



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

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International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 10, October 2024

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

**Impact Factor: 8.524**

9940 572 462

6381 907 438

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# The Assessment and Monitoring of Leachate and Groundwater Contamination at Three Major Landfill in Indochina Peninsular

Phetyasone Xaypanya, Jiro Takemura, Chart Chiemchaisri

Lecturer, Faculty of Water Resources, National University of Laos, Vientiane Capital, Laos

Professor, Department of Civil and Environmental Engineering, Tokyo Institute of Technology, Japan

Professor, Department of Environmental Engineering, Faculty of Engineering, Kasetsart University, Thailand

**ABSTRACT:** In this study, leachate and groundwater samples were collected from three major landfills in three countries, namely Nonthaburi landfill in Nonthaburi Province, Thailand; Dangkor landfill in Phnom Penh, Cambodia; KM-32 landfill in Vientiane, Laos. The paper reports the results of the site investigation, including in-situ and laboratory measurements, and duration of study was 3 years. Most of parameters of the leachate, such as Cl, TDS, BOD<sub>5</sub>, and COD were found much higher than effluent standard. Nonthaburi and Dangkor landfill have some similar highest values at some points, but KM-32 landfill shows relatively low values due to the lower waste high as compare to other two landfills. Seasonal variations were confirmed regarding basic parameters, such that most parameters showed higher concentrations in dry seasons than wet seasons, while DO and ORP were higher in wet seasons. Rather opposite trends were found for the groundwater. Some seasonal variation was also observed in the concentration of heavy metals (As, Pb, Cd, Cr and Zn) for the leachate and groundwater. The general trends over the time on leachate properties are slight increase for the basic parameters and decrease for the heavy metals.

**KEYWORDS:** Landfill leachate, groundwater, heavy metals, monitoring programs.

## I. INTRODUCTION

Municipal solid waste management is one of the existing unsolved problems in the developing countries, e.g., Indochina peninsular countries under the status of developing and the least developed countries. Those countries have been facing a linear increase of municipal solid waste and waste management problems, especially the environmental risk by the landfill leachate. Moreland is needed for the ultimate disposal of these solid wastes, and issues related to disposal have become highly challenging for most countries [1]. Landfill leachate is the liquid residue resulting from the various chemical, physical and biological processes taking place within the landfill. The leachate could be a primary source of various contamination and pollution to the surrounding environments, e.g., surface water and groundwater in particular. The leachate is generated mainly by excess rainwater percolating through the waste layers in a landfill. The leachate problem has been worsened by the fact that many landfills in developing countries lack appropriate landfill facilities, such as bottom liner, leachate collection, and treatment system, which increases the possibility of groundwater and surface water contaminations [2]. Hazardous substances in MSW are presented in the form of paints, mercury-containing wastes, batteries, pharmaceuticals, vehicle maintenance products and many other diffuse products [5]. Heavy metals are one of common non-degradable pollutants found in the leachate, of which continuous accumulation could cause an acute risk to human and public health [4]. The leachate quantity and quality depend on site conditions, such as weather and geological conditions, the waste composition and age, waste disposal practice [3]. This study aims to assess the leachate and nearby groundwater qualities and their long-term monitoring, as well as the change over time of basic parameters and harmful heavy metals at the selected landfills in the Indo-China peninsular counties.

## II. METHODOLOGY

### Site Description

The sites of this study are the three large landfills located in three countries in Indochina Peninsular region; Nonthaburi landfill in Nonthaburi Province, Thailand Dangkor landfill in Phnom Penh, Cambodia and KM-32 landfill in Vientiane,

Laos. Nonthaburi is one of the provinces in Bangkok Metropolitan region; the most densely populated next to Bangkok, and the other two landfills are located in the capital cities of the two countries. These three landfills are serving as only one landfill for each municipality with many basic similarities such as climate and environmental condition, the lifestyle of the people, and also the culture and belief. The basic information of the three landfills is summarized in

Table 1.

Table 1 Summary of landfill information

Items	Nonthaburi landfill, Thailand	Dangkor landfill Cambodia	KM-32 landfill Laos
Coordination	14°0'58'' N and 100°18'53''E	11°28'59''N and 104°53'11''E	18°4'48'' N and 102°50'49''E
Year of operation	1982	2009	2008
Waste receive (tons/d)	1,300	1,800	500
Total landfill size (ha)	77	31.4	100
Elevation (MSL-mean sea level)	5	11	190
Area of closed dumping pit (ha)	34	11	24
Leachate pond area (ha)	28	1	12
Active area (ha)	20	5.5	8
Excavated /future area (ha)	0	3.8	12
Depth of pit (m)	Old pit = 5; New = 15	Area A, B = 10; C, D = 30	Pit No. 1-7 = 3 - 4
Height of garbage (m)	Old=4-5; New=10	Area A, B = 10; C, D=? 3,527,697	Pit No. 1-7 = 2-3
Leachate treatment system	None	None	None
Daily soil cover	Occasional	None	None
Final soil cover	80%	Area A-B(100%), others none	None
Soil type (bottom soil)	Clayey, $K=10^{-(9-10)}$ m/s	Sandy Clay, $K=10^{-(7-8)}$ m/s	Clay (CH), $K=10^{-(9-10)}$ m/s

### Investigation and Monitoring Methodology

Leachate and groundwater samples were collected from those three landfills. The sample collections at Nonthaburi landfill were made from 2014 to 2017 (five times in wet and seven times in dry seasons). Also, from the period of 2015 – 2017, five times of samplings and site investigations were conducted at Dangkor landfill (two in wet and three in dry seasons). At the same time, four times of field visits at KM-32 landfill were conducted (two in wet and two in dry seasons).

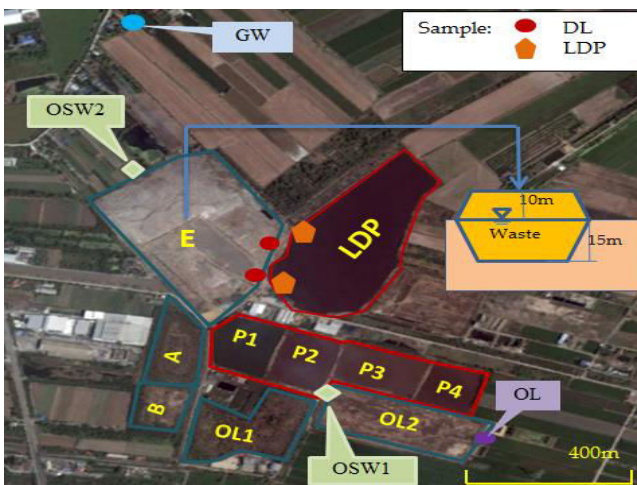
The basic parameters were measured at the site to assess the leachate quality such as temperature, pH, ORP, EC, Turb, DO, TDS, and Salt. The in-situ measurements were done by Multi-parameter Water Quality Meter “HORIBA-U50” for those mentioned parameters. At the same time, to confirm the sampling location, GPS photo tagger and Garmin Oregon 64st were used in this study. On the other hands, the biochemical parameters and heavy metals are the main targets for the assessment aside of those mentioned basic parameters. The leachate samples were filtered by using syringe filter with 0.45 μm pore size, then measured using ICP-AES (Inductively Coupled Plasma - Atomic Emission Spectrometry). Besides, SALMATE 100/W was also used to measure the chloride ion concentration. By the filtration, the concentrations of chemicals measured are considered as those dissolved in liquid part, not partitioned on the suspended solid.

## III. EXPERIMENTAL RESULTS

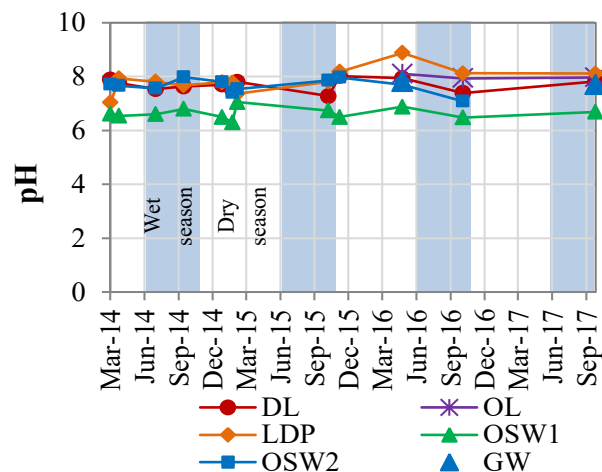
### Basic and Biological Parameters

**Nonthaburi landfill:** In order to discuss the leachate and groundwater qualities, six types of samples were collected at different locations in Nonthaburi landfill (Fig.1(a)); DL samples (fresh leachates taken from leachate drain ditch along

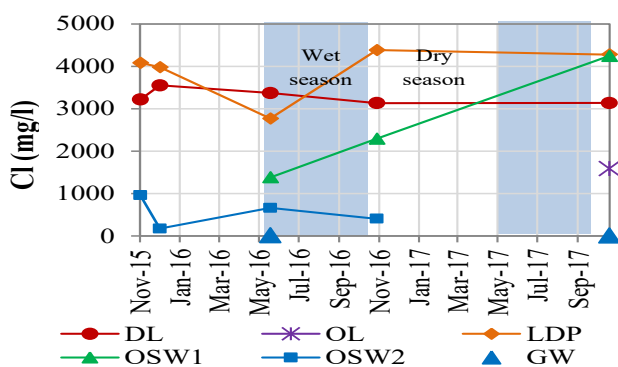
the toe of waste pile), LDP samples (leachate from leachate discharge pond), OL sample (leachate from old dumping area), and OSW1 & OSW2 (samples from observation wells No.1 and No.2), respectively. Also, one groundwater sample (GW) was investigated as background value for contamination. Fig 1 (b) shows the pH value over the period from March 2014 to Oct 2017. There was no significant change of pH in this period for all kinds of samples. The pH of leachate shows a little higher compared to those found in the OSW1 closed to old dumping areas. Chloride (Cl) concentration slightly changed and higher in the dry season for DL samples, and higher in the wet season for LDP and relatively low for OL and OSW2 (Fig.1(c)). Considering to the Cl difference and variation in OSWs 1 and 2, Cl can be used a tracer for the monitoring of percolation of leachate into GW. While dissolved oxygen (DO) (Fig.1(d)) shows opposite trend to Cl. Seasonal variation of COD and TDS of DL samples are much more significant than LDP samples (Fig 1 (e)-(g)), especially TDS of DL, which are partially attributed to the seasonal change of percolated water volume in the waste and equalization effects of huge storage capacity of LDP. However, it can be confirmed that the overall quality of LDP leachate has been deteriorated with time. Regarding ORP it has not much changed for DL with large negative value, but LDP and OSW1 show continuous decrease. This implies deterioration of water quality of LDP and OSWs 1 and 2 by the fresh leachate over time as result of the contaminant accumulation in LDP pond and the percolation to ground, respectively. The contaminations of OSWs are considered due to the leakage through shallow area not indicating the contamination of aquifer beneath dumping pit due to concentration of all assessed parameters of GW were found very low. The depth of clay below the pit of old area are very deep more than 10m. The closed dumping area (OL) is still producing the leachate with similar quality to DL, but slightly lower for most parameters, showing stabilization of biological degradation processes after closer.



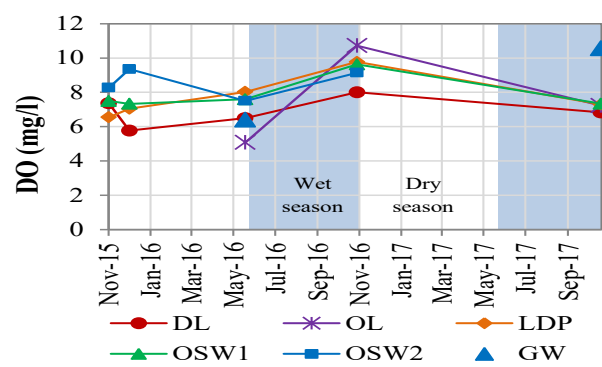
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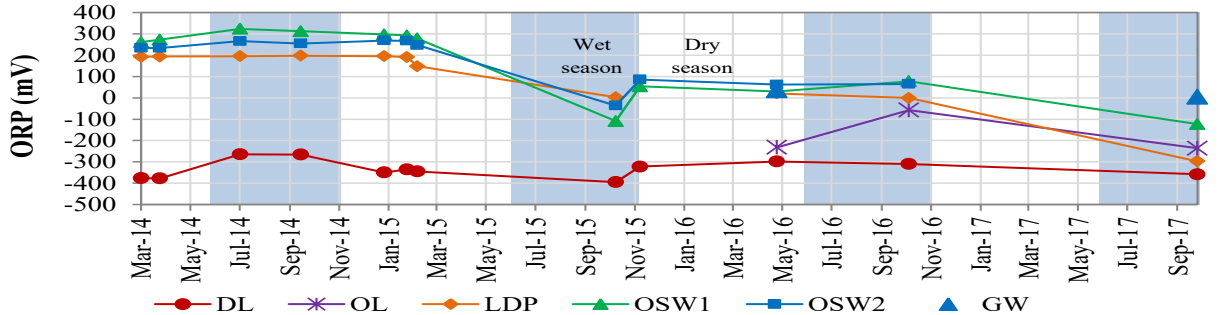
(b)



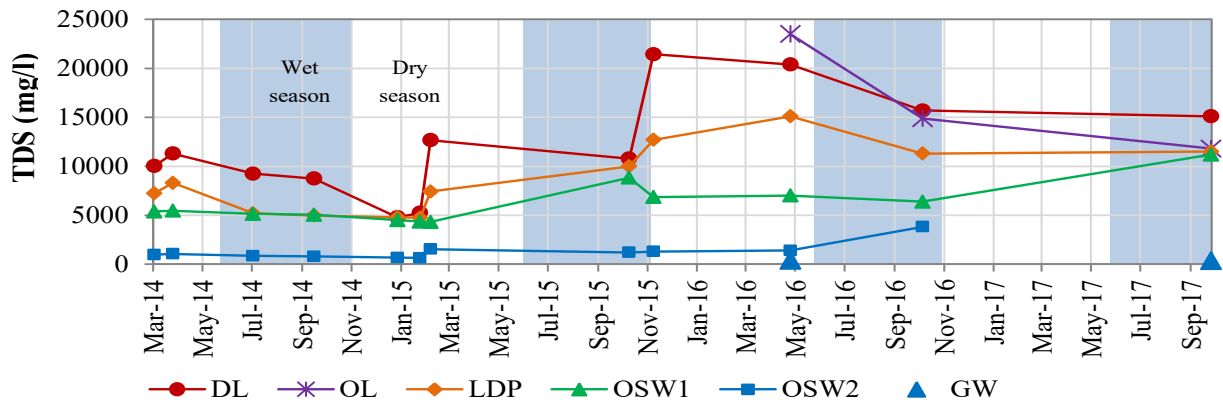
(c)



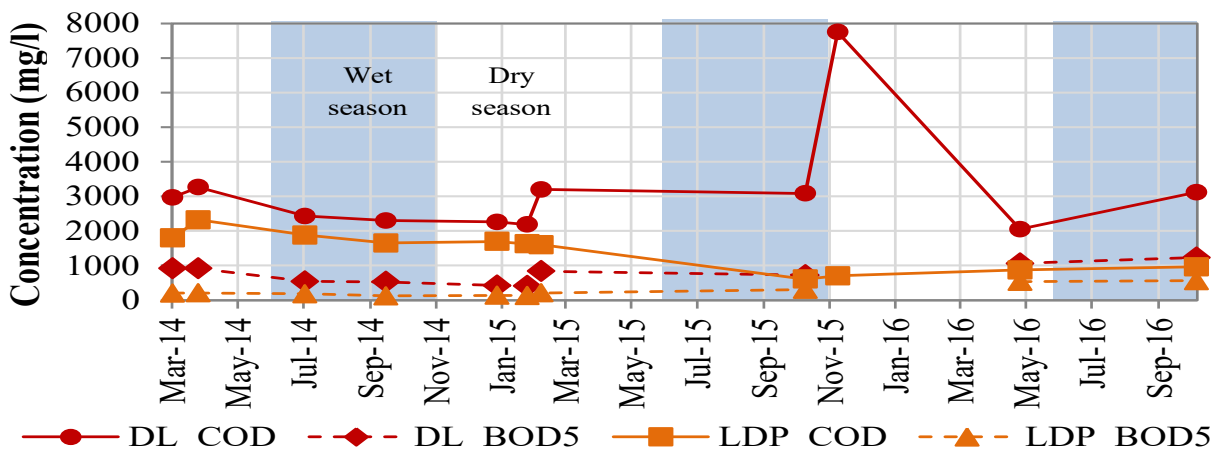
(d)



(e)



(f)

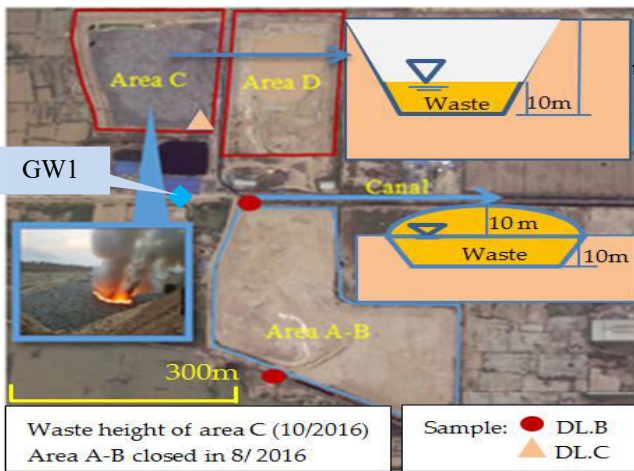


(g)

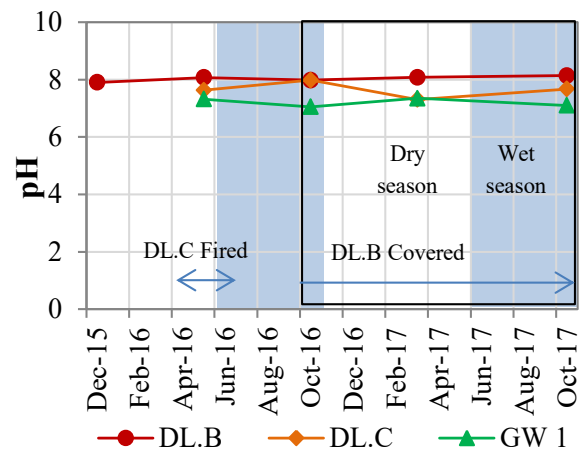
Figure 1 Variation of observed parameters for the time of study at Nonthaburi landfill

**Dangkor Landfill:** Two types of leachates and one groundwater samples were selected to discuss the long-term effect of the contaminated level at the Dangkor landfill (Fig 2 (a)). DL.B is fresh leachate drained out from Areas A-B, and covered by soil in Oct 2016, while DL.C is fresh leachate inside the deep Pit of Area C, which could receive surface wall runoff and underground water intrusion especially the wet season. A big fire in April to June 2016 is resulted in clear leachate production during that time and continuously for some periods. GW1 is the existing well recently use as

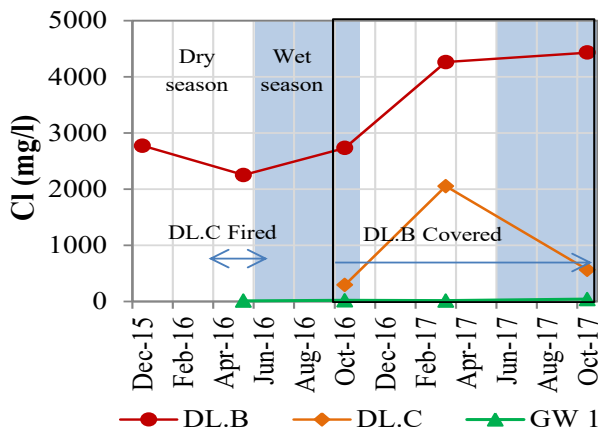
a water source in that area and about 40m from Areas A-B edge. Fig 2 (b)-(f) show the parameters measured during the study period. As observed in the fresh leachate of Nonthaburi (DL), pH is quite stable regardless of wet and dry seasons. However, as compared to Nonthaburi site, distinct seasonal differences can be seen for other parameters, higher in the dry than the wet season, especially DL.C. Large variation of the parameter could be attributed to the dilution effects by rainwater and groundwater intrusion in the dumping pit and the waste fire breaking before the sampling in the wet season. DL.B has higher Cl concentration, with increasing trend with time after covering. The ORP of DL.B before covering was similar to that of Nonthaburi DL, but increased after covering. GW1 showed no clear evidence of contamination by the leachate, thanks to the very low permeable thick natural soil beneath the dumping area. However, the deep pits of Areas C and D could have potential risk of GW contamination due to large downward hydraulic gradient at the bottom layer. Cl can be a good tracer chemical for monitoring against GW contamination by the leachate.



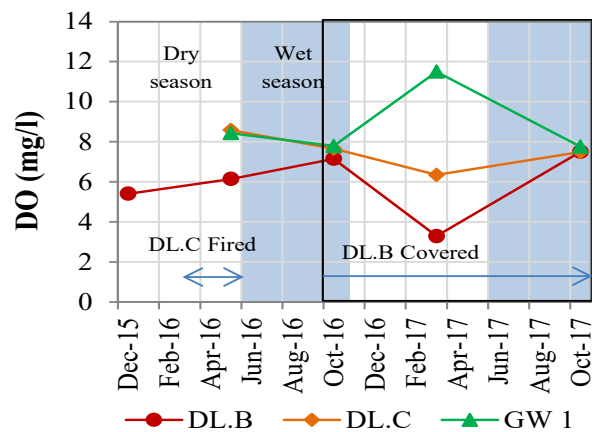
(a)



(b)



(c)



(d)

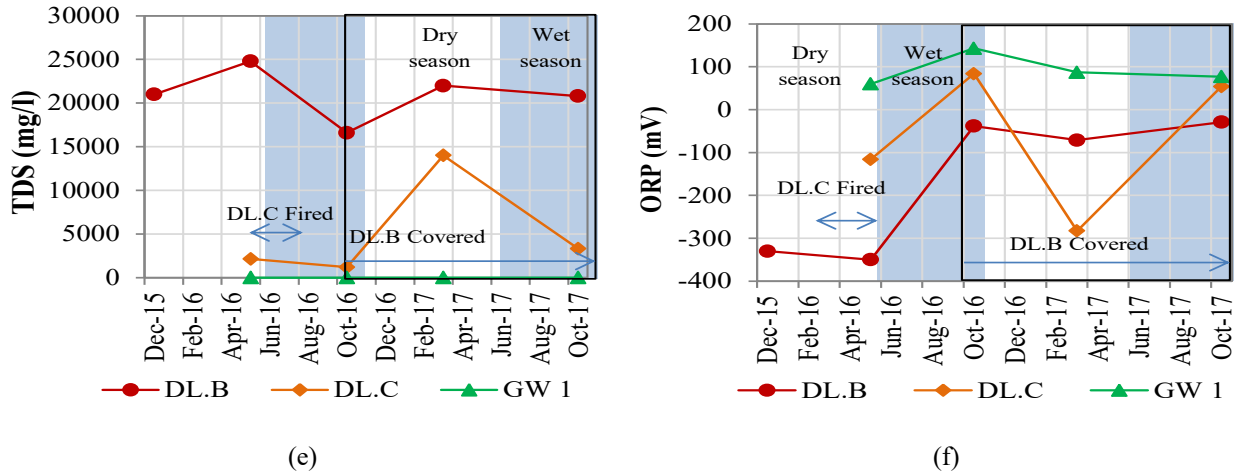
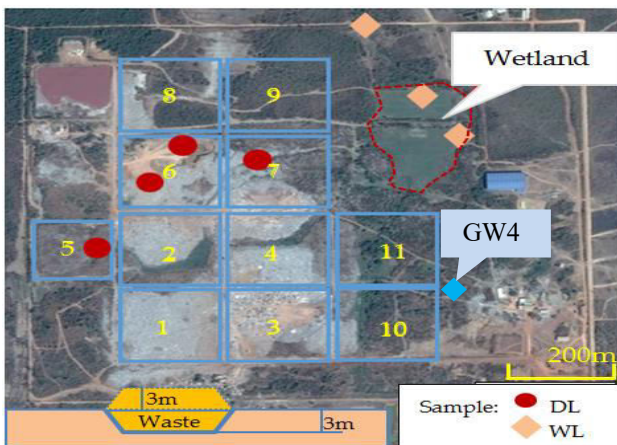
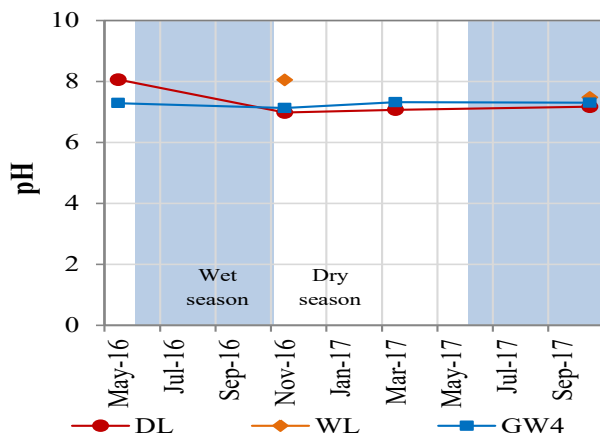


Figure 2 Variation of observed parameters for the time of study at Dangkor landfill

**KM-32 landfill:** Similarly, three kinds of samples were taken as shown in Fig 3 (a). DL is fresh leachate collected at dumping area, of which exact location cannot be fixed due to the changing of active landfill extension and garbage refilling, and lack of leachate storage ponds. WL is leachate from the natural wetland area located at the downstream part of dumping area. WL samples can be taken only wet season because all water was dried up during the dry season. GW4 (ground water) samples were also taken. Fig 3 (b)-(f) show the variation of measured parameters over the study period. Though data points are limited, the results are similar to those found in Nonthaburi and Dangkor landfill, namely stable pH values and higher concentration for the other parameters in the dry season. KM-32 shows the lower concentration compared to the other two landfills, but similar trends in the most of parameters. Wide open space and thinner waste layer without cover soils should be subjected to significant dilution effects by the rain and surface water. Moreover, DO, and ORP are higher during the wet season as found in others.



(a)



(b)

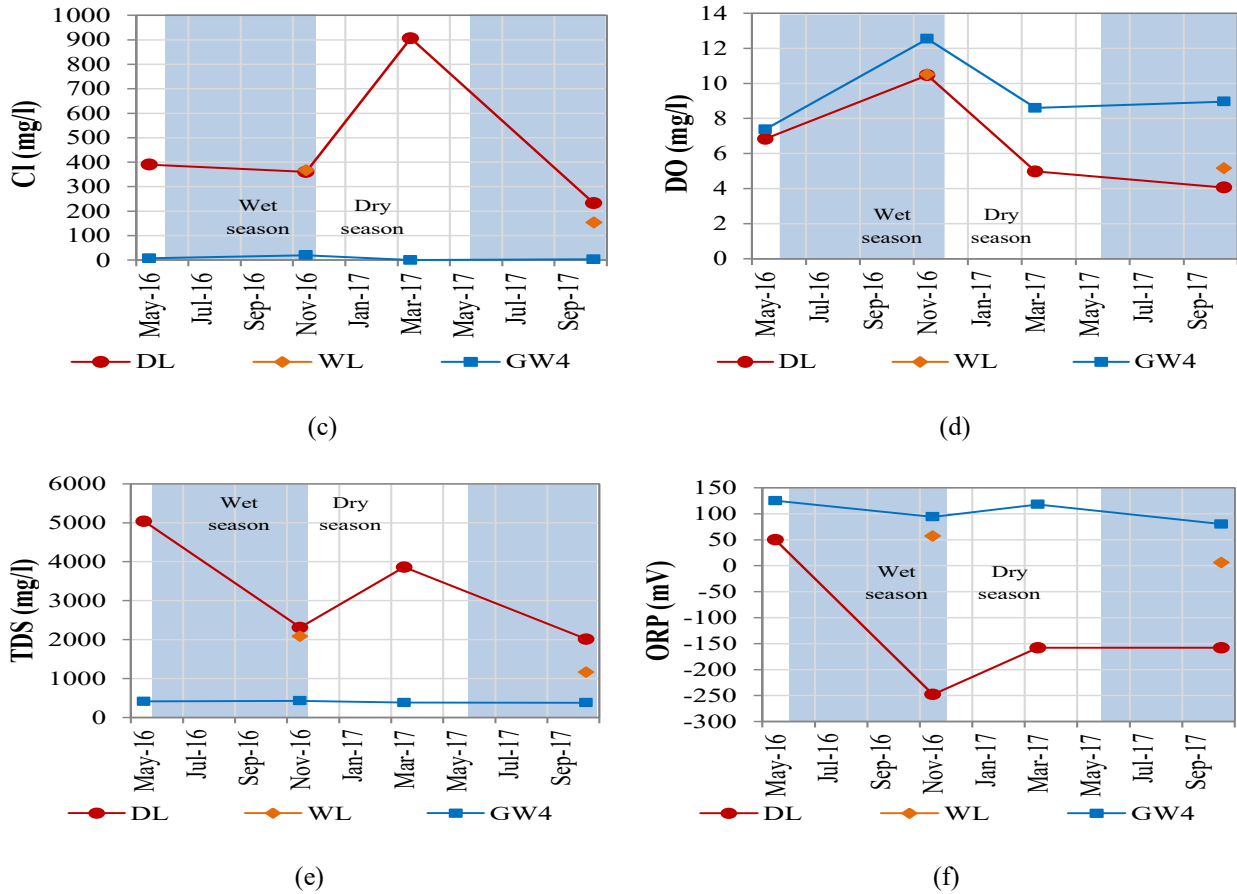


Figure 3 Variation of observed parameters for the time of study of KM-32 landfill

### Heavy metal content

Heavy metals concentration dissolved in liquid part of leachate ( $C_L$ ) for the three landfills were assessed, which is considered to be the contaminant source to groundwater. Figs. 4, 5 and 6 shows As, Zn, Cd, Pb, and Cr dissolved concentrations observed at three landfills respectively. Most of observed concentrations for leachate are between ground water and industrial effluent standards of Thailand for 2016 notation. The detection limit of each heavy metal was identified as showed in in figures. Less of seasonal variations can be seen, except for DL.C at Dangkor, which could be large water supply to the pit in wet season. The concentration of fresh leachate shows the decreasing trend, which could be attributed to the acid formation in early methanogenic phase [6]. Stability with slightly increase can be found in LDP, showing the slow accumulation of HMs in the pond. The magnitude order of  $C_L$  is similar to basic parameters in the previous section, Nonthaburi > Dangkor > KM32. Data of the groundwater is very limited, GW  $C_L$  of most heavy metals were smaller than that of the leachates with some exceptions, such as As in GW4 of KM-32, and Pb in GW1 of Dangkor. However, judging from the very small  $C_L$  concentration of groundwater at three sites, these relatively high HM concentrations are considered as background values at the particular site. Although at the current moment no clear evidence of contamination by the leachate in the aquifer beneath the landfills has not been confirmed, it is highly recommended to conduct the future prediction the by ground water modeling. Hydrogeological investigation and long term monitoring on the existing wells in the surrounding area are also needed for the future prediction.



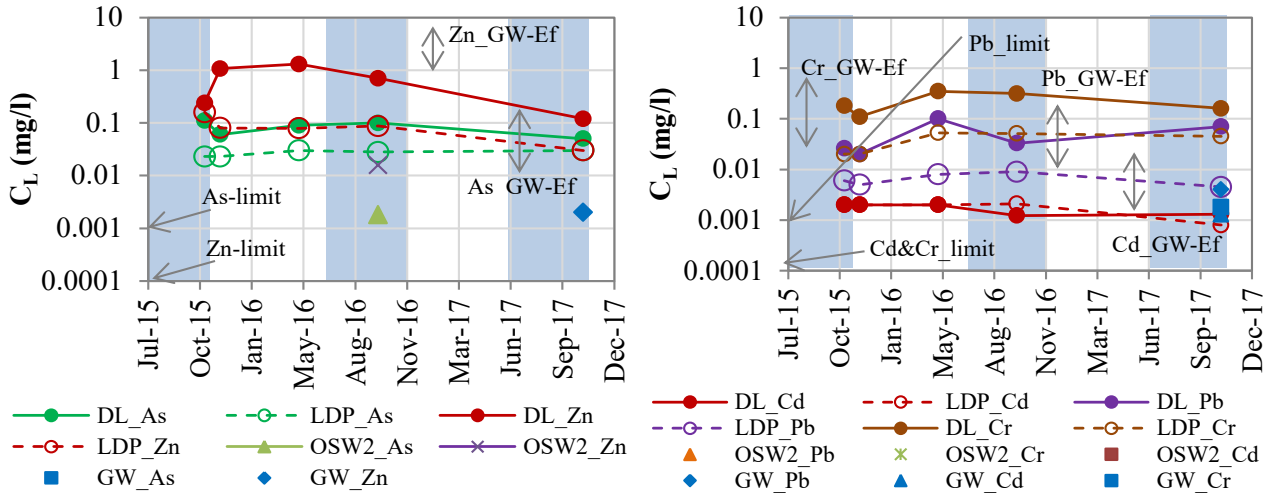


Figure 4 Heavy metal concentration over the time of study of Nonthaburi landfill

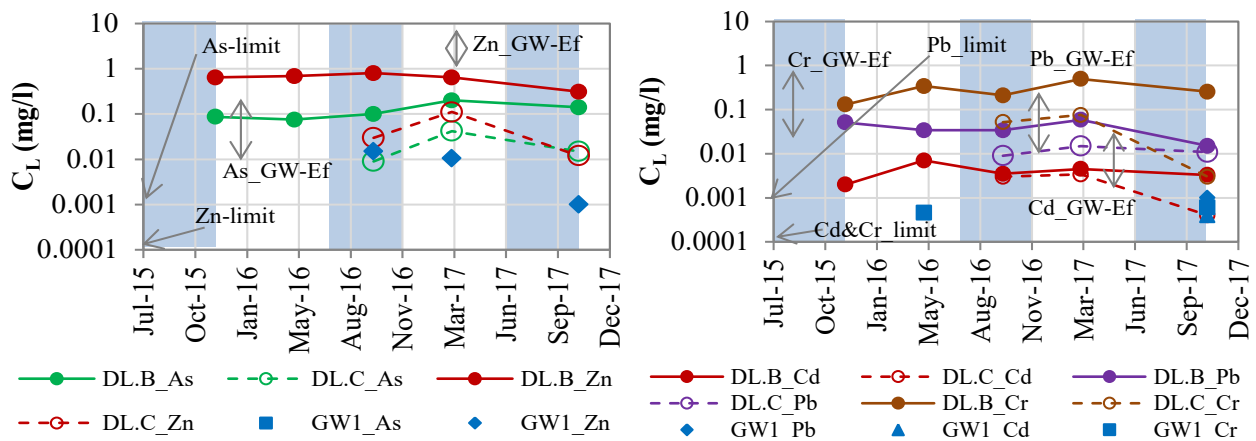


Figure 5 Heavy metal concentrations over the time of study of Dangkor landfill

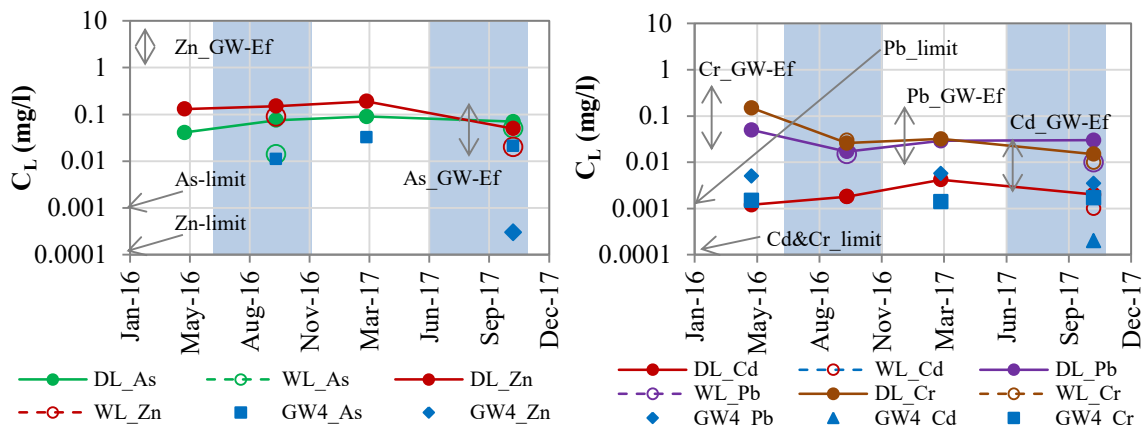


Figure 6 Heavy metal concentration over the time of study of KM-32 landfill

#### **IV. CONCLUSION**

The leachates and nearby groundwater at the Nonthaburi, Dangkor and KM-32 landfills have been collected and assessed for basic parameters, as well as the harmful heavy metals which are commonly found in most leachates for two to three years at different seasons. At Nonthaburi landfill, DL samples (fresh leachate from the active area) showed higher concentration for all parameters than those found in LDP, OL, OSW1, and OSW2 samples. At Dangkor landfill, the concentrations of DL.B samples from the old closed area were higher than that of DL.C collected from the deep pit with increasing the waste and leachate height. At KM-32 landfill, DL samples are also higher than the WL samples and groundwater samples with the same trend to the other two landfills. The seasonal variation is confirmed as higher concentration during the dry season regarding the basic parameters with the slight increasingly trends over time. The heavy metal concentrations showed decreasing trend in the fresh leachate but slightly increasing in the huge leachate pond. At the current moment, the groundwater near the landfill has not been affected by the landfill at all sites. However, long-term observation is highly recommended for assessing the future risk.

#### **ACKNOWLEDGEMENT**

This work was supported by JSPS Core-to-Core Program, B. Asia-Africa Science Platforms. Special thanks to landfill authority of Nonthaburi, Dangkor, and KM-32 landfill for their support and provide the basic information of the landfills.

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