Environmental risk assessment of landfill

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Abstract. The paper aims to conduct a risk analysis approach that can be used to manage landfill impacts on the environment and public health. This study reviewed the application of environmental risk assessment in landfills. Assessment has been conducted for 30 articles from 2018-2022 resulting in the summary of the baseline data, hazard identification, exposure assessment, risk characterization, and risk management. The study found the necessity of detailed baseline data of landfill sites, identifying relevant toxicity data, recognizing exposed receptors, and potential exposure pathways. It is necessary to conduct research that considers the age of the landfill (old and new landfill) to find out the cumulative effects of the landfill and research related to the impact of the landfill on the health of communities around the landfill at a certain distance from the landfill.

1 Introduction

Landfill is important for adequate waste disposal. Landfills reduce the amount of waste illegally dumped into the environment, help prevent the transmission of diseases to the environment, and keep the environment clean [1]. During the waste decomposition process, products are created in the landfill in three stages. These products include solids (decomposed waste), liquids (leachate, which is the contamination of water by waste), and gases (landfill gas). Additionally, the atmosphere, lithosphere, and hydrosphere are all susceptible to pollution caused by landfills and the mentioned products [2]. Pollutants are transmitted through these media and directly or indirectly affect humans, the natural environment (including terrestrial and aquatic flora and fauna), and the built environment.

Decomposition of waste in landfills will produce leachate. Leachate movement within open landfills is a major source of heavy metals in surface water, groundwater, soil, and plants.. Many more compounds with harmful effects leached from domestic solid waste landfills adversely affect the environment and human health.

Heavy metals can enter the environment through leachate production and migration from landfills, posing a potential threat to soils, groundwater, and even surface waters.[3]. The leachate is potentially important as a source of groundwater pollution [4] [5], heavy metals [6] [7], and organic pollutants [8], [9]. Leachate can travel long distances in groundwater and accumulate at every link in the chain, resulting in decreased cellular activity, disruption of the endocrine system in humans and animals, and even various negative health effects. Analysis conducted by [9] shows that the landfill caused heavy metal, inorganic, and organic pollution of groundwater downstream of the landfill. Therefore, landfills must be risk-assessed and managed to protect the environment from harm [2]. Environmental impact assessment systematically identifies the potential impacts of a proposed project, plan, program, or legislative action on the physical, chemical, biological, cultural, and socio-economic components of the overall environment [10]. This review paper aims to implement a risk analysis approach that can be used to address the environmental and public health impacts of landfills.

2 Methodology

This review study began by searching for scientific articles using the following criteria: (i) Manuscripts published between 2018 and 2022. (ii) the landfill was located in Asia; (iii) the study did not include any hazardous waste landfills; A search for scientific articles with these criteria was performed using an online search engine using the specific keywords “landfill” and “environmental risk assessment”. Additional keywords representing additional criteria (municipal waste in Asia) were defined to narrow down the results.

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A cross-reference study was conducted after the expected manuscripts were found to obtain further results. All collected papers are grouped by year and key information e.g. Baseline data, hazard identification, exposure assessment, risk characterization, and risk management) were prepared before analysis and comparison activities. The screening of articles is from a hundred articles becomes fifty articles and then thirty articles. Environmental risk assessment includes four paths:
1. Baseline study/data
2. Hazard identification
3. Exposure assessment
4. Risk characterization and management

3 Results and Discussion

3.1 Baseline study/data

The baseline study/data is defined as the earliest step of hazard assessment as well as risk analysis where basic information is collected, classified, and analyzed. The risk and hazard assessment process is based on the baseline study. For areas contaminated by landfill leachate, a baseline study should be conducted covering a wide range of information and subjects [11]. The information collected can be categorized into:
1) Geology,
2) Hydrology,
3) Hydrogeology,
4) Topography,
5) Meteorology,
6) Geography,
7) Area management
8) Human influence

Geology, topography, meteorology, geography, and site management are important data to assess landfill. Site management includes waste collection, total years of operation, and current status of the landfill. When evaluating a landfill, the landfill is noted as a closed area of contamination sources. Environmental factors and the landfill context can have an important influence on the accumulation of specific heavy metals and their content.

3.2 Hazard identification

At this stage, all hazards are identified. Hazard can be defined as any substance, property, process, even layout or setting that can cause a disturbance or has the potential to cause a disturbance. All potential hazards from leachate whether pollutants (heavy metals, or emerging pollutants) or properties (pH, BOD, COD, leachate age, hardness) are investigated and classified for more comprehensive, effective, and categorized. The process performed: estimation of leachate quality. They are categorized as pollutants and properties. From the measurement of leachate quality, it can be categorized as toxic non-toxic, or both, which can be further analyzed as carcinogen non-carcinogen, or both. In environmental risk analysis, it is necessary to take into account time and spatial variations. It can assist in obtaining more specific estimations, such as migration of the leachate via various media of pathways from the pollutant source to receptors. Migration considers the transfer of leachate as a physical phenomenon (dispersion, advection, and retardation) and attenuation regards variation of qualities of leachate [11].

3.3 Exposure Assessment

This stage is a contaminant exposure assessment process that identifies and categorizes all potential hazards at the source of the contaminant, contaminant pathway, and environmental target/receptor. Quantified risk analysis measures or quantifies exposure to identified targets or receptors through recognized hazards over identified pathways. The level of exposure also plays an important role in determining the presence of risk. When determining the source, landfills are identified as the source of pollution. Geometric determination of the center point is also determined and then the distance to the target/receptor and exposed media is determined. Pathway identification is the relationship between the source and the receptor/target, which previously listed all environmental types that can be affected by hazards in the contaminated area. Receptors or targets are not only humans but also plants or animals and abiotic components. Quantification of exposure to living targets/receptors is divided into 3 (points) of entry: ingestion, inhalation, dermal contact, or others. Ingestion includes eating and drinking. Skin contact includes bathing and swimming activities. Inhalation relates to inhalation of contaminated air, gas, or water vapor. Consideration should also be given to entering leachate hazards from leachate-contaminated aquifers into water bodies. Concentration assessment consists of hazard concentrations at the pollutant source, cross-media concentrations from the pathway, mainly exposure media, concentrations at the target site, and critical concentrations compared to the standard.
<table>
<thead>
<tr>
<th>No</th>
<th>Study Area</th>
<th>Baseline Data</th>
<th>Hazard Identification</th>
<th>Exposure Assessment</th>
<th>Risk Characterization &amp; Management</th>
<th>Ref</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Landfill in Vientiane, Laos</td>
<td>Topography and site management</td>
<td>Concentrations of heavy metals (Cd, Cr, Cu, Pb, Zn, Ni) in water, soil, and plants in landfill and surrounding areas during the rainy and dry seasons</td>
<td>Bio Accumulation Factor and potentially health risk of heavy metals in edible plants</td>
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<td>2</td>
<td>Paddy rice field near landfill in Kambon village, Thailand</td>
<td>Topography and site management</td>
<td>Concentrations of heavy metals (Cd, Cr, Cu, Pb, Zn, Ni) in water, sediment, and plants of the landfill</td>
<td>Water quality and hazard indices are used to assess potential risks to human health.</td>
<td>The Leachate Pollution Index (LPI) is determined to prevent water contamination and leachate collection ponds</td>
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<td>3</td>
<td>Bhalswa landfill, India</td>
<td>Geology and hydrology</td>
<td>The measurements of physicochemical parameters and heavy metals concentration of landfill leachate during pre and post-monsoon</td>
<td>Water quality and hazard indices are used to assess potential risks to human health.</td>
<td>The Leachate Pollution Index (LPI) is determined to prevent water contamination and leachate collection ponds</td>
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<td>4</td>
<td>Chandigarh landfill, SAS Nagar, and Panchkula, India</td>
<td>Geography and hydrology</td>
<td>The concentration of COD, BOD, pH value, and ammonia nitrogen in the leachate are determined. Measurement of heavy metals concentration in groundwater near the landfill</td>
<td>Human risk assessment includes the Hazard Quotient (HQ) and Potential Ecological Risk Index (PERI).</td>
<td>Evaluation of pollutant indicators and geochemical analysis of heavy metals contamination in closed landfills</td>
<td>[21]</td>
</tr>
<tr>
<td>5</td>
<td>Chandigarh landfill, SAS Nagar, and Panchkula, India</td>
<td>Geology, topography, site management</td>
<td>Measurement of the concentrations of Al, Cr, Fe, Mn, Ni, Pb, and Zn in soil, standing water, and grass</td>
<td>Control of distribution and accumulation of heavy metals in different soil types</td>
<td>Control of distribution and accumulation of heavy metals in different soil types</td>
<td>[22]</td>
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<tr>
<td>6</td>
<td>Landfill at Lahore, Pakistan</td>
<td>Site management, soil, and geology</td>
<td>The concentration of Cr, Mn, Fe, Ni, Cu, Zn, and Cd in soil, standing water, and grass</td>
<td>Control of distribution and accumulation of heavy metals in different soil types</td>
<td>Control of distribution and accumulation of heavy metals in different soil types</td>
<td>[23]</td>
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<td>7</td>
<td>Air Hitam landfill, Sungai Kembong landfill, and Kubang Badak landfill, Malaysia</td>
<td>Site management, soil, and geology</td>
<td>The concentration of Cr, Mn, Fe, Ni, Cu, Zn, and Cd in soil, standing water, and grass</td>
<td>Control of distribution and accumulation of heavy metals in different soil types</td>
<td>Control of distribution and accumulation of heavy metals in different soil types</td>
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<td>8</td>
<td>Air Hitam landfill, Sungai Kembong landfill, and Kubang Badak landfill, Malaysia</td>
<td>Site management, soil, and geography</td>
<td>The concentration of Cr, Mn, Fe, Ni, Cu, Zn, and Cd in soil, standing water, and grass</td>
<td>Control of distribution and accumulation of heavy metals in different soil types</td>
<td>Control of distribution and accumulation of heavy metals in different soil types</td>
<td>[25]</td>
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<tr>
<td>9</td>
<td>Eastern Guangdong Landfill</td>
<td>Site management, soil, and geology</td>
<td>The concentration of Cr, Mn, Fe, Ni, Cu, Zn, and Cd in soil, standing water, and grass</td>
<td>Control of distribution and accumulation of heavy metals in different soil types</td>
<td>Control of distribution and accumulation of heavy metals in different soil types</td>
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<td>Hazard Characterization &amp; Management</td>
<td>Exposure Assessment</td>
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<tr>
<td>11</td>
<td>Taiwan Landfill, Aruba</td>
<td>Geology, site management, meteorology, hydrology, site management</td>
<td>The potential health risk of heavy metal exposure through chronic daily ingestion (CDI) is considered through three major routes: ingestion, dermal contact, and inhalation.</td>
<td>Leachate and groundwater quality are determined by cadmium (Cd), zinc (Zn), lead (Pb), nickel (Ni), and copper (Cu) concentrations in soil and surface water.</td>
<td>[27]</td>
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<tr>
<td>12</td>
<td>Two sanitary landfill sites in Central Macedonia, Greece</td>
<td>Site management, topography, hydrology, geology, meteorology</td>
<td>Soil contamination risk is determined using Igeo, PI, PLI, and NWPI.</td>
<td>Leachate and groundwater are monitored for heavy metal concentrations.</td>
<td>[28]</td>
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<tr>
<td>13</td>
<td>Landfill at Chiang Rak Noi City, Phra Nakhon Si Ayutthaya Province, Thailand</td>
<td>Site management, topography, hydrology, geology, meteorology</td>
<td>Soil contamination risk is determined using Igeo, PI, PLI, and NWPI.</td>
<td>Leachate and groundwater quality are determined by cadmium (Cd), zinc (Zn), lead (Pb), nickel (Ni), and copper (Cu) concentrations in soil and surface water.</td>
<td>[29]</td>
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<tr>
<td>14</td>
<td>Sungai Udang, Ladang Tanah Merah, Bukit Palong, Ulu Masoop, Pajam, Kampung Keru Landfill in Malaysia</td>
<td>Site management, topography, hydrology, geology, meteorology</td>
<td>Soil contamination risk is determined using Igeo, PI, PLI, and NWPI.</td>
<td>Leachate and groundwater quality are determined by cadmium (Cd), zinc (Zn), lead (Pb), nickel (Ni), and copper (Cu) concentrations in soil and surface water.</td>
<td>[30]</td>
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<td>15</td>
<td>Bhalaswa landfill site, India</td>
<td>Geography</td>
<td>Soil contamination risk is determined using Igeo, PI, PLI, and NWPI.</td>
<td>Leachate and groundwater quality are determined by cadmium (Cd), zinc (Zn), lead (Pb), nickel (Ni), and copper (Cu) concentrations in soil and surface water.</td>
<td>[31]</td>
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<tr>
<td>16</td>
<td>The landfill is located in Guwahati, Assam, India.</td>
<td>Geography</td>
<td>Soil contamination risk is determined using Igeo, PI, PLI, and NWPI.</td>
<td>Leachate and groundwater quality are determined by cadmium (Cd), zinc (Zn), lead (Pb), nickel (Ni), and copper (Cu) concentrations in soil and surface water.</td>
<td>[32]</td>
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<tr>
<td>17</td>
<td>Landfills at Naqu, Nyingchi, Shigatse, Maizhokunggar, and Lhasa, Tibet</td>
<td>Geography</td>
<td>Soil contamination risk is determined using Igeo, PI, PLI, and NWPI.</td>
<td>Leachate and groundwater quality are determined by cadmium (Cd), zinc (Zn), lead (Pb), nickel (Ni), and copper (Cu) concentrations in soil and surface water.</td>
<td>[33]</td>
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<td>No.</td>
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<td>18</td>
<td>Saravan Landfill, Rasht, Iran</td>
<td>Topography, meteorology, geology, meteorology, geology</td>
<td>[34]</td>
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<td>19</td>
<td>Gunung Tugel Landfill, Banyumas, Indonesia</td>
<td>Topography, geology, meteorology, topography, geology, meteorology</td>
<td>[35]</td>
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<td>20</td>
<td>Kahrizak Landfill, Tehran, Iran</td>
<td>Topography, geology, meteorology, topography, geology, meteorology</td>
<td>[36]</td>
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<tr>
<td>21</td>
<td>Landfill at Ziyang City, Sichuan Province, China</td>
<td>Hydrogeology, meteorology, topography, hydrogeology, meteorology, topography</td>
<td>[37]</td>
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<tr>
<td>22</td>
<td>Landfill near Assam, India</td>
<td>Topography, geology, meteorology, topography, geology, meteorology</td>
<td>[38]</td>
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<tr>
<td>23</td>
<td>The landfill is located in Piyungan, Yogyakarta, Indonesia</td>
<td>Geological, geology, hydrogeology, geological, hydrogeology</td>
<td>[39]</td>
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<td>24</td>
<td>Landfills in a region in Southern Lebanon</td>
<td>Site management, biological, chemical, physical</td>
<td>[40]</td>
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<td>25</td>
<td>The landfill is located in Qingdao, Shandong Province, China</td>
<td>Meteorology, site management, meteorology, site management</td>
<td>[41]</td>
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<td>No</td>
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<tr>
<td>26</td>
<td>Landfill located in Lhasa, Tibet</td>
<td>Geography, site management, meteorology</td>
<td>Heavy metal concentrations in the soil</td>
<td>To assess the pollution level of heavy metal elements in the topsoil, the pollution index (Pi), Nemerov pollution index (PN), geo-accumulation index (Igeo), and pollution load index (PLI) were quantified.</td>
<td>Reduce health risks by continuously monitoring groundwater, soil and leachate treatment processes</td>
<td></td>
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<tr>
<td>27</td>
<td>Landfill at Baglung Municipality of Nepal</td>
<td>Geography, site management, meteorology</td>
<td>The estimation of the concentrations of Zn, Cu, Pb, Ni, Cr, and Cd in the soil</td>
<td>For ecological risk assessment, Heavy metal contamination in soil and estimate the extent of the impact caused by pollutants in the environment.</td>
<td>Heavy metal pollution control and human health risk assessment management at Kheshut Landfill</td>
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<tr>
<td>28</td>
<td>Landfill in Lopburi Province, Thailand Central Region</td>
<td>Meteorology, geography, geology</td>
<td>The concentration of Pb, Ni, Cd, Mn, Fe, Cr, and Al in groundwater and soil</td>
<td>For ecological risk assessment, Geo-Accumulation Index (Igeo) and Contamination Factor (CF), as well as the Pollution Load Index (PLI) were quantified.</td>
<td>Protecting human health and well-being requires continuous risk assessment of heavy metals potentially harmful to human health in different land uses.</td>
<td></td>
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<tr>
<td>29</td>
<td>Landfill in Kheshut City, Iran</td>
<td>Meteorology, geography, geology</td>
<td>The concentrations of Cu, Co, Ni, Cd, Zn, and Pb were measured in soil samples from the study area</td>
<td>For ecological risk assessment, Geo-Accumulation Index (Igeo) and Contamination Factor (CF) were estimated for health risk assessment.</td>
<td>Heavy metal pollution control and human health risk assessment management at Kheshut Landfill</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Landfills in Peninsular Malaysia</td>
<td>Site management, geography</td>
<td>The concentrations of Cd, Pb, Ni, Co, Cu, Zn in the topsoils are estimated</td>
<td>Heavy metal pollution control and human health risk assessment management at Kheshut Landfill</td>
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</table>
3.4 Risk Characterization and Management

Health risk characteristics in at-risk populations are expressed quantitatively by a combination of dose-response and exposure analyses. The estimated health risk figures are used to develop risk management options to control the risk. The risk management options are then communicated to interested parties so that potential risks can be identified, minimized, or prevented. The results of the research explain landfill impact on health. Research [12] shows that children and residents living near the Awotan landfill have greater health risks than those far from the landfill. Communities living closer to landfills have higher health risks than those living farther from landfills [13]. The increased risk of carcinogenic and non-carcinogenic diseases in adults and children living near landfills is associated with the presence of Pb, As, and Cd in groundwater contaminated with landfill leachate [14]. Research [15] reported that illegal dumping has adverse health impacts on people living near landfills and is more dangerous for children, as their immune systems are still developing and because they spend most of their time outdoors.

Several studies provide recommendations related to landfill management. Some researchers provide the following recommendations. Education and legislation on landfill management should be academic and rigorous, from primary schools to universities. The government should pay attention to improving landfill systems such as leachate and wastewater treatment systems [13]. Adequate landfill management is essential. Landfills should be located away from housing and institutions to prevent health and environmental risks [16]. Landfills with a high-risk category must be closed and no more landfilling activities in the landfill [17]. There are several ways to improve landfill management [18]: First, the government should improve the quality and quantity of recycling facilities. Second, extension of basic services such as the provision of bulky waste collection facilities. Third, waste disposal services should be more flexible in various service situations where waste is generated in large quantities and weather conditions should be taken into consideration. Public-private collaboration can be an effective way to improve waste management services. The study of environmental risk assessment of landfills in Asia countries is represented in Table 1.

In general, the minimum stages carried out in environmental risk assessment are hazard identification, exposure assessment, and risk characterization. From environmental risk analysis studies conducted in Asian countries, it appears that the detail of the baseline study is critical in supporting the next steps. The need for seasonal variation in hazard identification is also needed to make the study more comprehensive. The age of the landfill is also important in supporting the risk assessment as it is related to the quality of the leachate produced. Fluctuations in leachate quality that occur with the age of the landfill affect risk characterization and management, including management when the landfill is closed.

4 Conclusion

The study found the necessity of detailed baseline data of landfill sites, identifying relevant toxicity data, recognizing exposed receptors, and potential exposure pathways. It is necessary to conduct research that considers the age of the landfill (old and new landfill) to find out the cumulative effects of the landfill and research related to the impact of the landfill on the health of communities around the landfill at a certain distance from the landfill.

References

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