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Technologies Available For Leachate Treatment: A Technical Review

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Abstract—*Management of explosively increasing quantity of solid waste with a reported value of 1.3% every year has become a major issue for sustainable development of mankind. In India, Municipal solid waste (MSW) contributes for 60 to 65% of total waste generation, out of which only 15-20% waste is used for recycling, composting, RDF, WTE etc. and rest is directly dumped either on open ground or in engineered landfills. Major problem associated with open dumping or land filling is generation of unwanted toxic and hazardous wastewater called as leachate which contains broad range of xenobiotic organic compounds. Therefore, discharge of leachate without any prior treatment is considered to be threatening to human health, ground water, soil and environment.*

Number of technologies available to treat this leachate can be demonstrated in five major categories such as: (1) Physico – Chemical processes, (2) Biological Processes, (3) Membrane Processes, (4) Natural Processes and (5) Combined Processes. A sincere effort has been made through this paper to demonstrate all the technologies falling in these categories with a comparative analysis of them, including their advantages, disadvantages, area of application, limitation and suitability of specific technology as per economy involved (wherever applicable).

1. INTRODUCTION

Urbanization and Industrialization are emerging rapidly in India. Such industrial and technological hikes are in proportion with solid waste generation. According to Ministry of Urban Affairs, Govt. of India estimate, India is generating approximately 100,000 metric tons of solid waste everyday of which 90 % is dumped in the open place. Escalation in solid waste generation, improper utilization and disposal of waste leads to unsanitary conditions. They also pose a wide variety of administrative, economic and social problems that needs to be solved.

Collection, segregation, treatment and disposal are the steps taken for solid waste management. Selecting an optimal collection route and its proper treatment is a complex issue. Relevant methods like incineration, energy recovery, composting, digesting and sanitary landfill etc. are followed. Despite of substantial progress in waste reduction by reuse and recycling, the bulk of municipal waste is still disposed off in landfill site. [8]

Landfills come up with 2 of the by product, methane and leachate. The precipitation that falls into a landfill coupled with any disposed liquid waste results in the extraction of water soluble compounds and particulate matter of the waste and the subsequent formation of leachate. This garbage soup presents a major threat to the current and future quality of groundwater. The release of hazardous waste and non-hazardous waste components may render an aquifer unusable for drinking water purposes. Leachate impacts to groundwater may also present a danger to the environment and to aquatic species of the leachate-contaminated groundwater plume discharges to wetland or streams. It contains harmful and complex compounds i.e. organic matter leading high COD, BOD and heavy metals which may adversely affect plant growth and impair the ecosystem as it penetrates the soil. Some studies have shown that leachate is a genotoxic agent in mammalian cells and can cause oxidative damage on brains and liver of mice. Toxicological effects & reproductive impairments in female perch were also observed. Thus leachate treatment is essential as it threatens from various impacts. And this paper covers those leachate treatments that some MSW landfill sites can adopt for the same. [5]

2. LEACHATE GENERATION

When solid waste is dumped on the open site in a systematic manner with certain protective measures it considered as land filling site. This land filling site may contain hazardous or municipal solid waste, according to which characteristics of leachate differ. After certain period of time this solid waste undergoes physical compaction, chemical conversions and biological degradation. So, when any water falls on the landfill surface, amount of water percolates through the layers of solid waste absorbing and dissolving heavy metals, toxic and hazardous materials, nutrients and contaminants present within landfill. This leachate is collected at the bottom of the landfill.

Fig. shows the various water inputs and its movement in the landfill resulted in leachate production.

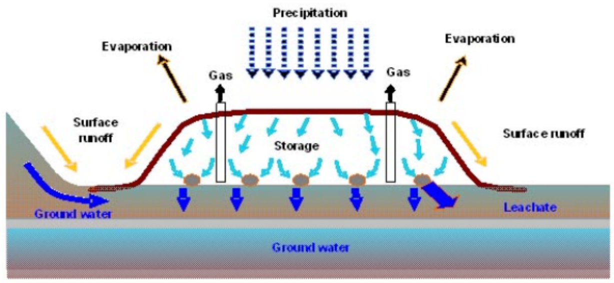

Fig. 1: Leachate generation process

Numbers of components are contributing in the formation of leachate, following a certain pattern based on the physical processes happening within the landfill that can be synopsized as follows:

- Any water come in contact with the landfill surface, amount of it precipitates and initiates runoff while some amount infiltrates into the surface.
- Some of the infiltration evaporates from the surface and/or fall outs through vegetative cover while some part is withheld as moisture within soil.
- The rest of the infiltration percolates within ultimately forming leachate at the base of the landfill.
- Percolation may be amplified by infiltration of groundwater. [4]

3. QUALITY AND QUANTITY

Leachate quality:

Leachate is a complex material which contains water, organic and inorganic materials, bacteria and other microbes. The leachate composition variegates with different and environmental conditions contingent to the nature of deposited solid wastes, soil characteristics, elapsed time, temperature, moisture, available oxygen, rainfall pattern, on the age of the landfill, engineering &operational factors of the landfill, pH and landfill's chemical and biological activities. The composition is dominated by biodegradable waste with naturally present bacteria. [11]

According to the landfill age, Leachate can be classified into 3 types:

1. Young leachate
2. Intermediate
3. Stabilized leachate

Mostly young and intermediate leachate are viewed in one category. They contain high concentration organic compounds such as volatile fatty acids (VFAs), high BOD (4000-13000 mg/l), high COD (6000-60000 mg/l), high Ammoniacal nitrogen (2000-5000 mg/l) and high BOD/COD ratio (0.4-0.7).

As the landfill ages, biochemical degradation takes place resulting into methane and CO_2. Also reducing CO_2 with H_2, the pH increases and now the leachate is no more biodegradable.

Now the leachate turns to stabilized leachate. It contains high COD (5000-20000 mg/l), high Ammonical nitrogen (2500-5000 mg/l) and low BOD/COD ratio (< 0.1). [5]

Leachate quantity:

Volume of the leachate is affected by: initial moisture content of the wastes, solid waste composition, biochemical and physical transformations taking place in them and causing changes in humidity and inflow of water from outside of landfill. It variegates widely through the successive aerobic acetogenic, methogenic and stabilization stages. [12, 13]

Leachate quantity is not constant in the scale of the year. It is most frequent from November to April with maximum yielding in December while we have dry period from May to October.

4. LEACHATE TREATMENT

There are numbers of techniques available for leachate treatment. determinants in the leachate characteristics for selection of adequate treatment options COD/TOC and BOD/COD ratios, absolute COD concentration and age of the landfill are necessary.We have classified that options mainly into 5 categories and each are compared with each other on the bases of different applicable parameters.

(i) Physico – chemical processes
(ii) Biological Processes
(iii) Membrane Processes
(iv) Natural Processes
(v) Combined Processes

<u>Physico – Chemical Processes</u>:
When bio-refractory materials like humic, fulvic acid and troublesome compounds like heavy metals, AOXs, PCBs, etc. Are present in the leachate it is needed to treat by physico chemical treatment to enhance efficiency of biological treatment. Treatments

Table 1: Comparison of various physico chemical processes:

	General Description	Focused area	Best Recommended for	Material used	Advantages & Dis-advantages	Economic Factor	Efficiency (%)
Floatation	-Post-treatment	Colloids, ions, macromolecules, microorganisms and fibers, humic acid	No data found	-	Sludge generation	Comparatively less expensive	60-90[3, 5, 10]
Adsorption		Toxic heavy metals, AOX, PCB,COD, Ammonical nitrogen	Medium age landfill Leachate	Activated carbon, zeolite, Vermiculite, alumina and municipal waste incinerator bottom ash	Installation and running cost is high	Very expensive	50-70[2]
Precipitation	-Pre-treatment	High strength ammoniacal nitrogen, humic acid		Lime, aluminum sulphate, ferrous sulphate, ferric chloride, & ferric chloro sulphate	Large amount of wet sludge	Comparatively less expensive	85[4]
Coagulation and flocculation		Metals, Suspended solids, Suspended COD, Colloidal particles	Stabilized and old age landfill leachate		High sludge generation volume	Comparatively less expensive	75[5]
Chemical Oxidation	-Used as both post and pre treatment	Refractory organic compound, toxic substance	Medium and old age landfill leachate	Chlorine, Ozone, Potassium permanganate & calcium hydrochloride	Not suitable for large scale industry	Comparatively expensive	20-50[2]
Ammonia Stripping	-Mostly post treatment	High concentration of ammoniacal nitrogen	Medium and old age landfill leachate	-	Calcium Carbonate scaling	Comparatively less expensive	89[10]
Ion Exchange	-Post polishing step for meeting with the compliances	Trace of metal impurities and compound containing humic acid	Good for all age landfill leachate	-	Comparatively Clean process	High operational cost	No data found

Table 2: Comparison between various biological treatments

Treatment	General Description	Focused area	Best Recommended for (leachate age)	Material used	Advantages &Dis-advantages	Economic Factor	Efficiency [4] (%)
UASB[a]	Anaerobic (pre-treatment)	NH_4-N+, BOD, COD,	Young , intermediate, old	Flow distributors, treatment media, vents	3 phase separation, High efficiency rate	Less expensive	60-75%
SBR[b]	Pre/post treatment, Aerobic/ anaerobic, denitrification	NH_4-N+, Organic matter, suspended solids	Young , intermediate	Aerator	Minimum operator interaction, Highest efficiency, treats wide influent volume	Comparatively less expensive	62-76%

Reed beds	post treatment,	Organic matter, nitrogen, phosphorus, BOD, COD	Young , intermediate, old	Common reeds	Simple , robust	Less expensive	30-45%
MBBR[c]	Pre/post treatment, Aerobic/ anaerobic, denitrification	NH_4-N+, BOD, COD	Young , intermediate	Polymeric media	Less sludge production, higher biomass concentration, lesser footprints	Very expensive	42-45
Lagoon	Pre-treatment, Aerobic/ denitrification	Organic matter, phosphorus, BOD, COD	Young , intermediate	_	Long RT, low maintenance and operation cost	Less expensive	40%
ASP[d]	Pre- treatment, Aerobic	NH_4-N+, Organic matter, suspended solids, nitrogen, phosphorus, BOD, COD,	Young , intermediate	Aerators, pumps	Inadequate sludge settleability, microbial inhibition	Comparatively expensive	50-52%
MBR[e]	Pre/post treatment, Aerobic	BOD, COD, metals, salts,	Young , intermediate, old	Membranes, diffusors	Cannot reduce chlorides, sulphates	Very expensive	58-64%

[[a]UASB – Up flow Anaerobic Sludge Blanket, [b]SBR – Sludge Bed Reactor, [c]MBBR – Moving Bed Biofilm Reactor, [d]ASP – Activated Sludge Process, [e]MBR – Membrane Bioreactor]

Table 3: Comparison of varied membrane techniques

Treatment	General Description	Focused area	Best Recommended for (leachate age)	Advantages &Dis-advantages	Economic Factor	Efficiency (%)[10]
Microfiltration	Pre-treatment/ combination treatment	Colloids and suspended matter	medium, old	Operates at relatively low pressure	Expensive	50%
Ultrafiltration	Pre-treatment/ combination treatment	Macromolecule of organic matter	medium, old	Provides a physical disinfection barrier	Expensive	25-35%
Nano filtration	Pre/post treatment	Organics, inorganics, microbial contaminants, polyvalent ions	Young , medium, old	High rejection rate for sulphate ions, dissolved organic matter, chloride, looser membrane structure	Expensive	65%
Reverse Osmosis	Post treatment	Monovalent ions, TDS, metal salts	Young , medium, old	98-99% heavy metals and COD concentration decrease	Expensive	80%

Table 4: Advantages and disadvantages of natural treatments

	Advantages	Disadvantages
Irrigation	-Leachate quantity, nutrient content decreases by oxidation, nitrification and sorption process.	-Contaminate ground environment in terms of pH, nutrients concentration and water salt content.
Overland flow	-Microbial remediation technique to control suspended, colloidal organics, total nitrogen, and ammonia, phosphorus and trace elements removed by filtration through soil layer.	-Need to keep close watch on application rate, slope length and soil temperature for better performance and less land contamination.
Constructed wet land	-Self maintaining, self-regulating biological filters very effective in removing BOD, TSS, organic nitrogen and suitable also for controlling race metals and other toxic materials.	-Deterioration of natural source land.

Aquatic system	-Reported to remove 75%-80% BOD and 60% of total nitrogen removal which can be reach up to 80% during summer.	-Require large land and some form of fencing to minimize hazard to human health. It is only approved to selected countries only (EPA, 2003).
Combined treatment with domestic sewage	-Addition of nutrients like nitrogen and phosphorus are not needed. If ratio sewage/leachate is 9/1, it is reported efficiency for BOD and NH_3-N reduction is 95% and 50% respectively.	-Exceeded leachate input over 10% can cause decrement in efficiency and for this recommended solution of installing powdered activated carbon can increase capital cost.
Recycling	-One of the least expensive methods improving leachate quality and shorten the stabilization phase from several decades to 2-3 years.	-High recirculation rate and volume may adversely affect anaerobic degradation of solid waste and cause problems such as saturation, ponding and acidic conditions within the landfill.

which fall under these categories are described in Table 1. [2, 3, 5, 6, 7, 10]

Biological Processes:

One of the most known treatment for waste water – Biological treatments can mainly be divided into Aerobic, Anaerobic, and Nitrification – Denitrification. These treatments are known for their feasibility and viability. Table 2 is showing the pros and cons of these technologies. [1, 2, 3, 4]

Membrane process:

This is used to remove particles that are too small to be removed for ordinary filters. This treatments show better efficiency than other process but at same time are expensive too. Table 3 shows comparison of different membrane performance for leachate treatment. [10]

Natural Processes:

Natural leachate treatment is eminent from conventional systems based on the source of energy. In conventional systems, chemical addition, forced aeration, and mechanical mixing are the inputs for the pollutant degradation. Whereas natural systems more emphasized on renewable energy sources such as solar radiation or wind. These systems are land demanding and that is why they are not much popular in dense populated country like INDIA. Typical natural systems for leachate treatment include leachate recirculation, irrigation, wetlands and aquatic systems explained and compared above in Table 4. [2, 6, 7]

Combined Processes:

When we are talking about the combined treatments than in most of the cases it is referred by combination of physical and biological treatments. In certain cases leachate is having high concentration of NH_4^+- N and COD which cannot be treated by alone physical or biological treatments. On the bases of the characteristics of the leachate and discharge limit requirement one can combine different techniques. These combinations may be of membrane and bioreactor, or may be of ultrafiltration and biologically activated carbon or in the form of combined nitrification – denitrification with ultrafiltration or may be coagulation – activated sludge and chlorination – ammonia stripping or may be combined unit of microfiltration with reverse osmosis. These all combinations are experimented and derived on the basis of young leachate's characteristics. [4]

5. CONCLUSION

We have discussed and compared over 24 techniques of municipal solid waste landfill leachate in our paper. It is very challenging to define a common solution for treating leachate. The leachate composition and characteristics varies from site to site according to parent solid waste characteristics and age of the landfill site. As per the recent era's demand for better environment and conservation of sources one need to become capable of achieving even more stricter discharge regulations for leachate. It has become mandatory to find out the treatment which is simple, universal and adaptable.

Every treatment whether it is biological, physico-chemical, membrane or natural, having their own disadvantages. For the modern world it is more advisable to combine one or more required and applicable processes on the basis of leachate characteristics. While doing this one is also needed to keep economical factor in consideration.

REFERENCES

[1] Jude I. M., Water & Environmental Engineering, Lund University, Pg. No.: 2-3.
[2] Absnlhussain A.A., Guo J., Liu Z. P., Pan Y. Y., Wisaam S. A., American journal of Applied Science 6(4): 2009, Pg. No.: 673-680.
[3] Sameer K., Dhruv K., Gaurav S., International Journal of Environmental Engineering & management, Volume 4, Number 5 (2003), Pg. No.: 440-443.
[4] State of Art review, Landfill leachate treatment, Publishing jointly by, Environmental Engineering & Management, & National Engineering research center for Urban Pollution Control. Pg. No.: 9-56.
[5] Madu J. J., Master's Thesis: 2008-02, Lund University, April 2008, Pg. No.: 11-25.
[6] Landfill Mannual, EPA, 2000, Pg. No.: 63-73
[7] Dang Yu, Masters of Science thesis, Royal Institute of Technology, 2007, Pg. No.: 5-33.
[8] Sanjay M, Amit D, Mukharjee S. N., Journal of Environmental Research 7 Development, Vol 8, No. 2, October – December, 22 November, 2013, Pg. No.: 267-269.

[9] Julie M. R., Master's. Thesis, September 1999, Biological treatment of Landfill Leachate, Pg. No.: 13-27.
[10] S Renon, J. G. Givandan, S. Pontain, F. Dirassouyan, P. maulin, Pg. No. 6-24.
[11] Sha Liu, Master's Thesis, 2013, Lund Universisty, Landfill Leachate Treatment Methods & Evaluationof Hedeskoga & Masalukl Landfills, Pg. No.: 11-28.
[12] K. u. Heyer & R. Stegmann, Ingenieurburo fur, Abfallwirstchaft, Hamburg Pg. No.: 2-6.
[13] Somezynska, T. Slomezynski, Journal of Environmental Studies, Vol. 13, No. 6 (2004), June 5, @004, Pg. No.: 628-632.