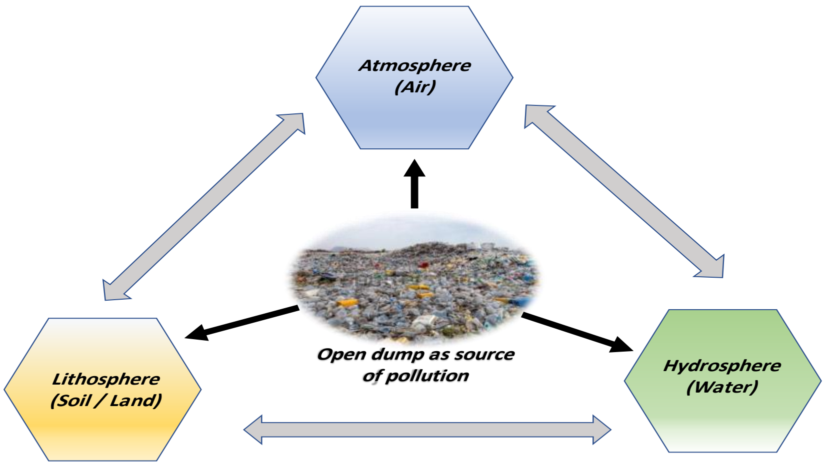
CHAPTER

8

RISK-ASSESSMENT AND SAFETY MEASURES

8.1. Introduction

Rapid population development and urbanization have resulted in massive amounts of municipal solid waste (MSW) being generated, as well as environmental deterioration. From one side integrated waste management requires the safe and sustainable disposal of municipal solid wastes. On the other hand, open dumping of MSW, which occurs in around three-quarters of the world's countries and territories, is a primitive form of waste disposal. Because they are vulnerable to open burning, groundwater pollution, and scavengers and disease vectors, open dumps or dumpsites harm the environment (Figure 8.1).



A

B

Figure 8.1. The most important environmental locations and pathways for (open dump) threats to go through (A), as well as the inputs and outputs of an open dump degradation process (B).

Several key issues can be identified related to the open dumpsites such as lack of cover and leachate collection and treatment, insufficient compaction, poor site design, etc. (Butt et al., 2008). Growing public health, environmental quality, and risk concerns about existing open dumps demand an integrated approach to their long-term management (Sexton & Hattis, 2007). Assessing the dumpsites' relative health and environmental risks could aid in the prioritization, planning, and implementation of dumpsite rehabilitation. Identifying the risk variables that are of concern will allow a community to focus its efforts on reducing the landfill's danger potential as well as its expense (Figure 8.2).

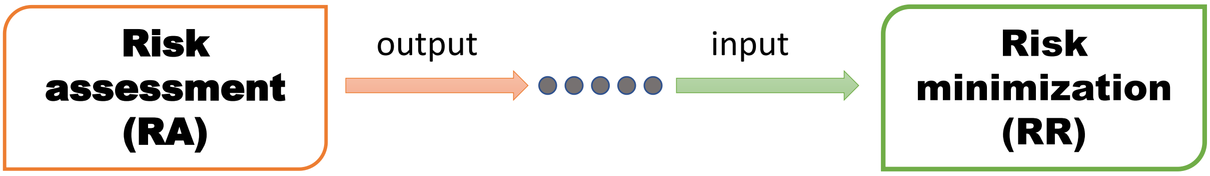


Figure 8.2. Relationship between risk assessment and minimization.

8.2. Risk Assessment Methodology

Risk assessment evaluates the possibility of an event occurring as well as the implications of that event taking place. It is a method for defining and assessing the type, impact, and level of exposure that a susceptible receptor can be exposed to in connection to a certain hazard. An environmental threat is an occurrence or ongoing process that, if realized, will result in situations that have the potential to deteriorate the environment's quality, either directly or indirectly.

8.2.1. Building up a Conceptual Model

Any assessment of the cumulative effects of various stressors, such as those posed by open dumpsites, requires the creation of a conceptual model. For an accurate ecological evaluation, it usually gives a visual depiction of the stressors, as well as their immediate and unintended consequences (Menzie et al., 2007). Due to the complexity of multi-stressor evaluations, balancing information and clarity within the conceptual model is a major problem (s). Using multiple models is one method for achieving this balance. Another option is to employ interactive in silico simulations that can be expanded and employed to provide outlines of the problem as well as specific detailed information related to the specific analysis performed.

A pathway is a direction taken by a particle of water, a drug, or a pollutant as it moves through the environment, coming into touch with, or otherwise affecting, a receptor. There must be a source of hazard, a conduit, and a receptor for a risk existing. The Source-Pathway-Receptor (S-P-R) concept for environmental management is based on this assumption.

Furthermore, a conceptual model is useful for scoping any research since it can identify the places/actions with the highest risk to the environment, as well as the S-P-R links that relate to the greatest risk.

The risk assessment approach allows for a clear decision-making process. When a strategy to mitigate any potential hazards is developed, it is obligatory identified in the conceptual model. The detailed information gathered throughout the investigation will help determine the scope of the risk management actions that will be required, which may include blocking the pathway, removing the source, or monitoring the receptor in some circumstances (Mohd & Che, 2019).

8.2.2. Identifying Shared Receptors and End Points

Identifying the shared receptors and end goals are usually used for grouping and analyzing the combined impacts of different stressors, as well as determining how stressors and effects interact. The term "assessment endpoint" refers to the result of combining the receptor and effect endpoints. Individuals, communities, and populations are the most prevalent human and ecological receptors. An evaluation of numerous stressors in human health risk assessments may often involve a specific labor population or a specific neighborhood. Receptors for ecological or environmental assessments could comprise habitats, specific ecological systems, or larger regions. Ecological processes like carbon sequestration by oceans or forests, or nitrogen cycling, are examples of receptors (Solomon et al., 2016).

The condition being assessed is referred to as an end goal. This could be stated as a frequency, rate, or condition of receptor characteristics. Mortality, the prevalence of a disease such as cancer or asthma, reproductive or developmental consequences, changes in populations, and habitats are just a few examples. One or more assessment endpoints may be used in a combined effects evaluation.

The assessment endpoints must be chosen and communicated in a way that is sufficiently specific for the concerns being assessed while also allowing for the aggregation of many stressors' combined impacts (Menzie et al., 2007). The requirement for these will become more apparent as assessment endpoints grow more defined. Having numerous distinct assessment endpoints (together with corresponding evaluations of combined effects) is preferable in respect to performing only one comprehensive assessment.

8.2.3. The Phased Approach

In risk assessments, phased approaches, sometimes known as "tiered" or "iterative" evaluations, are widely employed (Code of practice; EPA 2007). They balance resources against the aim thus reducing the uncertainty in the risk evaluations. Assessing the combined effects of numerous stressors can be difficult. This is specifically true when supplementary stressors are integrated into the evaluation and a comprehensive range of effects and interactions is desired. The issue is examined from the standpoint of the added value of data for decision-making. As a result, a strategy is proposed that begins as simply as feasible while remaining as detailed as is acceptable for the situation. Only as much in-depth, more sophisticated analysis is required to differentiate risks at a level adequate for management decision-making.

Recognizing the fundamental aspects that should be included in the evaluation from the start is an important aspect of a phased approach. This offers a broad conceptual approach, as well as a preliminary effort to rank the relative importance of distinct stresses. The conceptual model can be used to highlight the corresponding significance of stressor and pathway patterns, as well as track numerous exposure pathways and interrelationships. It is feasible to represent the extent of the problem while also focusing on its key characteristics.

The following are the components of a phased approach:

- ✓ Develop a conceptual model that incorporates all important stressors and explain how they could interact (Figure 8.3).
- ✓ Screen stressors to get at reasonable and manageable information to resolve the problem. Other stressors and pathways can be embodied in the conceptual model, but efforts are focused on studying the stressor and pathway patterns that are thought to have the biggest impact.
- ✓ Examine the specific effects of each stressor to see if any of them mostly or potentially contribute to the effect(s) of interest.
- ✓ Identify the overlapping of effects and potential stressors, for example, study their features or temporal and spatial linkages. Furthermore, the cumulative impacts of stressors are also evaluated (e.g., synergism or antagonism).
- ✓ Depending on the information available, evaluate the cumulative effects of stressors.

- ✓ It is critical to reconsider all key steps at the intermediate stages of the assessment. This ensures that main stressors, impacting factors, and affected endpoints are all taken into account. So, the joint effects and principal risks can be well characterized to the extent that existing knowledge allows. This approach can be successfully used in both effects- and stressor-based evaluations.

The impact(s) of concern are the starting point for effects-based assessments. Increased cancer rates or other health concerns in a community, or changes in the biota of a river or a forest, are examples of these effects. One or more stressors may be present, and the following forms of information are useful for management decisions:

- ✓ The stresses that are contributing to the reported impacts must be identified.
- ✓ Information about how the stresses, either separately or in combination, are creating the effect.
- ✓ Perception how to mitigate the effect by reducing or preventing the stressor from producing it.
- ✓ Detailed information on the short- and long-term consequences of various management options.

8.3. Risk Assessment of Open Dump Sites

The risk assessment approach used to assess the possible threats posed by open dumpsites should be a systematic, clear, and practical procedure that aids decision-making. For this risk assessment, a phased approach is a particularly effective methodology (Figure 8.3) (Code of practice; EPA 2007). It guarantees that the largest amount of effort and resources are directed toward the most susceptible receptors, or where there is high uncertainty paired with the possibility of considerable environmental damage.

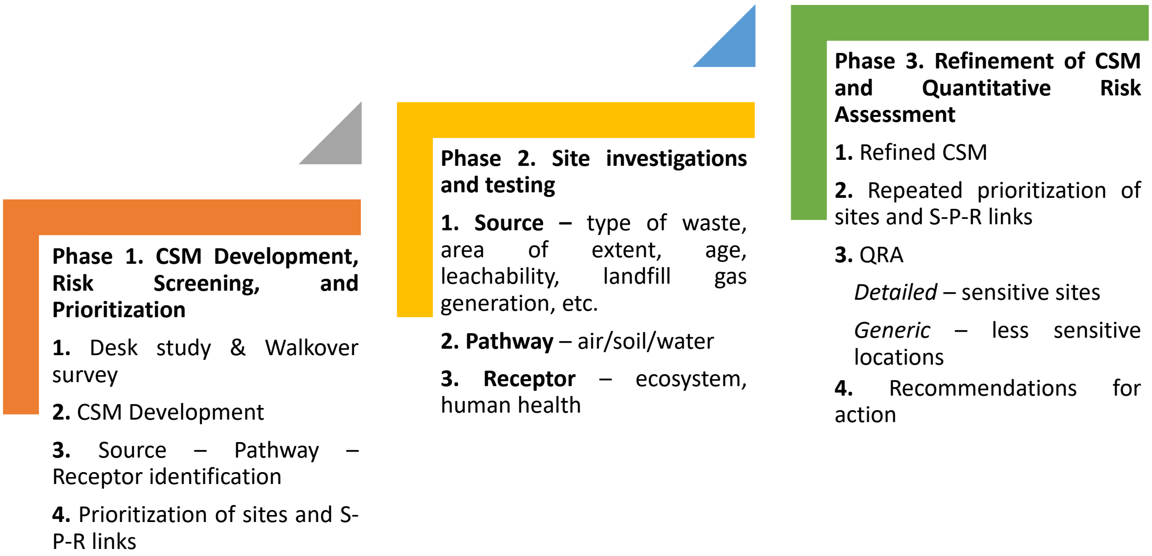


Figure 8.3. Methodology for assessing the risks of open dumpsites: a Phased Approach (adapted by Code of practice; EPA 2007).

8.3.1. Phase 1: Conceptual Site Model Development, Risk Screening, and Prioritization

An initial study of the site, as well as the elaboration of a Conceptual Site Model (CSM) employing data acquired from the desk study and site inspection, and the preliminary risk assessment, are all part of the first step in the process of risk assessment of an open dumpsite (Tier 1). The CSM describes the various Source-Pathway-Receptor (S-P-R) relationships and hence offers data for the risk-screening component. A rating method is used to prioritize sites based on their danger.

8.3.1.1. Conceptual Site Model (CSM)

A conceptual model is a way of predicting how a system employed in a waste-related activity would behave. Straightforwardly, this implies that a picture is built up gradually, based on systematic research, using a conceptual model of the association between the presence of a potential hazard and the link to the likely receptors. The primary goal of these actions is to determine the real situation and to be used in the detection of all probable sources (S), pathways (P), and receptors (R). Furthermore, the processes and uncertainties that are expected to occur along each of the source-pathway-receptor (S-P-R) links are also identified.

The ideas used in CSM development are well-matched with the recommended approach to risk assessment methodology, as shown in Figure 8.4. The three main stages of CSM development are:

1. Desk study and site inspection
2. Site Investigation

3. Environmental monitoring to validate the CSM.

The development of a CSM should be a part of Tier 1 of the Risk Assessment Methodology, and a CSM should be produced for all sites, regardless of their size and scope. Tier 2 investigations should be planned and designed with the help of the CSM. It should also serve as a useful tool for effectively expressing the risk's nature and comprehending the monitoring outcomes. Finally, it aids in the policymaking procedures when it comes to remediation choices. The level of detail necessary is determined by the site's S-P-R.

All uncertainties and concepts made during the preparation of the CSM should be acknowledged and considered when planning the site investigation program and evaluating potential remediation strategies.

Desk study

The goal of the desk research is to gather all essential data helping in characterizing the site, as well as to develop an initial CSM and its hydrogeological context.

When determining the scope of a desk study, keep in mind that developing a conceptual model involves a working hypothesis of what is the type, quantity, and the condition of the source; what are the mechanisms for its transportation, and what are the possible migration pathways; what are the receptors.

Figure 8.4 depicts the link between these elements, and these issues are discussed in greater depth further down.

Figure 8.4. Source – Pathway- Receptor Conceptual Model (adapted by Code of practice, EPA 2007).

Source/Hazard

Leachate and landfill gas may be considered the primary sources of contamination/hazard in the event of unregulated waste disposal. The waste type must either be known or assumptions made about its categorization must be made in order to determine the possibility for leachate production. The potential toxicity of the leachate, and hence the degree of harm it can cause to surface water and groundwater, is determined by the type of waste.

Furthermore, a study of the potential for landfill gas generation should be conducted. If landfill gas is present, it becomes a source, and its potential for fugitive gas emissions migration must be evaluated.

Dust isn't considered a major source because most historical waste disposal locations have a vegetative cover that reduces dust production. Dust can be formed if waste is exposed to the surface, so this should be considered.

Pathways

A pathway is a process or channel through which a contaminant interacts with or affects a receptor. If a danger represents a risk to a receptor, it must have a pathway. The possibility of contacting or transporting to a receptor is determined by that pathway. In all circumstances, it should be presumed that historical landfill sites are unlined with no synthetic containment barrier in place.

Leachate Migration Pathways

There are three possible routes for leachate migration: vertically to the water table or top of an aquifer, where groundwater is the receptor; vertically to an aquifer and then horizontally in the aquifer to a receptor, such as a well, spring, or stream; and horizontally at the ground surface or shallow depth to a surface receptor.

The permeability and thickness of the subsoil, as well as the permeability value and type of the bedrock, all influence the movement and attenuation of leachate from a landfill. The following elements are included in these factors:

- ✓ Groundwater Vulnerability
- ✓ Groundwater Flow Regime
- ✓ Surface Water Drainage

The capacity of contaminants to move vertically to an aquifer is measured by groundwater vulnerability, which is a function of subsoil permeability (which is mainly based on subsoil type) and thickness.

The length of the aquifer's groundwater flow routes (or horizontal flow component), the attenuation of contaminants in the aquifer, and the possibility of interaction with surface water are all measured by the groundwater flow regime.

The assessment of the direct relationship between surface water drainage associated with the waste body and adjacent receptors is known as surface water drainage. It indicates the chance of rain or contaminants flowing horizontally at or near the ground surface to a receptor, such as a stream, via overland flow or leakage.

Receptors

A receptor is a human, a living entity (such as livestock, crops, pets, or animals), an ecological system, regulated waters, the atmosphere, structures, or utilities that may be harmed by the source. The potential for receptor exposure to the hazard, whether leachate or landfill gas, is determined by the pathway and distance between the hazard/source and the receptor, or the value of the resource in the case of an aquifer.

Leachate Migration Receptors

Human presence, which is a sign of the possibility for specific water sources and a risk to human health, is regarded as a sensitive receptor in terms of leachate migration. Protected Areas (including wetlands/ecosystems), which are other potential sensitive receptors, also have an impact on the risk score due to their vicinity to the facility. Groundwater is a significant receptor for leachate and is a possible target in the event of leachate migration. Public water supplies are regarded as an important receptor because they are an indicator of the risk to public health. The risk score is affected by the proximity of open dumps to a water source, as well as their placement relative to groundwater and/or surface water flow direction. Rivers, lakes, estuaries, and coastal water bodies are examples of surface water bodies, and their proximity to receptors is a key aspect.

Landfill Gas Migration Receptors

Due to the potential for the build-up of gas within confined areas such as schools, houses, and other similar establishments, human presence is considered to be the primary sensitive receptor about landfill gas (and other related nuisance factors such as dust and odors). In general, the risk of flammability and explosion from landfill gas exposure outside is negligible. All potential receptors' minimum distances should be determined and marked on a map.

Where accessible and suitable, the following data (Table 8.1) should be presented in the Conceptual Site Model:

Table 8.1. Key data for the SCM development

Element	Description	Information Required
Source	Composition of waste and its amount	✓ Amount of waste ✓ General description of the topography ✓ Actual waste kind and site area (delineated in plan and cross-section) ✓ Period of open dump exploitation ✓ Evidence (or possibility) of leachate or landfill gas generation (after site inspection (including walkover) with an infrared detector (IR) ✓ The age of the waste, as well as the history of the site
Pathway Leachate	Groundwater migration	✓ Flow direction ✓ Groundwater Vulnerability Rating ✓ Groundwater Flow Regime ✓ Surface water drainage
	Landfill gas migration	✓ Type of subsoil and bedrock ✓ The possible presence of underground services
Receptors	Leachate migration	✓ Groundwater sources ✓ Drinking water supplies within 1000 m (both surface water and drinking water) ✓ Location of houses, schools, industrial development, including land use within 1000 m ✓ Protected Areas: Any groundwater or surface water-dependent ecosystems within 1000 meters of the site perimeter ✓ Wetlands ✓ Any surface water bodies within 1000 meters of the site's perimeter
	Landfill gas migration	✓ The position of dwellings, schools, industrial developments, temporary housing within 250 meters of the site perimeter ✓ Details and locations of underground services

Data sources

Each local government is in charge of identifying waste disposal and recovery facilities in its jurisdiction (Waste Management Act of the Republic of Bulgaria - SG No. 26/30.03.2012;

Environmental Law No.2872 in Turkey; Act on Waste from 14 December 2012 in Poland; Legislative Decree 36/2003 in Italy; and Emergency Government Ordinance no.78/2000 in Romania), and steps should be taken to ensure that the data compiled is as accurate as possible. At the very least, the area and thickness of the waste body should be drawn on a GIS, as well as the age and type of waste should be identified.

Site Inspection (including Walk Over Survey)

As part of the Tier 1 Risk Assessment Methodology, a site inspection (including a walkover survey) should be done by a sufficiently qualified/trained person and should allow the information gathered during the desk study to be documented.

In circumstances where the information utilized in the risk assessment has a low level of confidence, a walkover survey is required to verify basic facts before applying the risk screening approach. In any case, if a facility is to be eliminated from further consideration, a walkover study is required. If significant concerns are discovered during the walkover, the site should be considered a potentially high-risk site, and proper site investigations should be conducted.

The site inspection (which will include a walk-over survey) will aim to explore each of the potential S-P-R linkages and collect further information in the form of photographs, sketching, mapping, and other methods. It will assist in the planning of any intrusive inquiries. During the Tier 1 stage, all sites must have a walkover survey conducted by a suitably trained/qualified individual.

During the walkover survey, delineation of the waste body, evaluation of waste type, assessment of leachate, and/or landfill gas generation (e.g. using a landfill gas analyzer) should be done. It should also be used to determine the efficacy of any capping materials and to locate any surface water swales. Vegetation discoloration, landfill gas odors, and leachate leakage should all be documented, and photographic evidence should always be collected. At this stage, a searcher bar, and a landfill gas analyzer (infrared, methane, and CO2) may help determine whether landfill gas is being generated on-site. Changes in slope and vegetation cover can be powerful indicators of the quantity of the waste or at least put material at older sites, which may be difficult to collect reliable information due to the fact that they may be covered in grass and not clearly recognizable.

If there is proof of pollution at this point, action should be taken, and landowners, residents, well owners, and other stakeholders should be informed of any known hazards or impacts.

The position of all potential receptors should be clearly highlighted on a map, with special emphasis paid to any significant wetland within 1 km of the site.

Presentation of Information

The information needed to create a conceptual site model can be delivered in a variety of ways. The most frequent format is graphical, which comprises cross sections indicating S-P-R and a Site Plan (Figure 8.5), with the level of information varies depending on the site's complexity. It's critical that CSM data be well-documented and easily accessible in the form of text, figures, and tables.

Figure 8.5. Site Plan showing source and receptors (adapted by Code of practice, EPA 2007)

8.3.1.2. Risk Screening

The source-pathway-receptor (S-P-R) links in the conceptual model are assessed during risk screening. It evaluates whether the place poses a risk to receptors or could pose a risk. It also develops a conceptual site model to identify prospective Source-Pathway-Receptor (S-P-R) connections. It gives the site a preliminary or qualitative risk evaluation. It involves a determination of the likelihood and size of any linking effects. The screening procedure also divides the site into many trash types, such as the ones listed below:

- ✓ Historical construction and demolition waste landfill
- ✓ Historical local operated municipal landfill
- ✓ Historical Privately operated municipal landfill
- ✓ Hazardous Waste landfill
- ✓ Illegal Waste Facility (disposal)

A separate risk assessment for leachate migration and landfill gas migration is required. The overall risk is calculated based on both risk assessments.

8.3.1.3. Risk Prioritization

The initial screening procedure allows sites to be categorized as high, moderate, or low risk, allowing resources to be dedicated to the investigation of the higher risk sites while also focusing on the examination of the associated S-P-R linkages at each site (Table 8.2). Each linkage receives a score as part of the risk prioritization process, and the overall site score is the sum of the individual linkages for the site in question. This enables the identification of the possibly most dangerous sites and their substantial interconnections. Some S-P-R links are likely to be more essential than others, resulting in the identification of the most sensitive receptors at each site.

Because the scoring system assigns greater values to higher-risk sites, it is possible to make meaningful comparisons between different locations and specific links. Each of the S-P-R links will be assigned a score that can be used to determine which receptor is most vulnerable. The sites can also be listed in order of importance to help with resource and attention allocation. The bigger the risk, the higher the score a site/link obtains. When there is a considerable degree of doubt (or when information is unknown) about a particular element of risk, the highest score should be presumed until data from the site investigations can be collected that more firmly characterizes the risk classification.

Risk is defined as the chance of an event occurring as well as the consequences of that event. This provides a simple method for calculating the level of risk in a given situation.

$$\text{Risk} = \text{consequences} \times \text{likelihood}$$

Table 8.2. Risk Classification (Code of practice, EPA 2007).

Risk classification	Range of risk scores
Highest Risk (Class A)	Greater than or equal to 70% for any individual SPR linkage
Moderate Risk (Class B)	Between 40-70% for any individual SPR linkage
Lowest Risk (Class C)	Less than or equal to 40% for any individual SPR linkage

8.4.1. Phase 2: Site Investigations and Testing

Tier 1 will help to define the scope of Tier 2: Site Investigation and Testing. The focus of the site investigations should be on gathering enough data to identify whether a link exists, as well as the magnitude of the link and the danger posed by the hazard (waste type).

When studying a hazard/source (waste body), for example, it may be acceptable to use investigative techniques such as trial pitting, geophysics, probing, or boreholes in a staged approach. The level of ambiguity at each location, as well as the expense of the investigations, should be weighed against the perceived risk. The site assessments must identify whether the waste body has the capacity to generate landfill gas and leachate, both of which may include hazardous compounds, as well as the depth to which they could reach the water.

A communication plan should be developed to notify all relevant parties (including adjacent landowners) about the site research activities. Any findings of the site investigation work that may suggest a major risk to any person or property must be informed to those involved, and advice on relevant actions must be offered.

The highest-risk sites (Class A sites) should have a comprehensive site investigation program that will deliver information to confirm (or refute) their risk classification as well as inform the quantitative risk assessment that will be conducted as part of Tier 3 and subsequent remediation recommendations. In the case of the lowest-risk sites (Class C), investigations should be organized so that enough information is available to verify the site classification and make recommendations for the next steps (should they be required).

If unexpected discoveries are discovered that have the potential to have significant ramifications for the objectives, it is critical to regularly analyze the information presented at each stage of the SI and adjust the design of the investigation program.

The overall goal of the site investigations (SI) is to offer information that will allow an assessment of the presence of major pollutant links on-site, which may necessitate the implementation of remediation measures.

The following broad questions should be considered while developing the objectives for the site investigation (SI):

- ✓ What types of inquiries does the SI need to be able to answer?
- ✓ What information is required, and to what level of accuracy and detail?
- ✓ What is the SI's aim in relation to the risk assessment technique in question?

Various types of information should be collected depending on the site's risk status/classification. (Table 8.3).

Table 8.3. Information required for open dumps risk assessment performance.

	Class A sites (higher risk)	Class B sites (moderate risk)	Class C sites (lower risk)
What types of inquiries does the SI need to be able to answer?	• Are the data utilized in the conceptual model and risk assessment exercise correctly and valid? • Is it necessary to enlist the help of a professional, such as an ecologist? • Do you have any biodegradable or hazardous waste? • Is there a risk of landfill gas migration? • Is there a geological impediment in the way? • Is it possible to discharge a specified material directly into groundwater? • How connected are groundwater and surface water in terms of hydraulic connectivity? • Do you see any repercussions? • What are the necessary corrective actions? • Have any corrective actions been taken, and have they been successful?	The information necessary for moderate risk sites (Class B sites) is not as extensive as that required for high-risk sites (Class A sites), but it should be significantly higher than that required for low-risk sites (Class C sites).	• Are the data utilized in the conceptual model and risk screening exercise correctly and valid? • Do you see any repercussions? • Have any corrective actions been taken?
What information is required, and to what level of accuracy and detail?	• Waste type and age across the site • Waste depth • Any capping layer depth and composition • Leachate monitoring • Subsoil type, thickness, and permeability (in-situ or laboratory testing required) • Hydrogeological properties • Bedrock type		• Does the site produce landfill gas and/or leachate? • Monitor the nearest receptor for waste gas

	• Aquifer type and flow regime • Groundwater level and flow direction • Groundwater Trigger Levels to be determined • Surface water drainage location and hydrological setting, including water levels and flow rates • Surface-water classification • Ecological survey, including value and functions • The compliance point requirements to be defined for monitoring • Monitoring requirements for landfill gas within the waste body and at nearby receptors (including the need for installation of monitoring points and use of gas probes) • The criteria for monitoring typical leachate parameters in surface waters • Groundwater monitoring for typical leachate values both upstream and downstream of the location (including the need for installation of monitoring boreholes)		• Is there any seepage of leachate? If so, sample the surrounding surface waters and all private wells within 250 meters. • Is there enough cover material on the site to prevent infiltration into the waste body?
What is the SI's aim in relation to the risk assessment technique in question?	• Confirmation that the site is a Class A site, and that the situation requires additional quantitative risk assessment and remediation. • Gathering enough data for a quantitative risk assessment. • Gathering sufficient data to demonstrate the efficacy of the recommended remedial techniques.		• It serves as the foundation for recommended corrective activities by ensuring that the site does not pose a concern to the environment or human health (if any).

The level and scope of the Site Investigation Program are determined by the level of environmental risk that the site poses. There are various degrees of site investigation that can be used, ranging from a preliminary investigation to a primary investigation and, in certain cases, specialist supplemental investigations that may be necessary for further examination of specific problems.

For the various types of sites, the amount of site investigation could be as follows:

- ✓ Preliminary Investigation (Tier 1) – Desk Study and Site Inspection (including Walkover Survey) – all locations
- ✓ Exploratory Investigation (Tier 2) – all Class A, B, and C Sites
- ✓ Main Investigation (Tier 2) – Class A and B Sites
- ✓ Supplemental Investigations (Tier 2) – site-specific but should be conducted for each class of site as needed.

The conceptual site model (CSM) and the source-pathway-receptor (S-P-R) links determined during Risk Assessment Tier 1: Conceptual Site Model, Risk Screening, and Prioritization should be considered in all circumstances. Because the real requirements may vary depending on the ground conditions observed during the site investigations, the aim of the Site Investigation should allow for flexibility in the methods of investigation. Before the start of the job, a site plan specifying the anticipated site investigations and sampling locations must be set up. During the site investigations, an adequate Health and Safety Plan must be drawn up and followed, adhering to all relevant Health and Safety legislation.

8.4.2. Phase 3: Refinement of CSM and Quantitative Risk Assessment

Following the site investigation program outlined in Risk Assessment Methodology Phase 2: Site Investigations and Testing, the information gathered should be used to refine the conceptual site model (CSM) as needed, and the risk screening workout should be repeated to confirm the initial risk status defined in the Risk Assessment Methodology Phase 1: Conceptual Site Model, Risk Screening, and Prioritization.

The site investigations should have established the source-pathway-receptor relationships and their relative relevance. In some circumstances, a relationship will be found to be non-existent, so eliminating that risk; in other cases, previously unknown linkages will be discovered, resulting in a re-evaluation of the site's risk categorization. The refinement of the CSM is critical because the first screening was based on preliminary/exploratory investigation data, and it is critical that the risk categorization be confirmed only after a full risk screening exercise based on high-quality data.

The improvement of the conceptual model enables the evaluation of known risks and the determination of the degree of uncertainty, allowing for a choice to be made in a timely manner.

When a site is determined to pose a high or moderate danger to the environment or human health through the risk screening procedure, a quantitative risk assessment is necessary. There are two types of quantitative risk assessments: generic quantitative risk assessments and detailed quantitative risk assessments. Generic quantitative risk assessments use relevant generic assessment criteria (GAC) (i.e. values that are generally applicable to an entire class or group, e.g. based on proposed future land use) or guidelines, while detailed quantitative risk assessments use site-specific assessment criteria and RA tools and models. The choice of which form of QRA to utilize is site-specific and is based on the site's sensitivity as well as the trust in the available data.

Following the implementation of either a Generic QRA or a Detailed QRA, the site's overall risk must be assessed. The essential receptors, the degree of uncertainty connected with the site and the data utilized, as well as the assumptions made, must all be defined, and the risks associated with them must be assessed.

8.5. Tools for Risk Assessment

Risk assessment is a tool that is always evolving. This is true not only in terms of waste management and other environmental issues but also in terms of the food industry, ecology, health physics, radiation, earthquakes, finance, construction management, business, regulatory systems, etc. The main theme or foundations are the same regardless of the type of risk assessment or the environmental area of application. That is, a target/environmental receptor must be influenced by a hazard or undesirable event via a pathway. Similarly, there are three approaches to control risks: eliminate the source of the hazards, remove the receptors of the hazards, or manipulate the paths connecting the hazards.

Hazards can be defined, their impacts can be simulated, and risk analysis can be conducted with greater accuracy thanks to the development of computational methodologies and the ability to model systems more precisely, resulting in more effective risk management. These advances are essential in all fields of human endeavor, but they are especially relevant to environmental challenges, where the risks are increasingly perceived to be significant.

Several computer-based technologies have been identified as being directly related to landfill risk assessment (Robu et al., 2007), including:

- ✓ LandSim
- ✓ HELP – Hydro-geological Evaluation of Landfill Performance
- ✓ GasSim
- ✓ GasSimLite, and
- ✓ RIP – Repository Integration Programme

Although the functions of the RIP were later extended to take landfills into account on a fairly wide scale, the first four computer programs are specifically intended for risk assessment of solid waste disposal. The other sorts of software aren't clearly linked to waste risk, but they could be used to support some aspects of this type of risk assessment. Drill Guide, for example, is useful in that it can be included in the geology module of an open dumps baseline research, which will aid in the risk assessment process.

In terms of software programs dedicated to landfill risk assessment, they do not comprehensively encompass all aspects of the RA approach for open dumps leachate. For example, the LandSim software, which is solely for solid waste risk assessment, probabilistically forecasts potential leachate pollutant concentrations that can reach a particular site in the ground (e.g., groundwater abstraction point) in a certain time (in years). It also accommodates temporal and spatial changes. It does not, however, include the quantification portion of exposure studies, such as the quantity of exposure that people (or cattle) would receive if they consumed this groundwater. As a result, the LandSim feature of pollutant concentration estimation in an exposure medium such as groundwater can be extended to quantify exposure (for example, for cattle or a fish farm), allowing for a more comprehensive quantitative risk assessment.

Furthermore, it is primarily a technique that focuses on groundwater as a receptor, rather than other environmental sensors like human population, livestock, and crops in a farm area. Even though the program allows for the classification of dangers into categories such as toxic, non-toxic, carcinogenic, and non-carcinogenic, there is no provision for categorizing hazards into groups such as toxic, non-toxic, carcinogenic, and non-carcinogenic. To summarize, the LandSim is a component of the overall RA system, not the entire RA system. Similarly, the HELP program only includes a portion of the open dumps/landfills risk assessment. These mostly handle landfill design features (such as liners and capping) as well as some baseline study components (such as precipitation and surface runoff), but they do not cover many other RA modules and sub-modules.

Even though it includes essential risk assessment modules such as gas generation, migration, impact, and exposure, the software GasSim is developed for assessing landfill gas, not leachate. The GasSimLite was also created with landfill gas in mind and can only be used to calculate gas emissions. Both GasSim and GasSimLite, like the other models listed, are not total RA models in a category and algorithmic sense.

The RIP, on the other hand, is an integrated probabilistic model for environmental systems that were not designed explicitly for assessing open dump/landfill risk. It was created with any conceivable pollutant source in the earth in mind, such as a chemical storage tank. As a result, risk assessors must adjust the RIP, which is generic software, to their individual concerns, such as open dumps/landfills. This adaption takes time and is not a simple task for everyone. Although RIP can be used in landfills to address concerns like pollutant release and transportation, it does not readily provide a simple total risk assessment approach for landfill leachate that a risk assessor might follow sequentially and systematically.

GoldSim is another simulation program that may be used for a wide range of applications, the majority of which fall into one of three categories: environmental systems modeling, business, and economic modeling, or engineered system modeling. As a result, it outgrows even the RIP in terms of generics, and users must learn how to adapt the GoldSim to their individual situations in parallel to RIP.

The ConSim program is a tool for estimating the risks that contaminants migrating from contaminated land pose to groundwater quality. The authors discover that this was not built specifically for use with open dumps/landfills, especially when they include a leachate head and/or liners, which is extremely likely.

The Contaminated Land Exposure Assessment (CLEA) software solely analyses dangers to human health, not other environmental receptors such as plants, animals, buildings, or regulated waters. Pathways are only considered from the standpoint of soil as an exposure medium, not from the perspective of leachate. In the case of ConSim, the CLEA program was created for use with contaminated soil rather than open dumps/landfills, and neither ConSim nor CLEA provide a complete RA model for open dump/landfill leachate.

The Hazardous Waste Identification Rule (HWIR) methodology describes how a national-scale assessment in the United States is carried out to estimate human and ecological risks in order to create acceptable contaminant-specific exemption thresholds for relevant industrial waste streams.

The risk assessment process has also been automated using the HIWR modeling technology. The HIWR system's goal is to reduce the possibility of overregulation. By promoting waste minimization and the development of innovative waste treatment technologies, HIWR can contribute to long-term waste management. The HIWR method addresses a wide range of live receptors, including soil fauna, mammals, and plants, but it does not appear to treat non-living things as receptors. In the context of estimating open dump/landfill risks, the focus appears to be on wastes themselves rather than a specific open dump/landfill scenario.

SADA (Spatial Analysis and Decision Assistance) is software that combines technologies from the environmental assessment area into a problem-solving environment. Visualization, geospatial analysis, human health and ecological risk assessment, cost/benefit analysis, sampling design, and decision analysis are all included in these tools. Only the two most relevant tools or modules were chosen as examples from a large number of options. From a variety of land-use scenarios, the Human Health Risk module delivers a thorough human health risk assessment and accompanying databases. Land uses that fall under this category include residential, industrial, agricultural, recreational, and excavation, but not open dumps/landfills. Ecological Risk is another SADA module or unit that allows users to conduct benchmark screenings and compute forward risk for a variety of terrestrial and aquatic receptors that are currently being included.

Another computer-based application is the Multimedia Environmental Pollutant Assessment System (MEPAS), which is a set of environmental models intended to assess the contaminated environment. The software incorporates chemical and radioactive release transit and exposure paths to estimate their potential impact on the environment and populations. MEPAS modules have been integrated into the FRAMES software platform, allowing MEPAS models to be used in conjunction with other environmental models to complete the analysis. The situation with MEPAS and ARAMS in the context of open dumps/landfills is similar. Both computer programs are not intended to give a holistic risk assessment technique for landfill leachate and do not do so.

Risk Analysis Framework Multimedia Environmental Systems (FRAMES) is a software platform allowing users to create environmental scenarios and provide options for selecting the most appropriate computer codes for doing human and environmental risk management evaluations. This program takes a broad and flexible approach to figure out how industrial activities affect people and the environment. It includes models that span scientific disciplines, allowing for customized solutions to specific operations and providing useful data to business and technical management. The key to recognizing, analyzing, and controlling potential environmental, safety, and health hazards is to use FRAMES. FRAMES is a very broad program, but it lacks software for open dump/landfill leachate that might assist an assessor through a risk analysis using the vast variety of risk assessment elements.

8.6. Risk Assessment Validation

Each site risk screening exercise requires the preparation of a report. The conceptual model, as well as the calculation of risk scores utilizing the S-P-R linkage equations, will be the emphasis of the report. The report can be used to ensure that the approach outlined in the relevant legal texts and recommendations is followed.

The following items must be included in the report:

- ✓ Report on the walkover survey.
- ✓ Appropriate conceptual model illustrations (e.g. plan and cross-sections).
- ✓ A network diagram (or something similar) that depicts all of the source – pathway – receptor relationships that have been explored as part of the evaluation.
- ✓ A set of important GIS maps (all at the same scale) that were used as distinct layers of information in the risk assessment, with the outline of the waste body and a scale bar that clearly depicts the distance involved. This will allow double-checking the information in the risk screening tables.
- ✓ The S-P-R linkage equations that were used in the risk screening.
- ✓ A summary of the conceptual model, including any impact data that is available and any remediation steps that have been implemented.

A thorough report detailing the methods taken and assumptions made in connection with the quantitative risk assessment is necessary. It should clearly clarify the assessment criteria used, and in the case of a fully quantitative risk assessment, it should provide both the source and explanation for using site-specific assessment criteria. It must be provided to the relevant competent authorities and must comprise suggestions for the steps to be implemented on each site. A full verification report has to be submitted when the agreed-upon remediation option has been completed, demonstrating that the S-P-R linkage(s) has been broken and that the remediation has been successful (or otherwise).

8.7. The risk potential of open dumps

In the journal The Lancet Oncology, Senior and Mazza (2004) used for the first time the term "triangle of death" to describe the eastern part of the Campania Region (Southern Italy), which has one of the worst records of unlawful garbage dumping. This is a region in the Province of Naples, Italy, some 25 kilometers northeast of the city of Naples. The waste management crisis and the triangle of death are essentially the results of the government's failure to prevent illicit waste dumping. Pollutants such as dioxins, as well as polychlorinated biphenyls (PCBs), have been discovered in the soil as well as in the residents of the area. As a result, the region has seen an increase in cancer-related mortality, which has been attributed to pollution from open dumping (Triassi et al., 2015). That's is why much research has focused in recent decades on the possibility for illicit waste disposal to have negative health consequences.

The impact of waste is determined by its composition and illegal disposal techniques. Copper, arsenic, mercury, polychlorinated biphenyls, hydrocarbons, and other harmful wastes from the last phase of industrial activity are among the compounds found in the waste composition. Illegal burying is another harmful practice in locations not designated as toxic waste dump sites by law, such as cultivable regions, highways and buildings, and construction yards.

When waste is released into the environment, it poses several threats to the land and wildlife in the area. The magnitude of the impact, on the other hand, is not always clear and may take some time to manifest.

8.7.1. Water and soil contamination

There is a risk to the soil and water nearby when a large amount of waste is gathered in one location. Unlike certified sanitary landfills, which seek to safeguard the surrounding area from contamination, open dumps lack built-in environmental safety systems and continuous monitoring. Hazardous waste runoff can contaminate streams, rivers, lakes, and even drinking water if it is not monitored and managed. Chemicals can also penetrate the soil, making the land infertile or encouraging the spread of invasive plant that is resistant to the chemicals' effects. It's also likely that the chemicals will contaminate vegetation, which could lead to the contamination of food supplies.

8.7.2. Air pollution

Illegal dumping has the potential to pollute the air. Some waste may include molecules that, when decomposed, emit dangerous compounds into the air. These substances could include CO2 or other gases that are harmful to our ecosystem. As a result, open dumping might contribute to air pollution to some extent.

8.7.3. Wildlife disruption

Illegal dumping has an impact on animals as well. In fact, they are the ones who are the most affected. The best-case scenario is that a pile of waste obstructing their typical travel path causes them some inconvenience. Unfortunately, it isn't where the issues usually end. Hazardous compounds may be present in waste deposited in forests or other natural areas. When animals come into contact with these pollutants, they may get harmed. Furthermore, animals may be contaminated by hazardous microorganisms found in waste, resulting in illness transmission across different animals through the food chain.

Animals may also experience a shift in their normal living environment as a result of waste disposal. Many animals are highly sensitive to changes in their natural living environment and avoid contact with humans and human-made objects. As a result, illegal dumping may cause their migration to less contaminated locations where they can feel more at ease in their natural habitat.

Waste also attracts species that aren’t native to the area. This can result in the introduction of new illnesses and predators, such as mosquitoes and raccoons, upsetting the ecosystem's natural flow.

Open dumps may also have a severe impact on aquatic life. Many businesses in nations with loose environmental regulations throw their industrial waste into rivers and lakes. Water animals, as well as many other aquatic organisms, will be contaminated as a result. Many of these aquatic species will be harmed by toxic substances and may even die as a result of the negative effects of industrial waste compounds.

Waste dumping may also have an impact on birds. Birds frequently consume tiny creatures such as worms and insects. Insect concentrations may drop dramatically if a region is heavily contaminated by unlawful dumping. This may result in a scarcity of food for birds, resulting in a decrease in the birds’ populations.

8.7.4 Possibility of Local Fires Increase

The majority of waste is combustible. Because different types of waste can mix, flammable fumes can be released. If an open dumpsite is left unattended, the chances of a spontaneous fire escalating into a full-fledged forest fire increase. Furthermore, deposited waste can cause floods by blocking natural water channels or speeding up the erosion process.

8.7.5. Possibility of Health Issues Increase

Health issues are one of the most serious threats that open dumping poses to humans (Musmeci et al., 2010). Insects like mosquitoes and flies, as well as disease-carrying animals like rats, skunks, and opossums, thrive in areas where waste is disposed of. Dengue fever, yellow fever, encephalitis, and malaria are just a handful of the life-threatening diseases that these insects and animals can transmit. It was also mentioned that living in a neighborhood with obvious dump sites can be detrimental to one's mental health.

Broken glass, sharp metal, and hypodermic needles, among other physical hazards at open dumps, can cause severe injuries; appliances in which children or animals can become trapped; and tires that can catch fire and release toxic smoke. Waste from illegal drug labs might be dangerous right away (i.e., explosions, fires, chemical burns, or vapors). Toxic compounds such as antifreeze, paint, insecticides, and mercury from gas appliance pilot light sensors and other products are among the chemical risks that can be particularly dangerous.

Contaminated medical waste, for example, might induce life-threatening infections (HIV/AIDS or Hepatitis B or C). Disease-spreading rodents can be attracted to household waste (e.g., food leftovers, filthy diapers). Mosquitoes that carry encephalitis or the West Nile Virus can breed in discarded tires or other objects that accumulate standing water. Depending on the level and period of exposure, asbestos can cause lung illness or cancer.

In fact, open dumping pollutes the environment in a way that has both short and long-term health consequences. Congenital abnormalities, asthma, and respiratory infection are examples of short-term impacts. There have also been reports of tension, anxiety, headaches, dizziness, nausea, and eye and respiratory irritation. Chronic respiratory and cardiovascular disorders, cancer, and diseases of the brain, nerves, liver, lymphohematopoietic system, and kidneys are all long-term health consequences of waste exposure (Sexton & Hattis, 2007).

8.7.6. Property Values Decrease

The impact of open dumping on real estate investment and the residential environment is equally harmful. It is widely understood that a property's location has a positive or negative impact on the price or rent of the property. As a result, if the problem of illegal dumping is serious, property values in the affected areas are likely to fall. That is why, when comparing the rents of residential homes adjacent to open dumps with those further away, there is a significant variation in the rent.

8.7.7. Effects on tourism

People want to spend their vacations in locations that are pleasant and tidy. They are more likely to switch to other holiday places when there is too much waste dumped illegally in certain areas.

Tourism is the most significant source of revenue for many countries. Illegal dumping may thus pose a major threat to livelihood. Many governments, on the other hand, are aware of the problem and are taking steps to address it in order to maintain beaches and other natural areas as clean as possible.

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