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Groundwater Contamination by Leachate from Landfill and Open Dumpsite of Solid Waste: A Review

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Abstract

This research attempts to review most of the studies of groundwater contamination near landfills, mainly arising from un-engineered landfills or open dumps overseas, and its influence on human health. Leachate water from landfills contains various types of municipal toxic wastes as well as heavy metals, which eventually seep into the ground and infiltrate the groundwater table. Consumption of such water causes severe health risks and can occasionally be lethal if consumed over lengthy periods of time. Several investigations have demonstrated indications of significant quantities of heavy metals in both leachate water and surrounding groundwater sources. In addition, the environmental impacts of leachate on groundwater quality are critically analyzed, focusing on the Leachate Pollution Index (LPI) and the Canadian Water Quality Index (CCME WQI) as tools for assessing contamination levels. Finally, It is recommended that all open waste dumps be removed and engineered waste dumps be established in accordance with approved environmental specifications. Furthermore, the generated leachate should be collected by constructing wells from which the leachate should be diverted to a basin (with a suitable lining system) for treatment.

Keywords: Landfill, Leachate, LPI, CCME WQI, Solid Waste, Groundwater, Environmental impacts.

1. Introduction

Globally, the urban, municipal, and industrial sectors generate significant quantities of waste. This occurs mostly in developing countries, which commonly use landfilling and open dumping as common final methods of municipal solid waste disposal. These methods usually involve collecting municipal solid waste and finally transporting it to a disposal site, as reported by Glawe et al. (2005)[1].

Nowadays, many of these wastes find their way into the environment with minimal or no treatment at all [2].

The most serious problem results from rainwater or waste liquids seeping through the garbage, carrying harmful bacteria and dangerous chemicals from nearby dumps into groundwater, lakes, and streams. Polluted runoff is called leachate, consisting of water and water-soluble composites in waste that migrate from landfills and polluted soil and groundwater, posing a risk to human health as well as ecosystems[3].

Since the early 1970s, numerous cases of groundwater contamination by leachate from waste dumps have been recorded[4]. As a result of these problems, open dumping has been banned in many developed countries, but in developing countries, it is still used. However, efforts have been made to improve and upgrade open dumps.

2. Main Types of Solid Waste

Based on their origin, as identified in Table 1, solid waste may be classified into several categories[5].

2.1 Solid waste in cities

The solid waste from urban areas includes household waste, building waste, healthcare waste, demolition debris, and waste from highways. The majority of this garbage, on the other hand, is generated by settlements and commercial complexes. Since the beginning of urban expansion as well as the revolution in lifestyles and eating habits, the amount of municipal solid garbage generated has increased at an alarming rate, and the content of municipal solid waste has changed substantially as a result of these developments[6].

2.2 Hazardous waste

Industrial and hospital waste often contain toxic compounds, and household waste may also be hazardous. Waste can poison humans, animals, and plants. Household hazardous waste includes car batteries, shoe polish, medical instruments, paint, and medical devices. Harmful healthcare waste includes disinfectants and thermometers that contain formaldehyde, phenols, and mercury. Major polluters include the chemical, metallurgical, pesticide, paper, dyeing, plastic, and refining industries, along with food and beverage producers[7].

2.3 Hospital waste

Hospitals generate waste during human and animal diagnosis, treatment, injection, exploration, and laboratory testing. The waste stream includes cultured medical waste, dry waste, disposables, sharp tools, anatomical waste, chemicals, and abandoned medications. Environmental waste includes droppings, swabs, bodily fluids, bandages, and syringes. These diseases can be dangerous if not properly managed [8].

Table 1: The sources and types of solid waste issued by a community[9].

N.	Waste Source	Typical active places from which waste is issued	Solid Waste Types
1	Residential	multi-family, single-family,low, medium, and high-rise apartments.	barn waste, Food waste, cardboard, textiles, plastics, glass, paper, tin cans, aluminum, and other metals, specialwaste (including large items, electronics, separately collected batteries,oil, and rubber), household hazardous waste
2	Commercial	Restaurants, motels, markets, offices, hotels, printing houses, Shops, refueling, etc.	metal, glass, plastic, wood, food waste, cardboard, paper, waste special (includingbulky items, consumer electronics, barn waste, batteries,oil, rubber tires), hazardous waste, etc.
3	demolition and construction	road repair areas and new sites construction /places of demolition and repair of buildings, broken sidewalks	dust, cement, iron, Wood, etc.
4	Municipal services	Gardens, landslides, street cleaning, beaches, and placesof recreation	Tree felling, street sweeping, private waste, large boulder gathering places, andpublic waste from beaches and parks
5	Wastewater Treatment	Industrial treatment processes, wastewater,	Sludge

6	Agricultural	Dairy factories, fields, and Farms	Hazardous waste, food and agricultural Waste
7	Industrial	Refining plants, heavy and light industries, power plants and construction	Construction waste, scrap waste, dirt, hazardous waste and industrial process Waste

3. Solid Waste Composition

Municipal Solid Waste (MSW) is discarded materials in urban areas; it involves mostly some household waste, food waste, pieces of paper, wood, and some commercial wastes, the waste collected and disposed of by the municipalities. Waste varies in its composition based on dwelling structure, weather, time, habits of consumption, and other characteristics. Moreover, it differs from residence to residence, region to region, and even within the same residence. It may differ from week to week. Consequently, waste management solutions should be location-specific. In countries with low or middle incomes, organic waste comprises a significant portion of urban waste, whereas in countries with high incomes, inorganic materials such as paper, plastics, glass, etc. constitute a large proportion of solid waste[10]. Globally, organic waste is the largest share of world's MSW, which is 44%, followed by paper and cardboard 17%, plastic 12%, glass 5%, metal 4%, wood 2%, rubber and leather 2% and other 14%[11].

4. Solid Waste Generation Rate

Generation is defined as the quantity of MSW (substances and products) that enter the waste stream before any materials recovery, decomposition, or incineration. Recovery is the extraction of recyclable or compostable materials from the stream of waste[12]. Discards refer to the residual solid waste following recovery. The discards are typically burned or buried; however, they could be littered, stored, or disposed of on-site, particularly in rural areas[13]. MSW is a heterogeneous material due to its diverse sizes, shapes, and chemical constituents. Production rates and composition differ from location to location and season to season. The majority of previous studies have measured the amount of municipal solid waste at transfer stations and landfills [14]. Other studies, however, such as [15] and [16], have performed their surveys at the actual point of generation for the reasons given below:

1. During solid waste storage, collection, and transportation, climatic conditions affect waste properties. Therefore, sampling at the actual source of generation will provide more accurate data than results based on sampling at transfer stations or landfills, which are supposed to represent the true properties of the waste.
2. In order to evaluate the impact of socioeconomic status on municipal solid waste generation and composition, it would be impossible to determine socio-economic levels if samples were collected at transfer stations or landfill sites. Therefore, it is required to conduct a statistically planned sample survey in order to properly estimate the average amounts and composition of waste due to the heterogeneity, variability, the influence of meteorological conditions, and socio-economic level. Iraq, a middle-income country, generates roughly 0.35-0.65 kg of solid waste per capita per day. In Al-Diwaniyah city was assessed directly at the generating source by collecting the MSW from each residence, weighing it and repeating this process at different intervals, The generation rate is about 0.95 kg/day per capita [17]. Fig.1 shows quantity of solid waste in Al-Diwaniyah city[17].

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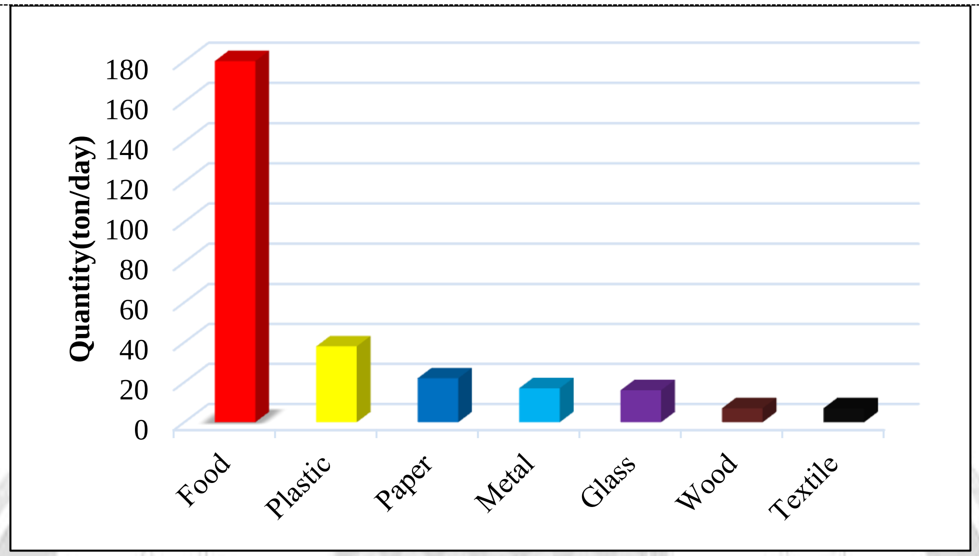

Fig. 1: Average Quantity of the components of SW in Al-Diwaniyah[17].

5. Landfilling of solid waste

Landfilling is historically one of the most popular ways to get rid of waste historically, as it has been during the past decades it has remained one of the main methods for disposing of municipal solid waste in most countries. Since the landfill is a site for collecting and accumulation of waste, it can become a significant source of environmental pollution if it is not implemented and operated in a scientific and planned manner.. For these reasons, attention has been paid to developing landfill sites and converting them from simple and random sites into integrated engineering systems (sanitary landfill sites), as is developed countries and some developing countries to properly contain pollutants [18]. Landfill sites is a biological reactor in which waste decomposes in aerobic and anaerobic conditions, and the outputs are gas and leachate[19]. The rate of waste decomposition increases when its moisture increases, as water (whether it comes from rainwater entering the waste or the moisture content of the waste itself) plays an active role in this decomposition, as it works to transfer the materials resulting from decomposition from inside the waste to outside in the form of polluted leachate[20]. Therefore, it is always recommended that it be implemented in areas far from population centers, especially if it is primitive and does not contain a system for treating pollutants, gaseous or liquid emitted from it[21].

6. Landfill leachate

Landfill leachate is one of the main contamination problems generated by rainwater leaks, the water content of wastes themselves, infiltration of groundwater through the landfill, and biochemical processes. Even after a landfill is closed, the waste may continue to create polluted leachate for 30 to 50 years [22]. The leachates and biogas, especially methane, represent about 50% of the organic part of the waste and result from the decomposition process[23]. They usually consist of massive amounts of organic matter, heavy metals, ammonium, inorganic salts, and chlorinated organic compounds, all of which are hazardous to the soil and water environment surrounding the landfill site. In Iraq, municipal solid waste density is 0.45 ton/m3[14]. Table 2 exhibits the general parameters of concentrations. Moreover, many cases have demonstrated the impact of seasonal fluctuation on the composition of leachate[24].

Table 2: Average concentration of leachate components for 80 burial sites[24].

Parameter	Units	Range
COD	mg/l	150- 152000
BOD_5	mg/l	100- 90000
pH	-value-	5.1- 8.5
Alkalinity as CaCO3	mg/l	300- 16000
Hardness as CaCO3	mg/l	500- 8900
Cl(Chloride)	mg/l	30-5000
EC (Conductivity)	µmohs	38-5200
NH4(Ionized Ammonia)	mg/l	1-4110
NO_3(Nitrate)	mg/l	0.1- 50
PO_4(Phosphate)	mg/l	0.3-25
Ca(Calcium)	mg/l	10-6250
Mg(Magnesium)	mg/l	25-1150
Na(Sodium)	mg/l	50-4000
K(Potassium)	mg/l	10-3100
SO4(Sulphate)	mg/l	0-1600

6.1 Leachate Generation

Leachate is produced when liquid percolates via waste, with waste's chemical composition and biochemical operations playing an important role in its formation. These liquids get tainted when they move through the waste as they come into contact with harmful microorganisms and pick up solutes and suspended solids from the waste [25]. Leachate pollution level is affected by the waste type it passes through and the degree to which that waste has been biodegraded. Leachate contains toxic substances that harm human health and marine life, especially those resulting from the biological decomposition of organic waste such as alkaline nitrogen and chlorinated natural and inorganic salts[26].

The formation of leachate is significantly influenced by weather conditions such as precipitation (rain and snow)[27]. With increased rainfall through the wet season, leachate levels rise[28]. Furthermore, surface spillage inside the landfill itself, as well as groundwater penetration if the landfill is built in a region with a relatively high groundwater level, may affect leachate quantities.

Aside from atmospheric conditions, water content and compaction level may have an impact on leachate generation. Less compaction can result in more leachate quantity because of the decreased infiltration rate[29]. As water moves via waste, it gathers contaminants in specific ways. Contaminants might be absorbed into the water through dissolution or suspension[30]. Because bioactivity degrades and decomposes organic waste materials, metabolic compounds and by-products can be absorbed. In addition, in 1999, Li et al.[31] observed that these by-products can result in dissolution of metals due to a decreased pH.

6.2 Leachate composition

Several factors influence leachate composition, including the age of the landfill, its location, and type of waste stored. As a result, generalizations can be drawn about typical waste and leachate, and each case must be treated individually[32].

Recent studies have indicated that leachate from landfills contains a higher toxic load than the untreated wastewater.

Christensen et al.[25] established a biochemical rundown of leachate columns produced by waste masses in cities, corporations, and industries. Several xenobiotic organic compounds have been found to be degradable in leachate contaminated groundwater, but degradation rates under anaerobic redox conditions have only been determined in a few cases.

According to Koda et al.[33] four categories of pollutants are likely to be present in landfill leachate are:(solved organic matter, inorganic macro components, heavy metals, and xenobiotic organic compounds).

COD, BOD, and TOC are analytical metrics used to quantify the organic content of leachate. Organic carbon and inorganic elements that dissolve in water include calcium, magnesium, sodium, potassium, alkalinity, iron, manganese, chloride, sulfate, and bicarbonate[34].

The amount of these components varies greatly from waste to landfill, with average sulfate concentrations ranging from 8 to 7750 mg/L, iron from 3 to 5500 mg/L, chloride from 150 to 4500 mg/L, and arsenic from 0.01 to 1 mg/L [34].

Table 3 illustrates the general characteristics of leachate in relation to age and its suitability for biodegradation, intermediate, and stabilized landfill leachate. At the beginning of leachate generation (in the acidification phase) pH is low as a result of the production of organic acids. Low pH increases the solubility of metals in leachate. As landfill age increases, pH increases, and the solubility of metals in leachate decreases which causes the decrease of metal concentration in leachate over time, with the exception of lead, which is a very stable complex with humic acids. [35].

Table 3: Relationships among treatment, leachate properties, and landfill age[35].

Landfill Age	**Parameter** / **Leachate Type**	pH	COD	BOD_5/COD	COD/TOC	VFA (% TOC)
< 5 (young)	**I(Biodegradable)**	< 6.5	> 10,000	< 0.5	< 2.7	> 70
5 to 10	**II (Intermediate)**	6.5 - 7.5	< 10,000	0.1 - 0.5	2.0 - 2.7	5 – 30
10 > 10 (old)	**III (Stabilized)**	> 7.5	< 5000	< 0.1	> 2.0	< 5

All parameters without unit except COD in mg/l

6.3 Leachate Migration

Leachate migration is affected by the manner in which waste is stored. The layering of waste and topsoil at the landfill site can create leachate streamlines as the permeability of the compressed waste decreases [36]. Christensen et al.[25] revealed that the length of time that rainwater can stay in a landfill site ranges from a few days to many years. This is reflected in the temporary nature of leachate springs, which appear during rainy seasons and disappear during drier ones, leaving behind tainted soil. As a result, assessments of leachate generation must concentrate on periods near the conclusion of rainy seasons or following heavy precipitation.

Hydrodynamic dispersion and advection are the primary mechanisms that govern the migration of leachate from landfills through groundwater till the surface water arrives. Hydrodynamic dispersion can be defined as the transmission of leachate as a result of varied pathways and turbulent mixing. This mechanism is influenced by the physical properties of the porous medium (such as porosity and hydraulic conductivity). These properties have led to the determination of the penetration depth of the leachate, and thus the velocity of solute column diffusion[31]. Likewise, advection is the movement of dissolved contaminants with flowing groundwater, so the direction of advection will be related to the water's streamlines[37].

In addition to the aforementioned mechanisms, Reinhard et al. [36], in 1984, identified sorption as one of the fate mechanisms responsible for the retardation of contaminants. It may occur on medium-sized particulates from which contaminants can be eliminated using hydrophobic holding and Van der Waals forces[29]. Mathematically, sorption can be expressed as equilibrium sorption isotherm models or non-equilibrium dynamic sorption models[25].

7. Biodegradation Phases of MSW in Landfill

Decomposition in landfills can be enhanced when there is sufficient moisture seepage to facilitate decomposition over a period of 20 to 50 years.

However, landfills may persist in the acidic stage or early stage of production of methane for a long time, if they are located in arid regions with little infiltration and desiccated waste.

Once the majority of biodegradable organic waste decomposes, the rate of decomposition will be greatly affected by the surrounding environmental conditions, especially (moisture content) which is found to be the most effective factor affecting the decomposition rate of organic matter, and thus the time required for decomposition to reach the stage of methane production will be reduced to almost zero[38].

It is generally accepted that waste (mixed organic and inorganic waste) buried in dry climates decomposes more slowly than waste buried in regions with greater than 50 to 100 cm of annual infiltration [24], [39].

There are several phases that leachate passes through the landfill starting from disposing of waste, and these phases are[40]:

1. **The Phase of Initial Adjustment:** This phase begins immediately after waste disposal and initial moisture accumulation in the landfill. The moisture promotes the development of an active microbial community.
2. **The Phase of Oxygen Depletion or Transition Phase:** where the waste transfers from aerobic to an anaerobic environment. Total volatile acids (TVA) and chemical oxygen demand (COD) appear in the leachate at the end of this phase.
3. **The Phase of Forming Acid:** The continuous solubilization to the mass of waste followed the microbial transformation of biodegradable organic content, the maximization of both COD and TVA in leachate.
4. **The Phase of Fermentation Methane:** Throughout this phase, acids are consumed and converted to methane and carbon dioxide. Complexation and precipitation remove heavy metals from the leachate.
5. **The Phase of Maturation or The Final Phase:** during this phase, the biological activity is decreased with decreasing the production of gas. The concentration of leachate is lower than in all other Phases.

Fig. 2 illustrates the five phases of stabilization for the landfill.

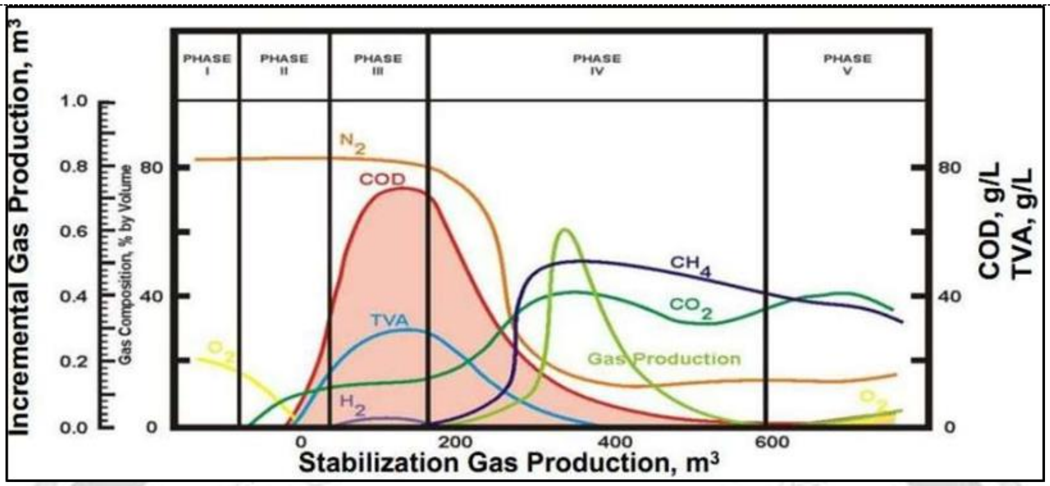

Fig. 2: Exposes landfill generalized phases showing gases and leachate parameters variation within phases[41].

The complete stability of solid waste dumps is contingent upon a number of elements, including the environment's chemical, physical, and biological composition, age, the type of waste that is dumped there, the operational and managerial controls in place, and the environmental circumstances unique to each site.

8. Environmental Impacts of Leachate on Groundwater

The generation of leachate and its effects on groundwater are of particular concern when investigating existing municipal landfills. Large volumes of groundwater can become unfit for residential and other uses due to contamination from small amounts of landfill waste[42]. In 1998 Mikac et al.[43] described a number of instances of groundwater contamination by unprotected landfills in Zagreb (Croatia), A relatively narrow non-continuous iron-reducing zone was found along the edge of the landfill in the prevailing directions of the groundwater flow. Even after a distance of 1200 m the redox conditions in the aquifer still remained anaerobic (nitrate-reducing), while a permanently aerobic zone was present only upstream from the landfill.

Legal or illegal dump sites and landfills can be sources of groundwater pollution if identified by permeable rocks and soils. Rainwater seeps in from above and dissolves additional soluble chemicals from the waste, exacerbating the problem. Leachate poses a significant hazard to groundwater because it contains multiple contaminants that may be difficult to eliminate or remediate[42]. Gravity leads to leachate travelling via a landfill and the soil beneath it until it reaches an aquifer, as shown in Fig. 3. Leachate combines with groundwater stored in soil voids as it descends to the subsurface, and this mixture follows the groundwater's flow route as a polluted groundwater plume. Leachate pollutants first infiltrate the unsaturated zone before eventually reaching the groundwater table of the saturated zone. The most important evidence of leachate migration through the subsurface groundwater aquifer beneath the landfill is the rise in the concentration of inorganic elements, which poses a risk to groundwater quality[42].

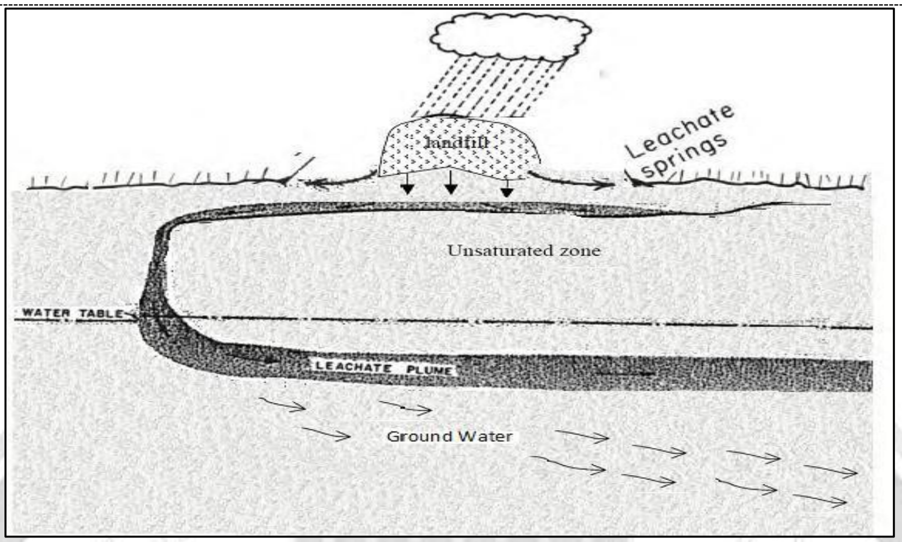

Fig. 3: Generalized movements of leachate plume[44].

9. Literature Review

The effect of the leachate on the groundwater was investigated by several studies in the literature.

To create a database for Kirkuk landfill and evaluate the effect of leachate on groundwater resources, in 2015 Awaz [45] examined samples of leachate from the pre-treatment basin, post-treatment basin, and leachate pond for their physicochemical properties. Two nearby monitoring wells were also analyzed in the same way. The results revealed that the main examined parameters in the monitoring wells samples exceeded the acceptable limits of WHO standards concerning drinking water, and the analytical results of leachate samples demonstrated that Kirkuk landfill was in the early acidic biodegradation stage. Pre-treatment leachate samples had a high Leachate Pollution Index (LPI) value, which highlights the role of leachate treatment in reducing pollution.

In order to determine the groundwater quality under the effect of a dumpsite near Sangamner city, in 2016 Deshmukh and Aher[46] used WQI and then integrated and interpolated its data in GIS software using the IDW approach. Groundwater samples around the dumping yard were collected and analyzed by Physicochemical characteristics along with heavy metals. Likewise, SAR, SSP,RSC and KRs were also determined to evaluate its suitability for irrigation. on one hand, results revealed that the groundwater around the dumpsite was Invalid for drinking and domestic purposes according to WQI/BIS standards and on the other hand, it was suitable for irrigation.

Al-Suraifi (2017)[47] in his study to evaluate the groundwater quality and leachate pollutants transport from Al-Rafdhia landfill site in al-Basra city using a 3-dimensional simulation model through Visual MODFLOW software to simulate pollutants transport during the current year and to predict changes in water levels and contaminant transport for 15 future years. Many soils and water samples were collected to know the aquifer characteristics and analyze the pollutants concentration values during a six-month observation period. According to the final simulation and prediction results, the landfill is the primary source of contamination. If the current solid waste disposal situation continues, with an increase in pumping from the aquifer from its current rate in the future, the pollution would occur in the aquifer at high levels and with an approximate lateral transporting of 285 m/year.

Mishra et al. (2018)[48] focused their attention on the groundwater quality and leachate pollution near unsanitary landfills in Varanasi City. The results demonstrated that EC, No3, hardness, TDS, and Fe contents exceeded drinking water quality standards in all periods, also high pollutants level in leachate was revealed through LPI value. Spatial maps of WQI by GIS showed that the majority of the areas had excellent water quality before the monsoon and middling water quality afterwards.

Thirteen samples of groundwater and leachate were taken by (Vahabian, et al.[32] during (2014–2016) period to analyze groundwater quality and leachate from landfill in Iran (Hamedan) to assess the environmental influences of waste landfills, and in order to determine the landfill role in groundwater contamination, a statistical approach incorporating leachate age and distance from the pollutant source was developed. This method revealed a direct correlation between groundwater quality parameters and leachate physicochemical properties. The results confirmed that the high variability in pollutant concentration is associated with the age of the leachate and that the leachate is both biodegradable and unstable.

In Hyderabad, India,2020 Kamble et al.[49] assessed the impact of MSW dumpsite on groundwater. Samples of leachate and groundwater were collected to analyze for many characteristics. Also, WQI, HEI, and Cd were calculated for groundwater samples. On one hand, the result revealed that leachate was extremely contaminated with both organic and inorganic salts and the dumpsite was old and stabilized. On the other hand, about 75% of the water samples were poor according to WQI Similarly, the majority of groundwater was low metal pollution as appeared from HEI and Cd results. Spatial distribution through GIS software revealed high concentrations of various parameters due to raised solid waste degradation during rainfall.

Alghamdi et al. (2021)[50] investigated potential environmental risks from MSW landfill leachate in AlMadinah City, Saudi Arabia. Three leachate samples, fifty-four groundwater samples, and forty-four samples from surface soil were collected for analysis of physicochemical characteristics and toxic metals. It's concluded that 59.3 percent of water samples were identified to be unsuitable for irrigation. Similarly, a significant percentage of the groundwater samples were unfit for human consumption. EF revealed severe contamination of the soil with Mo, high Cd and notable soil contamination with Pb, Zn, and Co, moderate soil contamination with Cu and Ni, and minimal soil contamination with Cr and Mn.

Hammash and Abed (2022)[51] studied the environmental impact of the landfill in the south of the city of Baiji on the surrounding ecosystem using pollution indicators. The concentrations of heavy metals were analyzed in samples from groundwater, surface water and wastewater. The results in the study area showed that wastewater samples were highly polluted, Tigris River water samples were in the medium pollution category and the groundwater varied from medium to low pollution. Generally, ground and surface water varied in their suitability for consumption, from medium to acceptable.

Farzaneh et al. (2022)[52] assessed the impact of landfill leachate in Tehran Province, Iran on groundwater quality. LPI and WQI were calculated for leachate and groundwater, respectively. Groundwater quality map developed by ArcGIS software which exhibited high pollution of groundwater and deterioration of water quality in landfill sites. In addition, most parts of the study area displayed extremely poor water quality. LPI indicated that leachate from active site was less contaminated than that of the closed cell. It was concluded through the application of Geostatistical interpolation methods on groundwater quality parameters that cokriging is more accurate than kriging.

In 2023 Yahooa and Mawlood [53] examined the groundwater quality near a dumpsite in Erbil central basin as a result of the impact of a landfill on groundwater. The static water level was assessed to examine groundwater movement direction using Surfer software version (16) as well as pollutant movement was represented using the GIS software (10.6.1). The analysis covered the physical and chemical parameters of groundwater in addition to heavy metals. The results showed a riser effecting of landfill appears in groundwater that flows toward the Greater Zab River as many wells experience high contamination.

In 2025 Jalal and Darwesh [54] focused on assessing the effect of solid waste on the groundwater quality in and around Erbil's landfills by analyzing samples from leachate and groundwater over the period from 2021 to 2022 covering both dry and wet seasons. The selected samples were investigated by several physicochemical parameters and heavy metals. measuring of groundwater quality in the research region was done using CCME WQI model and IDW approach in ArcGIS software. According to the CCME WQI, most wells were in the poor category through both seasons except wells 4 and 8 had WQIs ranging from fair to marginal (WQI). According to the resulting data, groundwater was unfit for human use and in some sites was suitable for irrigation.

10. Conclusion

This research discusses the generation of large wastes and their impact on groundwater, particularly in developing countries where unengineered open landfills lacking leachate drainage channels are commonly used. It highlights the environmental hazards posed by leachate, toxic runoff from waste that contaminates groundwater and ecosystems.

Furthermore, this research discussed the details of landfill operations and types, including sanitary landfills and those designated for industrial and construction waste. It explains the formation and migration of leachate, its composition, and the phases of biodegradation of waste in landfills. The environmental impacts of leachate on groundwater quality are critically analyzed, focusing on the Leachate Pollution Index (LPI) and the Canadian Water Quality Index (CCME WQI) as tools for assessing contamination levels.

Additionally, it reviewed various studies investigating leachate's effects on groundwater quality in different regions, demonstrating the widespread issue of groundwater contamination due to landfill practices. It concludes with a discussion on groundwater contamination modelling and the use of Geographic Information Systems (GIS) for monitoring and predicting pollution levels, underscoring the need for effective waste management strategies to mitigate environmental impacts.

References

[1] U. Glawe, C. Visvanathan and M. Alamgir, “Solid Waste Management in Least Developed Asian Countries–a Comparative Analysis”, International Conference on Integrated Solid Waste Management in Southeast Asian Cities, pp. 5–7, 2005.

[2] Y. Abu-Rukah and O. Al-Kofahi, “The Assessment of the Effect of Landfill Leachate on ground-water Quality—a Case study. El-Akader Landfill Site—north Jordan”, Journal of Arid Environments, vol. 49, no. 3, pp. 615–630, 2001.

[3] P. L. Bjerg, H.-J. Albrechtsen, P. Kjeldsen, T. H. Christensen and I. M. Cozzarelli, “The groundwater geochemistry of waste disposal facilities”, Treatise on Geochemistry, vol. 9, p. 612, 2003.

[4] E. Bou-Zeid and M. El-Fadel, “Parametric sensitivity analysis of leachate transport simulations at landfills”, Waste Management, vol. 24, pp. 681–689, 2004.

[5] C. B. Karakuş, D. Demiroğlu, A. Çoban and A. Ulutaş, “Evaluation of GIS-based multi-criteria decision-making methods for sanitary landfill site selection: the case of Sivas city, Turkey”, Journal of Material Cycles and Waste Management, Springer, pp. 1–19, 2020.

[6] R. Hatamleh, M. Jamhawi, S. Al-Kofahi and H. Hijazi, “The use of a GIS system as a decision support tool for municipal solid waste management planning: the case study of al Nuzha District, Irbid, Jordan”, Procedia Manufacturing, vol. 44, pp. 189–196, 2020.

[7] E. E. Nwosu and G. T. Pepple, “Site selection and analysis of solid waste dumpsites in Ile-Ife, Nigeria”, FIG Working Week, Christchurch, New Zealand, pp. 86–92, 2016.

[8] S. A. Ali, F. Parvin, N. Al-Ansari, Q. B. Pham, A. Ahmad, M. S. Raj, D. T. Anh, L. H. Ba and V. N. Thai, “Sanitary landfill site selection by integrating AHP and FTOPSIS with GIS: a case study of Memari Municipality, India”, Environmental Science and Pollution Research, vol. 28, pp. 7528–7550, 2021.

[9] G. Tchobanoglous, H. Theisen and S. A. Vigil, “Integrated Solid Waste Management Engineering Principles and Management Issues”, 1993.

[10] S. Nanda and F. Berruti, “Municipal solid waste management and landfilling technologies: a review”, Environmental Chemistry Letters, vol. 19, pp. 1433–1456, 2021.

[11] K. D. Sharma and S. Jain, “Municipal solid waste generation, composition, and management: the global scenario”, Social Responsibility Journal, vol. 16, no. 6, pp. 917–948, 2020.

[12] European Commission-Eurostat, “Guidance for the Compilation and Reporting of Data on Municipal Waste According to Commission Implementing Decisions 2019/1004/EC and 2019/1885/EC, and the Joint Questionnaire of Eurostat and OECD”, 2023.

[13] G. Tchobanoglous and F. Kreith, “Handbook of solid waste management”, 2002.

[14] M. Al-Anbari, M. Thameer, N. Al-Ansari and S. Knutsson, “Landfill site selection in al-najaf governorate, Iraq”, Journal of Civil Engineering and Architecture, vol. 10, pp. 651–660, 2016.

[15] J. A. Ibrahim and B. H. Graimed, “Residential Solid Waste at Point of Generation (A Case Study AL-Ammarah City)”, Journal of Wasit for Science and Medicine, vol. 3, pp. 102–117, 2010.

[16] Ibrahim and O. A. Hussein, “Adding cellulosic ash to composting mix as a soil amendment”, Journal of Engineering, vol. 22, pp. 79–97, 2016.

[17] M. D. Abbas, A. M. Falih and K. G. A. AL-Mutawki, “Comparative Study between Municipal Solid Wastes Management Options in Processing Stage of Al-Diwaniyah city/Iraq”, IOP Publishing, p. 012131, 2020.

[18] T. Christensen, “Sanitary landfilling: process, technology and environmental impact”, Elsevier, 2012.

[19] P. T. Imhoff, D. R. Reinhart, M. Englund, R. Guérin, N. Gawande, B. Han, S. Jonnalagadda, T. G. Townsend and R. Yazdani, “Review of state of the art methods for measuring water in landfills”, Waste Management, vol. 27, pp. 729–745, 2007.

[20] K. Sormunen, M. Ettala and J. Rintala, “Detailed internal characterization of two Finnish landfills by waste sampling”, Waste Management, vol. 28, pp. 151–163, 2008.

[21] C. Ludwig, S. Hellweg and S. Stucki, “Municipal solid waste management: strategies and technologies for sustainable solutions”, Springer Science & Business Media, 2012.

[22] B. Bhalla, M. Saini and M. Jha, “Effect of Age and Seasonal Variations on Leachate Characteristics of Municipal Solid Waste Landfill”, International Journal of Research in Engineering and Technology, vol. 2, no. 8, pp. 223–232, 2013.

[23] E. de Almeida, E. Lima, M. Crespi, C. Ribeiro and V. Schalch, “Kinetic studies of urban solid residues and leachate from sanitary landfill”, Journal of Thermal Analysis and Calorimetry, vol. 97, pp. 529–533, 2009.

[24] E. Mohammad-Pajooh, D. Weichgrebe and G. Cuff, “Municipal landfill leachate characteristics and feasibility of retrofitting existing treatment systems with deammonification–A full scale survey”, Journal of Environmental Management, vol. 187, pp. 354–364, 2017.

[25] T. H. Christensen, P. Kjeldsen, P. L. Bjerg, D. L. Jensen, J. B. Christensen, A. Baun, H.-J. Albrechtsen and G. Heron, “Biogeochemistry of landfill leachate plumes”, Applied Geochemistry, vol. 16, pp. 659–718, 2001.

[26] S. Renou, J. Givaudan, S. Poulain, F. Dirassouyan and P. Moulin, “Landfill leachate treatment: Review and opportunity”, Journal of Hazardous Materials, vol. 150, pp. 468–493, 2008.

[27] T. Abunama, F. Othman and T. Ibrahim, “Comparison of landfill leachate generation and pollution potentials in humid and semi-arid climates”, International Journal of Environment and Waste Management, vol. 27, pp. 79–92, 2021.

[28] L.-C. Chiang, J.-E. Chang and T.-C. Wen, “Indirect oxidation effect in electrochemical oxidation treatment of landfill leachate”, Water Research, vol. 29, pp. 671–678, 1995.

[29] Y. Deng and J. D. Englehardt, “Treatment of landfill leachate by the Fenton process”, Water Research, vol. 40, pp. 3683–3694, 2006.

[30] S. H. Lin and C. C. Chang, “Treatment of landfill leachate by combined electro-Fenton oxidation and sequencing batch reactor method”, Water Research, vol. 34, pp. 4243–4249, 2000.

[31] X. Li, Q. Zhao and X. Hao, “Ammonium removal from landfill leachate by chemical precipitation”, Waste Management, vol. 19, pp. 409–415, 1999.

[32] M. Vahabian, Y. Hassanzadeh and S. Marofi, “Assessment of landfill leachate in semi-arid climate and its impact on the groundwater quality case study: Hamedan, Iran”, Environmental Monitoring and Assessment, vol. 191, pp. 1–19, 2019.

[33] E. Koda, A. Sieczka and P. Osinski, “Ammonium concentration and migration in groundwater in the vicinity of waste management site located in the neighborhood of protected areas of Warsaw, Poland”, Sustainability, vol. 8, p. 1253, 2016.

[34] T. H. Christensen, P. Kjeldsen, H.-J. Albrechtsen, G. Heron, P. H. Nielsen, P. L. Bjerg and P. E. Holm, “Attenuation of landfill leachate pollutants in aquifers”, Critical Reviews in Environmental Science and Technology, vol. 24, pp. 119–202, 1994.

[35] A. Amokrane, C. Comel and J. Veron, “Landfill leachates pretreatment by coagulation-flocculation”, Water Research, vol. 31, no. 11, pp. 2775–2782, 1997.

[36] M. Reinhard, J. F. Barker and N. L. Goodman, “Occurrence and distribution of organic chemicals in two landfill leachate plumes”, Environmental Science & Technology, vol. 18, pp. 953–961, 1984.

[37] R. Agarwal, M. Yadav, R. P. Agarwal and R. Goyal, “Analytic solution of fractional advection dispersion equation with decay for contaminant transport in porous media”, Matematicki Vesnik, vol. 71, pp. 5–15, 2019.

[38] S. Altouqi, “Modeling Leachate BOD and COD Using lab-scale Reactor Landfills and Multiple Linear Regression Analysis”, Master thesis, University of Texas at Arlington, Civil & Environmental Engineering, 2012.

[39] M. Endait, S. Patil and W. Zjup, “Laboratory investigation of compaction characteristics of fresh and degraded municipal solid waste”, Waste Disposal & Sustainable Energy, vol. 2, pp. 305–312, 2020, doi:10.1007/s42768-020-00049-6.

[40] M. Warith, X. Li and H. Jin, "Bioreactor landfills: state-of-the-art review", Emirates Journal for Engineering Research, vol. 10, pp. 1–14, 2005.

[41] F. G. Pohland, S. R. Harper, K.-C. Chang, J. T. Dertien and E. S. Chian, "Leachate generation and control at landfill disposal sites", Water Quality Research Journal, vol. 20, pp. 10–24, 1985.

[42] A. El Naqa, "Aquifer vulnerability assessment using the DRASTIC model at Russeifa landfill, northeast Jordan", Environmental Geology, vol. 47, pp. 51–62, 2004.

[43] N. Mikac, B. Cosovic, M. Ahel, S. Andreis and Z. Toncic, "Assessment of groundwater contamination in the vicinity of a municipal solid waste landfill (Zagreb, Croatia)", Water Science and Technology, vol. 37, pp. 37–44, 1998.

[44] B. Moreno and L. Stella, "Characterization of leachate from two municipal waste disposal landfills in Puerto Rico and its possible impact on nearby soils and groundwater wells", Dissertation Abstracts International, vol. 72, 2011.

[45] B. Awaz, "Leachate and ground water assessment at kirkuk sanitary landfill site in zindana village, Iraq", International Journal of Environmental Research, vol. 9, 2015.

[46] K. K. Deshmukh and S. P. Aher, "Assessment of the impact of municipal solid waste on groundwater quality near the Sangamner City using GIS approach", Water Resources Management, vol. 30, pp. 2425–2443, 2016.

[47] A. Al-Suraifi, "Simulation of contaminants transport and groundwater flow for Basrah landfill site", Engineering and Technology Journal, vol. 35, no. 6, pp. 560–570, 2017.

[48] S. Mishra, D. Tiwary, A. Ohri and A. K. Agnihotri, "Impact of Municipal Solid Waste Landfill leachate on groundwater quality in Varanasi, India", Groundwater for Sustainable Development, vol. 9, p. 100230, 2019.

[49] B. S. Soujanya Kamble, P. R. Saxena, R. M. Kurakalva and K. Shankar, "Evaluation of seasonal and temporal variations of groundwater quality around Jawaharnagar municipal solid waste dumpsite of Hyderabad city, India", SN Applied Sciences, vol. 2, pp. 1–22, 2020.

[50] A. G. Alghamdi, A. A. Aly and H. M. Ibrahim, "Assessing the environmental impacts of municipal solid waste landfill leachate on groundwater and soil contamination in western Saudi Arabia", Arabian Journal of Geosciences, vol. 14, no. 5, p. 350, 2021.

[51] S. M. Hammash and M. F. Abed, "Environmental Evaluation of the Surface Water, Ground Water and Wastewater using Pollution Indices at the Landfill Site, Southern Baiji, Salah Al-Din Northern Iraq", The Iraqi Geological Journal, pp. 105–112, 2022.

[52] G. Farzaneh, N. Khorasani, J. Ghodousi and M. Panahi, "Assessment of surface and groundwater resources quality close to municipal solid waste landfill using multiple indicators and multivariate statistical methods", International Journal of Environmental Research, vol. 15, pp. 383–394, 2021.

[53] N. K. Y. Yahooa and D. K. Mawlood, "Analyzing the Groundwater Contamination-Central Basin-Erbil City Kurdistan Region-Iraq", Zanco Journal of Pure and Applied Sciences, vol. 35, no. 2, pp. 1–8, 2023.

[54] S. Y. Jalal and D. A. Darwesh, "Leachate characterization and evaluation of ground water quality around landfill area using the canadian council ministers of the environment water quality index", Iraqi Journal of Science, pp. 6175–6192, 2023.

ARTICLE
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تلوث المياه الجوفية بعصارة النفايات الصلبة من المطامر والمكبات المكشوفة: مراجعة

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الخلاصة:

يحاول هذا البحث مراجعة معظم الدراسات التي تناولت تلوث المياه الجوفية المجاورة لمدافن النفايات، والناجمة بشكل رئيسي عن مدافن النفايات غير الهندسية أو المكبات المفتوحة في الخارج، ودراسة تأثيرها على صحة الإنسان. تحتوي مياه الراشح او العصارة المتسربة من مدافن النفايات على أنواع مختلفة من النفايات البلدية السامة، بالإضافة إلى المعادن الثقيلة، التي تتسرب في النهاية إلى الأرض وتنضم إلى المياه الجوفية. يُسبب استهلاك هذه المياه مشاكل صحية خطيرة، وقد يكون مميتًا في بعض الأحيان إذا استُخدم لفترات طويلة. وقد أظهرت العديد من الدراسات مؤشرات على وجود كميات كبيرة من المعادن الثقيلة في كل من مياه الرشح ومصادر المياه الجوفية المحيطة. بالإضافة إلى ذلك، يتم تحليل الآثار البيئية للرشح على جودة المياه الجوفية بشكل دقيق، مع التركيز على مؤشر تلوث الراشح (LPI) ومؤشر جودة المياه الكندي (CCME WQI) كأدوات لتقييم مستويات التلوث. وأخيرًا، يُوصى بإزالة جميع مكبات النفايات المفتوحة وإنشاء مكبات نفايات هندسية وفقًا للمواصفات البيئية المعتمدة. كما يُنصح بجمع الرشح الناتج عن طريق حفر آبار، ثم تحويله إلى حوض (مُبطَّن بشكل مناسب) لمعالجته.

الكلمات الدالة: مكبات النفايات، الراشح، LPI, CCME WQI، النفايات الصلبة، المياه الجوفية، الآثار البيئية.