Article **Journal of Environmental Sciences and Natural Resources**
June 2021, Vol. 7 No.19 31-39

Proposal to treat leachate from the open-air dump of the Municipality of Zacatecas

Propuesta de tratamiento del lixiviado proveniente del tiradero a cielo abierto del Municipio de Zacatecas

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DOI: 10.35429/JESN.2021.19.7.31.39 Received: January 25, 2021; Accepted June 30, 2021

Abstract

In this work, a feasible proposal is generated for the treatment of leachate from the municipal dump of the city of Zacatecas. Solid waste disposal sites that were not technically planned are commonly known as "open-air" dumps. These sites are basically landing where municipal solid waste is deposited and accumulated without any technical, sanitary and operational control, as well as the absence of infrastructure works to minimize negative impacts on the environment. The waste that ends up in these final disposal sites is decomposed by the presence of water, forming leachate. Due to the above, different pollutants are produced, which makes proper management necessary to preserve the environment, as well as public health. Current leachate treatment options include recycling, re-injection, on-site treatment, discharge to a municipal water treatment plant, or a combination of several.

Leachate treatment, Garbage dump, Contamination

Resumen

En este trabajo se genera una propuesta factible para el tratamiento del lixiviado proveniente del tiradero municipal de la ciudad de Zacatecas. Los sitios de disposición final de residuos sólidos que no fueron planeados técnicamente se conocen comúnmente como tiraderos "a cielo abierto". Estos sitios básicamente son terrenos en donde se depositan y acumulan los residuos sólidos municipales sin ningún control técnico sanitario y operativo, así como la ausencia de obras de infraestructura para minimizar los impactos negativos al ambiente. Los residuos que terminan en estos sitios de disposición final se descomponen por la presencia de agua, formándose el lixiviado. Debido a lo anterior se producen diferentes contaminantes, lo que hace necesario un manejo adecuado, para preservar el medio ambiente, así como, la salud pública. Las opciones actuales del tratamiento de lixiviado incluyen el reciclaje, la re-inyección, el tratamiento in situ, la descarga a una planta municipal de tratamiento de aguas o una combinación de varias.

Tratamiento de lixiviado, Tiradero de basura, Contaminaciós

Citation: SOSA-VÁZQUEZ, Olga Lidia, VILLEGAS-MARTÍNEZ, Rodrigo Cervando, CONEJO-FLORES, Ricardo and GARCÍA-GONZÁLEZ, Juan Manuel. Proposal to treat leachate from the open-air dump of the Municipality of Zacatecas. Journal of Environmental Sciences and Natural Resources. 2021. 7-19:31-39.

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Introduction

One of the most important problems in designing and maintaining an open-air dump is in the management of the leachate that is generated after the passage of water through the garbage. An important factor to consider is the climate in the landfill, as well as, rainfall, atmospheric humidity, temperature, evaporation, evapotranspiration, runoff, infiltration, the topography of the landfill that influences the leachate output patterns, as well degree of compaction of the wastes, degree of initial humidity of the garbage, the covering material of the cells, field capacity of the landfill, etc. (Ticante *et al.*, 2015). Currently the landfill located in the municipality of Zacatecas has no control over the leachate that is generated or the treatment that is given to it. So it is vitally important to stop this process and have control over the leachate. For this, the terrain and the conditions in which the dump is located were examined in detail and, in turn, the physicochemical characteristics were analyzed in order to provide the appropriate treatment.

The objective of this research is to propose a process for the treatment of leachate from the open-air dump of the municipality of Zacatecas, based on physicochemical techniques.

Background

The final disposal of urban solid waste has evolved from open-air landfills to highly technical landfills where liquid and gaseous emissions potentially dangerous to the environment are controlled. Both in the open-air landfills and in the first sanitary landfills, liquid emissions (called leachates) were not controlled and these drained to surface water sources or infiltrated to the lower layers of the ground and in many cases contaminated the underlying aquifers them (Novelo *et al.*, 2002).

In Mexico, the most common practices for the final disposal of solid waste on the ground are: sanitary landfill (RS), controlled landfill (RC) and open-air dump (TCA). A RS is an infrastructure work that involves engineering methods and works for the final disposal of urban solid waste (MSW) and special management, in order to control, through compaction and additional infrastructure, environmental impacts.

A landfill of this type must fully comply with the regulations indicated in NOM-083-SEMARNAT-2003. The Ministry of Environment and Natural Resources reported that, in 2010, there were 186 RS. An RC is an inappropriate final disposal site that meets the specifications of a sanitary landfill in terms of infrastructure and operation works but does not meet the waterproofing specifications or the technical conditions and requirements, in accordance with the legal provisions and sanitary facilities, the National Institute of Geographic Statistics and Informatics reported 23 sites of this type in 2006, there are no more recent data. In a TCA, the waste is dumped directly and daily on the ground without covering it with soil (Figure 1), an inappropriate practice due to the health and environmental problems it causes, but it is the most used in the country because it is the most economical and easy to operate for municipalities. Most TCAs are clandestine and can be family or municipal. Due to their diversity and irregularity, there is no record of most of these sites.

To implement the ATTs, it is not customary to carry out a preliminary study, they are only created arbitrarily in the different states of the Mexican Republic and, for this purpose, canyons and riverbeds, lakes and lagoons, abandoned mines, swampy areas, are used vacant lots and geologically unstable areas. This unconscious final disposal of solid waste has caused problems of water, air and soil pollution, as well as the proliferation of harmful fauna, so the negative effects on public health and the environment could be enormous, but the dimension is unknown exact problem.

Regarding this solid urban waste, INEGI reported that, in 2010, 10,211.5 tons were deposited in TCA. To this is added the social problems among the groups of scavengers, due to the inadequate conditions in which they live and carry out their activities; However, the fear of losing their only source of work causes them to oppose any alternative aimed at improving the techniques of final disposal and / or closure and sanitation of the TCAs.

ISSN: 2444-4936

Figure 1 Landfill
Source: https://energiasrenovablessolar.blogspot.com/2017/11/relleno-sanitario.html), Relleno controlado (Fuente: https://www.laestrella.com.pa/nacional/150509/primer-relleno-vertedero-controlado-inaugurado) y Tiradero a cielo abierto (Fuente: http://www.centuria.mx/denuncian-tiradero-a-cielo-abierto-en-el-riego-pvem

Cortes, (2021), carried out a study on the management of solid waste in the region of the upper basin of the Apatlaco River, in the State of Morelos, due to the effect that these have on the nearby population (Cortes, 2021). Arce, DJF and Guerrero, MY (2021), designed an environmental management strategy for the management and use of solid waste in the San Fermín sector of the municipality of Ocaña, N. de S., due to the high pollution due to Solid waste. Zuloaga (2021), generated a Sustainable Prevention and Comprehensive Waste Management Strategy (ESPGIR), whose purpose was to prevent the generation of waste and promote its proper management by community members, through environmental education and infrastructure. Engumenta (2021), made a diagnosis and proposed optimal sites for the relocation of the final disposal site of solid waste in the community of Jesús María Garza, municipality of Villaflores, Chiapas.

Effects on health and the environment

One of the aspects that must be taken into special consideration are those related to the effects that the interaction of leached liquids with surface or groundwater can potentially generate on health.

The effects that leachates produce on human health during the decomposition of organic solid waste in a humid sanitary landfill range from: Effects on the cardiovascular, respiratory, peripheral nervous and reproductive systems, damage to the liver, kidney, etc. (Corena, 2008).

The final disposal of urban solid waste in sanitary landfills or open dumps gives rise to the generation of different polluting products, derived from the processes of microbial decomposition and release of waste components. Certain materials commonly used in the home and disposed of in landfills may contain hazardous chemicals. As waste is deposited in landfills, it begins to break down through a series of complex chemical processes. The main decomposition products are leached liquids and gases. Both liquids and gases can affect the health of the surrounding populations. The waste is usually dumped in Open Pit Landfills (BCA). BCAs produce harmful actions on the environment and the economy: Contamination of water resources; Atmospheric pollution; Soil contamination; Impact on flora and fauna. Associated with the removal of a flora specimen and the disturbance of native fauna during the construction phase. The existence of vectors (animals that feed on discarded waste) cause the modification of the ecosystem of the surrounding area; Social and economic costs. Devaluation of properties, loss of tourism, increase of non-formal waste management systems; Impact on public health due to disease transmission (Recovery Plants, 2018).

For this, the importance of treating leachates from a landfill must be better understood. There are several studies around the world that account for the impact that landfills can have on the health of the nearby population. Here is a brief summary of some of them: Those carried out in the Tuscany region, Italy between 1995-2000 and found excess mortality from cardiovascular diseases, cerebrovascular diseases, non-Hodgkin's lymphoma and from liver and bladder cancer (Minichilli et al. 2005). In 1995 a study was published on families living near the municipal landfill "The Miron Quarry", in the City of Montreal, Canada, the landfill was used between 1968 and 1990 (third largest landfill in North America). The study revealed a high incidence of stomach, liver, prostate, and lung cancer among men, and uterine-cervical cancer among women. In Helsinki, Finland, incidence of risk of cancer and asthma was found in people who lived in houses on landfills. In 1998 the New York State Department of Health examined the incidence of seven types of cancer in men and women living near 38 landfills where gas is thought to be released.

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Of the 14 types of cancer studied (7 in men and 7 in women), it was found that in 10 cases, the values were high, but in only two types of cancer (bladder cancer and leukemia in women) were they statistically significant. The seven types of cancer studied were leukemia; non-Hodgkin lymphomas; cancer of the liver, lung, kidney, bladder and brain. In 1998 the Environmental Research Foundation presented a report mentioning several studies carried out both in the United States and Canada, as well as in Europe of populations living near landfills. From these it is concluded the most common types of cancer related to fillers are leukemia and bladder cancer. In Delhi, India, in a waste disposal center, the people who worked there presented symptoms of the respiratory system, inflammation of the airways, affected lungs and a series of associated problems. In Belo Horizonte, Brazil, the same symptoms were found in people living near landfills. The proximity of landfills or open dumps affects people with dermatological, neurological, hearing, respiratory problems, pain and itchy throat (Green Peace, 2008).

Main contaminants

One of the most important problems in designing and maintaining a sanitary landfill is in the management of the leachate that is generated after the passage of water through the garbage. The leachate consists of several diverse organic and inorganic compounds that can be found either dissolved or suspended. Regardless of the nature of the compounds, they pose a potential contamination problem for local land and surface waters. Many factors influence the production and composition of the leachate.

Leachate can be defined as the liquid that seeps through the decomposing solid waste and that extracts dissolved materials in suspension, the leachate is formed by the liquid that enters the landfill from external sources (surface drains, rain, etc.). As water seeps through decomposing solid waste, biological materials and chemical constituents are leached into solution.

Table 1 shows some of the physical, chemical and biological parameters that are monitored in the leachate.

Physical	Organic Constituents	Inorganic Constituents	Biological Constituents
Aspect	Organic Chemicals	Suspended solids, Total dissolved solids	Biochemical Oxygen Demand
pH	Phenols	Volatile solids in suspension, volatile dissolved solids, chlorides.	Bacteria, Total Coliforms
Reduction / oxidation potential	Chemical Oxygen Demand	Sulfates	Counting on standard plates
Conductivity	Total Organic Carbon	Phosphates	
Color Total	Total Acids	Alkalinity and Acidity	
Turbidity	Tannins, lignins	N-nitrate	
Temperature	N- Organic	N-nitrite	
Odor	Soluble in ether		

Table 1 Sampling parameters for leachate
Source: *http: //tesis.uson.mx/digital/tesis/docs/9952/Capitulo6.pdf*

The open-air dump in question is located in Lomas de Bracho, Zacatecas with geographic coordinates, Latitude: 23.0529 and Longitude: -102.6152. In 2014, the closure works began to be carried out, giving way to the use of the sanitary landfill (Empresa Jioresa). The open-air dump which is located on one side of the Bracho hills, in Figure 2, we have the satellite location of the dump where it is observed that it is only the land without any control. The dump currently has two gondolas that help transport the waste to the sanitary landfill located in the city of Guadalupe, Zacatecas.

Figure 2 Location of the open-air dump in the municipality of Zacatecas
Source: (Google Maps, 2018)

The conditions of the municipal landfill are shown in Figure 3 where the real conditions of the landfill are observed, in which it can be seen that there is no control over the leachate generated or the waste that is still there.

Figure 3 View of the Bracho dump.

Materials and equipment

Three stages were proposed to carry out this work. For the first stage, a review of the open-air dump of the municipality of Zacatecas was carried out: where possible physical risks and verification of the sampling area were analyzed for a better analysis of the data. In addition, the leachate is sampled to determine the concentration or load of pollutants in wastewater streams, generally over a long period of time. In a second stage, the samples were characterized in the laboratory, determining: pH (NMX, 2016), Temperature (NMX, 2013), Electrolytic Conductivity (NMX, 2001), Biochemical Oxygen Demand (BOD5) (NMX, 2012), Chemical Oxygen Demand (total and soluble) (NMX, 2015), Total suspended solids (SST) (NMX, 2001), Nitrates NO3 (NMX, 2014), Sulfates SO4 (NMX, 2001), Color (NMX, 2016), Metals (Na, K, Ca, Cd, Cr, Hg, Pb, Cu) (NMX, 2016) and Total Coliforms (TOC) (NMX, 1994). In the third stage, the experimentation was carried out under the following scheme: First is that for the treatment of the leachate, it is passed through an activated carbon filter, to reduce the color and some odors present in the sample. the leachate is passed through an ion exchange resin filter. Finally, a partial evaporation (approx. 90%) of the leachate was carried out in order to reduce pathogenic microorganisms and that the treated leachate can be re-sent to a wastewater treatment.

Analysis and discussion of results

The characterization of the leachate began with a sampling in which 5 samples with a volume of one gallon each were taken, three of these samples were for the characterization of the physicochemical and microbiological parameters, and two more samples, for experimentation with activated carbon, ion exchange resins and total evaporation.

The characterization of the leachate samples was carried out in the Special Studies Laboratory of the Academic Unit of Chemical Sciences, obtaining the following results for the physicochemical parameters (Table 2) and for the microbiological parameters (Table 3):

Parameter	Method	Results	Units
pH	NMX-AA-008-SCFI	8.13	-
Temperature	NMX-AA-007-SCFI	19.0	˚C
C.E	NMX-AA-093-SCFI	3,050	mS/m
BDO_5	NMX-AA-028-SCFI	504	mg/L
CDO	NMX-AA-030-SCFI	887.33	mg/L
Total Suspended Solids	NMX-AA-034-SCFI	5,476	mg/L
NO_3	NMX-AA-079-SCFI	2.0	mg/L
SO_4	NMX-AA-074-SCFI	7.0	mg/L
Colour	NMX-AA-045-SCFI	66	Pt/Co
Sodium	NMX-AA-051-SCFI	1,010	mg/L
Potassium	NMX-AA-051-SCFI	745	mg/L
Calcium	NMX-AA-051-SCFI	256	mg/L
Cadmium	NMX-AA-051-SCFI	0.01	mg/L
Chrome	NMX-AA-051-SCFI	4.3	mg/L
Mercury	NMX-AA-051-SCFI	1.8	mg/L
Lead	NMX-AA-051-SCFI	0.08	mg/L
Copper	NMX-AA-051-SCFI	0.08	mg/L

Table 2 Results of the physicochemical characterization of the leachate

Total Coliforms NMP/1ml	Fecal Coliforms NPM/1 ml	Aerobic Mesophils UFC/ 1ml
23	Not detectable	1500

Table 3 Results of the microbiological characterization of the leachate

In the first stage of the leachate treatment, the liquid passes through an activated carbon filter. Three samples of 25 ml each were placed, with 1 g, 2 g, and 3 g respectively of activated carbon. They were kept under stirring for 4 hours. Subsequently, each of the samples were filtered to remove the activated carbon and verify the color change in each sample (Figure 4).

Figure 4 Color difference in samples after shaking

It was concluded that the sample containing 3 g of activated carbon was the one that best reduced the color.

The quality of leachate is influenced by the biological, chemical and physical processes that occur within the landfill. Generally, as indicator parameters, the relationship BOD_5 and COD are considered, which vary within the acetic and methanogenic phase of a sanitary landfill or open dump.

The sampled leachates correspond to the storage tanks of the landfill, where leachates of different ages are mixed, so there is a mixture of the characteristics of acid fermentation and methanogenic fermentation (Table 4).

BDO_5	504	mg/L
CDO	887.33	mg/L
BDO_5/CDO	0.568	mg/L

Tabla 4 Relationship BDO_5/CDO

According to the BOD_5/COD ratio, it is concluded that the dump in question is mainly in the acetic phase.

The biodegradability of the leachate also varies with time, which is reflected in the BOD_5/COD ratio. In a new landfill the relationship will be in a range of 0.5 or more, the indicator that the organic matter in the leachates is easily biodegradable (0.4 to 0.6), while in old landfills the relationship is in a range of 0.05 to 0.2, indicating that leachates contain humic and fulvic acids that are not easy to biodegrade. The presence of dissolved metals indicates that there are anaerobic conditions (mainly acidogenic stage), for which the metals are solubilized, but when passing through the layers of the covering material, the pH rises again without reaching the values at which they precipitate.

Mass balance for container 1:

$$M_{LE1} - M_{LS1} = \frac{dM_{LS1}}{dt} \tag{1}$$

Where; M_{LE1} is the initial mass of the leachate [=] kg, M_{LS1} is the output mass of the leachate after treatment with activated carbon [=] kg, t = time [=] s.

Mass balance for container 2:

$$M_{LS1} - M_{LS2} = \frac{dM_{LS2}}{dt} \tag{2}$$

Where; M_{LS2} is the leachate exit mass after treatment with ion exchange resins [=] kg.

Material balance for the evaporator:

$$M_{LS2} = M_{LV} + M_{LL} \tag{3}$$

Where; M_{LV} is the mass of vapor in the distillate [=] kg, M_{LL} is the mass of the liquid [=] kg.

Energy balance for the evaporator:

$$Q_E = h_v M_{LV} + M_{LL} H_L \tag{4}$$

$$Q_E = M_{LS2}\, \lambda_{vap} \tag{6}$$

Where; Q_E is the energy required to evaporate the leachate [=] kJ, h_v is the enthalpy of vapor [=] kJ, H_L is the enthalpy of liquid [=] kJ, and λ_{vap} is the latent heat of vaporization of water.

Energy balance in the condenser (auxiliary equipment not included in the diagram)

$$Q_C = M_{H2O}\, cp\, (T_F - T_A) \tag{6}$$

Where; Q_C is the heat that must be removed from the condenser [=] kJ, M_{H2O} amount of water required to condense the steam; cp is the heat capacity of the water [=] kJ/kg K, T_F is the water leaving temperature [=] °C, T_A is the cooling water temperature [=] °C.

In Figure 5, the flow diagram and the results obtained in the experimentation are presented, which can be scaled by the storage volume of the open-air dump tanks.

ISSN: 2444-4936

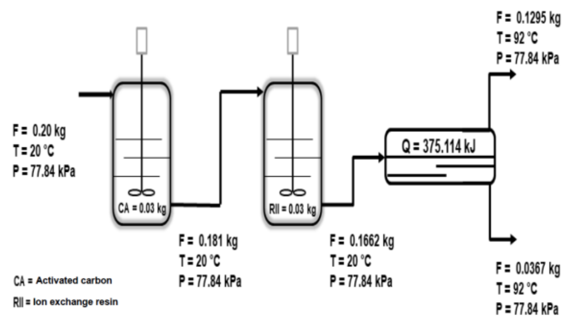

Figure 5 Flow diagram of the proposed treatment plant

According to the information provided by the workers at the dump, the mass of leachate received is 25,000 kg.

There is cooling water @ 21 °C, which according to the energy balance, requires 1,793.09 kg of water for the phase change and to condense the steam. Consideration should be given to using another refrigerant due to the large volume of water required for condensation. The condensed steam cooling water ratio is 13,846.25, if it is scaled to 25,000 kg, that's a great deal.

Conclusions

Municipal solid waste that ends up at a final disposal site decomposes, forming leachate. With the decomposition of the waste and the leaching of its components, different polluting materials are produced that could be dangerous, which makes it important to give it proper handling.

One of the main problems associated with the presence of open-air dumps is that due to the lack of control of the entry of waste, in most cases, these sites become key points for the illegal deposit of hazardous waste, which causes that in these places the effects of environmental contamination and risk to human health are further aggravated.

In this research, an alternative treatment was presented for the leachates that are generated, specifically in the open-air dump located in the municipality of Zacatecas, where when carrying out the entire experimental procedure, it is concluded that activated carbon filters, resins and evaporation are techniques that could represent a feasible treatment for the leachate that is produced. In this way, it is possible to contribute to the elimination of some pollutants that affect the environment, and to the health of the population around the dump.

Making a projection to the handling of 25000 kg of leachate (which is what is collected in the dump deposits), an amount of energy is required to evaporate it of 5.6 x 106 kJ. In the city of Zacatecas there is 5.4 kWh / m² of irradiance, which can facilitate the use of solar energy for the evaporation of the treated leachate.

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