Review Article

An Overview of Comparing Chemical Oxygen Demand Removal Methods from Landfill Leachate

Fatemeh Mohebbi[1], Rouhullah Dehghani[2], Faezeh Asgari Tarazouj[1], Marzieh Akbari[1], Mahsa Rah Rovan[1], Gholamreza Mostafaii[2]

[1]Department of Environmental Health Engineering, Kashan University of Medical Sciences, [2]Department of Environmental Health Engineering, Social Determinants of Health Research Center, Kashan University of Medical Sciences, Kashan, Iran

ORCID:

Fatemeh Mohebbi: 0000-0003-3261-7075

Gholamreza Mostafaei: http://orcid.org/0000-0002-7088-0133

Abstract

Aims: Landfill leachate contains many pollutants including chemical oxygen demand (COD), biological oxygen demand, ammonia nitrogen, organic matter, minerals, and toxins. Given the importance of COD removal from landfill leachate, this study was conducted to evaluate and compare different methods used for the removal of COD from leachate. **Materials and Methods:** This study was conducted as a narrative review using keywords of leachate, COD, landfill in related journals issued in scientific databases such as Web of Science, PubMed, SID, and Google Scholar. We reviewed different aspects of COD removal from leachate to find better options in this respect. **Results:** The highest rate of COD removal was observed for batch reactor methods of anaerobic and aerobic granular activated carbon and electro Fenton by 98.4% COD removal, and the lowest one was 22.7% for the electro-Fenton method. The most commonly used methods for removing COD from solidwaste leachate have been physical and chemical methods. **Conclusion:** This study showed that a wide range method has been used to remove COD from leachate. It seems that combined methods are more effective to reduce the content of leachate COD. Besides, methods such as Fenton and absorption are more preferable because of simple application and low energy consumption.

Keywords: Chemical oxygen demand, landfill, leachate, solidwaste

Introduction

Over the past decades, the advancement of industry and commerce in many countries around the world and improper pattern of consumption led to a rapid increase in the production of municipal and industrial waste which damages human health and the environment. Solidwaste landfill can be a good place for insects or pathogenic microorganisms to grow.[1,2] Unsafe disposal of solidwaste in landfills accompanied with unpleasant odor due to the rapid decomposition of waste, attract flies, mice, and other animals.[3] According to previous reports, the rate of solid municipal solidwaste production in 1994 was 1.3 billion tons per day (666 g per person per day) which reached 1.7 billion tons per day in 2008 by a 31% increasing rate.[4] It has been estimated that by increasing urban population around the world, the volume of produced solidwaste will surged to four or five times higher than the current amount in 2050.[5] The rate of solidwaste production in Iran is also high so that the collection and disposal of these materials are a substantial problem. Statistics issued by the Tehran Municipality's Materials Recycling and Transformation Organization showed that Iran ranks tenth in the world in terms of solidwaste production.[6] Overall, 86.3% of all municipal solidwaste generated in Iran is being transported to landfills, 10.5% is being biodegraded as compost, and 5.9% is being recycled.[5] Sanitary landfill is one of the most common methods of solid waste management in cities around the

Address for correspondence: Dr. Gholamreza Mostafaii, Department of Environmental Health Engineering, Social Determinants of Health Research Center, Kashan University of Medical Sciences, Kashan, Iran.
E-mail: mostafai_gr@kaums.ac.ir

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world.[7] Landfill leachate is complex sewage that is produced when the amount of moisture or water in solid waste is higher than the capacity of the landfill.[7,8] The production of leachate from sanitary landfills is a major problem because it contains a large amount of chemical oxygen demand (COD), ammonia nitrogen (NH4-N) with strong color and odor, organic, and mineral substances including humic acid, heavy metals, and toxic substances. The concentration of COD and ammonium in the leachate often increases to a few thousand milligrams per liter. Unfortunately, the contaminated leachate discharge into the environment without any proper pretreatment caused a series of hazards that threaten the environment and human life. Therefore, to meet the environmental standards for discharging the leachate into other places or sewage collection system, it must be treated on-site.[9-14] Many factors affect the characteristics of urban landfill leachate, such as age, local climate, burial site, so the quantity and quality of leachate in different cities are different[15,16] and a uniform method has not been provided for its treatment so far.[17] Therefore, many researchers focused on this issue and tested several ways and methods to treat leachate. The previous studies recommended several methods for treatment of leachate including membrane methods such as reverse osmosis[18] and physical and membrane filtration methods such as nano-filters,[19] adsorption methods,[20] application of different coagulants,[21] chemical methods such as Fenton and electro Fenton,[22,23] and various advanced oxidation methods such as ozonation.[24,25] Biological treatment processes alone cannot remove resistant organic matter, so additional treatment is required.[26] Biological processes such as anaerobic processes such as high flow reactor with anaerobic sludge coating,[27,28] hybrid bed reactor,[29] anaerobic filter,[30] and aerobic processes such as aeration lagoons, common activated sludge processes, and sequencing batch reactor[31] are suitable for the treatment of waste leachate in the early stages when the biological oxygen demand 5 (BOD5)/COD ratio is high. However, by increasing the age of leachate, the BOD5/COD ratio decreases, and these conditions alongside increased content of toxic and nonbiodegradable substances in leachate might lead to lower efficiency of biological treatment for the treatment of leachate.[32] There is a remarkable content of resistant organic matter and heavy metals in leachate, which usually causes adverse effects on humans and the environment.[10,33] With the increase in production solidwaste and consequently increase in production leachate, several methods have been used to eliminate and reduce the COD in leachate, the efficiency and effectiveness of these methods in different conditions and places are not very clear. Therefore, this study intends to review the rate of elimination and reduction of COD parameters in different methods of leachate treatment for elimination and reduction of COD.

Materials and Methods

This study was conducted using keywords: leachate, COD, and landfill. We searched sites and journals related to scientific databases such as Web of Science, PubMed, Systematic Review, Google SID, Scholar, and Medline. Articles published from 1995 to 2019 with an emphasis on COD removal methods from landfill leachate have been reviewed. First, 140 articles were reviewed and finally, 96 sources focusing on studies in Iran and the world were selected. The reviewed articles were related to aerobic, anaerobic, advanced oxidation methods, physical and chemical methods, and the use of membrane processes to treat leachate. The data obtained from this study were presented in the table and the results were discussed and compared and eventually the effective and efficient methods were introduced.

Results

From 104 articles published between 1995 and 2019 regarding COD removal processes, 90% had inclusion criteria and included in the study. The summarized results of the studies focused on the application physiochemical process to reduce COD from leachate are presented in Table 1. Accordingly, Fenton and absorption were the mostly used methods for the treatment of leachate. Among applied method, the most effective process for elimination of COD from leachate was a process in which Fenton has been accompanied with advanced oxidation. In addition, absorption methods revealed an acceptable rate of COD removal (85%), which substantially depends on the type of used absorbent.

When the biological process is concerned, aerobic, anaerobic, and the combination of both aerobic and anaerobic processes utilized to remove organic components from leachate. Wetlands were widely used to limit the organic content of leachate, as well. Table 2 outlined the applied biological methods used for the treatment of leachate and the removal efficiency of the methods. Anaerobic-aerobic granular reactors showed a high performance (98.4%) in reduction of COD from leachate, while some applied anaerobic-aerobic reactors had a low rate COD reduction (47%).

Discussion

According to the study conducted by Renou *et al*., the membrane technologies, especially reverse osmosis, were the most applicable method for leachate treatment,[94] while in the present study, the most widely used process for leachate treatment was Fenton and absorption. From 1995 to 2019, 96 research papers were conducted on COD removal methods. A summarize of the studied methods is presented in Tables 1 and 2.

Physicochemical methods include the Fenton process, absorption, coagulation, electrochemical, and a combination of two or more methods [Table 1]. In the Fenton process, the highest COD removal rate was 97% which was related to the advanced oxidation of the Fenton reagent and the lowest one (22.7%) was observed for the electro-Fenton method.[34-44] Fenton's reaction destroys a large number of organic compounds without the production of toxic substances.[95] This method is relatively

Table 1: The studied parameter of the elimination of chemical oxygen demand from leachate by physicochemical method in percentage from 2005 to 2019

Method	Color removal percentage	COD removal percentage	Reference
Fenton (electro Fenton, Fered-Fenton,…)	81-90	7.22-97	[22,23,34-44]
Absorbent (PAC, GAC,…)	3.58-85	75.48-85	[20,45-57]
Coagulation (alum, ferrosulfate,….)	98	43-73	[21,35,58-62]
Electrochemical	36.96	66-8.95	[34,63-66]
Combination of methods (oxidation ozone/zinc, Fered-Fenton + electrodialysis,….)	99-100	33-97	[24,25,55,67-77]

COD: Chemical oxygen demand, GAC: Granular activated carbon, PAC: Powdered activated carbon

Table 2: Biological removal of chemical oxygen demand from leachate in terms of percentage between 1995 and 2019

Method	COD removal percentage	Reference
Aerobic-anaerobic (sequencing batch reactor, sequenced anaerobic-aerobic treatment,…)	47-98.4	[78-83]
Aerobic (aerobic granular sludge, on-site aerated lagoon plants,…)	43-98	[31,38-88]
Anaerobic (anaerobic hybrid membrane bioreactor,…)	90-98	[27-30,89,90]
Constructed wetland (polyculture constructed wetland,…)	46.5-88	[91-93]

COD: Chemical oxygen demand

inexpensive and requires less time than other advanced oxidation processes.[96] In the case of adsorbents, the highest removal rate of COD (85%) was estimated for the absorbents made of sewage sludge and corn stalks, and the lowest removal rate was related to the application of photocatalysts, activated carbon, and titanium dioxide by 47.85% removal efficiency.[45-57] The absorption of pollutants on activated carbon columns or powdered carbon has a better rate of COD reduction compared to chemical methods. The main disadvantage of this method is the need for frequent reconstruction of the columns and high consumption of activated carbon powder.[94] In the coagulation process, the highest removal rate of COD (73%) was presented for the application of $FeCl_3$ and the lowest rate was related to electrocoagulation by 47% COD reduction rate.[35,58-62] This treatment method has a couple of disadvantages such as (1) the constant volume of produced sludge and (2) an increased concentration of aluminum or iron in the aqueous phase.[94] Advanced treatment methods have been utilized in recent years for the treatment of industrial wastewater and waste containing organic pollutants. The main process used in the advanced treatment is electrochemical methods.[63,64] Electrochemical methods are desirable due to their compatibility with the environment and the possibility of treatment in liquids, gases, and solid phases. The highest COD reduction rate in electrochemical methods was 95.8%, and the lowest one was 22.7%.[64-66] The combination of different methods for the removal of COD from leachate was also suggested. A high rate of COD reduction (97%) was reported for a method in which microwaves with the help of hydrogen peroxide had been applied. In contrast, the lowest removal rate of 33% was related to the use of an advanced oxidation process. When a combination of methods is used, it covers the disadvantages of individual methods.[55,67-77]

The efficiency of biological methods includes aerobic-anaerobic, aerobic, and anaerobic, and wetland processes have been illustrated in Table 2. In aerobic-anaerobic reactors, the highest removal rate was 98.4% which was related to anaerobic-aerobic granular reactors. Based on experimental researches, the lowest removal rate of COD was reported for anaerobic-aerobic reactors through which only 47% of COD had been reduced.[78-83] Aerobic treatment can reduce some of the biodegradable organic pollutants and ammonia. Among biological methods used for the reduction of COD, the activated sludge process and electron beam were highly effective methods for the reduction of COD from leachate by a 98% removal rate. In sharp contrast, it seems that the sequential batch reactor with zeolite adsorption technology has not been an appropriate method to remove COD from leachate because the method could reduce only 43% of COD.[84-88] When the anaerobic methods were concerned, by application of anaerobic hybrid membrane bioreactor, a high reduction rate of COD, more than 90%, was achieved. However, the lowest rate of COD removal was about 90% which was reported for the application of microorganisms resistant to humic acid and ammonia nitrogen.[89,90] Some researchers have made use of different types of wetlands aiming to reduce COD. Accordingly, the highest removal rate was 88% which was related to the on-site treatment and constructed wetlands, conversely, the lowest removal rate (46.5%) was related to the use of floating vegetation in wetland.[91-93]

In the present study, we comprehensively focused on the efficiency of different methods applied to reduce the COD load of waste leachate. Many publications were reviewed to make an integrated comparison between different types of treatment plants. However, the role of other important parameters such as metrological properties of study areas, the characterization of leachate, and the scale of studies – laboratory, batch, or full scales – were not considered, which could be reviewed in further studies.

Conclusion

This study showed that various methods have been used to eliminate COD contamination of waste leachate. The most effective method to reduce COD has been a combination of chemical and biological methods that have increased the removal rate to a maximum rate of 98.4%. Among the methods used, Fenton and absorption methods have been used more effectively rather than others treatment technologies. Therefore, it can be concluded that the frequent application of these methods has been due to simplicity, reduction of energy consumption, and reduction of leachate toxicity.

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Conflicts of interest

There are no conflicts of interest.

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