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Case Study

Characterization of Landfill Leachates and Its Impact to Groundwater and River Water Quality: A Case Study in Beris Lalang Waste Dumpsite, Kelantan

Widad Fadhullah[1,2]*, Mohamad Anuar Kamaruddin[1], Norli Ismail[1], Nurulilyana Sansuddin[2] and Hasmah Abdullah[2]

[1]*School of Industrial Technology, Universiti Sains Malaysia, 11800 USM, Gelugor, Penang, Malaysia*
[2]*Environmental and Occupational Health Program, School of Health Sciences, Health Campus, Universiti Sains Malaysia, 16150 USM, Kubang Kerian, Kelantan, Malaysia*

ABSTRACT

Solid waste management in developing countries including Malaysia is dominated by waste dumpsites which have a high possibility of transporting organic and inorganic pollutants to the underlying groundwater and surface water within the surrounding area. The objective of this study is to characterise the landfill leachates and its surrounding groundwater and river water quality and metals concentrations, namely arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb) and zinc (Zn) from Beris Lalang, Kelantan. Nine sampling points were collected within the dumpsite for analysis of *in-situ*: dissolved oxygen (DO), pH, total dissolved solids (TDS), conductivity, turbidity and ex-situ; Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Suspended Solids (SS) and the results were compared with permissible limits. As and Pb in groundwater samples were collected from the surface of two dug grounds within the vicinity of the dumpsites exceeded the standard of Ministry of Health. Cr, Cu and Pb in leachates exceeded Environmental Quality Act (EQA, 1974)'s standard, whereas Ni, Pb and Zn in surface water of Gali River exceeded the limit of class III National Water Quality Standard (NWQS). Exceeding metals concentration in leachates and its surrounding groundwater and river water relative to their respective standards points out toward potential leachate migration to the waterbodies within the surrounding vicinity of Beris

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E-mail addresses:
widad@usm.my (Widad Fadhullah)
anuarkamaruddin@usm.my (Mohamad Anuar Kamaruddin)
norlii@usm.my (Norli Ismail)
nurulilyana@usm.my (Nurulilyana Sansuddin)
hasmahab@usm.my (Hasmah Abdullah)
* Corresponding author

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Lalang dumpsite. This study provides the initial baseline data and preliminary monitoring assessments as a first step towards improving water security and waste management in Kelantan.

Keywords: Dumpsites, groundwater, Kelantan, leachates, metals, surface water, waste

INTRODUCTION

Solid waste management issues are critical in developing countries due to illegal dumping, an excessive amount of waste generated, and the lack of waste collection services provided (Aiman et al., 2016). Consequently, pollutants accumulate, leach or flow through the surrounding dumpsite before affecting the surrounding environment and health. Thus, majority of solid waste management practised in tropical countries, such as Kenya, Ghana, Nigeria (Oyelami et al., 2013) and Pakistan (Ali et al., 2014; Alam et al., 2017), were carried out without adequate lining materials and leachate treatment plants, which induced contamination through the soil, subsequently leached to the groundwater and eventually to the nearest river.

In Malaysia, only 13 out of 300 existing landfills are operating sanitary landfills. Particularly, in Kelantan, the existing active landfills are open waste dumpsites (Jabatan Pengurusan Sisa Pepejal Negara [JPSPN], 2015). Open waste dumpsites are piled with unattended wastes exposed to physical, chemical and biological processes simultaneously accelerating the waste decomposition together with the generation of leachate and landfill gases (Oketola & Akpotu, 2015). The situation further aggravates due to the high temperature and humid conditions of the tropical countries such as Malaysia (Suleman et al., 2015). Subsequently, these wastes gradually degrade and accumulate substantial amounts of dissolved organics, xenobiotic organic compounds, inorganic salts, ammonia, metals and other toxicants (Kanmani & Gandhimathi, 2013).

Household products of electronic waste, painting waste and used batteries contain metals such as Pb, Cd, mercury, As, Cu and Zn. These products are among the waste discovered in waste dumpsites, which cannot be biodegraded. Thus, solid waste disposals (open dumps, landfills, sanitary landfills or incinerators) represent a significant source of metals into the environment (Kanmani & Gandhimathi, 2013).

Dumpsite leachates contain mixtures of both dissolved and suspended materials based on their method of burying, climate, rainfall, moisture content, the geological nature of the site, the age of the landfill and the waste composition (Arunbabu et al., 2017). Therefore, the quality of leachates is site-specific. Studies about leachates in waste dumpsites (sanitary and non-sanitary landfill, open waste dumpsites) are not new (Ishak et al., 2016; Kamaruddin et al., 2017; Moody & Townsend, 2017). The growing interest in leachate characterisation emerges from the potential migration impacts of leachates to the surrounding environmental receptors may increase the likelihood of hydrogeological and water pollution. Hence, this study is conducted to evaluate the environmental contamination from the leachates and its potential effect to the groundwater and surface water nearby Beris Lalang dumpsite area of 8 years. This baseline monitoring may assist in analysing the extent of risk to water security and planning for future sanitary landfill in Kelantan.

MATERIALS AND METHODS

Study Site and Field Sampling

The sampling was collected at Beris Lalang, the largest active waste dumpsite covering Kota Bharu district in Kelantan. Beris Lalang is a peat swamp area surrounded by palm oil plantations and consists of a small stream leading to Gali River, which eventually flows to Kandis Beach, Bachok. It receives approximately 350 tonnes/day of daily waste (Kamaruddin et al., 2016). Nine locations were selected as the sampling points within Beris Lalang (Figure 1). Two of which were groundwater samples collected from the surface water of dug grounds (GW1 and GW2), another five sampling points representing leachate samples (L1-L5) and the other two sampling points were surface waters (SW1 and SW2). SW1 was located from a stream flowing out of the leachate collection pond before it is released to Gali River whereas the second surface water samples were collected from Gali River within 500 m from SW1 (SW2). Table 1 sets out the coordinate of sampling locations.

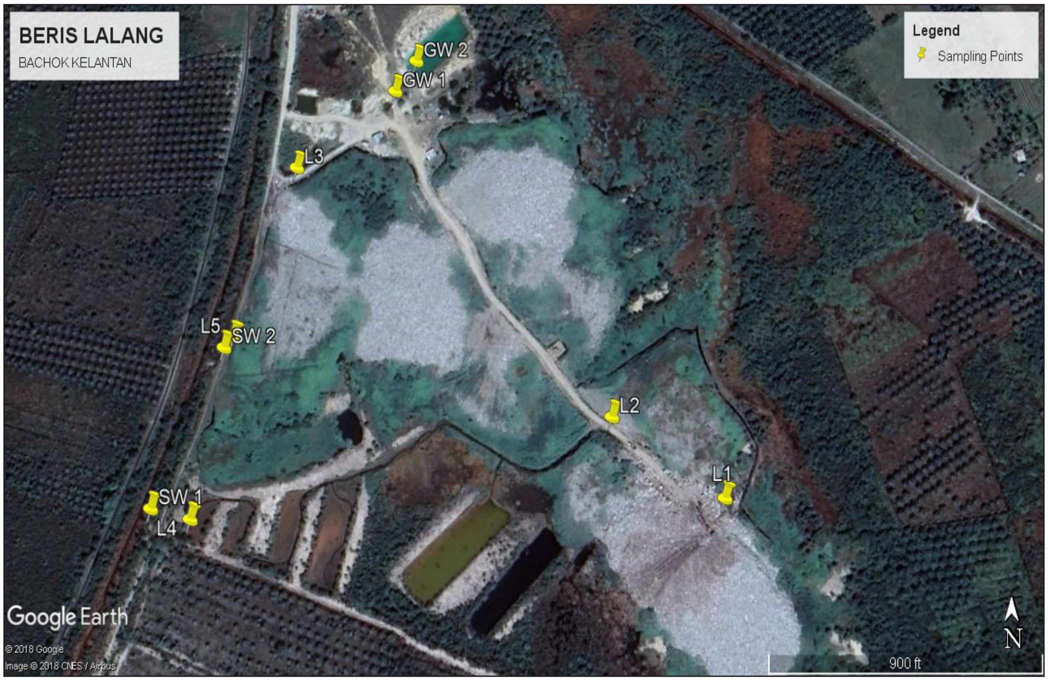

Figure 1. Nine sampling points of environmental constituents sampling at Beris Lalang dumpsite, Kelantan

Table 1
Coordinates of sampling locations from Beris Lalang dumpsite, Kelantan

Station	Latitude	Longitude	Description
GW1	N 05°55.780'	E102°24.729'	Groundwater used for ablution by landfill workers and waste collectors
GW2	N 05°55.796'	E102°24.741'	Groundwater occasionally used for a dip by locals
L1	N 05°55.576'	E102°24.915'	Fresh leachates near lorry unloading the waste
L2	N 05°55.615'	E102°24.853'	The passageway of lorry unloading waste
L3	N 05°55.740'	E102°24.673'	Near MPKB's landfill supervisor office
L4	N 05°55.566'	E102°24.620'	Between the dumpsite's entrance and leachate collection pond
L5	N 05°55.654'	E102°24.640'	Exit-entry before flowing to Gali River, a small stream
SW1	N 05°55.571'	E102°24.598'	After leachate discharge to Gali River
SW2	N 05°55.649'	E102°24.635'	Gali River opposite L4

Beris Lalang dumpsite has a size of 30.5 hectares. It is located 400 m away from the nearest house, 1 km away from two schools, namely Sekolah Kebangsaan Beris Lalang and Sekolah Menengah Ugama Darul Iman and 7 km from Tok Bali, a popular tourist spot. The sampling of groundwater, leachates and surface water within the vicinity of the dumpsite were conducted to assess the degree to which the environmental constituents were contaminated in the study area. In this study, surface water samples from groundwater and river water samples were collected about 10cm below the surface water by employing a water sampler or a pail attached to a rope. Within 24 hours prior to samples collection, the pre-washed HDPE bottles were soaked with 10% concentrated nitric acid.

On-site measurements of water pH, DO, temperature, TDS and Electrical Conductivity (EC) were performed by using YSI 556 MPS (Multi-Probe System) Multiparameter. On the other hand, turbidity was measured by utilised a HACH Portable Turbidimeter Model 2100P.

Laboratory Analysis

Biochemical Oxygen Demand (BOD_5) and Chemical Oxygen Demand (COD) were analysed according to the standard method of APHA at Occupational Safety and Health Laboratory, Universiti Sains Malaysia Health Campus. On the other hand, Ammoniacal Nitrogen (AN) was analysed by utilising HACH DR 2010 spectrophotometer. Furthermore, Suspended solids (SS) was analysed by using the USEPA standard method. The water samples were filtered with 0.45µm membrane filter for analysis of metals. The samples were subsequently transferred into 15 mL vials and a total of 7 metals were analysed by employing Inductively Coupled Plasma Mass Spectrometry (ICPMS) model Agilent 7700. Leachate samples were filtered twice by using Whatman 0.45-mm filter paper. Raw leachate samples were diluted 25 times before transferred into 50 ml polypropylene tube. Agilent multi-element standard solutions were adopted to prepare the calibration curve and the calibration curves with $R^2 > 0.999$ were accepted for concentration calculation. Precision analysis from the triplicate measurements of each sample for metals concentration indicates a % relative standard deviation of less than 10% per cent recovery for all metals that were within the range of 92-104%.

Statistical Analysis

Data were analysed by using SPSS version 24.0 (SPSS Inc., Chicago, IL, USA) and GraphPad Prism version 7 (GraphPad Software Inc, San Diego, USA). The statistical analyses were adopted to reveal the significant value of each element in the 95 % confidence level (a=0.05). Data were presented as average and standard deviation for water quality parameters and average and standard error for the metals. Statistical differences between the means of groundwater and river water samples were compared by utilising t-test, whereas using one-way ANOVA for leachate samples at p-value <0.05. National Guidelines for Raw Drinking Water Quality, Ministry of Health (MOH, 2011) was adopted for groundwater samples whereas Class III NWQS was used for river water to monitor the guidelines of selected water quality and metals analysis in Beris Lalang waste dumpsite. Leachates was compared with Second Schedule (Acceptable Conditions for Discharge of Leachate) of the Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009, Environmental Quality Act 1974 [Act 127] (Department of Environment [DOE], 2009).

RESULTS AND DISCUSSION

Physicochemical Characteristics and Metal Concentrations of groundwater, River Water and Leachates from Beris Lalang Waste Dumpsites

Tables 2-4 indicate the water quality results of groundwater, river water and leachate at Beris Lalang dumpsite. In the groundwater, DO was low in GW1 (1.41 ±0.16) and 0.9 ±0.05 in GW2. DO is generally low in groundwater samples as reported from a study conducted by Rahim et al. (2010). The parameters were compared with groundwater standards established by MOH (2011) and DOE (2011). The groundwater qualities were within the standards for all parameters measured except for pH in GW2 (Table 2). pH in GW2 was discovered to be below the recommended standard and was very acidic (3.88±0.02). The acidic condition of GW2 may expose the workers and scavengers of Beris Lalang waste dumpsite to the possibility of skin irritation if they were in frequent contact with the water. The acidification might have been caused by oxidation of sulfide minerals within the original peat conditions of the dug grounds (Appleyard et al., 2004). Another implication of using acidic groundwater is the corrosion of plumbing materials if being used (Ugwoha & Emete, 2015). Low pH may also cause metals, such as cadmium, to dissolve and encourage high iron concentrations (MacDonald et al., 2002).

All groundwater samples were significantly different between GW1 and GW2 (t-test, $p<0.05$). EC values were lower in GW1 (0.049± 0.005 mS/cm) compared to GW2 (0.373± 0.010 mS/cm), indicating that GW1 contained less soluble salts than GW2. EC is a measurement of the ability of water to conduct electric current which is largely influenced by dissolved salts such as sodium chloride and potassium chloride (Isah et al., 2015). Based on observations, the colour of both groundwaters was also different. For instance, GW2 had a turquoise blue-like colour, whereas GW1 was with a turbid colour. This might explain the differences in the TDS and turbidity readings. Higher BOD_5, COD and AN was reported in Yusoff et al. (2013), reflecting site-specific influences and affecting the groundwater samples (Table 2). The BOD_5 and COD values of the groundwater samples in GW1 are 10.88 ± .076 and 8.33± 1.53, respectively, indicate the presence of insignificant biologically and chemically oxidizable organic contaminants in the groundwater. This implies that the groundwater is safe to be used for ablution by the workers and scavengers in that area. The values of BOD_5 and COD in both GW1 and GW2 indicate that there is no organic contamination from the leachate to the groundwater surrounding the site. This is supported by Hassan and Ramadan (2005), who assessed the effects of sanitary landfill leachate on the groundwater and discovered that no organic contamination of piezometer wells around the active cells of the landfill. Nevertheless, GW1 is more suitable to be used with skin contact considering the acidity of GW2.

Table 2
Physicochemical parameters of groundwater samples from dug grounds within the vicinity of Beris Lalang dumpsite. Data are presented as mean ±SD, n=3

Parameter	Groundwater		Standard	Other studies
	GW1	GW2		
DO	1.41 ±0.16	0.9 ±0.05	-	0.11-0.82[b]
pH	6.77 ±0.09	3.88±0.02	5.5-9.0	6.39-6.81[b]
EC (mS/cm)	0.049± 0.005	0.373± 0.010	*0.3	0.1-0.9[a]
Temp (°C)	28.44 ±0.036	29.71±0.145	-	26.5-27.5[c]
TDS	0.029±0.004	0.224±0.004	1500	18-342[c]
Turbidity (NTU)	38.27±5.52	4.00±1.20	1000	1.6-6.6[c]
BOD_5	10.88 ± .076	2.58 ± 0.06	6	123-142[d]
COD	8.33± 1.53	ND	10	2715-2890[d]
AN	0.29± 0.006	1.34±0.006	1.5	15.76-19.70[d]

Note. ND-not detected; Standard refers to Ministry of Health Malaysia (MOH, 2011) except the ones marked with asterisk* refers to World Health Organization (WHO, 2011); [a]Chakraborty and Kumar (2016); [b]Rahim et al. (2010); [c]Akinbile (2012); [d]Yusoff et al. (2013)

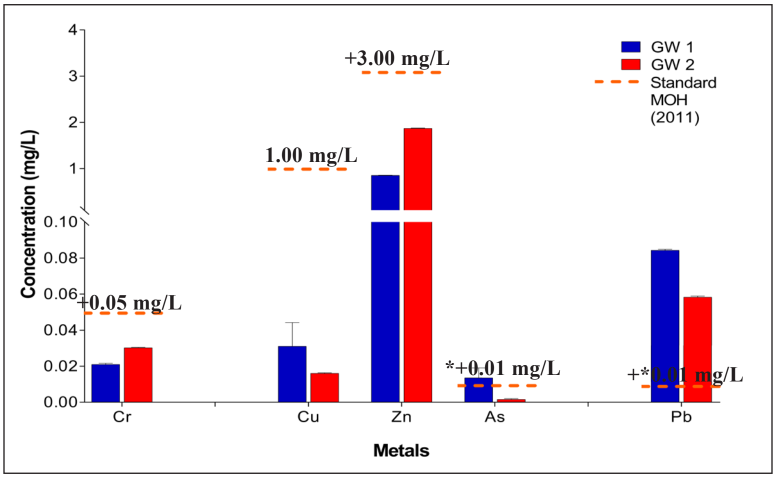

Figure 2. Metals concentration in groundwater samples from dug grounds within the vicinity of the waste dumpsite in Beris Lalang, Kelantan reported as mean ±SEM, n=3. * denotes exceeding MOH (2011), + significant difference (t-test, $p<0.05$)

Cr, Zn and Pb are significantly different between GW1 and GW2 (t-test, $p<0.05$). Zn has the highest concentrations for GW2 relative to other metals in the groundwater samples of the dug grounds (Figure 2). As and Pb were discovered to exceed the permissible limits of MOH (2011) in both GW1 and GW2. As is categorized as poisonous despite it is in small quantity. Therefore, the usage of the groundwater by waste workers in Beris Lalang may increase the exposure to health issues related to respiratory illnesses, lung cancer and cardiopulmonary associated with As contamination (Farooqi et al., 2007; Muhammad & Zhonghua, 2014). Apart from that, Pb is toxic to human and could lead to health implications such as mental deficiency to the waste collectors and waste workers at the dumpsite (Al Sabahi et al., 2009). Pb is also carcinogenic, which may increase the potential of having cancer (Rousseau et al., 2007).

Out of all leachates, leachates in the L1 exhibit the highest concentration of EC, SS, turbidity, BOD_5 and COD (Table 2). The pH of L1 was also very acidic, suggesting young leachate with a pH of less than 6.5 (Foo & Hameed, 2009). Leachate collected from L1 was gathered near the new wastes dumped by the disposal lorries from Kota Bharu Municipal Councils, Bachok Municipal Councils and Pasir Puteh Municipal Councils and were considered reflecting fresh leachates composition. The wide range of pH found in each study corresponds to the different stages of waste stabilization and evolution, from the transition aerobic, acid, methane and stabilization phase (Kamaruddin et al., 2017; Mukherjee et al., 2015). Typical leachate samples are reported to have a pH range between 4.5 and 9 (Kawai et al., 2012; Muhammad Umar et al., 2010). Low pH in the early phases of the landfill is associated with high concentrations of volatile fatty acids during the solubilisation phase of the organic acids (Kamaruddin et al., 2017; Muhammad

Umar et al., 2010). Nevertheless, pH in other leachates collected at L2-L5 indicates pH ranges between 7.52 and 8.41, reflecting old and stabilised leachates associated with the conversion of organic acids into gaseous phase (Kamaruddin et al., 2017; Muhammad Umar et al., 2010). Other studies reported in the literature has shown pH ranges between 7.0 and 7.8 (El-Salam & Abu Zuid, 2015), 6.7 (Bahaa-Eldin et al., 2008) and an average of 7.6 and 8 (Zin et al., 2013).

The black colour and high EC and SS in L1 also suggested the presence of high suspended matters and high dissolved organic matters in the waste stream (Ishak et al., 2016). The black colouration of leachate was associated with the oxidation of ferrous to a ferric form and the formation of ferric hydroxide colloids and complexes with humic substances (Chu et al., 1994; Ishak et al., 2016). The results from this study were also compared the leachate characteristics from other landfills or waste dumpsites (Table 3). The data were within the range of other reported studies and some parameters were discovered to be higher than the others, specifically for L1. On the other hand, the findings from other studies indicated that the leachates characteristics are site-specific and based on the nature of the waste and source location (Bahaa-Eldin et al., 2008; Ishak et al., 2016; Rahim et al., 2010)

Table 3
Physicochemical parameters of leachates present within Beris Lalang dumpsite. Data are presented as mean ±SD, n=3

Parameter	Leachates					Standard	Other studies
	L1	L2	L3	L4	L5		
DO	0.70 ± 0.15	0.76 ± 0.078	1.59 ± 0.017	1.60 ± 0.05	1.17 ± 0.09	-	2.93 ± 0.19[b]
pH	2.03 ±0.02	8.31 ± 0.076	8.41± 0.012	8.01± 0.06	7.52 ± 0.08	6.0-9.0	6.70±0.28[b] 6.64-8.21[c]
EC (mS/cm)	22.56 ± 0.83	10.92 ±0.096	7.16± 0.05	3.83± 0.09	6.63 ± 0.05	-	26.5[a]
Temp (°C)	32.30 ± 0.16	32.94 ±0.09	33.87 ± 0.71	32.06 ± 0.15	34.39 ± 0.20	40	37[d]
TDS	13.48 ± 0.14	6.13 ± 0.064	3.91± 0.05	2.41± 0.06	3.55 ± 0.05	-	28.19±3.91[b]
SS	4013 ± 33.29	381 ± 2.52	240 ± 1.25	971 ± 8.19	394 ± 4.58	50	255-1050[e]
Turbidity (NTU)	4505 ± 29.44	1483 ± 0.28	416 ± 5.55	129 ± 1.61	102 ± 3.32	-	155[d]
BOD_5	1965 ± 2.28	798 ± 0.86	202 ± 0.71	191 ± 0.86	183 3.11	20	144[a]
COD	1640 ± 11.14	328± 19	163± 10	69 ±18	154 ± 18	400	139-9958[c]

Note: Standard used: Second schedule (Acceptable Conditions for Discharge of Leachate) of the Environmental Quality Act 1974 [Act 127] (EQA, 1974); [a]Chakraborty & Kumar (2016); [b]Rahim et al. (2010); [c]Matejczyk et al. (2011); [d]Ishak et al. (2016); [e]Oketola & Akpotu (2015).

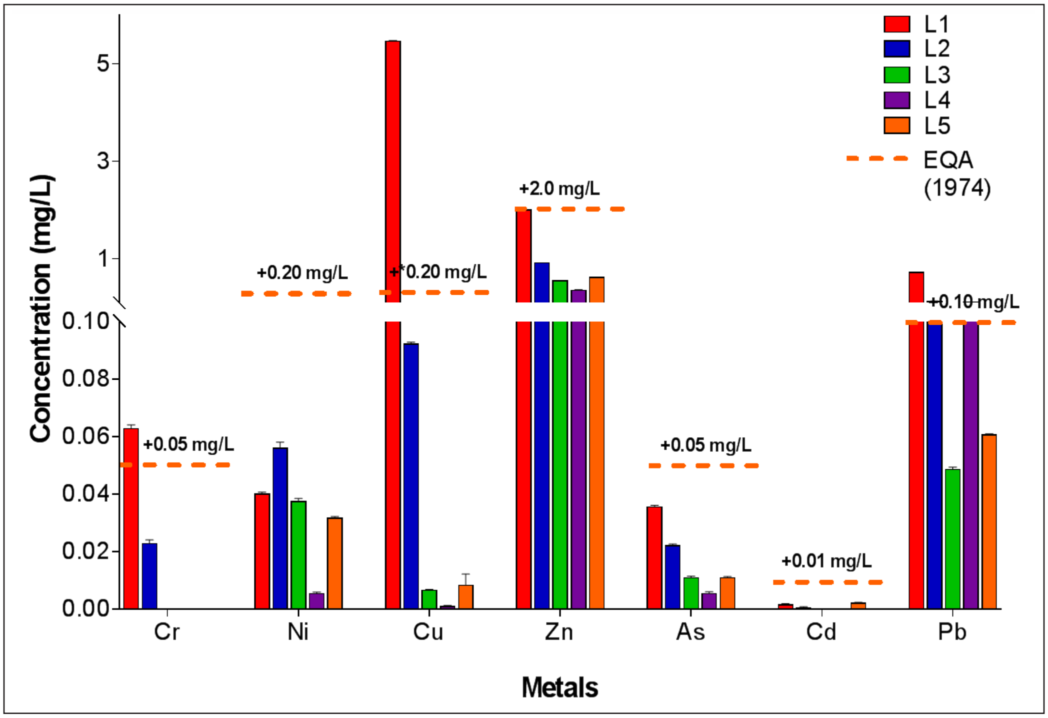

Figure 3. Metals concentrations in leachates collected at Beris Lalang waste dumpsites are reported as mean ± SEM, n=3. *denotes exceeding EQA (1974), +significant differences between sampling stations (one-way ANOVA, $p<0.05$)

Cu concentrations were the highest at L1, followed by Zn and Pb (Figure 3). The presence of higher Cu, Zn and Pb in L1 could be related to the low pH condition in L1, which has higher metal solubility caused by the production of organic acids during the acetogenic phase (Kamaruddin et al., 2017; Muhammad Umar et al., 2010). Cr, Cu and Pb concentrations at L1 have exceeded the standard of EQA (1974). Pb is carcinogenic whereas Cu and Cr are non-biodegradable, which may consequently be accumulated in the food chain, causing ecotoxicological consequences (Kjeldsen et al., 2002; Langston 1990). Metals concentrations (Cr, Ni, Cu, Zn, As, Cd and Pb) were significantly different based on the sampling locations (one way ANOVA, $p<0.05$). This indicates that the variations of metals contaminations are strongly affected by locations, especially leachate samples collected from the locations nearest to the active activity of unloading waste conducted by the lorries of the municipal council and scavenging of wastes by waste collectors.

Surface water was compared to class III NWQS. Table 4 indicates the physical-chemical analysis of surface water after the leachate collection pond that flows into Gali River. The data showed that most parameters for surface water from the Gali River were higher (worse) than the Class III NWQS standard. Hence, it can be categorized as Class IV, indicating the water can be utilised only for irrigation (DOE, 2012).

Table 4
The physical-chemical analysis of surface water after the leachate collection pond that flows into Gali River

Parameter	Surface river water		Standard	Other studies
	SW1	SW2		
DO	1.15±0.06	1.23±0.06	3-5	5.98-6.87[b]
pH	6.71 ±0.09	3.93±0.06	5-9	4.63 ± 1.1[a] 7.10-7.24[b]
EC (mS/cm)	1.24± 0.11	1.21± 0.04	-	0.83±0.5[a] 244-281[b]
Temp (°C)	32.47 ±0.11	29.86±0.04	-	27.85± 1.3[a] 24.24-26.34[b]
TDS	0.89±0.06	0.73±0.03	-	431 ± 247[a] 2345-2398[b]
Turbidity (NTU)	119.33±2.52	111±1	50	11.62±8.9[a]
BOD_5	20.52 ± 0.09	10.08 ± 0.06	6	88-97[b]
COD	50 ± 5	30 ± 5.56	50	1123-1210[b]
AN	0.29± 0.006	1.34±0.006	0.9	10.45-11.24[b]

Note: Standard used: Class III National Water Quality Standard for Malaysia (DOE, 2012); [a]Ishak et al. (2016); [b]Yusoff et al. (2013)

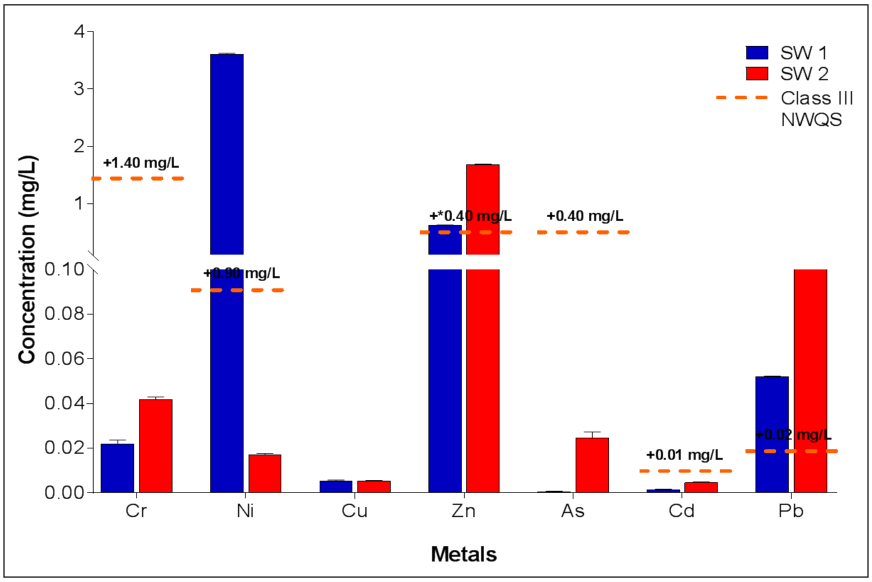

Figure 4. Metals concentration in surface water of Gali River within the vicinity of Beris Lalang waste dumpsite. Data are reported as mean ±SEM, n=3.SW1-surface water 1, SW2-surface water 2. *denotes exceeding class III NWQS, + significant differences between sampling stations (t-test, p<0.05)

Ni was discovered to be the highest in the surface water of Gali River, followed by Zn and Pb concentrations (Figure 4). All metals were significantly different from one another in the river water except Cu (Figure 4, t-test; p<0.05). Comparison with NWQS showed that Ni, Pb and Zn exceeded class III of NWQS. Thus, the surface water could be classified under class IV, which is only suitable for irrigation. These exceeding metals concentration could be the consequences of potential leachate migration from the leachate collection pond that flows to the river.

CONCLUSION

Based on the baseline monitoring conducted, the pH levels detected at the groundwater of GW2 posed a risk of skin condition to the waste collectors who occasionally used the groundwater to freshen up after working under the sun during a hot afternoon. As and Pb concentrations in groundwater also exceeded the standard, exposing the users to the risk of carcinogenic and health effects. Leachate samples exceeded EQA (1974) for toxic metals, such as Pb and Cr, which increased the risk of health implications, such as mental deficiency. The surface water of Gali River contains exceeding levels of Ni and Zn compared to class III NWQS. Thus, the water is inappropriate for any recreational or fishing activities. This shows the potential migration of leachates to the surrounding environmental constituents considering the exceeding metals concentration in the groundwater and surface water samples. Hence, full characterisation of the waste dumpsite is crucially required to evaluate the potential environmental risks and to identify suitable remediation options.

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