Performance of UV Reactor for Total Coliform Removal from High and Low Strength Landfill Leachates

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Abstract: The levels of bacteria in landfill leachate is recently determined by researchers, as they may affect human health through pathogenic bacteria contaminations in surface and groundwater. The current study evaluated the effectiveness of ultra violet (UV) oxidation process for total coliform bacteria removal landfill high and low strength leachates in Pulau Pinang, Malaysia. The UV oxidation was applied as follow; leachate sample from Pulau Burung Landfill Site (PBLS) which has low total coliform content (200 MPN/100 m/L) and high organics (COD 1400-1600 mg/L), while the other used leachate sample from Ampang Jajar Landfill Site (AJLS) with high initial total coliform (>24 x 10^4 MPN/100 mL) and low organics (COD 130-300 mg/L). The UV contact time was varied between 2 and 5 min at 75 x 10^3 (mW-s/cm^2) UV dosage. Highest removal (99.2%) in terms of Most Probable Number (MPN) was obtained for Total coliform from leachate with high initial total coliform and lower organic content, while 94% removal was attained for leachate with low initial total coliform and high organics content. The study revealed that UV is an efficient process for the removal of microorganisms from leachate with low dissolved and suspended organic and inorganic contents.

Keywords: Total coliform bacteria, Contact time, Landfill leachate, Most Probable Number (MPN), UV reactor.

1. INTRODUCTION

Landfilling is still the most common and preferred technique for the disposal and management of solid waste [1-3]. However, the main associated environmental problem is leachate. Leachate is defined as a liquid produced from solid waste landfills as a result of waste processing and organic waste decomposition [3, 4]. Leachate contains a high level of organic, inorganics, heavy metals and toxic materials which has high risk hazards on the water bodies surrounding a landfill site [5, 6]. Proper management of leachate, suitable collection and efficient treatment is required to minimize the level of pollutants before discharge to the water bodies [7]. A number of different treatment applications for landfill leachate have been reported in the literature such as persulfate oxidation, coagulation and electro-coagulation, Fenton and Electro-Fenton oxidation, ozonation and ozonation based advanced oxidation, adsorbtion and ion exchange [8-22]. These applications are only focused on removing organic, inorganic and some heavy metals from leachate. Previous works have reported the existence of pathogenic bacteria in landfill leachate [23-27]. However, the performance of several reported treatment processes in removing pathogenic bacteria from leachate has not been well reported. Aziz *et al*., [28] employed Electro-Fenton oxidation for removing total coliform bacteria from leachate. Total coliform is considered as an indicator for the existence of pathogenic microbes [29]. The indicator of bacteria implies the possible presence of pathogenic microorganisms [30]. A high level of total coliform (0.66 x10^4-4 x 10^4) has been reported in landfill leachate [28, 31]. The presence of pathogenic microbs in leachate can directly contaminate surface and ground water; and affects human health [24]. The levels of total coliform contamination in groundwater by untreated wastewater and leachate has been reported [32, 33], and a significant relation between total coliform level in drinking water and incidence of different types of water born diseases such as diarrhea, giardiasis, hepatitis A virus, and parasitic diseases have been reported. Thus, the content of bacteria in leachate should be monitored and controlled before discharge. Ultra violet radiation (UV) was used as one of the efficient water disinfection processes to inactivate bacteria from drinking water

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[34, 35], and recently used in photo-catalytic and advanced oxidation processes for organic removal from wastewater and leachate [36 – 38]. Chueca *et al*., [39] investigated inactivation of pathogenic microorganisms in freshwater using HSO5−/UV-A LED and HSO5−/Mn+/UV-A LED oxidation processes. Liu *et al*., [40] examined the effect of sequential UV/free chlorine on the community structure pathogens in simulated drinking water distribution systems. Zeng *et al*., [41] evaluated the effect of UV irradiation on inactivation of bacterial spores in drinking water. However, the performance of UV for removing bacteria from leachate was not well investigated. Therefore, the current study aimed to evaluate and compare the effectiveness of the ultra violet radiation (UV) technique for total coliform removal from high and low strength of leachate in Malaysia. In this study, samples from two types of leachate with different Total coliform bacterial contents and different initial concentration of physiochemical parameters were used. The effect of contact time, the different initial content of bacteria and concentration of physiochemical parameters of leachate on total coliform bacteria removal was investigated.

2. MATERIALS AND METHODS

2.1. Landfill Leachate Sampling and Characteristics

In this study, leachate samples were collected from two landfill sites: the Palau Burung Landfill Site (PBLS) and Ampang Jajar Landfill Site (AJLS). PBLS is situated in the Byram Forest Reserve, Pulau Pinang, Malaysia, with a total area of 62.4 ha at latitude of 5^0 12' 03''N and Longitude of 100^0 25' 24'' E and receiving around 2200 tons of municipal solid waste daily. AJLS is located in Seberang Perai, at latitude of 5° 24' N and longitude 100° 24'22'' E. It has a total surface area, at the mainland of the Pulau Pinang State of Malaysia, with a surface area of 17 acres and receives approximately 650 tons of solid waste daily. The type of waste in both landfills is mainly municipal wastes. The collected samples were transported immediately to the laboratory, characterized, and cooled at 4 °C. The characteristics of the two types of leachate are presented in Table **1**.

Table 1: Characteristics of Landfill Leachate Collected from PBLS and AJLS, Pulau Pinang, Malaysia

Parameters	PBLS	AJLS
	Range	
pH	8-8.5	7-8.5
COD (mg/L)	1400-1600	250 - 450
Color (PtCo.)	3500-4000	130-300
TDS (mg/L)	11414	2420
Total Coliform (MPN/100mL)	130-200	<240.000
Temperature (◦C)	25-30	25-30
TSS (mg/L)	203	97
Iron (Fe^{2+}) (mg/L)	9	3

2.2. Ultraviolet Radiation

Ultraviolet treatment was performed using a laboratory batch UV reactor with fixed volume (600 mL) with the following specifications: Model no 6500 3091, UV-Immersion Lamp TQ 150 order-no 5600 1725, total immersion length of 383 mm, total immersion length to light of 303 mm center position, light emitting length of 44 mm, lamp output of 150 W, and high radiation intensity level in the wavelength range of 400 nm to 500 nm (Figure **1**). The experiments were conducted as a lab scale in accordance to the reactor's specifications: The reactor operates at a reactor volume range of 200 mL to 600 mL and radiation time range of 2 minutes to 5 minutes. The reactor is supported with single mercury vapor discharge lamps with the medium pressure and cooled water quartz jacket as the surface temperature lamb is 600-900°C. The specific electric power lamp output of 150 W/cm was set with an effective spectral range of 200-300, and specific radiation flux ranged between 12 and 18 W/cm. UV radiation was applied to a 600 mL volume of two types of leachate with different physiochemical and microbiological qualities (Table **1**). UV radiation was also applied at varying contact times (2, 3.5 and 5 minutes). For each run; UV lamp was immersed well into the reactor, and cooled water was circulated inside quartz cooling jacket to maintain desirable and suitable temperature for UV lamp during the radiation process. The pH leachate samples were maintained as the initial value.

2.3. Analytical Method

The determination of Total coliform bacteria was performed before and after each UV run by using the Most Probable Number (MPN) technique [42]. Twenty-five mL volume bottles were used for serial dilution process (1 x 10, 1 x 10^{-1}, 1 x10^{-2}, 1 x 10^{-3}, and 1x10^{-4}) and incubated for 48 h at 37° C. The total coliform population size was calculated according to MPN statistical tables [43]. The bacterial total coliform count

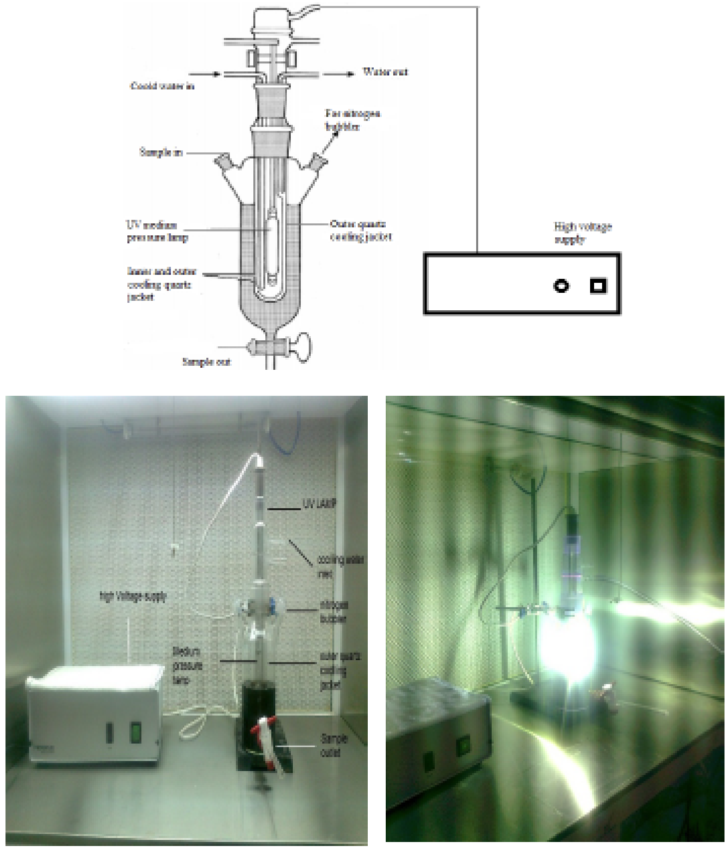

Figure 1: UV batch reactor.

is presented as the average of three measurements, and the difference between the measurements was less than 3%.

3. RESULTS AND DISCUSSION

The reactor of UV with fixed volume (600 mL) was used to inactivate Total coliform bacteria in two landfill leachate types with high and low total coliform bacterial content in AJLS: 240x1000MPN/100 mL and PBLS: 200 MPN/100 mL, respectively. Contact time of h 2, 3.5 and 5 minutes was performed. The maximum removal of Total coliform for PBLS and AJLS leachate was 94% (Figure **2**) and 99% (Figure **3**), respectively. The UV radiation is efficient for inactivation of different forms of microorganisms such as bacteria, viruses, and other

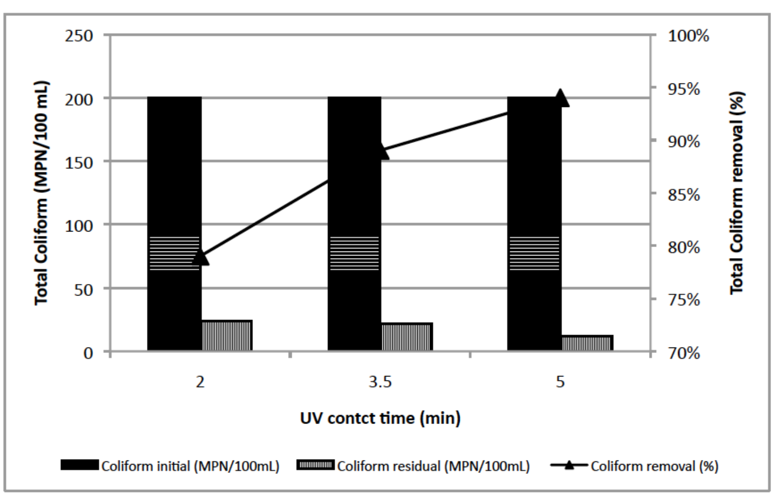

Figure 2: Performance of UV reactor (600 mL volume) for total coliform removal of PBLS.

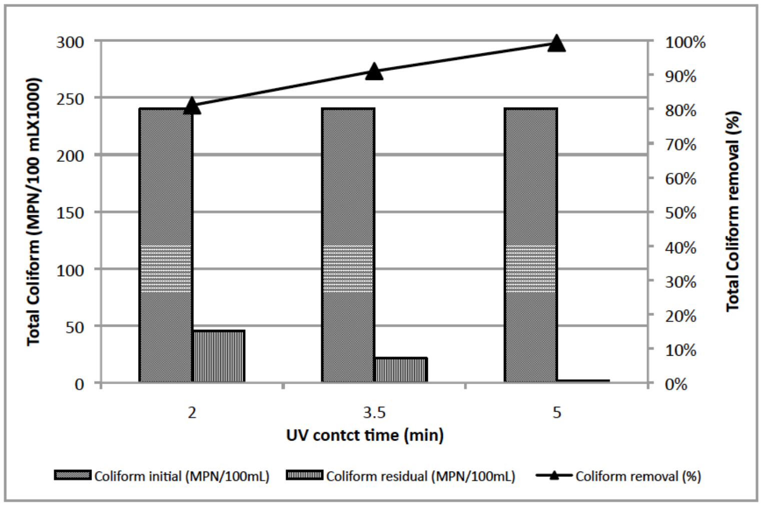

Figure 3: Performance of UV reactor (600 mL volume) for total coliform removal of AJLS.

pathogenic microorganisms. UV radiation inactivates microorganisms by absorption of UV which penetrates the microorganism cell wall resulting in damage in bacterial DNA and inactivate the bacterial cell [45]. Moreover, UV can generate higher concentrations of free radicals as a results of photochemical reaction (Eq. 1 & 2) [44], which has high oxidation potential and may oxidize the bacterial cell membrane [45, 46].

$$H_2O \xrightarrow{UV} H_2O^* \quad (1)$$

$$H_2O \xrightarrow{UV} OH^* + H^* \quad (2)$$

The effectiveness of a UV inactivation system depends on several limiting factors. The characteristics of leachate used, the sufficient dosages of UV radiation, the exposer time for microorganisms to the radiation, and the reactor configuration [47]. As shown in Figures **2** and **3**; the contact time is varied between 2 and 5 minutes for both types of leachate. The removal efficiency was increased by increasing the contact time.

Contact time with specific UV dose is an important factor to evaluate the degree to which the removal or inactivation of microorganisms. The UV dosage is calculated by the following equation (3) [47]:

$$D = I.t \quad (3)$$

Where D, is UV dosage (mW-$_S$/cm^2), I is UV intensity (mW/cm2) and t is contact time (s)

Although the total coliform content in AJLS is higher than that in PBLS; nevertheless, the removal of total coliform bacteria in AJLS leachate (99%) is reported higher than that in PBLS leachate (94%). The difference in the removal efficiencies may be attributed by the difference in the concentration of particulate constituents present in both leachate types (Table **1**). As shown in Table **1**, the concentration of Chemical Oxygen Demand (COD), color, Total Dissolved Solids (TDS), Total Suspended Solids (TSS) and iron in PBLS leachate is higher than in AJLS. Dissolved organics and inorganics, turbidity, color, and iron of greater than 0.1 mg/L can affect the effectiveness of UV for microbial inactivation [47, 48]. Table **2** presents the results of UV dosages applied at different contact times for both leachate types. As shown in the Table **2**, UV dosage ranged was between 30 x 10^3 (mW-$_S$/cm^2) and 75 x 10^3 (mW-$_S$/cm^2). Although the calculated dosage of UV is the same for both leachate types; nevertheless, different removal efficiencies for total coliform were obtained, which attributed to the difference in the leachate parameters in both leachate types. Although the total coliform content in AJLS leachate (240,1000 MPN) is higher than PBLS leachate (200 MPN), the highest removal for total coliform was reported at AJLS which has lower organic content (COD 250-450 mg/L) compared with PBLS (COD 1400-1600 mg/L). The results revealed that the significant amount of UV wavelength is absorbed by high dissolved and suspended organics and inorganics and inhibits the effectiveness of UV, thus reduce the sufficient dosage required. Previous results reported that the UV dosage ranged between 12 x10^3 and 60 x10^3 mW-$_S$/cm^2 is an effective for removing different microorganisms from drinking water [47, 39-41, 48]. The high level of humic acids, fulvic acids, hydrophilics, TOC and dissolved organic matters in leachate can quench the UV disinfection by diminishing the effect of

Table 2: Calculated UV Dosage used for Two Type of Leachate at Different Contact Time Combaring with Removal Efficincy and Total Coliform Bacteria Residual

	AJLS			PBLS		
Contact Time (min)	UV Dosage (mW-s/cm^2)	Total Coliform Residual (MPN/100mL)	Total Coliform Removal (%)	UV Dosage (mW-s/cm^2)	Total Coliform Residual (MPN/100mL)	Total Coliform Removal (%)
2	30 x10^3	45.6 x10^3	81%	30 x10^3	42	79%
3.5	52x10^3	21.6 x10^3	91%	52x10^3	22	89%
5	75x 10^3	1920	99.2%	75x 10^3	12	94%

UV radiation on bacteria due to UV light absorption and inhibit the reduction of bacteria [49-51]. Although the total coliform content in AJLS leachate (240,1000 MPN) is much higher than that in PBLS leachate (200 MPN), the highest removal for total coliform was reported at AJLS which is attributed to the higher level of COD, colour and suspended solids in PBLS compared with that in AJLS (Table **1**). Brahmi *et al*., [52] reported that the higher level of COD, colour and TSS in wastewater might inhibit the efficiency of UV process for bacterial inactivation. Bolton & Cotton [53] stated that the high level of dissolved iron and COD in water would reduce the UV transmission % and inactivate the bacterial removal. Walters *et al*. [54] presents the effect of TSS concentration on the on E. coli and Enterococci removal from wastewater using UV disinfection. The study reported that the higher concentration of suspended solids reduced bacterial removal efficiencies. The current results are in agreement with our previous work using Electro-Fenton oxidation for total coliform removal from the same leachate types [28].

4. CONCLUSION

The performance of UV oxidation in removing total coliform bacteria from two types of landfill leachate was investigated. The highest removal for total coliform bacteria (99.2%) was obtained from the leachate with higher initial content of total coliform and lower organic and inorganic concentrations. The results revealed that UV oxidation is more efficient at leachate with low dissolved and suspended organic and inorganic contents.

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