SEASONAL DYNAMICS, HYDROCHEMISTRY AND NATURAL ATTENUATION OF LANDFILL LEACHATE IN NORTHERN NIGERIA: A REVIEW

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Abstract

Concern about environmental protection has grown globally in recent years. Landfill is an unavoidable issue in the solid waste management system. In terms of simplicity, as well as low exploitation and capital costs, landfilling is recognized as the most common, desirable, integral, and indispensable solid waste management strategy for the sustainable disposal and elimination of residual wastes from separation, recycling, and incineration, both in fully industrialized and developing countries, accounting for approximately 95 percent of total municipal solid waste collected worldwide. Landfills are physically, chemically, and biologically complex heterogeneous systems by nature, with underlying hydrological conditions, refuse composition and compaction, temperature, moisture content, and seasonal variations as its defining characteristics. The difficulty in managing the resulting leachates, which are complex and highly contaminated wastewaters, is one of the main issues with the operation and non-treatment of landfilled waste. Furthermore, in developing countries with rapidly growing populations, such as Nigeria, solid waste dumping in landfills has increased significantly. The composition and characteristics of leachate are highly dependent on a variety of factors, including waste type, climate, organic matter content, landfill hydrogeological structure, and operational conditions. It is one of the most potentially hazardous sources of landfill emissions. There have been few reports of similar or related studies in Northern Nigeria. As a result, such studies are justified in providing recommendations that could aid in mitigating future environmental hazards.

Keywords: Landfill, Leachates, Waste, Environment, Season.

Introduction

Over the past several decades, exponential population and social civilization growth, changes in productivity and consumption habits, increasingly affluent lifestyles and resource use, as well as continued development of industries and technologies, have been accompanied by rapid generation of municipal and industrial solid wastes, creating the world's most intractable paradox (Benitez *et al.*, 2009). One of the major disposal methods in the solid waste management system is landfill, which is an unavoidable issue (Ziyang *et al.*,2009).Land filling is recognized as the most common, desirable, integral, and necessary solid waste management strategy for the sustainable disposal and elimination of residual wastes from separation, recycling, and incineration, both in fully industrialized and developing countries.).Landfill is an unavoidable component of the solid waste management system (Ziyang *et al.*, 2009).

In terms of simplicity, as well as low exploitation and capital costs, land filling is recognized as the most common, desirable, integral, and indispensable solid waste management strategy for sustainable disposal and elimination of residue wastes from separation, recycling, and incineration, both in fully industrialized and developing countries, accounting for approximately 95 percent of total municipal solid waste collected globally. Landfilling plays an important role in solid waste management of various countries in the world.

Landfills are physically, chemically, and biologically complex heterogeneous systems by nature, with the underlying hydrological conditions, refuse composition and compaction, temperature, moisture content, and seasonal variations serving as key functions (Renou *et al.,* 2008). More than 80% of municipal solid waste (MSW) in developing countries is currently disposed of in landfills without any pre-treatment process (Lantela *et al.,* 2012).In Nigeria, as in most developing countries, the common practice is to dispose a refuse through uncontrolled tipping or dumping, which is an operation in which waste is tipped or dumped to fill in a pre-existing hole, or in low economic value open dumps on selected pieces of land, without regard for the surrounding environment, nor taking any precautions to compact, cover, and prevent the spread of leachate to underlying waterways, with the intention of redeveloping the latrine (Ezeah, 2010). The difficulty in managing the resulting leachates, which are complex and highly contaminated wastewaters, is one of the main issues with the operation and non-treatment of landfilled waste. Furthermore, in emerging countries with rapidly growing populations, such as Nigeria, solid waste dumping in landfills has increased significantly (World Bank, 1999). Almost all landfills are open dumps where waste is discarded in an uncontrolled manner. Because of lack of adequate waste and leachate management systems, there has been concern that these open dumps pollute surrounding aquatic environments, including both groundwater and surface water such as rivers and coastal areas, with their leachates (Abu-Rukah and Al-Kofahi, 2001).

In general, landfill leachate, defined as any contaminated liquid effluent percolating through deposited waste and emitted within a landfill or dump site through external sources, is characterized by its generation rate and composition, both of which are influenced by the age of the landfill site (Lantela *et al.,* 2012).More precisely, it is a soluble organic and mineral compound formed when water infiltrates into the refuse layers, extracts a series of contaminants and instigates a complex interplay between the hydrological and biogeochemical reactions that act as mass transfer mechanisms for production of moisture content sufficiently high to initiate the liquid flow, induced by the gravity force, precipitation, irrigation, surface runoff, rainfall, snowmelt, recirculation, liquid waste co-disposal, refuse decomposition, groundwater intrusion and initial moisture content present within the landfills. Leachate composition and characteristics strictly depend upon various factors such as waste type, climate, organic matter content, landfill hydrogeological structure, and operational conditions. It represents one of the most potentially dangerous sources of emission from the landfill (Christensen *et al.,* 2001).. As a result, uncontrolled landfills (also known as refuse dumps) are common in all of the country's cities. This raises the possibility of groundwater contamination due to unrestricted attenuation of landfill leachate.Furthermore, there are no reports of similar or related studies in Northern Nigeria. As a result, such studies are justified in providing recommendations that could aid in mitigating future environmental hazards.

Landfill Leachate and its Characteristics

Municipal solid waste (MSW) is primarily disposed of in an open dumps in many developing countries, with no liner, leachate collection, or treatment facilities. This results in the formation of brown-colored concentrated leachate with a high chemical oxygen demand (COD) and a low BOD to COD ratio. When water penetrates waste in a landfill, leachate forms and transfers certain types of contaminants (Mojiri *et al.,* 2017). Municipal landfill leachate contains pollutants classified as organic contaminants and substrates, inorganic compounds, heavy metals, total dissolved solids (TDS), and color (Mojiri *et al.,* 2016).Landfill leachate can be classified into three types based on its age: young, intermediate, and old (Aziz, 2021; Tejera *et al.*, 2019). According to Aziz (2012) and Vaccari *et al.,* (2019), leachate in 'young' landfills (i.e. the acid phase) has low pH levels, high concentrations of volatile acids, and is simply degraded organic matter. Leachate methane production and pH are high in mature landfills (i.e. the methanogenic phase), and the organic materials present are primarily humic and fulvic fractions. However, some other studies show a slight difference due to differences in waste characteristics across countries (Wang *et al.*, 2018).

Organic and Inorganic Pollutants, and Heavy Metals in Landfill Leachates

Leachate's organic composition varies depending on waste characteristics, landfill age, and climatic conditions. Organic compounds are abundant in urban solid waste and landfill leachate (Scandelai *et al.*, 2019). Dissolved organic matter accounts for 80 percent of total organic compounds in landfill leachate and is typically composed of refractory humic substances and volatile fatty acids. Conventional biological treatments may not be effective in degrading such refractory organics. BOD5 and COD can be used to represent dissolved organics (Samadder *et al.*, 2017). Furthermore, landfill leachate may contain persistent organic pollutants. Scandelai *et al.*, 2020 found a wide range of organic compounds with medium and low polarity in leachate, including amines, alcohols, carboxylic acids, aldehydes, benzothiazolone, ketones, phenols, chlorinated benzenes, phosphates, nitrogen compounds, pesticides, and aromatic and polyaromatic hydrocarbons. Pharmaceuticals, personal care products, surfactants, plasticizers, fire retardants, pesticides, and nanomaterials are also found in many municipal landfills, necessitating attention to their management (Ramakrishnan *et al.*, 2015).

Anions and cations are found in inorganic macro components such as sulphates, chloride, iron, ammonia, aluminum, and zinc (Agbozu *et al.*, 2015). According to Taaaj, (2015), landfill leachate contains a large number of compounds, 80-95 percent of which are inorganic and approximately 52 percent are organic. Chloride (Cl), nitrites and nitrates, cyanide (CN), sulphides (S), and sulphates are all examples of inorganic ions (SO2 4). Inorganic cations also contain ammonia and ferrous (Taaaj, 2019).

Heavy metals are one of the most toxic contaminants in landfill leachate. Because segregation of nonhazardous wastes from hazardous wastes before disposal into a landfill is uncommon in most developing countries, several heavy metals in high concentrations have been reported in landfill leachates. Heavy metal removal is a difficult task; thus, we focus more on metal removal from landfill leachate in this study. According to Dan *et al.*, (2016), the most common heavy metals found in landfill leachate are chromium (Cr), manganese (Mn), cadmium (Cd), lead (Pb), iron (Fe), nickel (Ni), and zinc (Z). Metal concentrations are generally higher in young (acetogenic) leachate than in old leachate (Dan *et al.*, 2016).

Leachate Treatment Methods

Due to its toxicity, leachate from landfills can be a significant source of pollution of surface and groundwater. As a result, before being discharged into the environment, landfill leachate must be properly treated and disposed of. The treatment of landfill leachate is determined by the composition of the leachate and the types of organic matter present (Mandal *et al.*, 2017). In general, there are two methods for treating leachate: biological and a combination of chemical and physical methods.

Chemical & Physical Method

Prior to using biological methods, chemical and physical methods are used. One of the most common chemical treatment methods for landfill leachate is coagulation-flocculation. A colloidal suspension of the particles is destabilized with coagulants in this method, causing the particles to agglomerate with flocculants. The separation will then be accelerated, and the effluents will be clarified. Many factors can influence efficiency, including coagulant/flocculant type and dosage, pH, retention time, mixing speed and time (Rui *et al.*, 2012).As a result, optimizing these factors may affect the efficiency of the coagulation-flocculation process. Lime (calcium hydroxide), ferum chloride, aluminum sulphate, and polychlorinated aluminum are the most commonly used coagulants for leachate treatment. Adsorption, membrane filtration, sedimentation, and air stripping are the most commonly used physical methods for the treatment of landfill leachate (Amor *et al.*,2015). Physical-chemical treatment methods that are unsuitable for young leachate are generally recommended for matured or stabilized leachate.

Biological Method

Biological treatment is a popular option because it is both economically and technically feasible when compared to other options. Aerobic, anaerobic, and anoxic processes are among the key biological approaches used in tandem to treat landfill leachate. In general, biological processes are preferred for treating leachate with a high BOD/COD ratio. However, because biological processes are less effective, physicochemical methods may be considered better options (Renou *et al.*, 2008).

Seasonal Dynamics Hydrochemistry and Natural Attenuation

Several unregulated landfills exist adjacent to large cities in developing countries, releasing harmful contaminants and polluting the underlying aquifer. Several cases of leachate contaminating groundwater have been reported in the past (Christensen *et al.*, 2001). Pollution of groundwater resources has been a major environmental issue worldwide since the 1970s. Groundwater is a major source of drinking water, particularly in developing countries.It is also used for irrigation and in industry. This deterioration in quality may have an impact on environmental conditions.. In the developing world, landfilling is the primary method of waste disposal. A landfill, according to Wikipedia, is a disposal unit designed for the final disposal of Municipal Solid Wastes with the goal of minimizing environmental impact. However, many landfills are poorly managed and pose a serious environmental risk due to leachate runoff (Mangimbulude *et al.,* 2009). Trankler *et al.,* (2005) reported that in tropical countries such as Nigeria, approximately 90% of solid waste is disposed in open dump systems, resulting in significant surface leachate generation and gas emissions in many cases.According to Christensen *et al.,* (2001), the quantity and quality of leachate generated in a landfill are affected by the amount, composition, and moisture content of the solid waste, as well as local factors such as hydrogeological conditions, climate, height, and landfill type.

High local population densities, high annual precipitation (up to 2000 mm), temperature (25 - 350 C), and humidity (60 - 80 percent), as well as a distinct dry season of up to 150 days per year, in addition to a wet season with frequent downpours, all contribute to the variation and complexity of landfill leachate characteristics and composition in tropical systems, according to Miyajema *et al.,* (1997). It was also discovered that leachate compositions frequently exhibit seasonal variations (Christensen *et al.,* 2001). Because of the variability and seasonal flux in the composition of tropical landfill leachate, it is difficult to significantly reduce its environmental impact. If leachate and/or water treatment plants are designed to handle typical leachate quality,there is a possibility (Trankler *et al.*, 2005) that the plants will be overloaded on occasion due to high leachate discharge during certain seasons. In 1997, Akesson and Nilsson discovered lower concentrations of leachate components during the wet autumn season while studying seasonal variations in leachate hydrochemistry in Swedish landfills. Fan *et al.,* (2006) reported a high organic loading rate and short retention time in the wet season in a separate study of leachate in a tropical landfill, which were attributed to the problems associated with leachate treatment.

Seasonal chemical variation in leachate composition must be studied and monitored in order for treatment strategies to be effective and successful.

Among the various treatment methods, one of the possible strategies for mitigating leachate pollution of groundwater and leachate plumes is to study and rely on natural attenuation. Natural attenuation makes aquifers suitable for use as natural subsurface treatment systems. Pollution can be reduced through processes such as degradation, sorption, dilution, volatilization, precipitation, and ion exchange (Christensen *et al.,* 2001), but only degradation removes the bulk of organic contaminants. Degradation of spreading organic pollutants frequently results in an oxidation-reduction zone sequence. Predicting the development of these zones is especially important for NA evaluation because the potential and rate of degradation of specific organic compounds is dependent on the subsurface redox conditions (availability of oxygen, nitrate, iron oxide, and sulphate).Redox processes can be inferred from the distribution of redox sensitive compounds in aquifers. Secondary geochemical processes, such as induced degradation reactions, control the concentrations of redox sensitive compounds (Lantela *et al.*, 2012). The USEPA (1999) proposed a three-tiered approach to assessing the potential for monitored natural attenuation (MNA), which includes documentation of contaminant mass reduction, data directly indicating the occurrence and rate of specific Natuarl attenuations processes, and field or laboratory studies directly demonstrating the extent of degradation. As a result, all major processes (geochemical and hydrological) must be studied in order to provide information governing the Natuarl attenuations process.

Conclusion

Landfilling plays an important role in solid waste management of various countries in the world. By nature, landfill is physically, chemically and biologically complex heterogeneous systems, with the underlying hydrological conditions, refuse composition and compaction, temperature, moisture content along with the seasonal variations as its key functions. One of the main problems about the operation and non-treatment of landfilled waste is the difficulty in managing the resulting leachates, which are complex and highly contaminated wastewaters. In addition to this, in emerging countries with rapidly increasing populations, such as Nigeria, dumping of solid waste in landfills has increased greatly. Leachate composition and characteristics strictly depend upon various factors such as waste type, climate, organic matter content, landfill hydrogeological structure, and operational conditions. It represents one of the most potentially dangerous sources of emission from the landfill. As seen from this reviewthere are little reports of similar or related studies in the whole of Northern Nigeria. Therefore, there is justified need for such studies to provide recommendations that could help in mitigating future environmental hazards.

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