is not only affected by the accumulation of uncollected waste [4–6] but can also be compromised by waste management facilities, including dumps, landfills, and incinerators [7]. Without protective equipment and awareness on how to handle these potentially risky materials, household waste becomes hazardous and poses health risks to those handling garbage.

Waste management infrastructure and services target the collection and transport of household waste, with the aim of maintaining and guaranteeing public health [8,9]. Waste management implies a wide range of distinct actors and different practices. The form in which waste is handled matters profoundly and decisions over which methods or technologies to apply can have long-term consequences. The absence or mismanagement of basic infrastructure poses serious consequences to human and environmental health. Focusing on the everyday life experience of city inhabitants disposing of their waste and waste pickers collecting recyclable materials reveals the risk factors and health hazards different groups of individuals are exposed to. "The everyday is both a key domain through which practices are regulated and normalised as well as an arena for negotiation, resistance and potential for difference" ([10] p. 2). Urban infrastructure and service provision is structured by the political economies and respective power relations that make up the city. Decisions over infrastructure and services are political and policymaking can involve various levels of democratic and participatory praxis, with variable outcomes [11].

Currently, more than one-third of the global urban population lives in informal settlements [12,13], often poorly connected to basic services [14]. In these neighbourhoods, open dumping of solid waste generates soil and water contamination as well as methane and other gas emissions, posing risks to human and environmental health [15]. Low-income residents are not passive about deteriorating socio-environmental conditions in their communities and create extensive informal sectors of waste pickers who collect and recycle household waste [16,17]. Driven both by the desire to maintain a healthy environment and by the need for jobs, residents initiate and support their own ability to provide and improve critical services, thus reducing the carbon footprint in their cities [18–21], recovering resources, improving the environmental conditions and health of low income residents. The informal waste sector creates many "low barrier" jobs needed for the poor [22].

Adequate collection and redirection, particularly of hazardous materials within household waste, must be safeguarded. In many cities in the global South, door-to-door selective waste collection is operated by waste pickers organized in cooperatives and community-based initiatives [23]. If recognized and supported by the local government, these community-oriented waste collection systems have the potential to minimize waste-induced risks to the community and specific health risks and vulnerabilities of waste pickers [24].

This paper discusses the risks and hazards for waste pickers in low- and medium-income countries from inadequately handled household waste. We draw on the review of existing literature and on our own empirical results from community engaged and participatory research to describe and discuss the nature and scope of household waste-borne risk factors to which the waste pickers, the community, and the environment are exposed. The literature review focusses mostly on recent work (since 2000) published in international academic occupational health journals. The primary data were collected by the first author during workshops, conversations, and field visits, in 2011 and following years, in Brazil [25–27].

Our research seeks to highlight particularly the everyday hazardous situations under which organized waste pickers work with household waste. The participatory research then suggests some measures as to how household waste-borne risks and hazards can be mitigated and how vulnerabilities can be made visible and reduced.

Theoretical background

Critical systems theory [28,29] applied to waste studies captures the circularity and the linear flows of the materiality in production, consumption, and discard and helps identify hierarchical power structures involved in these processes. Waste needs to be looked at through an interdisciplinary perspective. The idea of cities as urban metabolisms describes the different material and energy flows that take place in and around cities. Fluxes, networks, and processes of metabolically transformed nature form a new "socio-natural hybrid" [30–32]. The systems perspective identifies those flows, linkages, actors, social relations, and power dynamics that happen in city management and decision making, also with respect to waste management [33]. The present research takes an analytical systems approach and a social and environmental justice lens to uncover risk factors and health hazards involved in household waste disposal and collection. We understand household waste as the solid waste generated at the household level. This includes packaging, organic and inorganic waste as well as all household appliances and other consumer goods disposed of by households. Household hazardous waste includes chemical products such as cleaning solvents, paints, pesticides, and other substances that can catch fire, react with other chemicals, explode, or are corrosive or toxic and are disposed

of by residential consumers. Poorly discarded hazardous household waste generates environmental health problems.

Environmental health is defined as "the theory and practice of assessing and controlling factors in the environment that can potentially affect adversely the health of present and future generations" ([34], p. 18). The original environmental health approach reflects a mostly natural science perspective, with concerns focused on the direct, biophysical effects of the environment on human health, thus oriented towards the protection of human health through regulation and standards. A critical systems perspective to environmental health in addition provides attention to the social environment. It acknowledges the importance of factors such as crowding, social inequalities, or historical, socio-economic and cultural determinants, underlining the political economy of socio-economic factors such as deprivation and poverty and the psychosocial processes that influence health [28]. Such an integrated conceptual framework also becomes essential to understanding and acting on environmental justice and environmental equity concerns. Certain individuals, households, and societies are more exposed to health hazards in the physical environment than others, burdening disproportionately those already characterized by socio-economic inequality, discrimination, and/or psychosocial stress from their social environment [35–37].

This paper uses the lens of the "prism framework of health and sustainability" [38], which integrates the biophysical and social sciences with the traditional environmental health. It links ecosystems and social systems as the foundation for health and sustainability. This lens further distinguishes equitable community and social development, including socio-economic determinants of health as well as the social network cohesion, health promotion, and education. Importantly, Parkes recognizes that dialogue between diverse stakeholders can make a difference, helping to better understand health and sustainability challenges. Empowerment, justice, and social cohesion are thus essential factors to build better environmental health [39].

Hazardous waste

Household hazardous waste is defined as the fraction of waste, originated from households, which contains corrosive, explosive, flammable, toxic, ignitable, or reactive ingredients and is difficult to dispose of or which put human health and the environment at risk because of its bio-chemical nature [5,40]. A major portion of municipal solid waste is household waste, of which 4 or more per cent [41,42] can be potentially harmful for both the environment and human health. For example, a significant proportion of water pollutants originate from the household waste stream [43]. In this paper, we consider household waste as hazardous if not properly collected or managed, both in urban and peri-urban settings, causing health and environmental hazards.

A range of health problems have been documented for waste workers which were caused by hazardous household waste or mismanaged household waste. Work-related disorders and injuries have been detected among the waste collectors around the world, such as respiratory problems, infectious diseases, gastrointestinal issues, muscle pain, fever, headache, fatigue, irritation of eyes and skins, mechanical trauma, pulmonary problems, chronic bronchitis, musculoskeletal damage and hearing loss, poor emotional well-being, and other specific types of injuries [26,44,45]. E-waste workers/collectors in Ghana are among the poorest and most vulnerable group in this country's urban population. They work under hazardous conditions, being frequently exposed to burns and cuts at their hands [46]. If household waste is mixed with hospital waste, it can cause serious infections, including hepatitis B virus infection [47] among those who handle waste. Research shows that a higher occurrence of anti-hepatitis A virus (+) is found among the municipal waste workers than the non-waste-exposed group [48]. A review of occupational health problems and their possible causes shows that the health issues may be caused by the exposure of waste collectors to bio-aerosols (e.g. microorganisms) and volatile compounds (metabolites and toxins from these microorganisms) during the waste handlings [45]. Household hazardous waste not only has direct impacts on human health but also contaminates groundwater and increases the risk of contaminating wildlife's habitats [40]. Pollutants can leach from littered household waste into the ground, contaminating the soil. Improperly disposed batteries and fluorescent lamps pose significant threats to the environment as described for Brazil [49]. Heavy metal contamination in foodstuff, house dust, farm soil, and groundwater were found in an e-waste recycling area in China, where work processes are currently not regulated [50].

Vulnerability

Vulnerability has been referred to in a wide range of multidisciplinary contexts, including development, medical, public health and nutrition, and environmental hazards, climate change and disasters [51–57]. Although researchers and authors from various disciplines define "vulnerability" differently, the concept almost always refers to the physical or mental risks or hazards for human beings by natural events or through anthropogenic activities. Vulnerability is defined as defencelessness, insecurity, and exposure to hazards, shocks, and stress [58]. Some argue that vulnerability should be seen not only in terms of individual harm but linked to the broader context of crises, including the differentiated nature of responses

across households, communities, and the environment at large [57]. Other authors speak of vulnerability "as a threat to which a community is exposed, taking into account not only the properties of the chemical agents involved but also the ecological situation of the community and the general state of emergency preparedness, at any given point in time" ([59], p. 325). The poor and near poor are considered vulnerable groups due to their low access to assets and their limited abilities to respond to risks [52]. The prescriptive and normative response to vulnerability is to reduce exposure, enhance coping capacity, strengthen recovery potential, and bolster damage control via private and public means [60]. On the other hand, a hazard is defined as "a potential condition or dangerous phenomenon existing within a system, which when actuated becomes an actual mishap event resulting in damage, loss, injury, and/or death" [61,62]. Vulnerability of waste collectors and waste pickers can be defined as the exposures to toxic chemicals and hazardous wastes generated either from household or non-household sources, which may have serious consequences for their health. Significant initiatives have been taken in recent years to reduce human vulnerability from various kinds of hazards and risks related to disasters and climate change from community to global levels [63]. Besides these particular initiatives, vulnerability of people to waste-borne hazards has received less attention, particularly in the low- and medium-income countries.

Defining the research study: vulnerable groups, vulnerable places, and vulnerable environments

Vulnerable groups

Vulnerable groups, exposed to household waste-borne hazards, include waste pickers, municipal and private waste collectors, small waste traders, and potentially residents [64–68]. However, waste pickers are the largest and most vulnerable group, because of their level of exclusion and the lack of protective measures when working with waste [69–72]. Exposure to airways inflammation and glucan can cause health hazards and waste workers, particularly waste pickers are affected significantly, due to unsorted hazardous household waste [73]. As such, household waste collectors and waste pickers are at risk of developing chronic respiratory symptoms such as cough, phlegm, wheezing, and chronic bronchitis [74,75].

A growing global problem is the exposure of these vulnerable populations, including children, to waste and specifically to e-waste-borne hazards and harm [68]. A recent study addresses some of the harmful health effects on children and pregnant women caused by e-waste exposure [68]. E-waste recycling operations can cause higher levels of polychlorinated dibenzo-*p*-dioxins and dibenzofurans which may even impact on the health of next generations [66]. Children, living in or next to informal recycling areas, are exposed to higher polycyclic aromatic hydrocarbons than others, thus adversely affecting their height and chest circumference [76]. The concentration of nitric oxide (NO) and nitrogen dioxide (NO_2) gas is higher than the standard limit of US-EPA and WHO guidelines in and near landfill sites, translating into health hazards for the communities nearby landfill sites [77]. Research has revealed that waste management workers also have increased incidences of accidents and musculoskeletal problems [64].

Finally, bags filled with garbage can contain all sorts of hazardous substances posing a risk of contamination to waste pickers. In 1987, several waste pickers were separating recyclables from hospital waste in Goiânia, Brazil, when they were exposed to mixed in radioactive waste. Other community members were also contaminated due to the contact with these workers. This was the largest accident involving radioactivity in Brazil [78].

Vulnerable places

Vulnerable places discussed here are communities, particularly those where household waste is not collected or where the collection is insufficient or neglected. Informal settlements face serious challenges due to improper waste management infrastructure, lack of collection services, and inadequate waste disposal [24,79,80]. There are large intra-city inequalities in low- and medium-income countries, related to waste disposal and collection services [81]. Sometimes waste is collected at the household level but then remains at transfer points without being evacuated from the neighbourhood [82–84]. Both liquid and solid waste management practices in urban informal settlements can pose significant risks to the environment and human health [85]. Open drains regularly receive household waste which can contain hazardous substances, polluting the wider environment and affecting the health of the local population [81,86]. Often local authorities fail to provide frequent garbage collection services due to the government's low human and financial resource availability, high population density, and unplanned residential areas [87]. Waste disposed in the streets for many hours awaiting collection becomes a nuisance, forming foul-smells and leachate from the waste pile, attracting insects and rodents, which become vectors of diseases [85,88]. Improper disposal of waste creates and disseminates pathogens which can quickly spread among human and animal populations in the city. High-concentrated leachate potentially causes environmental threats affecting ground

water and surrounding environments [89]. There is also the risk of explosion and fire due to the production of methane gas on landfilling sites [88].

Vulnerable environments

Informal dumping and uncollected household waste in watersheds gets carried into waterways by runoff water and often contaminates the local drinking water. A recent study shows that a maximum of 12.7 out of 275 million metric tons plastic waste enters the ocean, creating hazards for marine ecosystems [90], resulting in the cost of 13 billion USD/year for marine conservation initiatives [91]. Improper waste management practices contaminate the oceans and freshwater bodies in many parts of the world [85]. The vegetation near landfill sites is often damaged due to the replacement of oxygen by other gases produced in the root zones, causing the death of plants on the long term [85,92]. Research confirms that plants die due to various gas mixtures generated in typical landfill sites [93]. A range of hazardous pollutants (e.g. NO_x, SO_x, carbon dioxide, ozone) are emitted during waste collection processes, posing potential hazards to human health and the environment [94].

Landfilling is the most common waste disposal method in low- and middle-income countries and most landfills are open or "controlled" dumps while few can be considered sanitary landfills. Landfills also emit various air contaminants. Landfill biogas, for example, contains approximately 48–56% methane; which, if not captured, contributes to the greenhouse gas effect, affecting our global climate [95]. The groundwater under or near dump sites is contaminated due to a range of hazardous and toxic wastes and their components concentrated in the leachate which is anaerobically fermented [96] and also due to the disposal of waste into the highly permeable alluvial sediments [97]. Additionally, high concentration of carbon dioxide and presence of vinyl chloride and other volatile hydrocarbons produced in dumps and landfill sites may cause groundwater pollution due to its high-solubility characteristics [91]. The concentration of various parameters such as chlorides, sulphate, cadmium, and chromium is higher in aquifers near urban landfill sites, exceeding the standard values for drinking water. This can occur due to various factors such as low depth of the water table, high soil permeability, absence of a proper drainage system for the leachate, direct contact of groundwater with leachate at the bottom of the landfill, and semi-arid climate conditions [98]. Research shows that a high concentration of total dissolved solids, electrical conductivity, total alkalinity, chlorides, sodium, and lead are present in the groundwater samples near landfills, which are higher than the standard limits [99]. In the case of a high-income country like Canada, benzene, toluene, ethylbenzene, and *m*-, *p*-, *o*-xylene were also detected in the groundwater near former landfill sites in the eastern subarctic region [100]. Adverse effects on the environment such as groundwater contamination have been found due to the migration of chloride, manganese, and coliform bacteria from landfill sites. The coliform bacteria multiply when leachate enters in the oxygenated groundwater system. Some other groundwater contamination indicators include Cl, HCO_3, Cl/HCO_3, Zn, Na, NH_4, SEC, hardness, P, metals, NH_4, NO_3, TDS, SO_4, Fe, COD, Cr, Ni, Cu, CN, microorganisms [101]. The dispersion of toxic pollutions from municipal dumps and landfills through groundwater contamination compromises the quality of the surrounding environments.

Research findings on waste pickers' health risk perceptions

As part of the *Participatory Sustainable Waste Management* project (PSWM), the knowledge creation process was a collective one. The PSWM project was a community–university partnership between the University of Victoria in Canada and the University of São Paulo, Brazil, conducted with 30 recycling cooperatives in the metropolitan region of São Paulo, between 2005 and 2012 [95]. The vision that has inspired PSWM is the aspiration of transforming the life of informal sector recyclers, improving their working conditions and their livelihood outcomes. The project which over the years expanded into a programme aimed at building participatory processes and strengthening the organization of waste pickers to expand existing capacities and to increase the effectiveness and safety during collection, separation, stocking, and commercialization of recyclables. Capacity-building is concerned with social and political relationships and concentrates on enabling people to overcome discriminatory practices that limit their life-chances. It is a process of collective learning that enables people to determine and achieve livelihood improvements. This includes making information available, because information reduces uncertainty and widens decision-making options [102]. One of many action-oriented and capacity-building initiatives of this project was aimed at occupational health and risk perception of waste pickers. The research involved six recycling cooperatives of the metropolitan region of São Paulo (two members per cooperative). The first author participated in the three research phases conducted between March and July 2011: mobilization, workshops, and feedback sessions, which generated the results of this intervention presented here. Research was obtained by the Human Research Ethics Board at the University of Victoria (Protocol number 05-129). During the mobilization, phase information about the research objectives was disseminated and recycling cooperative members were invited to participate in the workshops and agreed to become knowledge transmitters between the researchers and the other cooperative

Table 1. Waste is separated into the following categories.

Paper	Plastics		Metals	Glass	Other
White paper	PP	Diverse materials	Iron	White glass	Electric and electronic waste
Coloured paper		Plastic cups	Aluminium	Green glass	Batteries
Mixed paper		Plastic lids	Cupper	Brown glass	Fluorescent lamps
White paper trims	PS	Diverse materials	Zamac	Mixed glass	Car batteries
White and coloured paper trims		Plastic lids			Tetra Pak
Cardboard	HDPE	White			
Newspaper		Coloured			
Journals		Oil containers			
Cardboard tubes		Plastic lids			
	PET	Coloured			
		White			
		Oil container			
		Mixed			

PET: Polyethylene terephthalate; HDPE: high-density polyethylene; PS: polystyrene; PP: polypropylene.

Table 2. Risk factor perception of organized waste pickers.

	Health risk factors
Direct health risks associated to collection and separation of household waste	Biologic and chemical contamination of dirty and contaminated household waste: risk of biologic contamination
	Dirty and contaminated packaging and items: risk of biologic contamination
	Sharp materials from packaging and discarded household items, such as broken glass, wood, or metal: risk of cuts and perforation
	Contaminated plastics (soft/hard), e.g. PET, PP, and PAD containers sometimes containing urine, detergents, chlorine, food rests, etc.: risks of infection, allergies, respiratory diseases
	Separating e-waste facilitating the contact with toxic substances: allergies, respiratory diseases, and cumulative effects from heavy metal contamination
Indirect health risks associated to household waste	Presence of rats, cockroaches, and pigeons: risks of transmission of disease such as *Leptospirosis*,
	lack of ventilation in recycling centres causing disease vectors proliferation causing respiratory and pulmonary diseases
	Littering and discarded household waste (particularly plastics and containers with hazardous contents) affecting animals and environmental health

members. Throughout the second phase, five thematic workshops were conducted on occupational health and recycling cooperatives. The workshops involved brainstorming and active learning, applying collective mapping, acting, and drawing methods focused on possible risks and health hazards as well as respective strategies to overcome these. Participants listed the following categories in which they separate the materials (Table 1).

Interactive, creative arts-based methods (collective mapping, acting, and drawing, diagramming), were used to map key health hazards related to the work with household waste, based on the practical knowledge of the research participants (Table 2). While the results reflect specific working conditions of these cooperatives, most risk factors identified are common to the majority of organized recycling groups in Brazil and are also relevant to waste pickers in other low- and middle-income countries. During the final feedback phase the findings were discussed with all cooperative members to receive their input. After this research intervention, several field visits and conversations with waste pickers in this region and in different cities in Brazil were conducted to get their feedback on health risks related to their work in the recycling cooperative or association.

The quality of material separation at the household level is very important. Dirty or contaminated packaging bares diverse chemical and biological risks [26,27]. Packaging containing cleaning products, paint, dissolvent, etc. can become a health risk when there is direct contact with the liquids. Over time packaging containing food rests develop fungal growths and mould, which can still release airborne spores. One of the most common health problems linked to decaying organic matter are caused by *aspergillomas*, fungal balls that fix themselves in cavities such as the paranasal sinus.

Household waste containing organic materials attracts rats, cockroaches, and pigeons [103]. These animals are the source of many diseases. For example, pigeons are transmitters of *Candidiasis* (a yeast or fungus infection spread by pigeons), *Tuberculosis, Giardiasis* (is caused by an intestinal parasite Giardia found in contaminated food), *Histoplasmosis* (serious respiratory disease that can be fatal, especially in those with compromised immune systems, including children, transmitted when humans inhale the *Histoplasma capsulatum* fungus that grows in dried bird and bat droppings), or *Salmonellosis* (from droppings of pigeons). *Leptospirosis* is easily transmitted through inhalation or contact with infected animals' tissue or rat urine. These risks can be reduced by frequent pest controls and better work place organization, not to mention provision of cleaner material at the household level.

The spaces where the separation of recyclable material happens, for example recycling cooperatives

and associations, community recycling depots, as well as the scrap dealers' or middlemen' premises often don't have adequate ventilation or present leaking roofs which promotes bacterial growth and the development of fungus, which can cause respiratory disease to the workers in this environment.

Sharp metal pieces or broken glass (e.g. from light bulbs or bottles) mixed in with household waste can originate cuts. In some cities, e.g. São Paulo, the waste management company uses compactor trucks for the selective waste collection, allowing larger volumes to be collected. This also results in high levels of broken glass and other crushed materials once the household recyclables arrive at the separation table in the cooperative or association. The *Mega Central Carolina Maria Jesus*, a large-scale recycling facility run by the city of São Paulo and operated in part with the work force of waste pickers, receives the selected waste collection from neighbourhoods in the South of the city São Paulo. This facility, in contrast to all waste picker cooperatives in the region, does not recover glass and the mixed in class is treated as waste and gets deposited at the landfill. Since the municipality uses compactor trucks for the collection of recyclables, the glass gets crushed and contaminates the load of materials collected, thus disqualifying a significant amount of these materials from recycling.

Household waste further contains a few other hazardous materials, such as electric and electronic items, cooking oil, batteries, fluorescent lamps, or other materials which bare specific health risks. Very few recycling centres and cooperatives are equipped to deal with these materials.

Addressing the health risks of waste pickers in their work spaces

Vaccination against infectious disease, including hepatitis A, hepatitis B, and tetanus, significantly reduce the risks related to being in touch with dirty and contaminated materials. The empirical data demonstrate that most recyclers are aware of the existence of anti-tetanus vaccination and yet many participants were not vaccinated. They alluded to vaccination locations not being easily accessible, or they did not see the urgency for themselves. Education and facilitated access to these vaccines is an important measure to prevent risks.

The use of gloves, protection goggles, and mouth protection is another possible measure to reduce health risks. Particularly for those recyclers working in waste separation, gloves and mouth protection helps prevent infectious disease. These protection measures also reduce the risks of cuts and accidents, specifically affecting the eyesight as happens with sharp materials, particularly broken glass. Nevertheless, access to personal protective equipment (gloves and mouth protection) is rare in this activity, and even if available, recyclers do not always wear the equipment. The participants mentioned that gloves prevent tactile perception and yet it is important to identify different types of materials, particularly plastics. For that reason, they don't like to wear gloves. This problem could be solved by taking the tip of the thumb and index finger off of one glove to provide the ability to still identify materials while protecting most of the hand from contact with sharp objects and contaminated materials.

The overall risks related to the working conditions can be improved by mapping and addressing risks related to the physical work environment (including ground cover conditions, location of work equipment, work flow efficiency, illumination, ventilation). Every recycling group should undergo an assessment of their work flow and make adjustments. Furthermore, the waste pickers mentioned that the widespread exposure to pests, including rats, cockroaches, and pigeons, were serious health risk factors that urgently needed to be controlled. Local governments regularly run campaigns for pest eradication, and the recycling cooperatives and associations need to be targeted with these recurrent pest controls.

There are currently no specific public policies in place in Brazil to reduce health risks for waste pickers in informal household waste recycling. Informal recycling systems can be addressed with regulations facilitating co-production arrangements (collaboration of recycling cooperatives or associations with formal waste management programmes) which also tackle risks and hazards associated with waste [64]. The official recognition and formalization of the activities would protect the workers from health hazards [27,104]. Equally important are measures to improve the forms of disposal of hazardous waste, in order to manage the risks and reduce the hazards of people who are involved in the collection processes, particularly the informal waste pickers [104].

The International Labour organization (ILO) suggests training on health and safety for waste pickers and health check-ups and monitoring of children's and adults' health [105]. Although in several countries children are prohibited on landfills and recycling facilities, there are still many children involved in the activity of waste collection and separation. ILO recommendations to make the work of waste pickers safer include providing protection from hazards, suggesting the use of gloves, footwear and tools to sort waste, and also vaccination against tetanus [105].

Involving local stakeholders, particularly waste pickers, in household waste management can help improve waste collection and recycling and can reduce waste-borne hazards and vulnerabilities [106,107]. Waste pickers organized in unions, associations, cooperatives, or social enterprises can also act as environmental stewards, educating the population on clean source separation and on the recyclability of materials. Programmes can be established to

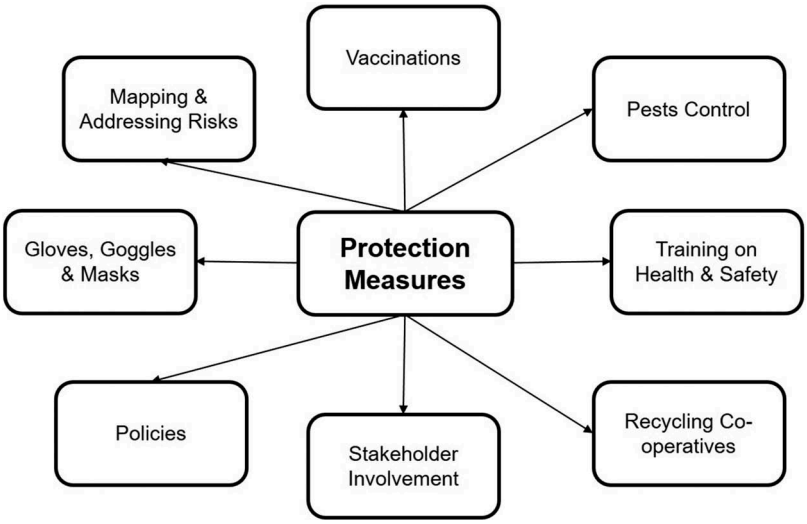

Figure 1. Protection measures to reduce health hazards.

assess and manage waste-related hazards in the communities [64,108].

Most waste pickers operate completely informal and are not related to any programme or organization. It is time for local governments to provide alternative options for those recyclers who have no opportunity to, or do not want to affiliate with a cooperative or an association. They are the most vulnerable group of waste workers, for usually comprising the most socially excluded and impoverished sector of society. Often the most vulnerable family members (children, women, and elderly) work under these informal conditions. Their stories need to be heard and taken into consideration when designing appropriate solutions for their recognition and inclusion in waste management. The following figure lists some of the protective measures that help reduce household waste-borne health hazards for waste pickers (Figure 1).

Addressing environmental health and vulnerabilities

Establishing door-to-door selective waste collection is a service that contributes to maximizing recycling rates and minimizing environmental hazards by avoiding inadequate waste discard. With their everyday activity of collecting materials for reuse and recycling, waste pickers are working towards resource recovery and are thus at the forefront of a significant change not just stressing waste collection but rather material reclamation. Their praxis is moving away from the growth-oriented logic of wasting towards an ethics of salvaging, recovering, and circularity.

During their interactions with households to collect recyclable materials, waste pickers often perform additional services, such as informing household members about which materials can be recycled, how to best separate and explain the significance of recycling to the environment. Waste pickers therefore are more than just collectors, and they have the skills and the potential to act as environmental stewards, with actively building awareness in the community.

For these tasks to become effective and the service reliable, municipal governments need to commit to a collaborative partnership in waste management. Most organized waste pickers require infrastructural support and capacity training in specific areas (e.g. administration, accounting, work-safe programmes). A set of incentives has been recommended for both private and public sectors for good partnerships in solid waste management service delivery [71]. They also suggest a careful analysis of the available theoretical and empirical data on public/private partnerships to minimize the related risks of these partnerships to negatively impact on vulnerable and marginalized populations [71]. Furthermore, environmental awareness and education programmes should target selective waste collection as a theme central to human and environmental health, targeting waste pickers and their organizations, communities, schools, child care centres, and health care centres. It is not enough to run occasional campaigns for selective waste collection. Continuous exposure to waste topics, through different media and using diverse methods (e.g. video, photography, theatre, *Instagrams*, and other social media), has the potential to create the desired effect of greater community engagement.

Conclusion and final considerations

In this paper, we have identified household waste-borne health risk factors and hazards and have discussed how these are affecting informal recyclers in low- and medium-income countries. We have particularly highlighted the perspectives of organized waste pickers who work in recycling cooperatives and associations. A literature review and empirical insights from research conducted

in Brazil informs our discussion. Hazards linked to household waste affect the environment and particularly those who work with waste. Occupational health risks of informal and organized recyclers have not been well documented and more research needs to be done to better understand the health impacts of household waste collection and separation and to address these risks. Not only does household waste contain hazardous materials and toxic substances, but the process of collection, separation, and transportation in itself can also pose severe health hazards and risks to those working with waste.

The vulnerable groups, exposed to waste-borne hazards, include waste pickers and particularly those that are not organized, municipal and private waste collectors/workers, small waste traders and potentially the residents at large. Communities, watersheds, and ecosystems in general are affected by hazardous waste originated from both household and non-household sources. Those urban and peri-urban communities where household waste is not collected or where the collection is partial or insufficient are the most visible vulnerable places, where waste directly affects the people' and animals' health and the environmental conditions. Solid waste accumulating in open spaces, streets, waterways, and drainages is a hazard per se, being a breeding ground for fungus and pests, carrying disease vectors for humans and animals.

Studies are needed to identify low-cost solutions, appropriate to specific geographic and political contexts to facilitate the work of waste pickers as service providers, as environmental stewards and waste educators in the community. There is a need to assess the costs of hospitalization or treatment due to diseases, cuts, injuries, or other accidents, evaluating the losses and health damage to waste pickers and community members.

Our research recommends

- Proper incentives/subsidies to promote safe door-to-door collection of household waste.
- Continuous educational programmes to create awareness about clean and safe separation of household waste and the recyclability of certain materials contained in household waste.
- The implementation of safe collection praxis (e.g. collection with proper bicycle driven carts, electric carts, or trucks) and sorting procedures (different levels of automatization), diminishing the contact of the workers with waste.
- The generation of reliable statistics and baseline information on the socio-economic conditions and health situation of waste pickers to design and implement risk prevention programmes, continuous workers' health monitoring and research/educational activities from local to national levels.
- Good waste governance on the local, regional, and national levels.

More research is needed to explore the wide-ranging ways in which household waste poses health threats to the environment and for those who manipulate waste and recyclables. Research can help identify those practices which are most efficient to reduce household waste-borne hazards and vulnerabilities particularly in low- and middle-income countries. Knowledge mobilization is critical for best practices in inclusive and sustainable waste management to be disseminated and for health conditions of waste pickers – the most vulnerable group in contact with waste – and the urban and suburban environment to significantly improve. Probably the best grassroots innovation we have seen in 2017, in improving waste pickers' health, has been the experience of *MTE Lanús Cooperativa Carton y Justicia* in greater Buenos Aires, Argentina. The cooperative employs a permanent health worker as part of the team, responsible for overlooking occupational health and risks in the cooperative, for example promoting vaccination, work space cleanliness, health information, health enhancing, and proactive measures (e.g. specific mother/child or elderly programmes). Since the implementation of this programme, the cooperative was able to reduce workers' absence due to health issues and an overall increase in workers' well-being and work productivity. These are small steps which can have huge impacts on waste pickers' health.

Acknowledgements

Without the many conversations and interactions with waste pickers in different parts of the world and without their everyday expert knowledge, this paper could not have been written. We are deeply grateful for their insights and stories. We also would like to acknowledge the many discussions and learning experiences with colleagues in Brazil, including Nidia N. Pontuschka, Angela M. Baeder, Sonia M. N. Felipone, and Tereza L. F. dos Santos. Finally, we want to thank the reviewers and editors of the Journal for their valuable suggestions.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Canadian International Development Agency: [Grant Number S61268-571/I].

ORCID

Jutta Gutberlet http://orcid.org/0000-0003-4602-1483
Sayed Mohammad Nazim Uddin http://orcid.org/0000-0002-6143-5572

References

[1] OECD Sector case studies: household energy and water consumption and waste generation: trends, environmental impacts and policy responses. (ENV/EPOC/WPNEP(2001)15/FINAL) Organisation for economic cooperation and development environment directorate 1999–2001 programme on sustainable development, 2001. Paris, France 7 OECD; 2001. p. 56–83 In, Slack, R. J., Gronow, J. R. and Voulvoulis, N. Household hazardous waste in municipal landfills: contaminants in leachate. Sci Total Environ. 2005;337:119–137.

[2] Slack RJ, Gronow JR, Voulvoulis N. The management of household hazardous waste in the United Kingdom. J Environ Manage. 2009;90:36–42.

[3] Ojeda-Benitez S, Aguilar-Virgen Q, Taboada-Gonzalez P, et al. Household hazardous wastes as a potential source of pollution: a generation study. Waste Manag Res. 2013;31(12):1279–1284.

[4] Stanek EJ, Tuthill RW, Wills C. Household hazardous waste in Massachusetts. Arch Environ Health. 1987;42(2):83–86.

[5] Slack RJ, Gronow JR, Voulvoulis N. Household hazardous waste in municipal landfills: contaminants in leachate. Sci Total Environ. 2005;337:119–137.

[6] Uddin SMN, Li Z, Adamowski JF, et al. Feasibility of 'greenhouse system' for household greywater treatment in nomadic-cultured communities in peri-urban ger areas of Ulaanbaatar, Mongolia: way to reduce greywater-borne hazards and vulnerabilities. J Clean Prod. 2016;114:431–442.

[7] Gutberlet J. Waste to energy, wasting resources and livelihoods. Integr Waste Manag. 2011;1: 219–236. Sunil Kumar (Ed.), ISBN: 978-953-469-6, In Tech.

[8] Heynen N, Kaika M, Swyngedouw E, Eds. In the nature of cities: urban political ecology and the politics of urban metabolism. London: Routledge; 2006.

[9] Swyngedouw E. Social power and the urbanization of water: flows of power. Oxford: Oxford University Press; 2004.

[10] Graham S, McFarlane C, Eds. Infrastructural lives. Urban infrastructure in context. London and New York: Routledge, Taylor & Francis Group; 2014.

[11] Offenhuber D. On infrastructure legibility. In: Offenhuber D, Schechtner K, editor. Inscribing a square: urban data as public space. Vienna and New York: Springer; 2012. p. 37–48.

[12] UN-Habitat. State of the world's cities 2010/2011: bridging the urban divide. overview and key findings. United nations human settlement program. Nairobi: UN-Habitat; 2010.

[13] Arimah BC. Slums as expressions of social exclusion: explaining the prevalence of slums in African countries. Nairobi: UN-Habitat; 2012.

[14] Hardoy JE, Mitlin D, Satterthwaite D. *Environmental problems in an urbanizing world: finding solutions for cities in Africa, Asia and Latin America*. London: Earthscan Publications; 2001.

[15] King A, Burgess S, Ijomah W, et al. Reducing waste: repair, recondition, remanufacture or recycle? Sustainable Dev. 2006;14(4):257–267.

[16] Katusiimeh M, Burger W, Kees W, et al. Informal waste collection and its coexistence with the formal waste sector: the case of Kampala, Uganda. Habitat Int. 2013;38(C):1–9.

[17] Oteng-Ababio M, Arguello JEM, Gabbay O. Solid waste management in African cities: sorting the facts from the fads in Accra, Ghana. Habitat Int. 2013;*39(C)*:96–104.

[18] Da Silva Carvalho M, Pinguelli Rosa L, Luiz Bufoni A, et al. Putting solid household waste to sustainable use: a cases study in the city of Rio de Janeiro, Brazil. Waste Manag Res. 2012;30(12):1312–1319.

[19] Mitlin D. With and beyond the state –co-production as a route to political influence, power and transformation for grassroots organizations. Environ Urban. 2008;20(2):339–360.

[20] Wilson DC, Araba A, Chinwah K, et al. Building recycling rates through the informal sector. Waste Manag. 2008;29:629–635.

[21] King M, Gutberlet J. Contribution of cooperative sector recycling to greenhouse gas emissions reduction: a case study of Ribeirão Pires, Brazil. Waste Manag. 2013;33(12):2771–2780.

[22] Dias S. Waste pickers and cities. Environ Urban. 2016;28(2):375–390.

[23] Gutberlet J. Cooperative urban mining in Brazil: collective practices in selective household waste collection and recycling. Waste Manag. 2015;45:22–31.

[24] Gutberlet J. More inclusive and cleaner cities with waste management co-production: insights from participatory epistemologies and methods. Habitat Int. 2015;46:234–243.

[25] Binion E, Gutberlet J. The effects of handling solid waste on the wellbeing of informal and organized recyclers: a review of the literature. J Occup Environ Health. 2012;18(1):43–52.

[26] Gutberlet J, Baeder AM, Pontuschka NN, et al. Participatory research revealing the work and occupational health hazards of cooperative recyclers in Brazil. Int J Environ Res Public Health. 2013;10:4607–4627.

[27] Gutberlet J, Baeder A. Informal recycling and occupational health in Santo André, Brazil. Int J Environ Health Res. 2008;18(1):1–15.

[28] Krieger N. Theories for social epidemiology in the 21st century: an ecosocial perspective. Int. J. Epidemiol. 2001;30:668–677.

[29] Midgley G, Reynolds M. Systems/operational research and sustainable development: towards a new agenda. Sustain Dev. 2004;12:56–64.

[30] Gandy M. Rethinking urban metabolism: water, space and the modern city. City. 2004;8(3):363–379.

[31] Gandy M. Cyborg urbanization: complexity and monstrosity in the contemporary city. Int J Urban Reg Res. 2005;29(1):26–49.

[32] Gandy M. Urban nature and the ecological imaginary. In: Heynen NC, Kaika M, Swyngedouw E, editor. The nature of cities: urban political ecology and the politics of urban metabolism, questioning cities series. Abingdon: Routledge; 2006. p. 62–72.

[33] Lawhon M, Ernstson H, Silver J. Provincializing urban political ecology: towards a situated UPE through African urbanism. Antipode. 2014;46 (2):497–516.

[34] WHO. A report of a world health organisation consultation on health and environment in preparation for 2nd European conference on environment and health, Helsinki 20–22 June, 1994. Sofia, Bulgaria: World Health Organization; 1993.

[35] Institute of Medicine. *Toward environmental justice: research education and health policy* needs. Washington, DC: National Academy Press; 1999.

[36] McMichael AJ, Smith KR, Corvalan CF. The sustainability transition: a new challenge. Bull WHO. 2000;78:1067.
[37] Stephens C. Environmental health and environmental equity. world resources report, 1998–99. a guide to the global environment. environmental change and human health. New York: Oxford University Press; 1998.
[38] Parkes MW *Linking Ecosystems and Social Systems for Health and Sustainability: Public Health Lessons from the Taieri River Catchment* [PhD Thesis]. Dunedin, New Zealand: University of Otago, Department of Public Health and Department of Geography, 2003.
[39] Parkes MW, Panelli R, Weinstein P. Converging paradigms for environmental health: theory and practice. Environ Health Perspect. 2003;111:669–675.
[40] Bass ES, Calderon RL, Khan ME. Household hazardous waste: a review of public attitudes and disposal problems. J Environ Health. 1990;52(6):358–361.
[41] USEPA. Proceedings of the fourth national conference on household hazardous waste management, 4, 1989. In, Meske, P. J. The solid waste dilemma: municipal liability and household hazardous waste management. Environ Law. 1993;23:355–376.
[42] Adamcova D, Vaverkova MD, Stejskal B, et al. Household solid waste composition focusing on hazardous waste. Pol J Environ Stud. 2016;25(2):1–7.
[43] Slack RJ, Gronow JR, Hall DH, et al. Household hazardous waste disposal to landfill: using LandSim to model leachate migration. Environ Pollut. 2007;146:501–509.
[44] Kuijer PPFM, Sluiter JK, Frings-Dresen MH. Health and safety in waste collection: towards evidence-based worker health surveillance. Am J Ind Med. 2010;53(10):1040–1064.
[45] Poulsen OM, Breum NO, Ebbehoj N, et al. Collection of domestic waste. Review of occupational health problems and their possible causes. Sci Total Environ. 1995;170:1–19.
[46] Akormedi M, Asampong E, Fobil JN. Working conditions and environmental exposures among electronic waste workers in Ghana. Int J Occup Environ Health. 2013;19(4):278–286.
[47] Shiferaw Y, Abebe T, Mihret A. Hepatitis B virus infection among the medical waste handlers in Addis Ababa, Ethiopia. BMC Res Note. 2011;4:479.
[48] Dounias G, Rachiotis G. Prevalence of hepatitis A virus infection among the municipal solid-waste workers. Int J Clin Pract. 2006;60(11):1432–1436.
[49] Chaves APL, Silva RBD. Environmental diagnosis of hazardous household waste and the family health strategy as liaison for the implementation of a management program in the South of Brazil. Cad. Saúde Coletiva. 2015;23(2):109–117.
[50] Zheng J, Chen K, Yan X, et al. Heavy metals in food, house dust, and water from an e-waste recycling area in South China and the potential risk to human health. Ecotoxicol Environ Saf. 2013;96:205–212.
[51] Adger WN. Social vulnerability to climate change and extremes in coastal Vietnam. World Dev. 1999;27(2):249–269.
[52] Alwang J, Siegel PB, Jorgensen SL Vulnerability: a view from different disciplines. Social Protection Discussion Paper Series. Washington D. C., USA: The World Bank; 2001.
[53] Cutter SL. Vulnerability to environmental hazards. Prog Hum Geogr. 1996;20(4):529–539.
[54] Gaillard JC. Vulnerability, capacity and resilience: perspectives for climate and development policy. J Int Dev. 2010;22:218–232.
[55] Glewwe P, Hall G. Are some groups more vulnerable to macroeconomic shocks than others? Hypothesis tests based on panel data from Peru. J Dev Econ. 1998;56(1):181–206.
[56] Haines A, Kovats RS, Campbell-Lendrum D, et al. Climate change and human health: impacts, vulnerability, and mitigation. Lancet. 2006;367:2101–2109.
[57] Webb P, Harinarayan A. Measure of uncertainty: the nature of vulnerability and its relationship to malnutrition. Disasters. 1999;23(4):292–305.
[58] Chambers R. Vulnerability, coping and policy (Editorial Introduction). IDS Bull. 2006;37(4):33–40.
[59] Gabor T, Griffith TK. The assessment of community vulnerability to acute hazardous materials incidents. J Hazard Mater. 1980;3(4):323–333.
[60] Watts M, Bohle H. Hunger, famine and the space of vulnerability. GeoJournal. 1993;30(2):117–125.
[61] Ericson CA. Hazard analysis techniques for system safety. 2nd ed. Hoboken, New Jersey: John Wiley & Sons, Inc.; 2016.
[62] UNISDR. Terminology of disaster risk reduction. Geneva, Switzerland; United Nations International Strategy for Disaster Reduction (UNISDR). 2009.
[63] Thomalla F, Downing T, Spanger-Siegfried E, et al. Reducing hazard vulnerability: towards a common approach between disaster risk reduction and climate adaptation. Disasters. 2006;30(1):39–48.
[64] Rushton L. Health hazards and waste management. Br Med Bull. 2003;68:183–197.
[65] Wilson DC, Velis C, Cheeseman C. Role of informal sector recycling in waste management in developing countries. Habitat Int. 2006;30:797–808.
[66] Cointreau S Occupational and environmental health issues of solid waste management -Special emphasis on middle-and lower income countries. Urban Paper. Washington, D.C.: The World Bank; 2006.
[67] Chan JK, Xing GH, Xu Y, et al. Body loadings and health risk assessment of polychlorinated dibenzo-p-dioxins and dibenzofurans at an intensive electronic waste recycling site in China. Environ Sci Technol. 2007;41(22):7668–7674.
[68] Heacock M, Kelly CB, Asante KA, et al. E-waste and harm to vulnerable populations: a growing global problem. Environ Health Perspect. 2016;124(5):550–555.
[69] Uddin SMN, Gutberlet J. Livelihoods and health status of informal recyclers in Mongolia, *Resource*. Conserv Recycl. 2018;134:1–9.
[70] Nzeadibe TC, Adama O. Ingrained inequalities? deconstructing gendered spaces in the informal waste economy of Nigerian cities. Urban Forum. 2015;*26(2)*,113-130. DOI:10.1007/s12132-014-9246-0.
[71] Ahmed SA, Ali M. Partnerships for solid waste management in developing countries: linking theories to realities. Habitat Int. 2004;28(3):467–479.
[72] Habitat UN. Solid waste management in the world's cities. London: Earthscan; 2010. Water and sanitation in the world's cities.
[73] Thorn J, Beijer L, Rylander R. Airways inflammation and glucan exposure among the waste collectors. Am J Ind Med. 1998;33:463–470.
[74] Yang CY, Chang YT, Chuang HY, et al. Adverse health effects among household waste collectors in Taiwan. Environ Res Section A. 2001;85:195–199.
[75] Hansen J, Ivens UI, Breum NO, et al. Respiratory symptoms among the Danish waste collectors. Ann Agric Environ Med. 1997;4:69–74.

[76] Xu X, Liu J, Huang C, et al. Association of polycyclic aromatic hydrocarbons (PAHs) and lead co-exposure with child physical growth and development in an e-waste recycling town. Chemosphere. 2015;139:295–302.
[77] Ezekwe CI, Agbakoba A, Igbagara PW. Source gas emission and ambient air quality around the Eneka co-disposal landfill in Port Harcourt, Nigeria. TLEP Int J Appl Chem Ind Sci. 2015;2(1):11–23.
[78] Da Silva C, Bodily T. Memory and the Politics of Remembrance: the aftermath of Goiânia Radiological Disaster. High Plains Appl Anthropol. 2001;21:40–52.
[79] Gowda K, Mn C, V PSM, et al. Solid waste management in the slums and squatter settlements in the city of Bangalore. International Journal of Scientific and Research Publications. 2013;3(2):1–10.
[80] Gutberlet J, Kain J-H, Nyakinya B, et al. Socio-environmental entrepreneurship and the provision of critical services in informal settlements. Environ Urban. 2016;28(1). DOI:10.1177/0956247815623772
[81] UN-Habitat Solid waste management in the world's cities. United Nations Human Settlement Program. London: Earthscan; 2010.
[82] Rouse JR. Seeking common ground for people: livelihoods, governance and waste. Habitat Int. 2006;30(4):741–753.
[83] Campos MJZ, Zapata P. Switching Managua on! Connecting informal settlements to the formal city through household waste collection. Environ Urban. 2013;25(1):225–242.
[84] Gutberlet J, Kain J-H, Nyakinya B, et al. Bridging weak links of solid waste management in informal settlements. J Environ Dev. 2016. DOI:10.1177/1070496516672263
[85] Mazhindu E, Gumbo T, Gondo T. Waste management threats to human health and urban aquatic habitats- a case study of Addis Ababa, Ethiopia. In: Rebellon LFM, editor. Waste management- an integrated vision. 2012. London, UK: INTECHOpen, DOI: 10.5772/48077. Available from: https://www.intechopen.com/books/waste-management-an-integrated-vision/waste-management-threats-to-human-health-and-urban-aquatic-habitats-a-case-study-of-addis-ababa-ethi.
[86] Gowda K, Chandrashekar MN, Sridhara MV, et al. Solid waste management in the slums and squatter settlements in the city of Bangalore. Int J Sci Res Publ. 2013;3(2):1–10.
[87] Henry RK, Yongsheng Z, Jun D. Municipal solid waste management challenges in developing countries - Kenyan case study. Waste Manag. 2006;26:92–100.
[88] El-Fadel M, Findikakis AN, Leckie JO. Environmental impacts of solid waste landfilling. J Environ Manage. 1997;50:1–25.
[89] Wang G, Lu G, Zhao J, et al. Evaluation of toxicity and estrogenicity of the landfill-concentrated leachate during advanced oxidation treatment: chemical analysis and bioanalytical tools. Environ Sci Pollut Res. 2016. DOI:10.1007/s11356-016-6669-2
[90] Jambeck JR, Geyer R, Wilcox C, et al. Plastic waste inputs from land into the ocean. Science. 2015;347(6223):768–771.
[91] UN Plastic waste causes $13 billion in annual damage to marine ecosystems; [cited 2016 Aug 2014]. Available from: http://www.un.org/apps/news/story.asp?NewsID=48113#.V2Mk9b9LfUI
[92] Gilman EF, Leone IA, Flower FB. Influence of soil gas contamination on tree root growth. Plant and Soil. 1982;65:3–10.
[93] Arthur JJ, Leone IA, Flower FB. The response of tomato plants to simulated landfill gas mixtures. J Environ Sci Health, A: Environ Sci Eng. 1985;20(8):913–925.
[94] Chang N, Pires A. Sustainable solid waste management: a systems engineering approach. USA: Wiley, IEEE Press; 2015.
[95] Gutberlet J. Urban recycling cooperatives: building resilient communities. London, New York: Routledge Taylor & Francis Group; 2016. p. 183.
[96] Xi B, Jiang Y, Li M, et al. Groundwater pollution and its risks in solid waste disposal sites. In: Xi B. et al. Optimization of solid waste conversion process and risk control of groundwater pollution. Springer Briefs in Environmental Sciences 2016; ISBN 978-3-662-49462-2 (E-BOOK); DOI 10.1007/978-3-662-49462;75–104.
[97] Mikac N, Cosovic B, Ahel M, et al. Assessment of groundwater contaminant in the vicinity of a municipal solid waste landfill (Zagreb, Croatia). Water Sci Technol. 1998;37(8):37–44.
[98] Chofqi A, Younsi A, Lhadi EK, et al. Environmental impact of an urban landfill on a coastal aquifer (El Jadida, Morocco). J Afr Earth Sci. 2004;39:509–516.
[99] Niloufer S, Rao KV, Swamy AVVS. Impact of municipal solid waste dumpsite on the groundwater quality in Vijayawada. Int J Appl Pure Sci Agric. 2016;2(5):31–41.
[100] Fonkwe MLD, Trapp S. Analyzing tree cores to detect petroleum hydrocarbon-contaminated groundwater at a former landfill site in the community of happy valley-goose bay, eastern Canadian subarctic. Environ Sci Pollut Res. 2016. DOI:10.1007/s11356-016-6802-2
[101] Klinck BA, Stuart ME *Human risk in relation to landfill leachate quality*. British Geological Survey Technical Report, WC/99/17, British Geological Survey Keyworth UK; 1999. pp. 45.
[102] Eade D. Capacity-Building: an approach to people-centred development. Oxford: Oxfam; 1997. Oxford Development Guidelines.
[103] Boadi KO, Markku K. Environmental and health impacts of household waste handling. J Environ Health. 2005;68(4):32–36.
[104] Hunt C. Child waste pickers in India: the occupation and its health risks. Environ Urban. 1996;8(2):111–118.
[105] ILO (International Labour Organization). Addressing the exploitation of children in scavenging (waste picking): a thematic evaluation of action on child labour. a thematic evaluation. Geneva, Switzerland: International Programme on the Elimination of Child Labour (IPEC), International Labour Office; 2004.
[106] Leon JCVD, Bogardi JJ. Focusing on the environment and human security nexus. In: Beer T, editor. Geophysical hazards: minimizing risk, maximizing awareness. Australia: Springer; 2010.
[107] Kironde JML, Yhdego M. The governance of waste management in urban Tanzania: towards a community based approach. Resour Conserv Recycl. 1997;21(4):213–226.
[108] Brunner PH, Fellner J. Setting priorities for waste management strategies in developing countries. Waste Manag Res. 2007;25:234–240.