Safety Management of the Characterization Activities of Illegal Dumpsites

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Abstract

Due to the ever-increasing amount of industrial waste, illegal dumpsites have been spreading out both in well-being and developing countries. Therefore, research and remediation programs have been promoted worldwide in order to limit the negative impact on both the environment and public health of uncontrolled waste disposal. Accordingly, a great attention has been paid to environmental aspects of remediation activities in contaminated sites and a consistent legislative framework to deal with environmental concerns was stated. However, in such a context occupational health and safety (OHS) issues related to the operators that have to deal with the remediation activities of this type of sites are not considered sufficiently. As a matter of fact, planning suitable safety measures to prevent workers from injuries and professional diseases is essential. That is particularly true during the characterization activities, when workers can be subjected to the direct contact with the polluted environment and are not completely aware about the pollution's entity and type. Hence, this study aims at reducing such a gap, providing a general framework to plan safety during characterization activities, starting from a case-study and the analysis of ISO 45001 approach.

Keywords
Illegal dumping, Occupational health and safety (OHS), Safety management, ISO 45001, Characterization activities

1. Introduction and literature review

In last decades, the growing industrial activity worldwide has brought a better welfare state for people and, consequently, an increasing consumption of goods and services, with a large production of waste (Singh et al., 2014). However, the increasing production of waste has often resulted in bad disposal practices, such as open dumpsites and uncontrolled/illegal landfills, especially in low-income countries (Kaza, S.; Yao, L.; Bhada-Tata, P.; Van Woerden, 2018).

According to the Environmental Protection Authority (EPA), the expression "illegal dumping" is referred to "*Waste materials that have been dumped, tipped or otherwise deposited onto land where no licence or approval exists to accept such waste. Illegal dumping varies from small bags of rubbish in an urban environment to larger scale dumping of waste materials in isolated areas, such as bushland*" (EPA, 2015). Illegal waste dumps take place in secluded areas, such as forest areas or unfenced private plots, or near water courses, waste management plants, wastelands, roadsides etc. (Malinowski et al., 2015; Senior & Mazza, 2004). In many developing countries open dumping sites are often very close to urban areas because they can be a "working place" for waste pickers (O' Hare, 2019).

Most illegal dumpsites were created to dispose of municipal solid waste (MSW), especially in developing countries (Chiemchaisri et al., 2007; Luong et al., 2013). However, they can also include healthcare waste, waste produced during construction and demolition works (C&D waste), asbestos-based materials, waste from the production of chemicals, corrosive, flammable and toxic materials, mercury-containing electrical equipment (e.g. fluorescence lamps, thermostats), chlorine fluoride carbides (e.g. air conditioners and refrigerators), residues from coal mining etc.(Ferronato & Torretta, 2019; Glanville & Chang, 2015; Marfe & Di Stefano, 2016).
As pointed out by several studies, illegal dumping leads to harmful environmental changes and public health issues. In fact, waste degradation is responsible for chemicals releasing, which alters the adsorption capacity of vegetation, the biological and chemical features of soil and groundwater properties (Bartkowiak et al., 2016; Lemanowicz et al., 2016; Schmoll, 2013). Illegal dumps are also accounted to be one of the main causes of cancer, respiratory and cardio diseases due to the spreading out of dioxins, contaminated dusts and toxic gases (Mazza et al., 2015; Njoku et al., 2019).
To deal with such a problem, several initiatives to remediate illegal landfills have been carried out (Asian Regional Research Program on Environment Technology (ARRPET), 2004; Extraordinary Commissioner for the Remediation of Illegal Italian Landfills, 2021; Hidalgo et al., 2019), according to a consistent legislative framework (Gong, 2010). For instance, in the U.S.A. the Resource Conservation and Recovery (RCR) Act (Resource Conservation and Recovery Act 42 U.S. Code §6901 et Seq., 1976) stated criminal provisions for treatment, storage, or waste disposal without/ in violation of a permit, transportation of hazardous waste without a manifest or to unpermitted facilities and illegal export of hazardous waste. In the European Union (EU), the Waste Shipment Regulation (Regulation (EC) 1013/2006 - European Parliament and Council, 2006) was issued to manage the problem of illegal waste trafficking among European and Extra-European countries (Limoli et al., 2019). In addition, to stop illegal dumping, the Directive 2008/99/EC on the protection of the environment through criminal law was issued, obliging member states to include specific penalties for waste dumpers in their national laws (European Parliament and Council, 2008).
Based on this, health and environmental problems related to illegal dumping and their management are deemed of major concern in most countries and a large number of studies addressing these issues can be found in literature (e.g. Porta et al., 2009, Ismail et al., 2019; Jahanfar et al., 2017; Krook et al., 2012; Silvestri & Omri, 2008). Besides, some guidelines to carry out the cleanup of these sites (*i.e.* the so-called "remediation activities") have been proposed, to limit risks for the population and the environment (e.g. UNEP, 2005). However, in such a context, occupational health and safety (OHS) issues concerning the operators who carry out these activities have not been considered sufficiently by either the normative or the scientific point of view.
The scarcity of information related to the hazards characterizing the dumpsites and their variety make risk management of remediation activities difficult to standardize. Moreover, in such context, the lack of specific safety legislations in most countries shows how important is research in this field. In fact, the opportunity to integrate the need to protect environment with workers' safety issues in remediation projects is left to national policies, providing no occupational health and safety (OHS) requirement at the general level.
Based on the above considerations, the goal of this paper is to give a specific contribute for safety management during uncontrolled dumpsites' remediation activities, focusing on the site's characterization stages. In fact, as reported by Gochfeld et al. (2006), the characterization activities of contaminated sites are of a particular concern due to the lack of a complete knowledge about the potential risks for the operators.
Hence, in this article the authors aim at pinpointing the main features of these activities by means of a case study. Then, based on the safety management issues provided by the ISO 45001 standard (ISO, 2018), safety planning strategies are developed, providing a general framework that can be applied for safety management of characterization activities of illegal dumpsites generated by industrial waste.
The remainder of the article is organized as follows: in the next section, there is a brief description of on-site characterization activities carried out in Donada landfill in Italy; in Section 3, the research approach is illustrated, while Section 4 shows a general safety plan for the characterization of illegal dumps. Finally, section 5 concludes the paper and addresses further work.

2. The characterization activities at the Donada landfill

As mentioned above, the input of this study is based on the analysis of the characterization activities that are carried out in practice. For this purpose, the case study of the landfill of the urban fraction of Donada (Porto Viro), which is located in the North-East of Italy, was considered. In this site an uncontrolled landfill has been generated since 1960s to dispose of manufacturing and construction industries' waste. In 2012 the Municipality of Porto Viro started characterizing this landfill, according to the requirements of Legislative Decree n.152/2006 (Republic of Italy, D.Lgs. 152/2006). The plan of works, the final report and test results are available on the website of Porto Viro Municipality in Italian (Porto Viro Municipality, 2013).

More in detail, the characterization activities were planned to detect all the landfill features (Di Fiore et al., 2017). Accordingly, workers were involved in surveys aimed to:

1. define the geometrical size of the source of contamination, in terms of lateral extent, depth of excavation and presence of contaminants leaking (plumes of contamination);
2. characterize waste (special, municipal etc.), to plan future remediation works;
3. evaluate the entity and type of pollution in the groundwater and soil surrounding the dumpsite.

To investigate the landfill site, the plan included on-site and off-site activities (e.g. laboratory tests). In particular, the on-site activities concerned:

- preliminary site visits and brushwood, brambles, weeds etc. cleaning up;
- topographic measures through total station to limit the landfill site and detect the survey points;
- a ground-penetrating radar analysis (n.15 radiograms to investigate 920 m) on the landfill body to exclude the presence of metal drums, bins, pipes in concrete or plastic materials (even very big), big pieces of construction and demolition waste etc. The depth of investigation was limited due to the increasing level of humidity under the landfill top soil;
- n.5 continuous core drilling up to 10 m deep, under the base of the landfill body, for waste sampling;
- n.4 continuous core drilling up to 10 m deep, outside the landfill body. Surveys were equipped with piezometers up to the same depth with a diameter of 4'';
- n. 6 destructive geognostic tests up to 10 meters deep, outside the landfill site, in order to install other n.6 piezometers with a diameter of 4'';
- n.23 geognostic surveys with cochlea, to investigate the continuous presence of waste in the landfill body and the accumulation heights (waste-cover soil);
- the installation of 10 meters long piezometers (n.10) around the landfill perimeter.

Analyzing the reports of these activities (Porto Viro Municipality, 2013), a general scheme of the site characterization was extracted and organized as in Table 1.

Table 1. Characterization of the Donada landfill

General characterization aims	**Donada landfill activities (on-site)**
1. Define the geometrical size of the primary source of contamination (the landfill body), in terms of lateral extent, depth of excavation and presence of contaminants leaking (plumes of contamination)	Topographic measures through total station
	a ground-penetrating radar analysis (n.15 radiograms to investigate 920 m)
	n.5 continuous core drilling up to 10 m deep for waste sampling
	n.4 continuous core drilling up to 10 m deep, outside the landfill body. Surveys were equipped with piezometers up to the same depth with a diameter of 4''
2. Characterize waste (to define their product, physical, chemical and geotechnical features)	a ground-penetrating radar analysis (n.15 radiograms to investigate 920 m)
	n.23 geognostic surveys with cochlea
	n.5 continuous core drilling up to 10 m deep for waste sampling
3. Evaluate the entity and type of pollution in the groundwater and soil surrounding the dumpsite	n. 6 destructive geognostic tests up to 10 m deep, outside the landfill site, in order to install other n.6 piezometers with a diameter of 4''
	installation of ten-meters long piezometers (n.10) around the landfill perimeter
4. Set up the working site	Preliminary site visits and brushwood, brambles, weeds etc. cleaning up

3. Research approach

The issue of the ISO 45001 standard (ISO, 2018) has updated and extended at an international level the safety management approach proposed by the BS OHSAS 18001 standard (BSI, 2007), providing an occupational safety management framework based on the well-known "Plan-Do-Check-Act" (PDCA) cycle (Darabont et al., 2017). Such an approach consists of the following main phases, which can be applied in an iterative manner:

- Plan: safety aims and strategies, making context, working tasks and risk assessment;
- Do: works in a safe way, i.e., providing workers with proper trading, safety measures and details on working operations;
- Check: working processes, the respect of legal requirements, investigating the causes of accidents, near misses and professional diseases and evaluating safety performance;
- Act: by evaluating new opportunities, revisiting policy documents and risk assessment to improve the HSM system.

Adopting such an approach to the context of illegal industrial waste management consists in implementing the PDCA cycle to the safety management of the remediation activities. In particular, focusing on the planning of the operations that are carried out during the characterization of illegal landfills, the main steps that should be followed in accordance with the "Plan" section of ISO 45001 standard concern:

1. the assessment of the context and stakeholders' expectations;
2. the definition of safety goals and the strategies to achieve them (e.g., correct working process and procedures);
3. the analysis of hazards, hazardous events and, consequently, risks related to each task that workers will perform (risk assessment).

The choice of focusing on the analysis of the characterization activities is due to the fact that these activities results in the most dangerous ones when performing remediation operations of a site because of the initial lack of information about the potential risks embedded in the site (Gochfeld et al., 2006).

4. Safety planning of the characterization of illegal industrial dumps

Based on the above considerations, starting from the characterization plan of the Donada site and other additional information on characterization available in the literature, a general safety plan based on the following activities will be implemented and discussed (Figure 1):

1. identification of the OHS issues through the context assessment;
2. organization of the on-site activities;
3. identification of possible OHS risks for each work task;
4. definition of proper safety measures to reduce these risks at an acceptable level.

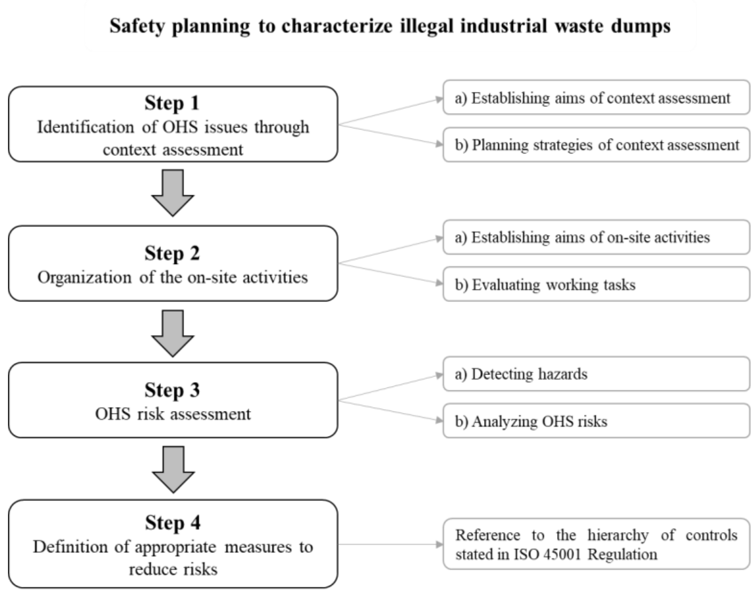

Figure 1. The proposed methodology

4.1 Context assessment

Making a good context assessment in illegal landfills means to collect information related to:

- the history of the site, i.e. the information regarding waste deliveries in the area and previous working activities;
- the geological/hydrogeological/hydrological features of the site, to understand whether extreme natural events are likely to occur (such as floods, earthquakes, landslides etc.);
- the presence of restrictions of legal nature due to territorial planning regulations;
- the occurrence of previous contaminations in the site.

In the characterization plan of Donada landfill, context assessment was mainly conducted by looking for previous studies on the site, collecting data from territorial planning databases and talking with public officers.

On the one hand, previous studies allow reconstructing solid waste deliveries and previous contamination events, which could impact on future works in the site. On the other hand, laws, municipal acts, urban plans etc., give a contribute to identify possible past uses of the area, as they define legal constraints. Both previous studies and territorial and legal planning tools are eligible sources to make a context assessment, as they are verified.

Additionally, interviews with the site's owner and/or manager, the site's occupants, government officials, people working/living in the neighborhood etc. is another useful strategy to collect information on the context (EPA, 2002), as well as to evaluate all stakeholders' expectations regarding safety issues (Uzun et al., 2018). For this purpose, the use of an ad hoc questionnaire is foreseen (i.e., "Are there any vulnerable receivers next to the site?"; "Has the site been used for different purposes?" etc.) to gather information in a systematic and effective manner.

Besides, remote sensing data can also be used to detect illegal dumps and to identify their approximate features. For example, remote sensing photos can be used either directly, i.e. through the analysis of spectral signatures of different items, or indirectly, through the assessment of temporal changes in spectral signatures of the same place (Glanville & Chang, 2015). Dumps are detected by studying the phenomena connected to environmental contamination, caused by solid waste presence, such as vegetation stress or unusually high soil temperatures due to organic fermentation with biogas production. Consequently, remote sensing data should be assessed using a methodology different from case to case, depending on the specific type of materials stocked in landfill (Silvestri & Omri, 2008).

4.2 On-site characterization activities

According to the ISO 45001 standard, planning safety policy requires a complete description of tasks and activities: accordingly, starting from the analysis of the Donada landfill plan, the following outputs emerged.

The preliminary site visit can be considered a visual activity: experts have to evaluate the site features, such as odours, wells, pits, ponds and lagoons, drums and storage containers, distressed vegetation, stained soil or pavement, waste storage areas and tank piping (EPA, 2002). In case of old landfills, the site visit should be also aimed to evaluate the condition of landfill plants. The preliminary site visit is considered essential to understand the use and condition of the property where the dump is located, and to identify areas in which a deeper investigation is required as well as to define possible contamination targets.

The brushwood, brambles, weeds etc. cleaning up is a mechanical activity which is aimed to prepare the working site for further activities. Generally, it requires cutting down vegetation through a chainsaw and, whether necessary, a ladder. Cleaning up can be followed by ground leveling.

Both preliminary site visits and brushwood, brambles, weeds etc. cleaning up can be related to the category of activities to set up the working site. In addition to them, workers can be involved in:

- delimiting the site through the installation of a safety fence, signs and a video-surveillance system, to avoid the entrance of unauthorized people in the area;
- organizing logistic services, such as toilets, dressing rooms, lunch areas, and temporary facilities (e.g., road structures, waste and materials storage areas, cleaning areas for tools and means of transport);
- ensuring electricity and water supplies.

Then, workers perform the characterization's activities, which can be divided in two main categories:

- Direct analyses, which employ machines to collect soil, waste and groundwaters samples to make further analysis in laboratory;

- Indirect analyses, which allow achieving data through electric or magnetic devices without a direct contact between the operator and waste or hazardous on-site substances. Among indirect investigations, interesting results for the detection of illegal dumps and waste characterization can be obtained by means of:
  - electric methods (Cardarelli & Di Filippo, 2004), based on the evaluation and comparison of materials' electric features (resistivity, induced polarization);
  - magnetic methods, which allow distinguishing solid waste and soil according to their magnetic attitude (Marchetti et al., 2002);
  - thermic methods, which are particularly useful to detect solid urban waste dumps, as they evaluate superficial temperature changes (Belghazal et al., 2013);
  - ground-penetrating radar investigations, based on the analysis of the propagation of radar waves inside solid waste and soil (Di Fiore et al., 2017; Orlando & Marchesi, 2001).

Topographic measurements cannot be included in this classification, as they are aimed to locate the investigation's points and to define the landfill's geometry, after the execution of the surveys mentioned above. Generally, they require using a total station and some benchmarks.

4.3 On-site hazards identification

The Job Hazard Assessment (JHA) method (OSHA, 2002) allows identifying possible hazards related to each activity: the application of this tool was made taking into account the literature on illegal dumping with the goal of identifying potential hazards for workers.

In particular, during the characterization activities, great attention has to be paid to the fluxes of contaminants released by illegal dumps in the surrounding environment, in terms of both gas, leachate and dust (Limoli et al., 2019). As stressed by Vaverková (Vaverková, 2019), in Municipal Solid Waste (MSW) landfills there are about 150–250 kg of organic carbon per ton of waste, which are transformed by microorganisms in biogas containing 40–60% of methane. The uncontrolled presence of biogas could cause states of illness and generate explosive climates, with severe consequences for workers. In industrial waste dumps toxic gases could be generated by waste burning too, which is unexpectedly common in landfills: for example, in U.S.A. 840 fire events were recorded in the period 2004–2010. Landfill fires can occur as surface and sub-surface fire (Chavan et al., 2019). In the first case, they can be easily detected; but if they are not controlled, they will become intensive and hazardous. Conversely, sub-surface fires involve old waste materials under the surface and can break the biogas collection system and leachate liner.

In addition, the anaerobic degradation of organic material and the rain's infiltration can increase leachate production. In case of direct (dermic contact and accidentally ingestion) and indirect (vapour and gases inhalation) exposure to leachate, workers can be subjected to occupational injuries and diseases.

Moreover, solid waste itself can be considered a hazard. On one hand, it could cause cuts and injuries due to the presence of sharps; on the other hand, it could lead to fatalities due to its poor geotechnical stability. As reported by Ismail at al. (Ismail et al., 2019), inappropriate compaction rate of waste and its anaerobic degradation inside landfill cause high deformations due to low levels of cohesion and friction angle of solid waste, which impact on its shear strength. When there are not proper facilities to avoid collapse states, waste landslides can occur. Hence, they configure safety risks for workers, such as waste falling from a height, cuts, sinking areas etc.

In addition, the presence of bacteria, rats, snakes and harmful birds (e.g., seagulls) inside waste could cause professional diseases and injuries, if workers are not provided with safety clothing. Finally, according to the specific activity, additional hazardous elements, that are typical of construction sites, have to be taken into account: e.g., the use of machinery and hazardous substances required for the field tests, as well as the presence of falling materials, electric plants, etc.

In table 2 OHS risks related to the characterization of illegal dumps are reported, where:

- The column "General characterization aims" identifies the main on-site activities;
- The second column includes the investigation methods used to carry out each activity;
- The third column refers to the main hazards the workers can be subjected to during their job. It has to be noted that human factors and hazards related to the presence of different contractors on site were not included, as they should be identified and assessed by the safety manager case by case;
- The last column lists the main OHS risks for workers involved in each activity.

Additionally, it has to be noted that in some industrial waste dumps safety management could be influenced by waste radioactivity and asbestos, whose intensity depends on waste composition. In the following tables, such hazards are not included as they require additional and specific safety procedures that are not object of the present study.

Table 2. Safety planning during the characterization of illegal landfills.

General characterization activities	**Characterization on-site activities for landfills**	**Main hazards for workers**	**Main OHS risks**
1. Define the geometrical size of the primary source of contamination (the landfill body), in terms of lateral extent, depth of excavation and presence of contaminants leaking (plumes of contamination)	Topographic measures through total station and benchmarks	solid waste, cutting objects, toxic gases, bacteria and pathogens	biologic risk, fire risk, chemical risk
	Electric investigation	solid waste, cutting objects, toxic gases, electricity, bacteria and pathogens	biologic risk, fire risk, chemical risk, electric shock
	Magnetic investigation	toxic gases, electricity	fire risk, chemical risk, electric shock
	Thermic investigation	toxic gases	fire risk, chemical risk
	continuous core drilling up for soil sampling (around the landfill body)	solid waste, cutting objects, toxic gases, geotechnical instability, leachate, extremely flammable waste, machinery, bacteria and pathogens, human factors	biologic risk, chemical risk, slipping and tripping, fire risk, risk of falling from the height, risk of falling materials, risks related to machinery
	Installation of piezometers for groundwater sampling (around the landfill body)	solid waste, cutting objects, toxic gases, geotechnical instability, leachate, extremely flammable waste, machinery, bacteria and pathogens, human factors	biologic risk, chemical risk, slipping and tripping, fire risk, risk of falling from the height, risk of falling materials, risks related to machinery
2. Characterize waste (to define their product, physical, chemical and geotechnical features)	*Georadar survey*	toxic gases	Chemical risk, fire risk
	Electric investigation	solid waste, uncontrolled gas, machinery	fire risk, machinery-related risks, biologic risk, chemical risk
	Magnetic investigation	uncontrolled gas, machinery	fire risk, machinery-related risks, chemical risk
	Thermic investigation	uncontrolled gas, machinery	fire risk, machinery-related risks, chemical risk
	Core drilling up for waste sampling	solid waste, uncontrolled gas, uncontrolled leachate, machinery, bacteria and pathogens	slipping and tripping, fire risk, biologic risk, chemical risk, risk of falling from the height, machinery-related risks

	geognostic surveys with cochlea	Solid waste, bacteria and pathogens, uncontrolled gas, uncontrolled leachate, machinery	biologic risk, risk of falling materials, fire risk, chemical risk, biologic risk, machinery-related risks
3. Evaluate the entity and type of pollution in the groundwater and soil surrounding the dumpsite	continuous core drilling up for soil sampling	Solid waste, cutting objects, geotechnical instability, extremely flammable waste, toxic gases, bacteria and pathogens, machinery, human factors	biologic risk, chemical risk, slipping and tripping, fire risk, risk of falling materials, risk of falling from the height, machinery-related risks, human factors related risks
	installing piezometers around the landfill body	Solid waste, cutting objects, geotechnical instability, extremely flammable waste, toxic gases, bacteria and pathogens, machinery, human factors	biologic risk, chemical risk, slipping and tripping, fire risk, risk of falling materials, risk of falling from the height, machinery-related risks, human factors related risks
4. To set up the working site	Preliminary site visits	Solid waste, cutting objects, toxic gases, leachate, bacteria and pathogens	risk of falling materials, slipping and tripping, fire risk, biologic risk, chemical risk
	delimiting the site through the installation of a safety fence, signs and video-surveillance system	Solid waste, cutting objects, toxic gases, leachate, bacteria and pathogens	biologic risk, risk of falling materials, slipping and tripping, fire risk, chemical risk
	brushwood, brambles, weeds etc. cleaning up	Solid waste, cutting objects, toxic gases, leachate, bacteria and pathogens, machinery, human factors	risk of falling materials, biologic risk, slipping and tripping, fire risk, machinery-related risks, chemical risk
	organizing logistic services, such as toilets, dressing rooms, lunch areas, and temporary facilities to do works (road structures, waste and materials storage areas, cleaning areas for tools and means of transport)	Solid waste, cutting objects, toxic gases, leachate, bacteria and pathogens, machinery, human factors	biologic risk, chemical risk, risk of falling materials, slipping and tripping, fire risk, machinery-related risks
	installing the site's plants ensuring electricity and water supplies	Solid waste, cutting objects, toxic gases, leachate, bacteria and pathogens, machinery, human factors	risk of falling materials, biologic risk, chemical risk, slipping and tripping, fire risk, machinery-related risks

4.4 Measures to reduce OHS risks

According to the hierarchy of controls reported in the ISO 45001 standard, the reduction of OHS risks can be addressed through the following measures:

- Elimination of the hazards;
- Substitution of hazardous processes, operations, materials or equipment with less hazardous ones;
- Use of engineering and organizational controls;
- Use of administrative controls;
- Provision of personal protective equipment (PPE).

With reference to the characterization of illegal industrial dumps, safety managers should consider that some hazards, especially those ones related to the environment (such as chemicals, bacteria and pathogens, cutting objects, etc.), cannot be eliminated or substituted. Hence, reducing OHS risks to acceptable levels necessarily requires implementing technical, organizational and administrative controls and, in most cases, to provide workers with appropriate PPE.

The following measures can be useful to mitigate OHS risks included in table 2:

- Detailing much more the sequence of operations and the working tasks for every activity identified in this paper, to make a precise risk assessment and evaluate preventive and protective measures according to the specific case;
- Making geophysical surveys before direct investigations, to prevent workers from direct contact with waste and its dangerous emissions and to plan positions of geotechnical drills avoiding buried hazardous materials or service networks;
- Providing workers with portable instruments to detect explosive atmospheres, due to high concentrations of CH_4 and other extremely flammable gases, to identify areas in anaerobic conditions and to evaluate their radiologic exposure. Instruments should be able to warn workers with acoustic signals in case of risk;
- Organizing working areas and activities to avoid/limit interferential risks;
- Before its use, checking machinery safety levels and evaluating the opportunity to use advanced and safer machines to make characterization activities;
- Providing all workers with adequate training. Every initiative of training should be planned considering internal factors of companies, such as the worker’s role, his/her level of education, nationality, gender etc. In fact, training is essential to ensure competence of workers during their activities;
- Giving suppliers and contractors checklists and questionnaires on OHS issues, to check their compliance with safety rules and legal requirements;
- Providing workers with appropriate PPE, according to the task performed, the context’s features and residual risks;
- Planning a response to emergency situations, which all workers should accept before entering the working site. That means to foresee predictable emergency scenarios, communicate to all workers their duties and responsibilities during emergencies, establish exit pathways and procedures, provide workers with training to manage different emergencies and set up a first aid point.

5. Concluding remarks

The study aimed at providing a health and safety management framework that can be used for the characterization activities of areas contaminated by illegal dumps or unauthorized landfills. In fact, although in the scientific literature there is evidence of hazards in these sites for both public health and environment due to the uncontrolled presence of waste, a scarce attention has been paid to OHS measures for workers involved in these activities, who are exposed to occupational risks because of the direct/indirect contact with the pollutants released by waste degradation and geotechnical instability of solid waste.

As many research institutions and governments have promoted remediation programs of illegal waste dumps, dealing with OHS issues seems a matter of urgency to prevent workers from injuries and professional diseases. Following this objective, the Plan section of a HSM system was developed, by combining the analysis of the characterization plan of Donada landfill (in Italy) with the ISO 45001:2018 approach. In particular, a general safety plan for the characterization of illegal industrial dumps was developed, considering the following main stages:

1. identification of the OHS issues through to the context assessment;
2. organization of the on-site activities;
3. identification of possible OHS risks for each work task;
4. definition of proper safety measures to reduce these risks at an acceptable level.

This output can be considered a step forward to sustainable management of safety in such contaminated sites, as required by Agenda ONU 2030 through the 8th Sustainable Development Goal. However, this study has to be considered an initial step of a more comprehensive approach to deal with OHS issues in industrial contaminated sites. Hence, further research is needed to complete it considering the other phases of the PDCA approach. Additionally, another improvement opportunity relies on the application of resilience engineering principles, which aim to build a strong response of the system to disruptions, instead to focus on identifying and alleviating risk factors (Li et al., 2019).

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