

Impact of Dumpsite Leachate Contamination on Surface Water at Beris Lalang Dumpsite, Kelantan

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Abstract. Leachate from dumpsites poses a significant threat due to its potential to contaminate surface water, damage local biodiversity, and negatively impact human health. This research focuses on assessing the environmental risks associated with leachate from the Beris Lalang Dumpsite. The aim of the study is to analyze the physical and chemical properties of leachate contamination in nearby surface water. Water samples were collected from four different locations, and the physical and chemical characteristics were evaluated. The Water Quality Index (WQI) and Leachate Pollution Index (LPI) were also calculated. The findings reveal the levels of pollutants were high at surface water samples close to the landfill. According to the WQI assessment, all locations fall under Class III. The LPI assessment indicates that the locations have a low pollution level. Although heavy metals such as zinc, arsenic, and iron were detected, the Heavy Metal Pollution Index (HPI) shows that all locations are considered safe and not highly contaminated. The study highlights the environmental impact of leachate and its potential effects on surface water near the Beris Lalang dumpsite. Additionally, it offers important insights into preventing pollution and safeguarding water resources.

1 Introduction

The complexity and diversity of waste generation have increased over time. This rise in solid waste (SW) production has contributed to the degradation of our environment. Rapid urbanization and industrialization have further strained natural resources and worsened urban environmental conditions. In many cities across the developing world, ineffective solid waste management and disposal practices have been major contributors to environmental decline [1, 2].

Leachate, produced by municipal solid waste, develops in landfills, incineration plants, composting facilities, dumpsites, and transfer stations due to physical, chemical, and biological processes. Managing leachate pollution is a global challenge and remains crucial for minimizing pollution sources and ensuring effective pollutant removal. To safely

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discharge or recycle leachate, integrated treatment methods must be applied to ensure it is properly treated before entering water bodies or being reused [3].

Leachate from dumpsites contains a combination of dissolved and suspended materials, with its composition influenced by various factors, including burial methods, climate, rainfall, moisture content, geological features of the site, landfill age, and the chemical makeup of the waste [4]. The sustainability of the ecosystem and public health are at risk when leachate is introduced into bodies of surface water. Water quality, ecological services, and biodiversity can all be negatively impacted by pollution in lakes and rivers. The higher probability that people would come into contact with hazardous substances through recreational or water-related activities highlights the need to understand dumpsite leachate characteristics [5]. The study aims to evaluate both the physical and chemical characteristics of leachate from the Beris Lalang Dumpsite in nearby surface water.

2 Materials and Methods

2.1 Materials and Instrumentations

Real-time assessments of water pH, dissolved oxygen (DO), temperature, and total dissolved solids (TDS) were performed using the YSI 556 MPS Multi-Probe System. Turbidity was quantified using a HACH Portable Turbidimeter Model 2100P. For ex-situ measurement, water samples were collected in sampling bottles and then preserved with acid until further usage. Concentrations of heavy metals were determined using atomic absorption spectrophotometry (AAS). The benchtop spectrophotometer (HACH DR 6000) was employed to measure chemical oxygen demand (COD), ammoniacal nitrogen (NH₃-N), and total suspended solids (TSS).

2.2 Study area

The research focusses on the surface water nearby to the Beris Lalang Dumpsite situated in Bachok, Kelantan. The research area's geographical coordinates for water sampling are between latitudes 5° 55' and 5° 56' North, and between longitudes 102° 24' and 102° 25' East. To evaluate the concentrations of contaminants in the study's area, samples of surface water were collected from river sources in close proximity to the landfill site. Four sampling points have been chosen to collect water samples. Table 1 and Figure 1 displayed both the corresponding coordinates and the map.

Table 1. The coordinates of each location description.

Location (Sampling Point)	Coordinates	Description
A	N 05°55'44.9" E 102°24'43.3"	The wastewater reservoir that was sucked from the drainage and then put into the black tank to be treated.
B	N 05°55'42.8" E 102°24'38.4"	Surface water's upstream of Gali River that nearby the dumpsite and palm plantation.

C	N 05°55'46.9" E 102°24'39.6"	Surface water which is Gali River at the in front of dumpsite's entrance that nearby palm plantation.
D	N 05°55'47.9" E 102°25'41.0"	Surface water which is Gali River at the area of Kampung Beris Lalang.



Fig 1. The map of each location by using Google Earth

2.3 Laboratory Analysis

The laboratory analysis in this study involved accurate measurements of BOD, COD, $\text{NH}_3\text{-N}$, and TSS. Additionally, various analysis methods, such as atomic absorption spectrometry (AAS), were used to determine the concentrations of heavy metals including chromium (Cr), copper (Cu), iron (Fe), nickel (Ni), lead (Pb), zinc (Zn), and arsenic (As).

2.3.1 Biochemical Oxygen Demand (BOD)

The study involved the collection of water samples using incubation bottles, followed by the measurement of dissolved oxygen (DO) levels on the first day. Subsequently, the bottles containing the samples were covered with aluminium foil and kept at a temperature of 20°C for a period of five days. After the incubation period, the final dissolved oxygen was measured to determine the oxygen concentration in the incubation bottles. Eq. 1 was applied to assess the oxygen concentration in the samples and derive the BOD value.

$$BOD\ value = \frac{Initial\ DO - Final\ DO}{P} \quad (1)$$

Where P is the fraction of sample/ 300 mL

2.3.2 Chemical Oxygen Demand (COD)

The testing process included two main procedures which were reactor digestion and colorimetric analysis. About 100 mL of a dumpsite's drainage water sample was blended for 30 seconds until it achieved homogeneity. The homogenised sample was placed in a 250 mL beaker and swirled gently using a magnetic stir plate to ensure precision. Next, a vial of HACH COD reagent was filled with 2.00 mL of homogenised sample, and another vial was made up of 2.00 mL of deionized water to act as a blank. Both vials were wiped clean, placed in a preheated DRB 200 reactor, and heated at 150 °C for 2 hours. After that, the reactor was turned off, and the vials were allowed to cool before being analysed. For the colorimetric procedure, the program 430 COD LR (HACH DR 6000) was started, and the blank sample cell was cleaned. Both the blank and prepared sample were placed in the cell holder, and COD levels were recorded. This process was repeated with water samples collected from other locations.

2.3.3 Total Suspended Solids (TSS)

About 10 mL of homogenized water sample was added to the sample cells. The program 630 Suspended Solids (HACH DR 6000) was used. The sample cell was placed in the sample holder and concentration of TSS in mg/L were obtained by pressing the read button and the result was recorded. Similar procedure was repeated for water from other locations.

2.3.4 Ammoniacal Nitrogen (NH_3-N)

The program 365 Nitrogen Ammonia (HACH DR 6000) was used to determine the concentration of ammoniacal nitrogen (NH_3-N) in the sample. To prepare the blank, 10 mL of deionized water was added to a sample cell. For each location, 10 mL of a homogenized sample was added to four sample cells. A powder pillow containing ammonia salicylate was added into each cell. The cells were thereafter sealed, shaken to facilitate the dissolution of the reagent, and allowed to react for a duration of 3 minutes. Then, a pillow containing ammonia cyanurate powder was added into each cell. The cells were then sealed again and vigorously shaken and left for a duration of 15 minutes. The presence of ammonia nitrogen was indicated by a green colour. The blank and prepared samples were inserted into the cell holder, and the results were shown in mg/L after pressing the read button.

2.3.5 Atomic Absorption Spectrometry

The atomic absorption method is commonly used to determine heavy metal concentration in the sample. Before performing AAS, samples must be prepared, often through dilution, to measure concentrations of elements such as Zn, Pb, Ni, Fe, Cr, and Cu in surface water near the Beris Lalang Dumpsite. A 50 mL sample is filtered through a 0.45-micron syringe filter before the analysis.

2.4 Water Quality Index Calculation

The WQI formula was established by Malaysia's Department of Environment (DOE) and computed using sub-indices of the parameters rather than the parameters themselves. SIDO, SIBOD, SICOD, SIAN, SISS and SIpH were the sub- indices. The Water Quality Index (WQI) for surface water samples collected from the sampling stations at the Beris Lalang Dumpsite was calculated using the WQI formula established by [6], as shown in Eq. 2.

$$WQI = (0.22 * SIDO) + (0.19 * SIBOD) + (0.16 * SICOD) + (0.15 * SIAN) + (0.16 * SISS) + (0.12 * SIpH) \quad (2)$$

Where;

SIDO = sub-index DO (% saturation)

SIBOD = sub-index BOD

SICOD = sub-index COD

SIAN = sub-index NH₃-N

SISS = sub-index SS

SIpH = sub-index pH

2.5 Leachate Pollution Index Calculation

The Leachate Pollution Index (LPI) was an effective tool for determination of the extent of leachate pollution from dumpsites or landfills. The LPI was determined by measuring the concentrations of different parameter variables as described in Eq. 3.

$$LPI = (C_1 + C_2 + \dots + C_n) / n \quad (3)$$

Where;

C_n = the concentration of different parameter variable

n = the number of parameters for which data is available

2.6 Heavy Metal Pollution Index Calculation

The heavy metal pollution index (HPI) was a rating method which reveals the composite effect of individual heavy metals on the overall quality of water. The rating was a number between zero and one that represents the relative importance of individual quality considerations and was inversely proportionate to the suggested standard which used the National Water Quality Standard (NWQS) Class III as the standards for each parameter with Eq. 4, 5 and 6.

$$W_i = K / S_i \quad (4)$$

$$Q_i = 100 \cdot (M_i - I_i) / (S_i - I_i) \quad (5)$$

$$HPI = \frac{\sum_{i=1}^n W_i Q_i}{\sum_{i=1}^n W_i} \quad (6)$$

Where;

Q_i = the sub index of ith parameter

M_i = the monitored value which concentration of the ith parameter

I_i = the ideal value of the ith parameter in µg/L which known as acceptable limit standard

W_i = the unit weight factor (W_i)

S_i = the standard or permissible limit for the ith parameter in µg/L (S_i)

K = the constant, 1

3 Results and Discussion

3.1 Water Quality Index Analysis

In this study, surface water quality was assessed in comparison to Class III National Water Quality Standard (NWQS) [1]. Table 2 presented the physicochemical analysis of surface water downstream from the leachate collection's drainage into Gali River.

Table 2. The physical-chemical analysis of surface water after the leachate collection's pond that flows into Gali River.

Parameter	Location				Standard (Class III)
	A	B	C	D	
pH	7.77 ± 0.619	5.46 ± 0.794	5.96 ± 1.414	5.54 ± 1.213	5.0 - 6.0
Turbidity (mg/L)	31.70 ± 9.588	8.77 ± 1.271	11.54 ± 8.116	17.40 ± 0.929	50
TSS (mg/L)	4.00 ± 8.505	2.70 ± 8.963	12.00 ± 15.620	6.67 ± 12.013	50 - 150
TDS (mg/L)	1.971 ± 0.361	0.77 ± 0.055	0.756 ± 0.045	8.05 ± 2.146	-
DO (mg/L)	0.80 ± 0.610	0.19 ± 0.339	12.14 ± 10.776	9.84 ± 16.758	3 - 5
EC (ms/cm)	3.27 ± 0.636	1.28 ± 0.090	1.23 ± 0.086	13.39 ± 3.516	-
Temperature (°C)	29.12 ± 0.728	29.05 ± 0.386	28.35 ± 0.745	29.24 ± 0.560	-
BOD (mg/L)	16.57 ± 14.881	3.34 ± 1.143	2.14 ± 0.717	3.92 ± 3.066	3 - 6
COD (mg/L)	141.00 ± 14.881	63.70 ± 36.474	66.00 ± 54.617	42.00 ± 9.849	25 - 50
AN (mg/L)	0.02 ± 0.006	0.003 ± 0.012	0.02 ± 0.011	0.007 ± 0.005	0.3 - 0.9
WQI	53.9 (Class III)	58.7 (Class III)	74.2 (Class III)	62.5 (Class III)	51.9 – 76.5

Among the designated sampling points, Location A displayed the highest concentrations of BOD, COD, and turbidity, indicating significant suspended particles potentially from fresh leachate contamination. Higher BOD and COD also was reported by [7] which indicate site-specific influences affecting water samples. Location B, unexpectedly, had the lowest pH (5.46 ± 0.794) and DO level (0.19 ± 0.339), despite its proximity to the leachate pond. The low DO levels might be attributed to dry weather conditions. During warm weather, surface water temperatures rise, reducing the solubility of oxygen [8]. The acidity was attributed to the farming practices of surrounding palm plantations, which can degrade soil and reveal acidic subsurface [9]. Location C showed the highest TSS and $\text{NH}_3\text{-N}$ concentration, likely influenced by nearby palm plantations and fertilization practices [10]. Location D exhibited the highest TDS and EC concentrations, possibly due to residential and fishing activities contributing pollutants to nearby water

bodies [7]. Despite these variations, all locations were classified under NWQS Class III for Water Quality Index (WQI), with Location C having the highest WQI of 74.2 and Location A the lowest at 53.8.

3.2 Leachate Pollution Index Analysis

The process of evaluating and disseminating information about overall contamination from leachate in samples of surface water using the Leachate Pollution Index (LPI) focused on several variables, including DO, BOD, TDS, AN, COD, pH and heavy metals. It simplified the understanding and comparison of water quality by providing a value based on a certain level of contamination which the value of high is more than 26.5, the value of intermediate is 26.5 – 23.6 and the lowest one is below than 23.6 [11]. Table 3 displayed the Leachate Pollution Index for Location A, Location B, Location C, and Location D.

Table 3. Results of Leachate Pollution Index at each location.

Parameter		Location			
		A	B	C	D
LPI inorganic	pH	7.77	5.46	5.96	5.54
	TDS, mg/L	1.971	0.776	0.756	8.050
	AN, mg/L	0.020	0.003	0.020	0.007
LPI organic	BOD, mg/L	16.57	3.34	2.14	3.92
	COD, mg/L	141.0	63.7	66.0	42.0
LPI heavy metal	Zn, mg/L	0.007	0.093	0.087	0.059
	As, mg/L	0.0050	0.0002	0.0010	0.0006
	Fe, mg/L	2.083	68.133	64.543	20.510
Total		169.43	141.51	139.51	80.09
LPI		21.18	17.69	17.44	10.01
Rating of leachate contamination ability		Low	Low	Low	Low

Based on the data shown in Table 3, Location A had the highest Leachate Pollution Index (LPI) among the sampled locations, with a value of 21.18. The increase in LPI was mainly caused by the presence of leachate pollution, which had higher levels of pollutants, especially COD concentration. The concentration of COD was classified as LPI organic, which could potentially increase the LPI reading and have negative impacts on water quality. It is important to note that all LPI values were classified as lower than the average of high LPI, suggesting that leachate pollution in surface water at Locations A, B, C, and D was not highly contaminated.

3.3 Heavy Metal Analysis

According to this study, the elements Cr, Cu, Ni, and Pb were not detected in any of the locations. This is probably because the concentrations were lower than the detection limits of the AAS instrument used for analysis. The concentrations of other elements, including Zn, Fe, and As, were successfully determined at different locations using AAS. The results are presented in Table 4.

Table 4. The physical-chemical analysis of concentration heavy metals.

Element	Concentration of the element at different Sampling point (mg/L)				NQWS Standard (mg/L) (Class III)
	A	B	C	D	
Cr	< 0.001	< 0.001	< 0.001	< 0.001	-
Cu	< 0.007	< 0.007	< 0.007	< 0.007	0.20
Ni	< 0.006	< 0.006	< 0.006	< 0.006	0.90
Pb	< 0.007	< 0.007	< 0.007	< 0.007	0.02
As	0.005 ± 0.002	0.0002 ± 0.0001	0.001 ± 0.0002	0.0006 ± 0.0002	0.40
Fe	2.08 ± 0.307	68.13 ± 14.858	64.543 ± 9.736	20.510 ± 6.150	1.00
Zn	0.007 ± 0.002	0.093 ± 0.017	0.087 ± 0.013	0.059 ± 0.012	0.40
HPI	11.14	12.46	12.41	11.51	-
Level of Average HPI	Very Good and Safe	Very Good and Safe	Very Good and Safe	Very Good and Safe	-

Location A showed the higher quantity of arsenic, at $0.005 \text{ mg/L} \pm 0.002$. This concentration did not exceed the NWQS Class III limit. Location B displayed the highest iron concentration ($68.13 \text{ mg/L} \pm 14.858$), attributable to the impact of nearby palm plantations. The heightened concentration may be ascribed to the geological character of the area, as proximity to palm plantations could inherently result in elevated iron levels [10]. Geological formations with iron-rich minerals or bedrock significantly contribute to elevated iron levels in surface water [12]. The zinc concentration is highest at Location B, reaching $0.093 \text{ mg/L} \pm 0.017$. But the zinc concentrations at all locations remained within the permissible limits set for NWQS Class III. The HPI values for locations A, B, C, and D are 11.14, 12.46, 12.41, and 11.51, respectively. The findings indicate that the locations are not significantly polluted and are environmentally safe.

4 Conclusion

The maximum Heavy Metal Pollution Index (HPI) of 12.46 was observed at Location B, which is rated as very good and safe. All sites classified as Class III according to the WQI, and Location C attaining the highest WQI value of 74.2. The LPI results demonstrated minimal leachate contamination at all locations. Future research could benefit from utilising ArcGIS software to improve the precision of illustrating leachate effects on surface water.

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