

Validation of the Framework for Assessing Occupational Health Risks of Municipal Solid Waste Handlers

France Ncube¹, Esper J. Ncube¹ & Kuku Voyi¹

¹ School of Health Systems and Public Health, Faculty of Health Sciences, University of Pretoria, South Africa

Correspondence: France Ncube, School of Health Systems and Public Health, Faculty of Health Sciences, University of Pretoria, Pretoria, South Africa. Tel: 27-781-321-247. E-mail: france.ncube257@gmail.com

Received: October 14, 2017 Accepted: November 15, 2017 Online Published: July 11, 2018

doi:10.5539/gjhs.v10n8p1

URL: <https://doi.org/10.5539/gjhs.v10n8p1>

Abstract

Background: The occupational health risks associated with municipal solid waste handling are widely documented in literature. However, no framework has been developed for their assessment. The aim of this study was to develop and validate a tool for use by local government structures.

Methods: Epidemiological evidence on human health risks associated with municipal solid waste management (MSWM) was obtained from literature and primary data collected from the study sites. An analysis of strengths, weaknesses, opportunities and threats (SWOT) of available human and environmental risk assessment frameworks was done and the findings were used as a base for the framework. The proposed framework was validated through iteration workshops in small, medium and large local government structures. Also, it was presented in a safety and health conference, in order obtain the input of occupational health and safety practitioners, researchers and policy makers.

Results: A draft framework was produced, validated and revised to incorporate resolutions made from the iteration workshops. The final framework constitutes four inputs, six phases and four principles. Each phase has defined outputs.

Conclusion: The applicability of the framework to situations of resource-constrained economies has been tested through validation workshops in small, medium and large local government structures of a low income country. In light of the multi-methods used in developing the framework and the input of practitioners in validation workshops, the framework appears relevant for the purposes of assessing occupational health risks of municipal solid waste handlers (MSWHs).

Keywords: framework, local government structures, municipal solid waste handlers, occupational health risks

1. Introduction

MSWHs are exposed to various occupational risks that may endanger their personal health (Dorevitch & Marder, 2001; Heldal et al., 2003; Kuijer & Frings-Dresen, 2004; Tsovili, Rachiotis, & Symvoulakis, 2014; Jerie, 2016; Ncube, Ncube, & Voyi, 2017a). Such risks may include bioaerosols (Heldal et al., 2003; Ncube et al., 2017a), physical stressors such as heat, dusts, vibrations and mechanical hazards (Jerie, 2016; Ncube et al., 2017a). Other risks may arise from new waste collection methods (Kuijer & Frings-Dresen, 2004) and the hazardous streams in domestic solid wastes (Jerie, 2016; Ncube et al., 2017a). According to the authors' best knowledge, currently there is no framework that has been developed for assessing the exposure of MSWHs to occupational risks. Such a framework is required for use by local government structures such as municipalities, city and town councils. Ramos and colleagues (2016) highlight the value of a regular assessment of workplace hazards. Particularly, they emphasize the contribution to designing and implementing preventive measures that are essential and sufficient for addressing among other issues, the level of risk.

Over the past three decades, several risk assessment and management frameworks have been developed and published (Health council of the Netherlands, 1996; ILO, 1998; Rampal & Sadhra, 1999; Canada, 2000; enHealth Council, 2002; U.S EPA, 2003; British Standards Institute, 2007; WHO/IPCS, 2009; IGHRC, 2009; Gormley et al., 2011; U.S EPA, 2014). In the present study, the process of developing a framework for assessing occupational health risks of MSWHs partly entailed analyzing and learning from the strengths and limitations of these frameworks. To accomplish this, a protocol was developed on the criteria to be followed in the selection, inclusion, exclusion and review of the afore-mentioned frameworks.

The review of the frameworks pointed out the lack of the problem formulation component, needed for setting appropriate risk assessment objectives (Health Canada, 2000; Gormley, Pollard, Rocks, & Black, 2011; U.S EPA; 2014). Furthermore, the frameworks lacked input of methodologically sound epidemiological studies, a risk judgment criteria, a stakeholder consultation and documentation guideline and emphasis on risk communication. The reviewed frameworks focused on three main issues: environmental pollution (Health council of the Netherlands, 1996; Gormley et al., 2011), health risks to general populations (Health Canada, 2000; enHealth Council, 2002; U.S EPA, 2003; WHO/IPCS, 2009; IGHRC; 2009; U.S EPA, 2014) and generic occupational settings (ILO, 1998; Rampal & Sadhra, 1999; British Standards Institute, 2007). Limitations from these frameworks influenced the development of the required framework, building on their strengths and limitations.

2. Methods

2.1 Input Data

In coming up with the required framework presented in this paper, below is a summary of the steps taken:

2.1.1 Step 1: Review of Epidemiological Literature on Waste Management

Evidence from reviews of epidemiological studies on MSWM showed that most studies could not conclusively link waste management processes with adverse health effects, due to their methodological shortcomings (Portia, Milani, Lazarrino, Perucci, & Forastiere, 2009; Ncube et al., 2017b). Basing on these conclusions, the proposed framework emphasizes the need for local government structures' waste managers to engage in methodologically sound investigations and to use findings from methodological sound studies in the risk assessment process. This requirement is emphasized in the framework's input 1 (Figure 1).

2.1.2 Step 2: Primary Data Collection

Identification of hazards to be considered in the framework for assessing occupational health risks of MSWHs and exposure assessment of biological, physical, chemical and ergonomic occupational hazards are reported elsewhere (Ncube et al., 2017a, Ncube et al., 2017c). Similarly, other investigators document that MSWHs are exposed to one or more of these hazard categories (Dorevitch & Marder, 2001; Heldal et al., 2003; Kuijer & Frings-Dresen, 2004; Tsovili, Rachiotis, & Symvoulakis, 2014; Jerie, 2016). Collectively, the findings on the various exposures of MSWHs constitute output 1 in phase 1 of the draft framework, shown in Figure 1. This output details the categories of waste management hazards to be addressed in the risk assessment process.

2.1.3 Step 3: Review of Available Frameworks

Findings from the SWOT analysis of available frameworks (Health council of the Netherlands, 1996; Gormley et al., 2011, Health Canada, 2000; enHealth Council, 2002; U.S EPA, 2003; WHO/IPCS, 2009; IGHRC; 2009; U.S EPA, 2014; ILO, 1998; Rampal & Sadhra, 1999; British Standards Institute, 2007), were used to develop a draft framework. In the next sections of the manuscript, the authors will detail: i) how the frameworks were selected and reviewed, ii) the process followed to produce the draft framework, iii) the methods used to validate the draft framework and iv) the components of the final framework.

2.2 Framework Selection

The internet search process involved using combinations of the terms: assessment, environmental, framework, management, model, occupational, risk and waste. Frameworks to be included in the review had to meet the criteria shown in Box 1. For each framework, references were checked to identify additional frameworks meeting the inclusion criteria.

Box 1Inclusion criteria

- (1) had a direct focus on environmental, human health or occupational health issues,
- (2) contain a diagrammatic representation of the components,
- (3) have a verifiable and authentic source,
- (4) written in English language and
- (5) latest version of the concerned framework.

Exclusion criteria

- (1) frameworks on effluent,
- (2) nanomaterial,
- (3) water pollution and
- (4) cancer.

A total of 49 frameworks were found and only 12 met the inclusion criteria described in Box 1. Each selected framework was examined with regards to emphasis on: problem formulation, toxicological assessments, risk judgment criteria, documentation, stakeholder consultation, risk communication, evaluation and consideration of findings from methodologically sound epidemiological studies.

2.3 Development of MSWH Focused Framework

A SWOT analysis of available environmental and human risk assessment frameworks was done. Table 1 shows the findings of the SWOT analysis on the enrolled frameworks. Most frameworks were freely available online for public use. The absence of a component on problem formulation in all occupational health frameworks (ILO, 1998; Rampal & Sadhra, 1999; British Standards Institute, 2007) may make it difficult to set risk assessment objectives and to select required methods for their accomplishment (Health Canada, 2000; Gormley, Pollard, Rocks, & Black, 2011; U.S EPA; 2014). Therefore, problem formulation has been considered a core component of the proposed framework (Figure 1). Additionally, all the frameworks lacked emphasis on the input of findings from methodologically sound epidemiological studies, a risk judgment criteria and a stakeholder consultation guideline (Table 1). Methodologically sound epidemiological studies have been observed to be requirement for establishing cause-effect relationships between waste management activities and associated health problems (Ncube et al., 2017b), whilst a risk judgment criteria is vital for decision making purposes. Some reviewed frameworks lacked emphasis on documentation and the few which contained it lacked a stakeholder consultation and documentation guideline (Table 1). Wachter and Yorio (2014) conclude that because of lack of worker engagement, the Occupational Safety and Health Assessment Series (OSHAS 18001) is not worker centric but process-centric. In the light of such shortcomings, the proposed framework provides a guideline for documentation and stakeholder consultation. Equally noteworthy the frameworks lacked strong emphasis on risk communication to affected populations (Table 1). In most frameworks it was implied (Health Canada, 2000; enHealth Council, 2002; U.S EPA, 2003; WHO/IPCS, 2009; IGHRC, 2009; U.S EPA, 2014), embodied in feedback (ILO, 1998; Netherlands Society of Occupational Medicine, 2005) in some it was completely absent (British Standards Institute, 2007; Netherlands Society of Occupational Medicine, 2005) whilst in others it was not on-going but terminally positioned such that it did not influence the risk assessment process (Rampal & Sadhra, 1999). In the proposed framework, risk communication is viewed as on-going and not terminal, and should be considered in the implementation of all phases of the framework.

2.4 Validation Process for the Developed Framework

A multi-step approach was used to validate the developed framework through: i) conducting workshops in large, medium and small local government structures and ii) presenting the framework in a safety and health conference. The purpose of the validation workshops was to test the applicability of the developed framework to the circumstances of different local government structures and improve it guided by their experiences and expertise. The conference presentation was meant to obtain additional input of occupational health and safety officers, researchers and policy makers on further required improvements on the framework.

2.5 Setting for Framework Validation

Validation workshops for the proposed framework were conducted in Zimbabwe, a low income country (World

Bank, 2017). The rationale was to develop a framework which could be used by municipalities in countries with similar resource-constrained economies. The study used a local government structure in the form of a municipality, city or town council.

Three different local government structures were used for the validation exercise: Bulawayo City Council, the municipality of Gwanda and of Bindura. Bulawayo City Council was chosen on the basis that it is a large town (second largest in Zimbabwe) with diverse expertise in municipal solid waste management. Gwanda town has a medium sized municipality with few waste management officers but works with the health ministry and local tertiary education colleges to deliver sound waste management programmes. In this town, participants who took part in the validation exercise were environmental health officers, technicians, health training officers and lecturers from local colleges. Bindura is a small town with three officers in charge of waste management activities: a director and two Environmental Health Technicians.

2.6 Stakeholder Composition

Attendees of the validation workshops included the Acting Directors of Health Services, the Assistant Director of Environmental Health Services, the Deputy Chief Nursing Officer, Environmental Health Officers, Public Health Officers, Health Promotion Officers, Health and Safety Officers, Pest Control Officers, Cleansing Supervisors, Cemeteries and Crematorium Officers and Sanitary Engineers. Such diverse expertise and experiences provided valuable opportunities to learn and improve the draft framework.

2.7 Process for Stakeholder Input

In the iteration workshops, the authors described how the framework was developed, its purpose, components and principles. Participants were split into groups of 5 - 10 members, given copies of the proposed framework and tasked to determine: (1) if there were any required improvements or changes on each component of the framework, (2) whether there were additional components deserving inclusion and (3) and the suitable conditions for the usage of the framework. In this context suitable conditions meant whether the framework needed to be used as a pre-assessment tool or as an assessment tool or whether it was completely not useable. The groups presented their work and discussions were held.

Group discussions were used to engage participants in critical thinking (Totten, 1991) and ensure different interpretations of the given situation (Bruner, 1985), both of which could have contributed to the identification of the required framework improvements (Table 2).

3. Results and Discussion

3.1 Iterations Towards Proposed Framework

Several resolutions were made in relation to the framework, in the validation workshops (Table 2). Firstly, the draft framework (Figure 1) contained the input, “results from improved epidemiological studies,” prior to validating it. However, in the validation workshops, participants felt that such phraseology was less clear and not self-explanatory to waste management practitioners who should understand it without referring to the review article (Ncube et al., 2017b). They recommended replacing it with, “results from methodologically sound epidemiological studies.” Since the limitations identified pertained to methodological shortcomings (Ncube et al., 2017b), the authors strongly concurred with the workshop attendees’ constructive suggestion and revisited the framework to improve it to its current status, where the concern constitutes input 1 (Figure 2).

Secondly, policies and legislation were recommended for inclusion as another input (input II) to the proposed framework. This addition was justified on the basis that requirements, omissions and contraventions of available policies and legislation are a source of information which waste managers can use in phase 1 (Figure 2). In the workshops, participants operationalised the term legislation to mean applicable local by-laws, national laws and international conventions, protocols and agreements, in the context of the proposed framework.

Thirdly, participants suggested combining two of the initial framework inputs into one. These were “toxicological assessments” and “incident and accident investigations.” These were observed to be qualifying as sub-components of the broader proposed input, “occupational health surveillance.” Resultantly, the refined framework contains occupational health surveillance, which is input III. Furthermore, participants concurred that the results, conclusions and recommendations from previous assessments were a valuable input for subsequent risk assessments. They were stressed as instrumental in identifying needed changes and improvements. Additionally, the workshop participants suggested inclusion of waste characterisation to the list of phase 1’s outputs. They defined waste characterisation as the physical waste compositional analysis and emphasized that the composition of municipal solid waste generated in each town differs in terms of quantities of health-threatening ingredients such as toxic, infectious and mechanical hazards.

Table 1. Strengths and shortcomings of reviewed frameworks

	<i>UK</i> (Gormley et al, 2011)	<i>HCN</i>	<i>Canada</i>	<i>USEPA</i>	<i>Australia</i>	<i>CRA</i>	<i>Rampal & Sadhra</i>	<i>NSOM</i>	<i>ILO</i>	<i>OSHAS 18001</i>
<i>Framework focus</i> <i>Criterion</i>	Assessment & management	Assessment & management	Assessment & management	Assessment & Decision making	Assessment & management	Combined exposures & effects	Assessment & management	Worker & environment surveillance	Worker & environment surveillance	Accidents & injuries prevention
<i>Problem Formulation</i>	✓	✓	✓	✓	✓	✓	-	-	-	-
<i>Stakeholder consultation</i>	✓	✓	✓	✓	✓	-	-	✓	✓	-
<i>MSES</i>	-	-	-	-	-	-	-	-	-	-
<i>Risk judgement criteria</i>	-	-	-	-	-	-	-	-	-	-
<i>Toxicological assessments</i>	✓	-	✓	✓	✓	✓	✓	-	-	-
<i>Risk communication</i>	✓	-	≠	≠	≠	≠	✘	**	**	-
<i>Documentation</i>	✓	✓	✓	✓	-	✓	-	✓	✓	✓
<i>Consultation guideline</i>	-	-	-	-	-	-	-	-	-	-
<i>Review or Auditing or Evaluation</i>	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

MSES: Methodologically sound epidemiological studies, OHS: Occupational health surveillance ✓= present; - = absent; ✘ = present but terminal; ≠ = implied; ** = embodied in feedback, HCN: Health council of the Netherlands, CRA: Cumulative risk assessment frameworks (U.S EPA, 2003; WHO/IPCS, 2009; IGHRC, 2009), NSOM: Netherlands Society of Occupational Medicine

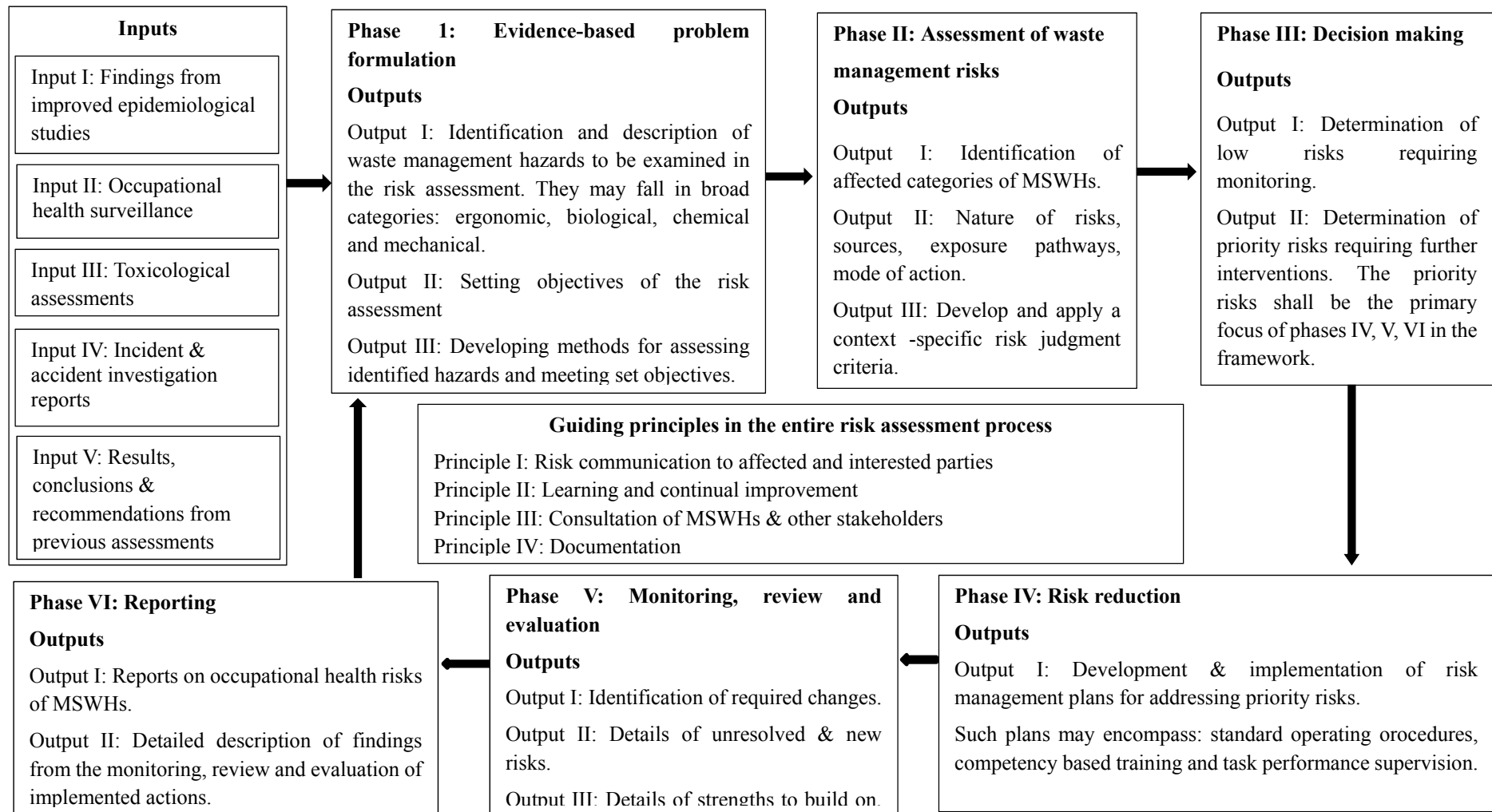


Figure 1. Draft framework for assessing occupational health risks of MSWHs.

Table 2. Resolutions made in the framework validation workshops and conference presentation

Participants	No.	Workshop resolutions
<i>Bulawayo City Council</i>		
- Director of Health Services	1	- The first framework's input, "improved epidemiological studies" was considered to be less direct and was refined to, "methodologically sound epidemiological studies."
- Deputy Director Environmental Health	1	- The practitioners suggested adding "policy and legislation requirements" to the framework inputs
- Deputy Director of Nursing Services.	7	- The term legislation was operationalised to mean applicable local by-laws, national laws and international conventions, protocols and agreements
- Environmental Health Officers and Technicians	2	- "Waste characterisation" was added to the list of phase 1 outputs.
- Public Health Officers	2	- The framework inputs, "toxicological assessments" and "incident and accident investigations," were combined into the broader term, "Occupational Health Surveillance."
- Health Promotions Officers	2	- An additional output was added to phase IV, "formulation of occupational health policies."
- Cleansing Supervisors	5	- Principle I revised to read, "Consultation of MSWHs, managers and other stakeholders." Initially, it read, "consultation of MSWHs and other stakeholders."
- Senior Health and Safety officer	1	- Framework noted to be suitable as an assessment tool
- Senior Pest control Supervisor	1	
- Crematories and crematorium officers	1	
- Sanitary engineers	4	
- Administration officers		
<i>Gwanda Municipality</i>		
- Environmental Health Officers and Technicians	7	- Psychological hazards were added to possible hazards as shown in phase 1 (Figure 2).
- Lecturers and tutors of local colleges	2	- Waste characterisation was added to the list of phase 1's outputs.
- Health Training Officers	1	- Waste characterisation was contextualised to mean the physical waste compositional analysis.
		- The framework observed to be a crucial assessment tool.
<i>Bindura Municipality</i>		
- Director of Environmental Health Services	1	- The comments were similar to those raised by the personnel from Gwanda Municipality.
- Environmental Health Technicians	1	- Framework was endorsed as an assessment tool, without major changes
<i>Safety and Health Conference</i>	>200	- The was framework endorsed as a useful assessment tool for occupational health risks of MSWHs.

The concept of consultation of workers was reinforced and the principle was broadened to elaborately highlight not only consultation of MSWHs but also managers (Table 2). The widening of the pool of stakeholders consulted, particularly the inclusion of practitioners such as waste managers provided the opportunity to learn from their valuable input. The framework validation workshops culminated in a recommendation to include the development of an organisational occupational safety and health (OSH) policy as phase IV's output I. Such a policy was understood to be the springboard for uniting MSWHs, waste managers and relevant stakeholders in efforts towards safety and health promotion. The resolutions from the iteration workshops were used to improve the draft framework to its current status (Figure 2). In the safety and health conference, attendees endorsed the framework as a useful assessment tool for occupational health risks of MSWHs.

3.2 Description of Components of the Developed Framework

The structure of the developed framework follows the risk assessment and management decision process. The four inputs (Figure 2) provide crucial evidence for the formulation of waste management problems to be addressed in the risk assessment. The framework's outputs in each phase serve to guide and focus the risk assessment process. Figures 2 and 3 constitute the final format of the developed framework and should be used together.

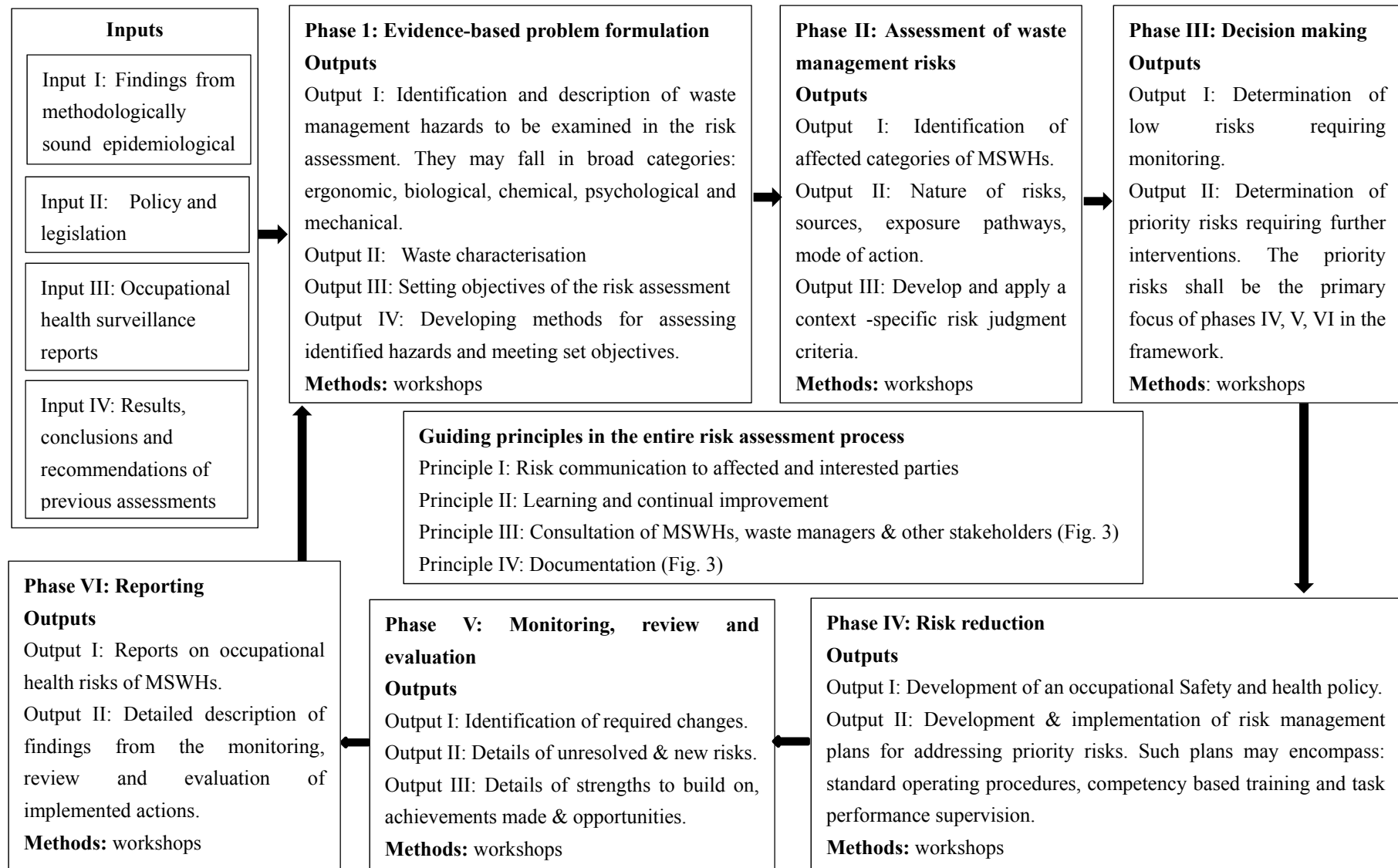


Figure 2. Validated Framework for assessing occupational health risks of MSWHs.

3.2.1 Phase I: Evidence-Based Problem Formulation

In phase I, output I's thrust is on the identification and description of waste management hazards to be examined in the risk assessment. In order to achieve this, the sources of information are the framework inputs (Figure 2). Output II focuses on waste characterisation. This involves performing a physical waste compositional analysis to identify the potential hazards associated with each waste stream. Collectively, output I and II culminate in the tabulation of a complete list of hazards deserving consideration in phase II. The list is the basis for setting objectives of the risk assessment (output III) and developing or identifying methods for assessing each hazard (output IV).

3.2.2 Phase II: Assessment of Waste Management Risks

Once phase I has been completed, the specific categories of MSWHs affected by each identified hazard are defined. This may facilitate identification of priority risks for each category. From validation workshops, the main categories of MSWHs were identified as: waste collectors, street and open areas sweepers, drivers, landfill operators, and those who man central waste collection points. Some issues to be addressed at the assessment phase are: what are the sources, exposure pathways mode of action of the identified hazards? Since outcomes of the assessment process influence the contents of the risk management plan (Figure 2), precautions must be taken to ensure that results are accurate and reflective of real situations on the ground. This may require assembling a multi-disciplinary team so that members complement each other's competencies and measures such as field visits to observe and document hazards of waste management operations. One key concern missing in reviewed frameworks was a risk judgement criterion (Table 1). This shortcoming is a key output of the developed framework (Figure 2). A resolution made from the validation workshops was that each local government structure should develop its own risk judgement criteria to address local scenarios. Further, participants recommended that the concerned criteria needs to address the following issues: (1) regardless of the likelihood of occurrence being low or moderate, risks contributing to death, incapacitation and irreversible health damage required inclusion in the priority risk management plan and (2) risks with low, moderate or high probability of occurrence but low severity need to be considered under a routine monitoring plan.

3.2.3 Guiding Principles in the Developed Framework

The proposed framework emphasises adherence to four main principles when assessing waste management risks (Figure 2). Since the principles apply to all phases of the framework, they were placed at a central position rather than under a particular phase. Principle I, "learning and continual improvement" recognises that no local government structure is perfect but opportunities exist for improvement with regard to assessing occupational health risks of MSWHs. Considering findings from the framework inputs in problem formulation (Figure 2) could assist in continual improvement. Principle II pertains to prompt communication of all identified risks to MSWHs and other stakeholders. Such communication is envisaged to increase workers' awareness of the workplace hazards and appreciation of the importance of the risk management plans highlighted in phase IV (Figure 2). In the developed framework risk communication together with other principles were centrally positioned, in order to show they should be considered in every phase of the framework (Figure 2). Methods of risk communication may include competency based training, feedback meetings, signage and publication of research findings. Principle III of the framework refers to consultation of MSWHs, managers and other stakeholders. Since MSWHs and their managers' routine work activities entail dealing with waste, consultation might help to fully identify occupational risks and to instil a sense of ownership and positive identification with the proposed framework. The notion of involvement of workers in managing occupational risks is strongly supported by several past studies (Prussia, Brown, & Willis, 2003; Fernadz-Mniz, Montes-Peon, & Vazquez-Ordas, 2007; Christian et al., 2003; Prussia, Brown, & Willis, 2003; Ramos, Afonso, Costa, & Santos, 2015).

Principle IV is on documentation. Identified documents which local government structures may need to keep include standard operating procedures, reports from job safety analysis, safety inspections, epidemiological studies and surveillance. A reference document may foster uniformity, consistency, continual improvement and ultimately perfection in the performance of waste management tasks. The framework contains a stakeholder consultation and documentation guideline (Figure 3).

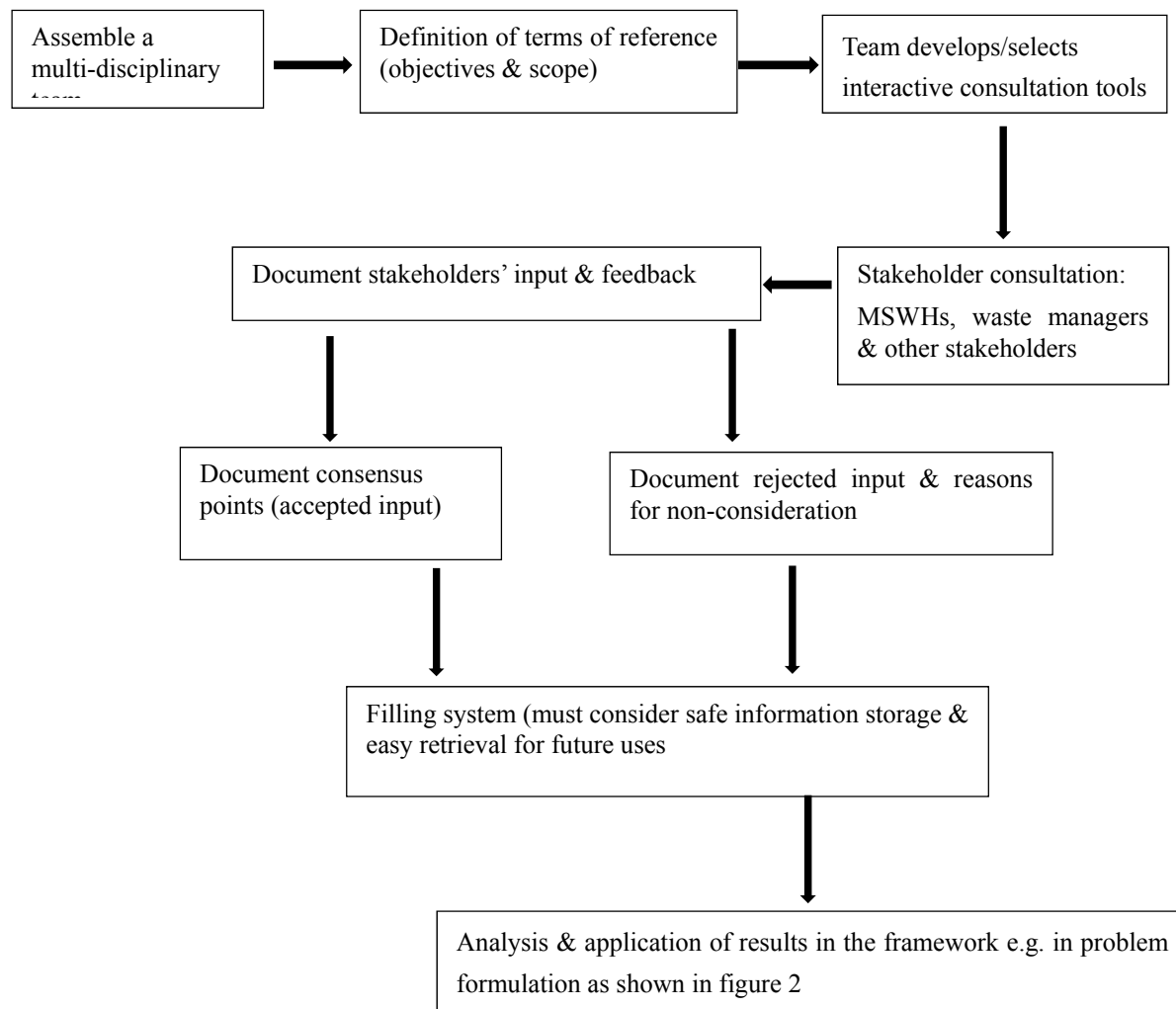


Figure 3. Stakeholder consultation and documentation guideline

The guideline (Figure 3) describes the approach and content of stakeholder consultation and documentation of input. The purpose of the guidelines is to improve on the management of information generated from stakeholder consultations and other phases of the framework. It highlights the need to record both accepted consensus discussion points during stakeholder consultations and rejected input together with reasons for no-consideration.

3.2.4 Phase III: Decision Making

In the developed framework, the assessment of risks encountered by MSWHs culminates in decision making. Decision making in this context means making judgement on which risks are priority risks requiring further interventions and the low risks requiring continuous monitoring. The priority risks shall be the primary focus of phases IV, V and VI in the framework. Where applicable scoring, checklist and scales maybe used in decision making.

3.2.5 Phase IV: Risk Reduction

Output I pertains to the development of an organisational OSH policy as phase IV's output I (Figure 2). The policy is envisaged to unite MSWHs, waste managers and relevant stakeholders in efforts towards safety and health promotion. Thus, it should detail the organisational vision, mission, values and aims. Output II emphasizes the need to develop and implement a risk management plan for the identified priority risks. The plan may encompass standard operating procedures, competency based training and task performance supervision (Figure 2). Some useful resources to this end include, for instance, the ISO 31000 standard which gives the principles and generic guidelines on the management of risks (ISO, 2009). Lastly, phase IV's output II (Figure 2) stresses that implementing the risk management plan requires the collection of data or feedback on the applicability of selected

interventions and areas for further improvement.

3.2.6 Phase V: Monitoring, Review and Decision Making

The focus of this phase is coming-up with a monitoring frequency, requirements and methods for each hazard in the priority risk management plan. In the proposed framework, this phase has three outputs. Output I stresses the need to identify required changes. The changes may relate to the process and methods used in the risk assessment or existing plans to address waste management risks. The idea behind identifying required changes is to learn from the shortcomings and further improve in line with principle II (Figure 2). New and unresolved risks need to be documented for further consideration (output II). Achievements made and limitations encountered should be recorded (output III), in order to show the nature of improvements made.

3.2.7 Phase VI: Reporting

Phase VI focuses on reporting. The framework places the responsibility of reporting the outcomes of the risk assessment on waste managers. The reports on occupational health surveillance, vehicle safety inspections, epidemiological studies and job safety analysis should be compiled, reported to relevant authorities and properly filed. Reports may yield valuable information not just for review but problem formulation (Figure 2).

3.3 Strengths and Limitations

To the authors' knowledge, this is the first framework specifically developed for assessing occupational health risks of MSWHs. The framework presented in this paper has been formulated through extensive efforts constituting: i) utilisation of primary data from the authors' work and ii) an assessment of the strengths and limitations of available frameworks and epidemiological literature.

Furthermore, this paper presents a validated framework for use by local government structures. Iteration workshops in circumstances of a low income country's small, medium and large local government structures usefully enriched the framework with expert input. This input was the basis for revising and refining the framework to its current status (Figure 2).

The use of a predefined protocol for framework selection (Box 1) and review (Table 1), enabled the authors to conduct a fair assessment of the relevant frameworks. However, the exclusion of frameworks written in languages other than English could have thwarted opportunities for our framework to learn from such frameworks. Further work may usefully broaden the review criteria in this regard. Similarly, our framework may richly benefit from other forms of validation, such as adoption and field usage by a municipality, town or city council, for at least two complete cycles. Such practical usage can help identify other required improvements on the framework. Lastly, the framework is yet to be disseminated and shared through further international conferences, particularly of industrialised nations.

4. Conclusion

The applicability of the framework to situations of resource-constrained economies has been tested through validation workshops in small, medium and large local government structures of a low income country. The framework was revised and refined based on the validation outcomes. In light of the multi-methods used in developing the framework and the input of practitioners in validation workshops, the framework appears relevant for the purposes of assessing occupational health risks of MSWHs. Its emphasis is on evidence-based problem formulation, defined outputs per each risk assessment phase and is hinged on four principles: i) risk communication, ii) consultation of MSWHs, waste managers and other stakeholders, iii) learning and continual improvement and iv) documentation. The developed framework fills the existing gap of lack of a framework for use by local government structures in assessing occupational health risks of MSWHs.

Acknowledgments

The authors warmly thank attendees of the iteration workshops conducted in small, medium and large local government structures. The contributions of occupational health and safety practitioners, researchers and policy makers in the conference presentations on the framework are highly treasured.

Competing Interests Statement

The authors have no competing or potential conflicts of interest.

References

British Standards Institute. (2007). *Occupational health and safety assessment series 18001*. London: British Standards Institute.

- Bruner, J. (1985). *Vygotsky: An historical and conceptual perspective. Culture, communication, and cognition: Vygotskian perspectives*. London.
- Christian, M. S., Bradley, J. C., Wallace, J. C., & Burke, M. (2009). Workplace safety: a meta-analysis of the roles of person and situation factors. *J Appl Psychol*, *94*(5), 1103-1127. <https://doi.org/10.1037/a0016172>
- Dorevitch, S., & Marder, D. (2001). Occupational hazards of municipal solid waste workers. *Occup Med*, *16*(1), 125-133.
- enHealth Council. (2002). *Environmental health risk assessment: Guidelines for assessing human health risks from environmental hazards*. Canberra: Department of Health and Aged Care and enHealth Council.
- Fernadz-Mniz, B., Montes-Peon, J. M., & Vazquez-Ordas, C. J. (2007). Safety culture: Analysis of the causal relationships between its key dimensions. *J Safety Res*, *38*(6), 627-641. <https://doi.org/10.1016/j.jsr.2007.09.001>
- Health Canada. (2000). *Health Canada decision-making framework for identifying, assessing and managing health risks*. Ottawa: Health Canada.
- Heldal, K. K., Halstensen, A. S., Thorn, J., Djupesland, P., Wouters, I., Eduard, W., & Halstensen, T. S. (2003). Upper airway inflammation in waste handlers exposed to bioaerosols. *Occup Environ Med*, *60*, 444-450. <https://doi.org/10.1136/oem.60.6.444>
- International Labour Organization. (1998). *Technical and Ethical Guidelines for Workers' Health Surveillance*. Geneva: ILO.
- Institute of Environment and Health. (2009). *Chemical mixtures: A framework for assessing risk to human health*. Bedfordshire: IGHC.
- International Organization for Standardization. (2009). *ISO 31000: Risk management principles and guidelines*.
- Jerie, S. (2016). Occupational risks associated with solid waste management in the informal sector of Gweru, Zimbabwe. *Journal of Environmental and Public Health*. <https://doi.org/10.1155/2016/9024160>
- Kuijjer, P. P. F. M., & Frings-Dresen, M. H. W. (2004). World at work: Refuse collectors. *Occup Environ Med*, *61*(3), 282-286. <https://doi.org/10.1136/oem.2002.001172>
- Netherlands Society of Occupational Medicine. (2005). *Guideline Worker Health Surveillance*.
- Ncube, F., Ncube, E. J., & Voyi, K. (2017a). Bioaerosols, noise and ultraviolet radiation exposures for municipal solid waste handlers. *Journal of Environmental and Public Health*. <https://doi.org/10.1155/2017/3081638>
- Ncube, F., Ncube, E. J., & Voyi, K. (2017b). A systematic critical review of epidemiological studies on public health concerns of municipal solid waste handling. *Perspect in Public Health*, *137*(2), 102-108. <https://doi.org/10.1177/1757913916639077>
- Ncube, F., Ncube, E. J., & Voyi, K. (2017c). Postural analysis of a developing country's municipal solid waste handlers and a reference group of hospital general hands using the RULA method. *Global Journal of Health Science*, *9*(10): 194-200. <https://doi.org/10.5539/gjhs.v9n10p194>
- Portia, D., Milani, S., Lazarrino, A.I., Perucci, C.A., & Forastiere, F. (2009). Systematic review of epidemiological studies on health effects associated with management of solid waste. *Environmental Health*, *8*, 60. <https://doi.org/10.1186/1476-069X-8-60>
- Prussia, G. E., Brown, K. A., & Willis, P. G. (2003). Mental models of safety: do managers and employees see eye to eye? *J Safety Res*, *34*, 143-156. [https://doi.org/10.1016/S0022-4375\(03\)00011-2](https://doi.org/10.1016/S0022-4375(03)00011-2)
- Rampal, K.G., & Sadhra, S.S. (1999). Basic concepts and developments. In S.S. Sadhra, & K.G. Rampal (Eds.), *Occupational health risk: assessment and management* (pp. 3-21). Oxford: Blackwell Science.
- Ramos, D., Arezes, P., & Afonso, P. (2016). Application of the Delphi Method for the inclusion of externalities in occupational safety and health analysis. *DYNA* *83*(196), 14-20. <https://dx.doi.org/10.15446/dyna.v83n196.56603>
- Ramos, D., Afonso, P., Costa, A & Santos, G. (2015, June). Workers' awareness and risk management effectiveness in integrated management systems: lessons from a case study in an intermunicipal waste company. Paper presented at the *Second International Conference on Energy and Environment: Bringing Together Engineering and Economics*, Guimaraes.
- Totten, S., Sills, T., Digby, A., & Russ, P. (1991). *Cooperative learning: A guide to research*. New York.

- Tsovili, E., Rachiotis, G., Symvoulakis, E.K., Thanasias, E., Giannisopoulou, O., Papagiannis, D. ... Hadjichristodoulou, C. (2014). Municipal waste collectors and hepatitis B and C virus infection: A cross-sectional study. *Infez Med*, 22(4), 271-276. <http://www.ncbi.nlm.nih.gov/pubmed/25551841>
- U.S Environmental Protection Agency. (2014). *Framework for human risk assessment to inform decision making*. Washington, DC: U.S EPA.
- U.S. Environmental Protection Agency. (2003). *Framework for Cumulative Risk Assessment*. Washington, DC: U.S EPA.
- Wachter, J.K., & Yorio, P.L. (2014). A system of safety management practices and worker engagement for reducing and preventing accidents: An empirical and theoretical investigation. *Accident Analysis and Prevention*, 68, 117-130. <https://doi.org/10.1016/j.aap.2013.07.029>
- World Bank. (2017). *List of economies*. <http://databank.worldbank.org/data/download/site-content/CLASS.xls>
- World Health Organization/International Program on Chemical Safety. (2009). *Assessment of Combined Exposures to Multiple Chemicals: Report of a WHO/IPCS International Workshop*. Geneva: WHO.

Copyrights

Copyright for this article is retained by the author(s), with first publication rights granted to the journal.

This is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (<http://creativecommons.org/licenses/by/4.0/>).