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Leachates Recirculation Impact on the Stabilization of the Solid Wastes – A Review

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ABSTRACT

In most countries, controlled landfills are currently the most common disposal method for municipal solid wastes (MSWs). Despite many benefits, the generation of heavily contaminated leachate with substantial differences in both chemical composition and flow rate represents a major drawback. The realization of this has compelled authorities to adopt ever more stringent establishment of pollution control requirements. Landfill leachate is a serious problem in the treatments of municipal solid wastes using landfills methods. This leachate is usually heavily contaminated, but little attention is paid to its treatment. Optimal treatment of leachates to completely decrease the harmful environmental impacts is today's challenge. However, the complex composition of leachates makes it challenging to formulate general recommendations. Leachate variability, particularly over time and within sites, suggests that the most appropriate treatments are adaptable, universal, and simple. Landfill leachate is characterized by high biological and chemical oxygen demand and is usually composed of undesirable ingredients such as inorganic and organic pollutants. Landfill leachate varies with landfill age and content, decomposition methods, hydrological and climate conditions. Recirculation of leachate does not affect alterations in the degree of biodegradability of the waste. During landfill operations, recirculation of leachate is often applied to help stabilize landfill degradation. Leachate recirculation is widely used in practical engineering, and recirculation using vertical wells is one of the more effective methods.

Keywords: solid waste management; leachate recirculation; landfill leachate; solid waste stabilization.

INTRODUCTION

The composition of solid wastes varies with income [Ibrahim and Hussein, 2016]: low-to-middle-income populations generate mainly organics solid wastes, while high-income populations produce more solid metals, glass, and paper wastes [Al-Ameen and Al-Hamdany, 2018]. The annual world production of food solid waste is about 1.3 billion tons, which can be used to provide a useful and inexpensive source of high chemical oxygen demand value compounds [Radeef and Ismail, 2021]. Municipal solid wastes management excludes incineration, recycling, conversion of wastes to energy, landfilling or composting. Landfills for solid wastes disposal are preferred in many communities around the world. Landfills act as ecological reactors where waste is physically, chemically and biologically transformed. Key elements of a sustainable landfill are therefore landfill lining, soil cover thickness, landfill gas recovery, leachate collection, and flaring systems [Redhwa and Al-Ameen, 2020]. The influence of landfill conditions such as geometry, temperature, weather, constructions, pH values, humidity, biodegradable materials and hydrogeological parameters on the formation of landfill gas and leachates should be checked. Bioreactor landfills are likely to be the next generation of sanitary landfilling, as they improve stabilization of solid wastes in a time-efficient method resulting from the controlled recycling of leachates and gas. Waste management is a problem that has not yet been fully resolved. This problem not only occurs at the regional and local level, but also at the national level [Nanda and Berruti, 2021].

Municipal solid wastes have been recognized as one of the most dangerous environmental problems that urgently need to be addressed due to the increasing urban population and accompanying changes in consumption patterns. Waste management includes all activities designed to minimize the environmental impact of solid waste. Landfill is one of the most popular methods of waste management in many countries around the world due to its low cost. Nevertheless, landfills combined with rainwater infiltration produce wastewater known as leachate. After closing the landfills, leachates will continue to be formed for up to 30–50 years. Landfill leachates are typically hazardous and heavily contaminated wastewaters. Disposal of untreated leachate can pose serious environmental problems as it can seep into the soil and contaminate groundwater as well as surface water. Therefore, pollutants must be removed before they enter the water receiving area to avoid environmental pollution by leachate. Leachates have different biological, physical and chemical properties and their composition depends on numerous parameters such as climatic conditions, type of waste, mode of operations and landfill age. Leachates can contain many organic compounds that are normally biodegradable. Nonetheless, refractory biodegradable materials are also usually found, consisting mainly of ammonia-nitrogen-heavy metals, chlorinated inorganics and organics, usually including suspended and soluble matter. The leachates also contain 0.2–1.5% dissolved solids, with the largest composition (80-95%) being monovalent salts and high chemical oxygen demand concentrations [Istirokhatun et al., 2018].

In most countries, sanitary landfills are currently the most common disposal method for municipal solid waste (MSW). Despite the many gains, the production of heavily contaminated leachate, with major dissimilarities in both volumetric flow rate and chemicals, represents a major problem. Awareness of this has compelled authorities to adopt ever-setting environmental protection requirements [Renou et al., 2008]. Various leachate treatments have been proposed using biological and physicochemical treatments. Sequencing batch reactors (SBR), rotating biocontactors (RBC), trickling filters, anaerobic sludge blankets (UASB), and moving bed biofilm reactors (MBBR), are common biotreatment methods. Physico-chemical treatments are flocculation chemical precipitation, coagulation-flocculation processes, adsorption and ammonia stripping. However, these processes require large areas, long residence times, high maintenance and operating costs, produce large amounts of sludge, and high energy consumption. Therefore, alternative techniques for leachate treatment are needed [Istirokhatun et al., 2018]. In addition, the implementation of leachates recycling in landfill with a high percentage of food wastes must take into account the potential loss of landfill gas production and rapid decomposition compaction. This keeps transportation facilities operating near landfills as well as improves the environmental and economic profits of leachates treatment [Liu et al., 2021]. This review aimed to determine the impacts of leachate recycling on solid waste stabilization.

Characteristics of Leachate

Leachates are highly complex liquids containing high concentrations of heavy metals non-biodegradable as well as biodegradable organics, phosphates, sulfides, ammonia nitrogen, and phenols. They can also indicate hardness, alkalinity, or acidity. When raw leachate is discharged directly into the environment (that is, without treatments), surface water and groundwater sources are severely polluted. Legislation requires treatments of hazardous leachates components before discharging to prevent contamination of water resources and avoid serious and ongoing toxicity [Aziz et al., 2011]. Leachate occurs when water seeps into landfill waste and permeates certain forms of pollutants. Municipal landfill leachates contain contaminants that could be classified into four main groups: inorganic compounds, organics contaminants and substrates, total dissolved solids (TDS), heavy metals, and colors. On the basis of their age, landfill leachates can be divided into three main groups: young, old and intermediate. The leachate from ‘young’ landfills (that is, acid phase) is categorized by high concentration of volatile acids, low pH values, and simply degraded organics matters. In mature (intermediate and old) landfills (i.e., methanogenic stage), methanogenic and pH of leachates is high, and the organic matter present is primarily fulvic and humic fractions [Mojiri et al., 2021]. Relevant liquid flow rates and composition in the case of leachates are two factors that characterize liquid wastewater. Landfill engineering (lining requirements like: waterproof covers, geotextiles, clay, and/or plastics) continues to be a fundamental factor in controlling the amount of water entering landfills and reducing the risk of contamination [Zhang et al., 2021]. Climate affects precipitation (P) and evaporative loss (EV); thus, it has a large impact on leachate production. Finally, leachate generation depends on the nature of the waste itself: its water content and the degree of compaction in the landfill. Compaction reduces the filtration rate; thus, generally, less compacted waste yields higher yields [Renou et al., 2008]. Many factors affect the quality of such leachate, including seasonal weather changes, precipitation, age, waste type and composition (which depends on the living standards of the surrounding population, and heap structure). In particular, the composition of landfill leachate varies greatly depending on the age of the landfill site. Landfill leachate properties are usually characterized by basic factors such as BOD, COD, BOD/COD ratio, pH value, ammonium nitrogen (NH_3-N), suspended solids (SS), heavy metals, and total Kjeldahl nitrogen (TKN). It can be expressed as a parameter. Landfill age and degree of solids stabilization have a significant impact on water properties. Although leachate composition may vary widely within the successive aerobic, acetogenic, methanogenic, stabilization stages of the waste evolution, three types of leachates have been defined according to landfill age [Renou et al., 2008].

LANDFILL LEACHATES TREATMENTS

Conventional treatment methods

Conventional treatments for landfill leachates be able to be divided into three main groups: (a) leachates transfer: combined recycling and domestic wastewater treatment; (b) biodegradation: anaerobic and aerobic processes; and (c) physical and chemical processes: coagulation/flocculation, chemical precipitations, adsorption, chemical oxidations, air stripping, and sedimentation/flotation. [Renou et al., 2008].

Recycling

Conventional sanitary landfills usually design without providing any processes that affect degradation of MSW. The rate of decomposition of municipal solid wastes is slow in the closed anaerobic environments of conventional landfill, and the landfill stabilization process takes considerable time. Various techniques have been recommended in engineering practices to enhance the stabilization of conventional landfill. The bioreactor landfill (BL) concept has been suggested to ameliorate the degraded environment of landfill using leachate recirculation (LR) [Zhang et al., 2021]. Leachate recycling has been widely used over the past decade, as it was one of the cheapest options available [Reinhart and Basel Al-Yousfi, 1996]. Recently, the authors demonstrated the advantages of this technique. Al-Yousfi and Pohland, [1998] reported that recycling of leachate increased the moisture content of the controlled reactor systems and enabled partitioning of enzymes and nutrients between methanogens and solids/liquids. A substantial reduction in methane production and COD was observed when the recycled leachate volume was 30% of the initial volume of waste bed. Rodriguez et al. [2004] reported recirculation had lowered COD values as well by 63–70% in an anaerobic pilot plant. The leachates recirculation not only develops the quality of leachate, but also reduces the time requirement for stabilization. Limited data are available on the effect of recycling rate on treatments efficiencies in controlled anaerobic digesters, although a positive impact on the decomposition of solid waste has been reported. High recycle rates can adversely affect anaerobic digestion of solid waste. For example, Ledakowicz and Kaczorek [2004] observed that leachate recycling can lead to inhibition of methanogenesis by high concentration of organics acids ($pH < 5$) that are toxic to methanogenesis. Additionally, problems such as ponding, saturation, and acid conditions can occur when the amount of leachate returned is very high.

LEACHATES RECIRCULATION IN THE LAST DECADES

A lot of attention has recently been dedicated to overcome technical and material limitations in order to create landfill liners that are commercially viable and cost-efficient, similar to clay. The goal of this review was to show the impact of leachates recycling on the stabilization of solid waste. There has been significant experimental research published in the past. This paper reviewed earlier studies (1995–2021).

Cho et al., [1995] studied the effect of recirculated effluent on the bed of solid waste. The periods of treatment for the completed digestion of solid wastes generally depend upon the performance of the methane fermenter, particularly on loading rates and HRT. Throughout the entire period, the methane produce was around 405–415 ml/gVS consumed. The methane potentials of cellulose, cooked meat, fresh cabbage, boiled rice, and mixed food waste were measured. Anaerobic biodegradability based on the stoichiometric methane yield was 0.92, 0.82, 0.73, 0.72, and 0.86, respectively. The methane yield and anaerobic biodegradability of Korea MFW were high. The rate of degradation was influenced by the recycling flow rates and the HRT of the methane digester in the leach-bed two-phase anaerobic digestion experiments on wastes. VFAs produced quickly at the initial fermentation stage need to be controlled using a digestion method with two-phase. After the VFA levels drop below 5–6 g/l (pH > 6) strictly-separated methanogenic and acidogenic fermentation could not be sustained.

Miller and Emge [1997] studied leachate recycling. They found that leachate recirculation is gaining popularity as an alternative to traditional single-pass leachate systems. Studies have shown that recycling leachate to landfills provides the following operational benefits: increased landfill stabilization, and volume reduction of by absorption or evaporation or refuse, enhanced microbiological treatment of leachate. However, leachate recirculation appears viable and economically attractive.

Al-Yousfi and Pohland [1998] first published modeling, design, and operational solutions for leachate recycling in landfills. Numerical models were developed to predict leachate quantity and quality and biogas production from solid waste. The PITILEACH model is based on the essential links between the hydrological, hydraulic, physicochemical and biological processes of landfills leaching and stabilization. Leachate migration and landfill stabilization have been predicted using the principles of pollutant transport and unsaturated flow in porous media in three main regions; Moisture distribution and fluxes, organic properties of leachate, and total production of methane gas. Microbial-mediated processes of wastes decomposition in landfill were simulated for solubilization of solid organics components (hydrolysis), acidogenesis (acidogenesis) and methane fermentation (methanogenesis). The design program and landfills leachates return configuration is based on fluid dynamics fundamentals and the application of Darcy's law, whereas the simulation of leachates return includes a surface cascade distribution network of perforated pipes and horizontal connecting pipes. It incorporates a system of vertical replenishment wells.

Lee et al. [2002] studied the recycling of landfill leachate. They found that by recycling landfill leachate, they could effectively reduce the amount of leachate processed by the leachates treatment plant. Though, nitrification and denitrification of ammonia nitrogen is possible after application of the leachates on land, producing the greenhouse gas nitrous oxide (N_2O). Due to the slight information on the impact of leachates recycling on his N_2O generation, a field study was conducted at Likang Landfills (Guangzhou, China), where leachate recycling has been in place for 8 years. From June to November 2000, the monthly production and flux of N_2O from leachate and soil were investigated. Moreover, the environmental and chemical factors that regulate NO production were assessed. No impermeable top liner was used at this time. Municipal wastes were simply covered with inert soil and compacted with a bulldozer. An N_2O release rate of (113 mg/m^2 h) was observed to rise from a leachates pond intentionally made in the topsoil within the boundary of the landfills after leachates irrigation. A high NO content (1.09 g/L) was discovered in gas samples discharged from the topsoil 1 m away from the leachate. On the basis of laboratory incubation studies, production of nitric oxide from denitrification in leachates-contaminated soils was at least twenty times greater than from nitrification. The N_2O levels released from leachates basins were compared to the values reported for various ecosystems, showing results from the current study to be 68.7 to 88.6 times higher. Leachates recycling is a cost-effective technique for decreasing the amount of leachates that needs to be treated in landfills. Nevertheless, to minimize N_2O fluxes, leachates must be irrigated and applied to the subsurface soil instead of flowing to the topsoil.

Vavilin et al. [2003] introduced a distributed model of SW digestion in 1-D bioreactor with pH adjustment and leachate recirculation. It was designed to evaluate the balance between the rates of polymer methanogenesis and hydrolysis/acidogenesis during anaerobic digestion of MSWs. The model was adjusted based on previously available experimental data recorded in a 2 L reactor filled with shredded waste, with leachates recycling and neutralizing. On the basis of model simulations, both wastes decomposition and methanogenesis were promoted when suppression was prevented from the outset throughout the reactor volume by recycling of leachates and neutralization. On the basis of model simulations, if the leachates neutralization and recirculation achieved by increasing the liquid flow rates initially prevents inhibition of methane production and hydrolysis/acid formation through the reactors volume, waste decomposition and methanogenesis are stimulated. This is an optimal approach to decrease the time required to digest solid wastes. Model simulations also show that hydrolysis/acidogenesis and methanogenesis rates need to be balanced in order to lessen the time required for destruction and methanogenesis of large volumes of solid waste. Optimal conditions for methanogenesis are more important.

Ozkaya et al. [2004] investigated municipal waste on the European side of Turkey, where it disposed of at the Odayeri landfill. A landfill area of approximately 1.5 hectares is selected as a test area for leachate return. Leachate is returned to wells, which are open at 14 locations, 18 m deep and 0.4 m in diameter. This study provides an overview of the results of the first large-scale sanitary landfill study conducted in Turkey. Furthermore, it presented the result of monitoring data obtained from the Odaeri sanitary landfill testing area. Attempts have been made to quantify the effects of leachates recycling in relation to numerous stabilization indices, landfills gas composition, leachates analysis, and landfills subsidence.

Guérin et al. [2004] investigated three sites for the experiment. Initial experiments have shown not only advantages (correlation between conduction anomalies and runoff), but also limitations of geophysical interpretation. At two other sites, 2D electrical imaging can be used to track leachate recirculation by examining relative changes in resistivity over time. Although some improvements are needed before geophysical measurements can be considered true bioreactor monitoring tools, the results are encouraging and may lead to the use of his 2D electrical imaging in bioreactors design. They found electrical resistivity to be a good physical property to track changes in moisture content. Electrical method can be used to locate water in landfills, confirm the diffusion of leachate through waste masses, and determine the extent of impact of leachate return systems. These promising results demonstrate the potential use of geophysical measurements as an efficient and useful tool for designing bioreactor leachate recycling systems. To be monitoring tools, these qualitative results must be calculated by converting electrical data to moisture contents. Continued studies of leachates and waste electrical resistivity as a function of temperature should contribute to our understanding of wastes moisture monitoring. All these studies must contribute to the technique improving and its use as useful daily tools for bioreactor monitoring and designing.

Ağdağ and Sponza, [2005] investigated the effects of alkalinity on the anaerobic treatment of organic solid wastes collected from the Engineering Faculty's kitchen at Dokuz Eylu University in Izmir, Turkey, as well as the characterization of leachate treated in three simulated anaerobic bioreactors. All reactors were operated with leachate recirculation. After 65 days of anaerobic incubation, it was detected that the (COD), volatile fatty acids (VFA) concentrations, and (BOD_5/COD) ratios in the leachates samples produced from the alkalinity added reactors were lower than the control reactor, though the pH values were higher than the control reactor. The alkalinity addition reduced the biodegradation time the organic content of the solid waste, and the waste quantity.

He et al., [2005] reported that 12 active microorganisms (AMs) isolated from the Hangzhou Tianzhiling landfills were isolated from MSWs in a methanogenic reactor using recirculation of treated leachate. On the decomposition, preliminary experiments showed that AM enhanced the biodegradability of MSW, increased bulk organic effluents from landfill reactors by 24%, and shortened the methanogenesis period in bioreactor landfill systems by about 91 days. The total gas production of the leachate recirculation-only landfill and the bioreactor landfill system without or with AM inoculation was about 66, 621, and 519 L, respectively, after 105 days of operation. The average concentration of methane in the gas produced by the bioreactor landfill system was over 70%. This suggests that the combination of AM and methanogenesis reactors using recirculation of treated leachates is an efficient way to maximize the level of MSWs stabilization and improve the gas production quality and rate for energy recovery.

Zhang et al. [2009] studied the influence of pH-neutralized leachates recycling on a combined aerobic and hydrolytic bio-pretreatment for MSW. Four experiments with neutralized leachate recirculation for different periods (1, 2, 3, and 4 days) and a control with purified water recycling for 4 days were set up to biomassify MSW by a combination of hydrolysis and aerobic processes. The effect of the recirculation period on pretreatment was evaluated. The results indicated that recirculation improved water removal and organic matter decomposition rates, thus possibly resulting in lower moisture content in the biologically pretreated material compared to the control. Four days of recirculation showed the highest water removal rate (83.7%) and organic decomposition (62.1%) and the lowest final water content (43.1%) because of removal of acid inhibition. Four days of recirculation resulted in the highest sorting efficiency (75%), highest calorific value (10570 kJ/kg) and lowest air permeability (98.6 mgO2/g). A 4-day recirculation of neutralized leachate was proposed for pretreatment of high-moisture municipal waste.

Bilgili, et al., [2009] studied comparative landfill performance in terms of solids decomposition. To determine the initial and residual CH_4 potential of solid waste, a biochemical methane potential (BMP) test was used during a 27-month landfill operation in two pilot-scales landfills furnaces. The methane initial potential of the solid waste fed to the reactor was about 0.347 $L/CH_4/g$ dry waste and minimized with the operating time of the landfills reactor to 0.117 and 0.154 $L/CH_4/g$ dry waste for leachate recirculated (R1) and non-recirculated (R2) reactors, respectively. The results showed that leachate recirculation increased the average constant velocity by 32%. Additionally, system performance was modeled using his BMP data for samples taken from the reactor at various operating times with a MATLAB program. The first-order rate constants for reactors R_2 and R_1 were 0.01195 and 0.01571d^{-1}, respectively. The correlation between the experimental and model parameters is over 95%, indicating an efficient fitting of the model. The results show a 32% increase in the average rate constant.

Soh and Hettiarachi, [2009] investigated the potential lateral movement of leachate in flushed bioreactor dumps during active leachate recirculation. This study presents the results of a laboratory study conducted to evaluate the impact of the existence of day/intermediate cover from low-permeability soils on leachates transfer within flushing bioreactor landfills. A laboratory-scale channel 0.2 m wide, 1.5 m long and 1.2 m deep was used to measure the amount of laterally diverted leachate under various soil-waste interface conditions. Two types of covering materials, silty clay and sand, combined with a simulated MSW material, were tested at two different densities of compaction of 350 and 550 kg/m^3 and three different gradients of 0, 2 and 5%. When using silt clay, less than 1% of the leachates generated percolated into the upper layer, but when using sand, 100% of the leachate generated permeated the upper layer without lateral migration. The hydraulic conductivities ratio of the cover soil and the compacted wastes determines the amounts of lateral leachates flow detected.

Schiappacasse et al., [2010] studied layout standards for sanitary landfills which caused a discount within side the stabilization instances of MSW primarily based totally on test effects received from a pre-pilot scale operation of sanitary landfill (0.5 tons), one with recycling of leachate dealt with in an anaerobic digester and the alternative with recirculation of untreated leachate. This turned into complemented with the aid of using any other pilot scale sanitary landfills (1440 Ton) with recirculation of leachates dealt with in an anaerobic filter, and additionally, with the aid of using a computer simulation of leachates production via the water stability of a theoretical cell of MSWs (850 Ton), wherein the preliminary humidity of the MSWs and the form of very last cowl have been evaluated. The effects received at the pre-pilot scale suggest that recycling of anaerobically dealt with leachate accelerated the price of MSW stabilization, whilst in comparison to the recirculation of untreated leachates, projecting a stabilization time discount of 72%. In the pilot sanitary landfill, a settling within side the settling rate of round 200% turned into determined whilst working with the recirculation of anaerobically dealt with leachates in place of operation without recirculation. The water stability achieved at the theoretical cell of MSWs verified the significance to leachates generation of each the preliminary landfills water saturation and the form of very last barrier. From those effects, it could be concluded that preserving waste moisture near the landfill is essential for landfill layout. Landfill is one of the most accepted MSW disposal systems. However, these systems have low organic matter decomposition rates and very slow waste disposal processes, resulting in low biogas productivity and short landfill life. From this study, initial water saturation of MSWs, leachate recovery system, leachates treatment by anaerobic reactor, and its whole or partial landfill. Additionally, during landfill operations, it is important to keep the MSWs moisture level close to FC and maintain adequate treated leachate application rates.

White et al., [2011] investigated how reintroduction of leachate into waste plays an important role in landfill management. Biodegradation can be accelerated by increasing water contents and transporting nutrients, bacteria and production of waste. It is also possible to store leachate within the body of the soil. It is useful for landfills operators to be able to estimate the rate at which landfills can receive leachates (maximum infiltration rate or infusion rate), the landfill storage capacity, and the residence time of the leachates. This study described some of the lessons learned from the application and development of a simple conceptual model of leachates recycling that could be used to estimation key parameters values based on the hydraulic properties of the waste. After the model has been described and partially validated using more difficult numerical analysis, it is used to interpret the data acquired from field tests on real sites. Shortcomings of the model in its current form are examined, and recommendations are given as to how those must be addressed in the perspective of developing the model as a designing tool. Important waste properties that control the response of the waste mass to leachate recirculation are the change in hydraulic conductivity with water content, the saturated and drainable water content, and how these parameters vary with depth.

Shahriari et al., [2012] investigated the effects of using untreated leachate for liquid recycling and supplemental water addition on anaerobic digestion of food wastes. They were assessed by combining cyclical water recycling operation and batch mesophilic biochemical methane potential (BMBP) assay. Cyclic BMBP assays demonstrate that the use of suitable proportions of recycled leachates and fresh make-up water can encourage methanogenic activities and improve production of biogas. On the other hand, increasing the percentage of leachates that is recycled to make-up water will ultimately reduce methane production and reduce food waste stabilization rates. Activity decline worsens as the number of cycles increases. This inhibition can be attributed to the increased concentration and accumulation of ammonia and other wastes by-products in the recycling leachates that inhibit methane production.

Kusch et al., [2012] investigated the impact of different leachate recycling strategies on discontinuous anaerobic digestion of solid substrates. Various leachates recycling strategies were useful to batch solid-phase digestion systems in laboratory-scales experiments. Comparative studies with continuous and intermittent return of exudate showed no advantage of continuous flow. The results suggest that if methanogenesis is the rate-limiting step, leachates recirculation should not be performed continuously during the start-up of the process. Continuous rinsing resulted in the accumulation of VFAs at the beginning of the process. Moreover, no requirement for continuous water circulation for the subsequent pulping process was found when hydrolysis was rate-limiting. Even without liquid recycling, adjusting the moisture contents of the biomass only slightly delayed decomposition.

Carpenter et al., [2013] studied seismic analyses to capture alterations in the mechanical properties of MSWs [modulus of shear (with shear wave velocity) and ratio of Poisson's] to derive the degree of degradation and use it to assess provided dynamic properties that are Seismic stability is required. To complete this objective, sequences of seismic surveys were conducted at the Veolia ES Orchard Hills landfills, 15 km south of Rockford, Illinois, to determine the Poisson's ratio and seismic velocity structure of the recirculation cell to the adjacent new landfills cells was compared with Recirculation of leachate. Seismic data were collected using direct P-wave (compression-wave) and S-wave (shear-wave) fan shot surveys, conventional P-wave refraction, and multichannel surface wave analysis methods. S-wave velocities are very analogous below 5 m depth, while P-wave velocities (from refraction seismic profiling) show a slight difference in velocity between the leachates recirculation cells and the new part of the landfills, showing a decrease. However, refraction and surface wave studies were depth-limited (below 8–9 m) compared to fanshots. Overall, this research presented that seismic surveys have the potential for monitoring temporal and spatial variations in MSW dynamic properties.

Reddy et al., [2013] used landfill leachate and gas for predicting the moisture distribution as well as pores water and pores gas pressure of a typical bioreactor landfills using VW as a leachates injection or recirculation system. A two-phase model assuming immiscible phases was investigated. The MSW gas properties and unsaturated liquid were simulated based on the van Genuchten model. In this study, the effects of the unsaturated hydraulic conductivity of MSWs, the heterogeneous and anisotropic nature of MSWs, and the geometry of VWs on moisture distribution and pore water and gas pressures were evaluated. The unsaturated hydraulic properties of MSW have a significant impact on the wetted areas and pores water pressure during the initial stage of leachates injection and subsequent gravity drainage. Numerical modeling results indicate that the gas pressure in landfills is on the order of 60-150 kPa. This is well above the liquid pressure for most typical liquid injection rates, assuming no accumulation of gas in landfills due to active gases extraction system. Therefore, bioreactor landfill slope stability should be evaluated against the effects of liquid and gas pressure, particularly if the gas extraction systems are operating at suboptimal efficiency.

Tran et al., [2014] studied mechanical biological treatment (MBT) techniques. MBT technology has been used for many years, especially in Europe, to reduce potential waste discharge before landfill. The main focus of MBT is the reduction of natural organic matter, not nitrogen compounds. As a result, the concentration of organics matter in the leachates from the MBT landfill is significantly minimized compared to the leachate from the MSW landfill, while the ammonia-nitrogen concentration remains at a high level. From stabilization of old landfill, it is known that leachates recycling and additional aeration can minimize emissions to standard levels in a relatively short time. The efficiency of this technique on MBA residues was studied under various boundary conditions in a series of laboratory-scale tests. The effect of leachates recycling is also well known for MBT tailings, but supplemental aeration has not been studied so far. The results revealed that this technology has a limited impact on the reduction of organic carbon compounds. Regarding nitrogen compounds, only additional aeration during recirculation has a significant impact on leachate quality, reducing ammonium and total nitrogen concentrations by more than 90%. The results show that a simple technique can rapidly reduce the long-term efflux behavior of MBA residues to acceptable levels.

Reddy et al., [2017] investigated the hydraulic behavior of unsaturated MSWs (pore fluid pressure and moisture distribution). A two-phase numerical model for flow was studied as a tool for predicting pressure of landfill MSW. The mathematical model chosen is the Fast Lagrangian Analysis of Continua, which assumes landfill gas and leachate as two immiscible phases. The principal numerical implementation and equations are presented along with general considerations for implementation of model. The model is validated by simulating published experimental studies, published model studies and field studies. Overall, the mathematical model is presented to be able to provide the necessary information for the designing of effective bioreactor dumps by including coupled hydrodynamic processes. Bioreactors landfills with leachate recirculation have emerged as a preferred option for MSWs management. Effective performance of bioreactor landfills can be accomplished by certifying uniform and proper leachate (moisture) distribution in MSWs landfills.

Feng et al., [2017] studied the combination of spray and vertical well (VW) recirculation system simultaneously, and reported the impact of simultaneous application of spray and VW recirculation system on leachates transport in landfill and some important findings. Design parameters (e.g., the cumulative leachate volume, the influence radius, and the steady-state flow rate) were analyzed. In addition, engineering application schemes were created using a dimensionless variable formulation. Recirculation of leachate in MSWs landfill operated as bioreactors offers substantial environmental and economic profits. However, recirculation of vertical well (VW) might not be a successful method because the recycled leachates flows directly down to the leachates collection system at the bottom of the landfills, wasting the recycled leachate. One solution to minimizing leachate misapplication is to combine a spray VW system with a horizontal flow of leachate to allow more MSW to pass through. Cao et al., [2018] studied the applications of computational fluid dynamics (CFD) in a hybrid bioreactor landfill; to the numerical simulation of subsurface leachates recycling and aeration systems. The purpose of this study was to investigate and model the biochemical and hydrodynamic manners within a hybrid bioreactor landfills. The results show that most of the methane potential is used and the appropriate transition time to ensure that the hybrid landfill switches to aerobic conditions to effectively reduce the stabilization process is 70–80% of the methane potential used. The results also indicate that a practical method of intermittent leachates recycling during aeration should be initiated when the water content drops to the minimum requirement for the hydrolysis reaction and stopped when the hydrolysis rate reaches a maximum. Finally, the configuration of the group-well systems has a clear influence on the leachates content, but seems to have a quite small influence on the air content.

Top et al., [2019] studied the impact of aeration on leachate recirculation and waste decomposition rates using leachate quantity and quality in a field-scale landfills test cell. The four landfills test cells with dimensions of 20 m*40 m*5 m were constructed. This can achieve many important advantages, especially in semi-aerobic or aerobic landfills. It should be noted that leachates recirculation appears to be the real solutions to minimize stabilization time and deliver in-situ treatments of leachates when aerobic landfills are not applicable. This study examined solid wastes stabilization in different landfills (semi-aerobic, anaerobic, aerobic and recirculating anaerobic leachates) in terms of leachates characteristics. Results presented that aeration accelerated the biodegradation rate of the wastes. Compared to anaerobic landfill, aerobic landfills decompose in a relatively short time. Higher solid waste decomposition rates shortened landfill life and reduced overall monitoring costs incurred by subsequent landfills closures. The results of a cost-benefit analysis of the whole implementation process from developments stages to final closure showed that semi-aerobic landfill evaluation can be used as practical methods in developing countries like Turkey. This work also revealed that anaerobic landfill had the highest pollutant concentrations in relation to the analyzed parameters. However, anaerobic landfills with leachate recirculation increased landfill gas production and leachate quality, reduced the amount of leachate, and accelerated waste decomposition within the landfill. This can achieve many important advantages, particularly in semi-aerobic or aerobic landfill. It should be noted that leachates recirculation appears to be a successful solution to lessen stabilization time and provide in-situ treatments of leachates when aerobic landfills are not applicable.

Priyambada and Oktiawan, [2020] studied the effect of leachates recirculation on the stabilization of leachate from solid waste in a simulated anaerobic bioreactor and found that leachate recirculation reduced organic contaminants in the leachate. Moreover, the effect of lowering the concentration of organic contaminants was analyzed. This was done in a laboratory scale experiments. It was studied using a simulated landfill anaerobic bioreactor. The leachates used in this work were artificial leachates produced at high (COD 7406.67 ppm and BOD 3758.19 ppm) and low (COD 1279.33 ppm and BOD 641.30 ppm) concentrations. Leachate recycling was performed on biodegradable waste in a bimodal reactor. The results show that leachates recirculation further increases the concentrations reduction in COD and BOD compared to reactors without leachates recycling. Adding artificial leachates to both reactor treatment groups considerably increased the organics matter content in the leachates. However, this increased the low organic content in the group to which low concentrations of leachates were added. The reactors with leachates recycling have higher BOD and COD removal efficiencies compared to the reactors without leachates recycling. Recirculation of leachate does not affect changes in the degree of biodegradability of the waste. Differences between the reactors without leachates recycling and the reactors with leachates recycling show the same pattern of pH change with no significant difference in biodegradability values. Ma et al., [2021] studied the effects of a Semi-Aerobic Bioreactor Landfill (SABL) and co-treatment of leachates recirculation and pre-aeration on landfills stabilization. They consisted of four landfill reactors, one anaerobic as a control and three semi-aerobic with different leachates recycling treatments (Reactors 1, 2, and 3: 300 ml leachates, 600 ml leachates, or 600 ml aerated leachates per week). As a result, reactor 3 showed the highest (COD) and ammonia nitrogen removal rates, reaching 97% and 88%, respectively. The degradation of organics matter can be described by an exponential decay model. COD, NH^{+4}-N, and BOD_5 rates for SABL increased to 0.029, 0.025, and 0.053 day^{-1} from 0.019, 0.018, and 0.035 day^{-1}, respectively, when leachates recycling rate was increased and pre-aeration was performed. Finally, the classification index evaluations revealed that reactor 3 had the lowest value of 312. This suggests that the combination of increased leachates recycling rate and pre-aeration may have a positive impact on the stabilization phase of MSW. This result provides experimental evidence for improved landfill management to promote MSWs stabilization in SABL.

Liu et al. [2021] offered a coupled model formulation to analyze landfill stabilization processes. Different recirculation conditions based on a hypothetical landfill site with a high proportion of kitchen waste were explored. It was concluded that leachate recirculation has the important effect of accelerating the decomposition of MSW with high food wastes content in the first two years and increasing the rate of landfill gas generation and decomposition compaction. Once the mineralization process enters the slow decomposition stage, the impact of leachates recycling is limited. The economic performances and integrity of the landfill infrastructures must be considered when planning leachate recovery. Leachate drainage eliminates some of the potential for landfill gas generation. Leachates collected from fresh MSWs can be used for recirculation when the active landfill gas production season begins. There are benefits from additional generation of landfills gas and removal of contaminants in fresh leachates. Finally, leachates recirculation can effectively reduce post-closure settlements. This helps in the operation and operation of construction facilities in landfill.

Oktiawan et al., [2021] studied leachate treatment to reduce contaminants in the leachates without using equipment that requires large investments and complex maintenances. The purpose of the study was to determine the influence of bulking agents and leachates recirculation on leachates quality. Fresh solid wastes are recirculated at a continuous flow rate of 1 liter/hour using synthetic leachate. This study was conducted on a laboratory scale for 14 days. On day 14, the combination of recirculation and bulking accelerates the increase in pH. During the hydrolysis process, leachate recycling increases the potential for contact between dissolved organic matter and methanogenic bacteria and helps buffer pH.

CONCLUSIONS

Leachate is a product of biodegradation processes in landfills and has various environmental problems. Appropriate treatment is necessary to avoid adverse effects. On-site treatment of leachates using leachates recirculation is one alternative technology for reducing hazards. Landfill leachates often have significant contamination potential with high concentrations of inorganic and organic contaminants. Primary technology for landfill leachates treatment consists of biological, chemical and physical methods. Due to the high contaminant concentration and low biodegradability of landfill leachates, integrated treatment processes and co-treatment with wastewaters are strongly recommended. Recirculation of leachate improves waste decomposition through permeation into the solid wastes mass. In addition, the potential loss of landfill gassing and rapid decomposition compaction should be considered when implementing leachate recycling in a landfill with high kitchen or food wastes content. Recirculation of leachates in municipal solid wastes landfill worked as bioreactor offers substantial environmental and economical profits. Gravity causes the recycled leachates to flow directly down to the leachates collection system at the bottom of the landfills, wasting the recycled leachate. Recirculation of the leachate increases the potential for contact between methanogenic bacteria and dissolved organic matter and helps buffer pH during the hydrolysis process. Landfill leachate generation was influenced by landfill conditions, such as geometry, construction, temperature, humidity, weather, pH, and biodegradables parameters. Bioreactor landfills are likely to be the next generation of sanitary landfill, as they improve stabilization of solid wastes in a time-efficient way as a result of controlled recirculation of leachates and gas. Leachate recycling provides benefits, such as accelerated biodegradation, lower pollutants concentrations and increased gases production. The results show that leachate recycling accelerates the decomposition of municipal solid wastes, including food-rich wastes, mitigates acidification, and improves gassing efficiency, resulting in less waste in landfills. It shows that early colonization can be increased.

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