E3S Web of Conferences 495, 03009 (2024) https://doi.org/10.1051/e3sconf/202449503009
ICYES 2023

Environmental risk assessment of landfill

Tuani Lidiawati Simangunsong[1,2*], *Indah* Rachmatiah Siti Salami[1]

[1]Environmental Engineering Department, Bandung Institute of Technology, Jl. Ganeca Bandung, Indonesia
[2]Chemical Engineering Department, University of Surabaya, Jl. Raya Kalirungkut Surabaya, Indonesia

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 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.

* Corresponding author: tuani@staff.ubaya.ac.id

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 impostant 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.

https://doi.org/10.1051/e3sconf/202449503009

Table 1. Environmental Risk Assessment Landfill in Asia

No	Study Area	Baseline Data	Hazard Identification	Exposure Assessment	Risk Characterization & Management	Ref
1	Landfill in Vientiane, Laos	Site management	Concentrations of heavy metals (Cd, Cr, Cu, Pb, Zn, Ni) in water, soil, and plants in landfills and surrounding areas during the rainy and dry seasons	Concentrations of Cr, Cu, Pb, and in the edible plant *Ipomoea aquatica* (ingestion pathway)	HMs concentration exceeds WHO standard (except Ni) Monitoring of the surface water, groundwater, and soil quality. Government improves landfill system	[16]
2	Paddy rice field near landfill in Kambon village, Thailand	Topography and site management	Concentrations of heavy metals (Cd, Cr, Cu, Pb, Zn, Ni) in water, sediment, and plants of the landfill	Bio Accumulation Factor and potentially health risk of heavy metals in edible plants	Proper leachate management for municipal landfill	[19]
3	Bhalswa landfill, India	Geology and hydrology	Leachate characterization and groundwater quality (physicochemical properties). The concentrations of Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn in groundwater were determined	Water quality and hazard indices are used to assess potential risks to human health.	Construction of lined technical landfills and leachate collection ponds	[20]
4	Landfill of Chandigarh, SAS Nagar, and Panchkula, India	Geography and hydrology	The measurements of physicochemical parameter and heavy metals concentration of landfill leachate of three landfills during pre and post-monsoon	The Leachate Pollution Index (LPI) is determined to prevent water contamination	Provide the remedial measure to control soil and groundwater pollution	[21]
5	Landfill of Chandigarh, SAS Nagar, and Panchkula, India	Geology, topography, site management	The concentration of COD, BOD, pH value, and ammonia nitrogen in the leachate is determined. Measurement of Pb, Cu, and Zn in groundwater near the landfills	Hazard evaluated the health risk due to the consumption of leachate-effected water was evaluated by Hazard Quotient (HQ) and Hazard Index	Increased risk for residents living near Chandigarh's landfill site. It needs more attention	[22]
6	Landfill at Lahore, Pakistan	Geology, topography, site management,	Leachate and drinking water samples are measured based on physicochemical parameters.	Human risk assessment includes the Hazard Quotient (HQ), Cancer Risk Effect (CRE), and Potential Ecological Risk Index (PERI).	Landfills are classified as medium risk but may become a severe risk over time	[23]
7	Air Hitam landfill, Puchong and Ampar Tenang landfill, Sepang, Malaysia	Site management	Measurement of the concentrations of Cr, Mn, Fe, Cu, Cd, and Pb in soil, standing water, and leaves/grass	The contamination/pollution index (C/p) and its significance interval were analyzed, the Ecological Risk Index (RI) was utilized to assess water pollution. The enrichment factor (EF) was analyzed to determine the origin of metals within the plant.	Evaluation of pollutant indicators and geostatistical analysis of heavy metal contamination in closed landfills	[24]
8	Ampar Tenang landfill, Sungai Kembong landfill, Air Hitam landfill, and Kubang Badak landfill, Malaysia	Site management, geology	The concentration of ten heavy metals (Al, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, and Pb) in the soil at different depths and radii	The pattern of heavy metal concentrations at different radii and depths represents the movement of contaminants through soil layers and into groundwater.	Control of distribution and accumulation of heavy metals in different soil types	[25]
9	Eastern Guangdong Landfill	Site management	The As, Cd, Hg, Cr, and Pb concentrations in the eastern Guangdong landfill are measured and the solid waste characteristics are determined.	The health risks of household waste workers exposed to heavy metal landfills were assessed using a health risk assessment model.	Fundamentals of landfill management and scientific evaluation of the health protection of landfill workers	[26]

https://doi.org/10.1051/e3sconf/202449503009

No	Study Area	Baseline Data	Hazard Identification	Exposure Assessment	Risk Characterization & Management	Ref
10	Landfill at Khamees-Mushait, Saudi Arabia	Meteorology, geology, hydrology	Concentrations of Mn, Zn, Cr, Pb, Ni, Cu, and Co are measured in surface and deep soils and in the leaves of native plants.	The potential health risks of heavy metal exposure through chronic daily ingestion (CDI) are considered through three major exposure routes, including ingestion, dermal contact, and inhalation.	Ecological risks from exposure to other environmental influences. For example: people, animals, plants, dust, groundwater, etc around the landfill are recommended.	[27]
11	Ramna Landfill, India	Geology, topography, site management	Leachate and groundwater quality are determined. It includes physicochemical parameters and heavy metals before and after monsoon	Leachate Pollution Index (LPI) and Water Quality Index (WQI) are measured to assess the impact of leachate on the water quality of groundwater around open landfills.	The groundwater very close to the landfill is gradually changing from good to poor quality. Protecting groundwater from good water quality as vulnerable water	[28]
12	Two sanitary landfill sites in Central Macedonia, Greece	Site management	Leachate concentrations of COD and BOD, TKN, ammonia, nitrite, nitrate, phosphorus, heavy metals, conductivity and pH were recorded and evaluated	The Leachate Pollution Index (LPI) is used to quantify potential contamination levels from municipal landfills.	Leachate from landfills is not yet stabilized and therefore poses a high risk of contamination. Leachate quality should be monitored.	[29]
13	Landfill at Chiang Rak Noi City, Phra Nakhon Si Ayutthaya Province, Thailand	Site management, topography, hydrology, geology, meteorology	Mg, Fe, Mn, Cu, Zn, Cd, Ni, Pb, Co, Cr, Al, Bi, Li, and Ga were measured in soil samples.	Contamination Factor (CF) is used to assess the contamination level of metals in soil. To assess the overall pollution, the Pollutant Pollution Index (PLI) and the Global Accumulation Index (Igeo) were used. Health risks to humans are determined based on the overall cancer risk.	Policymakers should consider mitigating occupational accidents and provide personal protective equipment to farmers working in rice fields and workers working in landfills. Also, an educational campaign	[30]
14	Sungai Udang, Ladang Tanah Merah, Bukit Palong, Ulu Masoop, Pajam, Kampung Keru Landfill in Malaysia	Site management	As, Cd, Cu, Cr, Ni, Zn, Mn, Fe, Pb, Se, and Co are measured in leachate and soil. Leachate is measured by temperature, pH, electrical conductivity (EC), and total dissolved solids (TDS). Turbidity and dissolved oxygen (DO).	The impact of heavy metal pollution in soil was measured using the global accumulation index (Igeo), pollution index (PI), and integrated pollution index (IPI).	Reduce ongoing pollution and manage current and future waste management approaches.	[6]
15	Bhalaswa landfill site, India	Geography	Plant, soil, and groundwater are determined by Cu, Cd, Fe, and Ag concentration	Chronic daily intake (CDI) values for oral ingestion, dermal absorbed dose (DAD) values , and hazard quotient (THQ) for dermal exposure	Groundwater and soil at the landfill were found to be contaminated up to a distance of 500 meters from the landfill. Leachate infiltration and transport need to be controlled	[31]
16	The landfill is located in Guwahati, Assam, India.	Geography	Concentrations of copper (Cu), manganese (Mn), and zinc (Zn) in soil were determined	To evaluate heavy metal pollution in soil, pollution load index, percent enrichment (PE%) geographical accumulation index (Igeo), individual pollution factor (ICF), global pollution factor (GCF), and ecological hazard index is measured.	Future remediation strategies that can conserve and protect the environment around landfills	[32]
17	Landfills at Naqu, Nyingchi, Shigatse, Maizhokunggar, and Lhasa, Tibet	Geography	Concentrations of Pb, Zn, Cr, Ni, Se, Cd, As, Hg, and Cu in the soil around the landfill	Soil contamination risk is determined using Igeo, PI, PLI, and NWPI	Trace element contamination was found in the soil at the landfill. Ecological soil management is highly recommended. Soil remediation needs to be carried out	[33]

No	Study Area	Baseline Data	Hazard Identification	Exposure Assessment	Risk Characterization & Management	Ref
18	Saravan Landfill, Rasht, Iran	Topography, geology, meteorology	The concentrations of As, Pb, Cr, Cd, Cu, Hg, and Zn in soil near the landfill are estimated.	To assess metal pollution, the geoaccumulation index (Igeo), pollution factor (CF), enrichment factor (EF), and pollution load index (PLI) were determined. The ecological risk was estimated using the ecological risk factor (Eir) and potential ecological risk index (PERI).	The monitoring of metal contamination in plants since the downstream of the landfill is agriculture	[34]
19	Gunung Tugel Landfill, Banyumas	Topography, geography	Concentrations of Cu, Cr, Cd, Pb, Zn, Mn, and Fe in water, rice, and cooked rice.	Hazard Quotient and Excess Cancer Risk in adults and children are observed to describe the risk of heavy metal contamination	There is a potential to be symptoms of cancer in the people living near landfills Therefore, heavy metal pollution must be controlled	[35]
20	Kahrizak landfill, Tehran, Iran	Meteorology, topography, site management	Concentrations of As, Cr, Cd, Cu, Ni, Pb, Co, Zn, Mn, Al, and Fe were detected in the soil samples.	Soil contamination is assessed using Enrichment Factor and Ecological Risk Index. To assess health risks, HI, HQ, Cri, and ILCR are determined	There is a need to raise awareness, especially among children, about heavy metal contamination of soil in landfills and residential areas	[36]
21	Landfill at Ziyang City, Sichuan Province, China	Hydrogeology, meteorology, topography	Groundwater contaminated and non-contaminated by landfills are detected the concentrations of Cl, SO_4, Fe, NO_2, and NO_3. The others parameters are Na^+, K^+, Ca^{2+}, Mg^{2+}, Mn, Cd, Fe, Pb, As, Hg, Cu and Zn	This assessment focused on the carcinogenic and non-carcinogenic risks (HI, CDI, and TRo/total carcinogenic risk) posed by typical contaminants in groundwater downstream of landfills	Drinking water sources for residents near landfills should be replaced, and water sources, processes, and final management measures should be implemented to ensure the future safety of groundwater drinking water sources	[37]
22	Landfill near Ramsar site at Assam, India	Meteorology, geology, geography	Soil samples were analyzed for three heavy metals (HM): chromium (Cr), manganese (Mn), and zinc (Zn).	The Geo Accumulation Index (Igeo), Enrichment Factor (EF), Mobility Factor (MF), Pollution Load Index, Potential Ecological Risk Index (PERI), Individual Contamination Factor (ICF), and Global Contamination Factor (GCF) were quantified to evaluate soil pollution and ecological risks. HQ and CR are used to assess health risks.	Due to the high levels of heavy metal contamination in soil, there is an urgent need to adopt safe waste treatment approaches and reform existing waste treatment mechanisms and policies.	[38]
23	The landfill is located in Piyungan, Yogyakarta	Geology, hydrogeology	The concentrations of Pb, Cu, Zn and Cd in the soil of the landfill are evaluated.	For heavy metal soil pollution assessment, pollution index (PI), pollution load index (PLI), and ecological risk index (RI) were measured	It needs more attention for certain zone in agricultural purposes	[39]
24	Landfills in a region in Southern Lebanon	Site management,	Biological, chemical, and physical parameters of water and soil were examined. The parameters are TN, pH, COD, sulfate, Fe, Cr, Zn, Cu, and Mn in two-season	Heavy metal contamination was quantified using the Pollution Load Index (PLI), Ecologic Risk Factor (ER), Total Ecologic Risk (RI), and Geo-Accumulation Index. Water quality was assessed using the Water Quality Index (WQI)	There is an urgent need to develop monitoring and remediation plans to reduce leachate intrusion into water resources.	[40]
25	The landfill is located in Qingdao, Shandong Province, China	Meteorology, site management	The measurement of Cr, Pb, Cu, Zn, Ni, Cd, Hg, and As concentrations in soil	To assess heavy metals pollution, pollution index, geo-accumulation, and potential ecological risk index were estimated	Regular monitoring of soil quality around landfills is recommended to prevent further deterioration related to heavy metal contamination	[41]

https://doi.org/10.1051/e3sconf/202449503009

No	Study Area	Baseline Data	Hazard Identification	Exposure Assessment	Risk Characterization & Management	Ref
26	Landfill located in Lhasa, Tibet	Geography, site management, geology	The measurement of Cu, Pb, Zn, Cr, Ni, Cd, As, and Hg concentrations in soil	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. Carcinogenic risks (CRs) and hazard quotient (HQ) for health risk assessment.	Heavy metal concentrations in the soil around landfills in the Lhasa region were significantly affected by the activities. Therefore, more efficient environmental protection measures are urgently needed.	[42]
27	Landfill at Baglung Municipality of Nepal	Geography	The estimation of the concentrations of Zn, Cu, Pb, Ni, Cr, and Cd in the soil. Physicochemical parameters: pH, EC, TDS, water content, bulk density, nitrogen, phosphorus, and potassium of the landfill soil were analyzed	PER assessment is considered a relevant tool to assess the potential of heavy metal contamination in soil and estimate the extent of the impact caused by pollutants in the environment.	Local governments are encouraged to separate heavy metal-related products at the source of solid waste before final disposal.	[43]
28	Landfill in Lopburi Province, Thailand Central Region	Geography, site management, meteorology	The concentration of Pb, Ni, Cd, Mn, Fe, Cr, and Al in groundwater and soil are assessed	Pollution degree (ER), pollution degree (ER), risk index (RI), hazard index (HI), Carcinogenic risk by oral (CR oral), lifetime carcinogenic risk (LCR), and WQI in groundwater on all sides of landfill is determined	Reduce health risks by continuously monitoring groundwater, soil and leachate treatment processes	[44]
29	Landfill in Khestht City, Iran	Meteorology, geography, geology	Heavy metal concentrations (Cu, Co, Ni, Cd, Zn, and Pb) were measured in soil samples from the study area	For ecological risk, Geo- Accumulation Index (Igeo) and Contamination Factor (CF), as well as the Pollution Load Index (PLI) were quantified. ADD, HQ, and CR were estimated for health risk assessment.	Heavy metals pollution control and human health risk assessment management at Khestht Landfill	[45]
30	Landfills in Peninsular Malaysia	Site management, geography	The concentrations of Cd, Pb, Ni, Cu, and Zn in the topsoils are estimated	Igeo, CF, PLI, ER, and PERI values were used to assess ecological risk. Hazard quotient (HQ), carcinogenic risks (CR), and hazard index (HI) were determined for health risk assessment	Protecting human health and well-being requires continuous risk assessment of metals potentially harmful to human health in different land uses.	[46]

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

1. T. E Butt, E. Lockley,& K. O. K Oduyemi, . Waste Management, 28(6), 952–964. doi:10.1016/ j.wasman .2007.05.012 (2008)
2. T. E Butt & K. O. K Oduyemi Risk Analysis II (WIT Press, 2000)
3. D Adamcova, M. D Vaverkova, S. Barton, Z. Havlicek, E. Brouskova. Solid Earth. 7:239–247. 10.5194/se-7-239-2016 (2016)
4. Y, Chen, H. Xie,C. Zhang, C. 2016 Adv. Sci. Technol. Water Resour., 36, 1–10.(2016)
5. S.R. Samadder, R. Prabhakar, D, Khan, D. Kishan M.S Chauhan, Sci. Total Environ. 80, 593–601 (2017)
6. M. Hussein, K. Yoneda, Z. Mohd-Zaki, A. Amir, N. Othman, Chemosphere 267, 1–19 (2021)
7. E. Koda, A. Miszkowska, A. Sieczka, P. Osinski, Environ. Geotech.. 7, 512–5 (2020)
8. V. R Propp, A.O De Silva, C. Spencer, S.J Brown, S.D. Catingan,J. E Smith, J. W Roy, Environ. Pollut. 276, 12 (2021)
9. K. Wang, F. Reguyal, T. Zhuang, Environ. Sci. Pollut. Res.28, 18368–18381 (2021)
10. R. Nagarajan, S. Thirumalaisamy, E. Lakshumanan. Iranian Journal of Environmental Health Science & Engineering, 9(1), 35 (2012).
11. T. E Butt, A.A Javadi,M. A Nunns, & C. D Beal, Science of The Total Environment, 569-570, 815–829. doi:10.1016/j.scitotenv.2016.04.152 (2016)
12. T. E.Olagunju, A.O. Olagunju, I.H Akawu, and C.U Ugokwe. Journal of Toxicology and Risk

Assessment 6(1) DOI: 10.23937/2572-4061.1510033 (2020)
13. O.P Njoku, J.N Edokpayi, and J.O Odiyo. J. Environ. Res. Public Health, 16, 2125; doi:10.3390/ijerph16122125 (2019
14. T.A. Laniyan and A. J. Adewumi Journal of Health & Pollution 9(24) 1-16 (2019)
15. A. Limoli, E. Garzia, A. De Pretto,C. De Muri. Environ Forensic 20:26–38 doi:10.1080/15275922.2019.1566291 (2019)
16. N. Vongdala, H. D Tran, T.D Tran Dang Xuan , R. Teschke, and T.D. Khanh Int. J. Environ. Res. Public Health 2 16, 22; doi:10.3390/ijerph16010022 (2018)
17. Widyarsana, I M W, Damanhuri E, Agustina E, Nur Aulia R N,(2019), Risk Assessment and Rehabilition Potential of Municipal Solid Waste Landfills in Bali Province, Indonesia, *International Journal of GEOMATE*, 17 (63).164 - 171 DOI: https://doi.org/10.21660/2019.63.39057
18. W. Yang,B. Fan, K. C. Desouza. Journal of Cleaner Production 227. 313-324, https://doi.org/10.1016/j.jclepro.2019.04.173. (2019)
19. P Rucuwararak, S. Intamat S, B. Tengjaroenkul, and L.Neeratanaphan. Human And Ecological Risk Assessment https://doi.org/10.1080/ 10807039.2018.1473755 (2018)
20. A. Ahamad, N.J Raju, S. Madhav, W. Gossel, & P Wycisk,.QuaternaryInternational. doi:10.1016/j.quaint.2018.06.011 (2018)
21. S. Mor, P. Negi, K. Ravindra. Environmental Nanotechnology, Monitoring & Management, 10: 467–476 (2018).
22. P. Negi , S. Mor, & K. Ravindra, Environment, Development and Sustainability doi:10.1007/s10668-018-0257-1 (2018)
23. A. Iqbal, A, B Tabinda, A. Yasar Human and Ecological Risk Assessment: An International Journal, DOI: 10.1080/10807039.2019.1706152 (2019)
24. A. Bakar, A. Minoru, M. Yoneda, N. T. Thuong, and N. Z Mahmood International Journal of GEOMATE 17(60): 136-143, DOI: https://doi.org/10.21660/2019.60.8234 (2019)
25. R. Othman, N. H Mohd Latiff, Z. M Baharuddin, K S H Y Hashim, L. H Lukman Hakim Mahamod, Applied Ecology, and Environmental Research 17(4):8059-8067. DOI: http://dx.doi.org/10.15666/aeer/1704_80598067 (2019)
26. Z. Tang, M. Liu, L. Yi, H. Guo, T. Ouyang, H. Yin, & M. Li, Applied Sciences, 9(22), 4755. doi:10.3390/app9224755. (2019)
27. I. H. Ali, S. M. Siddeeg, A.M. Idris, E. I Brima, K. A. Ibrahim, S.A.M Ebraheem, & M. Arshad, Toxin Reviews, 1–*14.* doi:10.1080/15569543.2018.156414 (2019)
28. S. Mishra, D. Tiwary, A. Ohri & A. K Agnihotri, Groundwater for Sustainable Development, 100230. doi:10.1016/j.gsd.2019.100230 (2019)
29. A. Koumalas, A, Dounavis, E. M. Barampouti, S. Mai. Journal of Environmental Research Engineering and Management. 75(4). 30-39. http://dx.doi.org/10.5755/j01.erem.75.4.23073 (2019)
30. S. Thongyuan, T. Khantamoon, P. Aendo, A. Binot, and P. Tulayakul Human and Ecological Risk Assessment: An International Journal, DOI: 10.1080/10807039.2020.1786666 (2020)
31. P. Johar, D. Singh, &A. Kumar, Environmental Monitoring and Assessment, 192(6). doi:10.1007/s10661-020-08315-0 (2020)
32. P. Borah, N. Gujre, E. R. Rene, L. Rangan, R. K. Paul, T. Karak,& S. Mitra, Chemosphere, 126852. doi:10.1016/j.chemosphere.2020.12 (2020)
33. X. Wang, Z. Dan, X. Cui, R. Zhang, S. Zhou,T. Wenga, … L. Zhong, . Science of The Total Environment, 136639. doi:10.1016/j.scitotenv.2020.1366 (2020)
34. M. Sadeghi Poor Sheijany, F. Shariati,N. Yaghmaeian Mahabadi, & H. Karimzadegan, *Environmental Monitoring and Assessment, 192(12).* doi:10.1007/s10661-020-08716-1 (2020)
35. F. M. Iresha, S Rahmawati, D. Wacano D. , Kasam, R. K. Sari, M. Yoneda International Journal of GEOMATE 20(80): 36-44, DOI: https://doi.org/10.21660/2021.80.6241 (2021)
36. S. Karimian, S. Shekoohiyan, and G. Moussavi. RSC Advances.,11: 8080–8095 DOI: 10.1039/d0ra08833a (2021)
37. F. Wang, K. Song, X. He,,Y. Peng, D. Liu, and J. Liu. Int. J. Environ. Res. Public Health, 18, 7690. https://doi.org/10.3390/ijerph18147690 (2021)
38. N. Gujre, S. Mitra, A. Soni,R. Agnihotri, L. Rangan,E.R Rene, & M. P. Sharma, Chemosphere, 128013. doi:10.1016/j.chemosphere.2020.1 (2021)
39. M. Muyassar and W. Budianta. Journal of Applied Geology. 6(2).128-135 DOI: http://dx.doi.org/10.22146/jag.65651 (2021)
40. G. Soubra, M. A. Massoud, I. Alameddine, M. Al Hindi, and C. Sukhn. Environ Monit Assess. 193:857 https://doi.org/10.1007/s10661-021-09640-8 (2021)
41. H. Liu, Y. Wang, J. Dong, L. Cao, L. Yu, J. Xin, Archives of Environmental Contamination and Toxicology, 81(1), 77–90. doi:10.1007/s00244-021-00857-9 (2021)
42. P. Zhou, D. Zeng,X. Wang, L. Tai, W. Zhou, Q. Zhuoma, and F. Lin, Int. J. Environ. Res. Public Health 19, 10704. https:// oi.org/10.3390/ijerph191710704 (2022)
43. T. Regmi, M. Ghimire, and S, M Shrestha. Environmental Challenges. https://doi.org/10.1016/j.envc.2022.100564 (2022)

44. P. Aendo, R. Netvichian, P. Thiendedsakul, S. Khaodhiar, and P. Tulayakul. Journal of Environmental & Public Health. https://doi.org/10.1155/2022/3062215 (2022)
45. A. Rouhani, B. Bradák, M. Makki, B. Ashtiani, M. Hejcman, Arabian Journal of Geosciences. 15:1523 https://doi.org/10.1007/s12517-022-10792-1 (2022)
46. C, L Yap, W. Chew, K. A. Al-Mutairi, R. Nulit, M. H. Ibrahim, K. W. Wong, A. R. Bakhtiari, M. Sharifinia, M. S. Ismail, W. J.; Leong, et al. Biology 11, 2. https:// doi.org/10.3390/biology11010002 (2022)