Evaluating Heavy Metals in Groundwater around a Waste Dumping Site

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Abstract— This study evaluates levels of four toxic metals, lead (Pb), nickel (Ni), cadmium (Cd), and mercury (Hg), in groundwater near a waste dumping site in the northeastern region, Thailand. Groundwater samples were collected from 17 wells, located around the dumping site, on a monthly basis during 2014 and 2015. The results indicated seasonal relationships of toxic metals concentration in groundwater. The average concentrations of lead, nickel, and mercury in rainy season were ranged from 1.0 to 3.7 ppb, 1.3 to 8.1 ppb and 0.7 to 2.5 ppb, respectively. During dry season, the average concentrations were ranged from ≤1.0 to 3.2 ppb, ≤0.2 to 6.7 ppb and 0.9 to 1.3 ppb, respectively. All cadmium concentrations were below the detection limits of ≤1.0 ppb. The average concentrations of lead, nickel and mercury were found within the World Health Organization (WHO) limits for consumption in the both season. The average concentrations of toxic metals in groundwater were higher in the rainy season. The concentration of metals contaminants in groundwater was influenced by leachate. Groundwater flow direction from waste dumping site to southeast of study area which is the location of the sampling point no. 13, 14 and 15. Toxic metals contaminations in groundwater were of concern for the people who use it.

Keywords— groundwater, contamination, toxic metals, northeast Thailand

I. Introduction

One of the major problems for waste dumping sites is leachate contamination in groundwater. Waste dumping sites contaminate groundwater when rain water leaks into disposal sites and down through the aquifers below the waste dumping sites. The percolating leachate toxic chemicals from batteries, broken fluorescent bulbs, electronic equipment, discarded household chemicals, and paints and solvents. Although landfills now are carefully regulated to prevent leakage to groundwater, but many older sites are unlined and leak. Leachate from waste dumping sites have concentration of contaminants, such as ammonium, calcium, magnesium, sodium, potassium, iron, sulphates, chlorides and heavy metals (cadmium, chromium, copper, lead, zinc, nickel, etc.) [1]. Leachate contains toxic and carcinogenic chemicals, which may cause harm to both humans and the environment. In addition, leachate contaminated groundwater can have an effect on human and agricultural activities that use groundwater. The use of contaminated water for irrigation can decrease soil productivity, contaminate crops, and move possibly toxic pollutants up the food chain as animals and humans consume crops grown in an area irrigated with contaminated water [2]. Leachate varies in composition depending on the type of waste at the waste disposal sites, waste characteristics (age, permeability, particle size, density and initial moisture content), climatic and hydrogeological conditions (rainfall, groundwater intrusion), site operation and management, decomposition of organic material and biodegradation processes [3]. This research aims to assess a potential impact of a waste dumping site on groundwater quality in terms of toxic metals (Pb, Ni, Cd and Hg) concentrations found in wells around the waste dumping site.

II. Materials and Method

A. Site Description

A waste dumping site is located in Pak Chong District, Nakhon Ratchasima province, Thailand. The waste dumping site covers an area of 104,000 square meters (Fig. 1), receiving about 150–180 tons of mixed waste per day. The site has been operated for more than ten years accepting solid waste from Pak Chong municipality as well its surrounding villages. The dumping site is located southwest of the Lam Takhong Reservoir, a source of surface water for more than 200,000 people. Over 5,000 people depend on groundwater in the area. Geographically, the area has elevations ranged from 282 m to 324 m above Mean Sea Level (MSL). The annual average rainfall (May, 2014 – April, 2015) was 57.3 mm [4].

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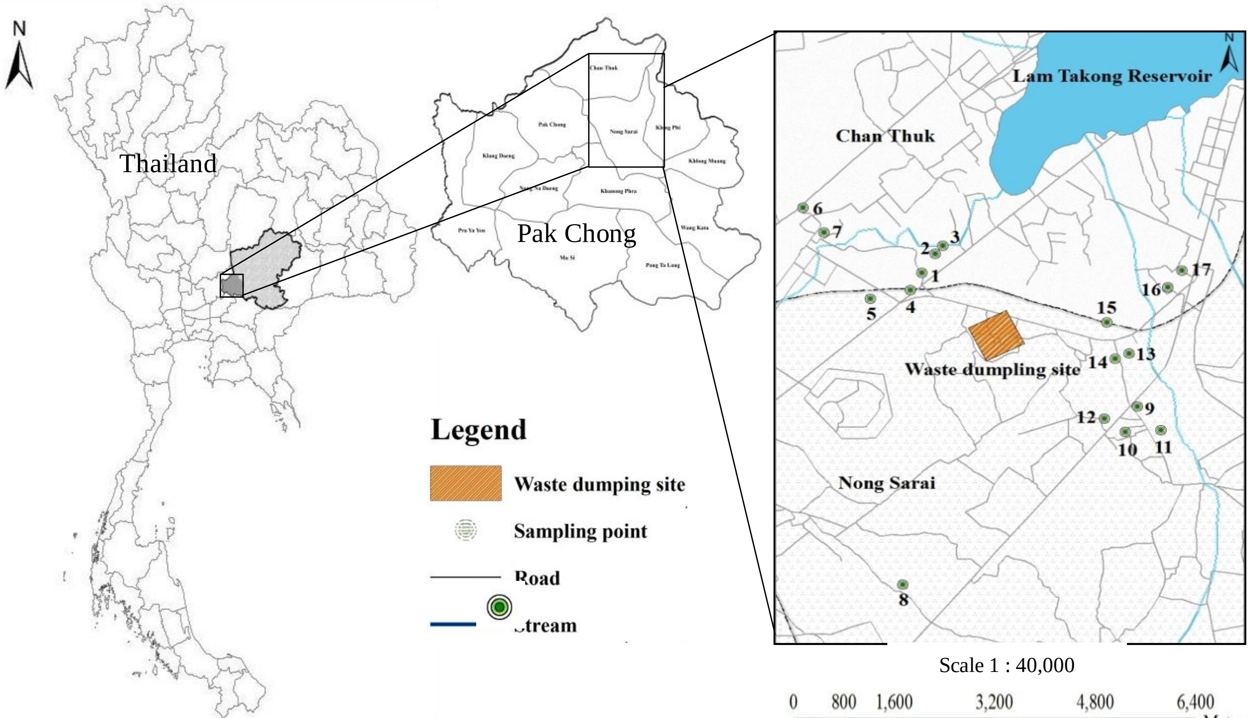


Fig. 1: Study area

B. Water sampling

Groundwater around the waste dumping was collected and analyzed monthly between May 2014 and April 2015. All accessible wells around the dumping site were surveyed and monitored, with the total of 17 wells (Fig. 1). Groundwater was withdrawn by the electronic pumps. Groundwater samples were collected in 1 L polyethylene bottles (pre-washed with 20% HNO3 and 20% HCl) and added the 1.5 ml of conc. HNO3 in the samples, transported in ice, and preserved at 4℃ until analyzed. The depth of the water level varied from 4 to 19 meters and the wells located between 1,000 and 5,000 m from the dumping site.

C. Water quality analysis

Groundwater samples were analyzed for Pb, Ni, Cd and Hg in laboratory. All samples were digested using microwave assisted acid digestion according to the Standard Methods for the Examination of Water and Wastewater 3030K [5]. The concentration of the toxic metals were analyzed by a Graphite furnace atomic absorption spectrophotometry (GFAAS) followed U.S. EPA Method 7010 [6], whereas Hg was analyzed by hydride generation atomic absorption spectroscopy (HGAAS) with reference to Standard Methods for the Examination of Water and Wastewater 3114C [7].

D. Spatial data analysis

Results of toxic metals concentrations were analyzed spatially with a Geographic Information System (GIS) to derive profiles of study area, groundwater sampling points and sampling points distant. The results were overlaid in GIS layers and an attribute table was constructed to represent the average toxic metal concentrations.

E. Determination of Groundwater Direction

The direct method of determining the direction of groundwater flow was by measuring the elevation of groundwater around the waste dumping site. Measurements were plotted on a map of the area and lines were drawn to connect water sampling points and location of waste dumping site in the middle. The groundwater flows from higher elevations to lower elevations. Direction of groundwater flow included coordinates of 3 water sampling points, depth of water table from surface elevation and distance between three water sampling points.

III. Results and Discussion

The average concentrations of lead, nickel, cadmium, and mercury in groundwater around the waste dumping site during the rainy and dry seasons were presented in Table 1. Average concentrations of cadmium were below the detection limits, ≤1 ppb, in both seasons. The average concentrations of lead, nickel, and mercury in rainy season ranged from 1.0 to 3.7 ppb, 1.3 to 8.1 ppb, and 0.7 to 2.5 ppb, respectively. The highest levels of lead, nickel, and mercury were 3.7, 8.1 and 2.5 ppb, respectively. They were found at wells number 12, 9 and 10, respectively. The average concentrations of lead, nickel and mercury in rainy season were within the safe limits set by World Health

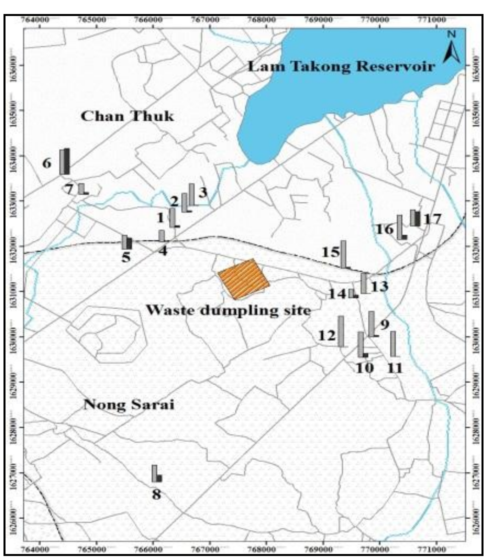
Organization (2011), lead <10 ppb nickel <70 ppb and mercury <6 ppb [8].

TABLE I:
AVERAGE CONCENTRATIONS OF TOXIC METALS IN GROUNDWATER DURING THE RAINY AND DRY SEASONS (2014-2015)

Sampling point	Rainy season				Dry season			
	Pb (µg/l)	Cd (µg/l)	Ni (µg/l)	Hg (µg/l)	Pb (µg/l)	Cd (µg/l)	Ni (µg/l)	Hg (µg/l)
1	2.3±4.0	N.D.	2.5±4.0	2.3±1.2	0.2±0.6	N.D.	1.1±1.7	1.3±0.8
2	2.2±3.8	N.D.	6.1±11.5	1.5±0.5	0.2±0.4	N.D.	0.5±0.9	1.3±1.1
3	2.6±4.1	N.D.	4.2±6.9	1.5±0.2	N.D.	N.D.	0.4±0.8	0.9±0.7
4	1.4±2.5	N.D.	3.6±6.3	0.9±0.9	N.D.	N.D.	0.2±0.3	1.2±1.0
5	1.7±3.2	N.D.	3.8±5.9	0.7±0.7	1.3±3.2	N.D.	0.4±0.8	1.0±0.9
6	3.0±4.6	N.D.	4.2±7.1	2.2±1.5	3.2±6.2	N.D.	0.3±0.7	1.1±0.8
7	1.4±2.1	N.D.	4.6±8.9	0.7±0.3	0.2±0.6	N.D.	0.7±1.2	1.0±0.8
8	2.0±3.7	N.D.	5.5±10.7	1.1±0.5	0.8±2.0	N.D.	0.7±1.0	1.1±0.9
9	3.1±5.1	N.D.	8.1±14.0	0.9±0.3	0.2±0.5	N.D.	0.2±0.4	1.2±1.0
10	3.1±5.6	N.D.	7.1±11.1	2.5±1.1	0.4±1.0	N.D.	6.7±13.5	1.1±0.7
11	3.0±4.6	N.D.	1.3±2.4	1.1±0.7	N.D.	N.D.	2.0±3.2	1.1±0.7
12	3.7±5.7	N.D.	6.4±9.9	0.8±0.7	N.D.	N.D.	1.8±3.0	1.0±0.8
13	2.4±3.8	N.D.	4.4±6.9	1.2±0.6	N.D.	N.D.	0.6±1.0	1.1±0.7
14	1.0±1.6	N.D.	6.4±13.0	1.3±0.9	0.3±0.8	N.D.	5.9±9.6	1.3±0.6
15	3.3±5.1	N.D.	2.2±4.0	1.0±0.2	0.1±0.2	N.D.	0.7±1.2	1.0±0.8
16	3.0±4.8	N.D.	2.9±6.3	1.4±0.4	0.6±1.4	N.D.	0.6±0.9	1.1±0.7
17	2.0±3.7	N.D.	3.7±5.8	1.3±0.3	1.7±3.6	N.D.	1.6±4.0	1.2±0.6

Noted: N.D. represent not detected.

During dry season, the average concentrations of lead, nickel, and mercury ranged from not detected to 3.2 ppb, <0.2 to 6.7 ppb, and 0.9 to 1.3 ppb, respectively. The highest concentrations of lead, nickel, and mercury were 3.2, 6.7 and 1.3 ppb, respectively. These were found at the wells numbers 6, 10 and 1, respectively. The average concentrations of lead, nickel and mercury in dry season were within the limits set by World Health Organization (2006). Seasonal variations of lead, nickel, and mercury were different (Fig. 2-4), higher in rainy season.



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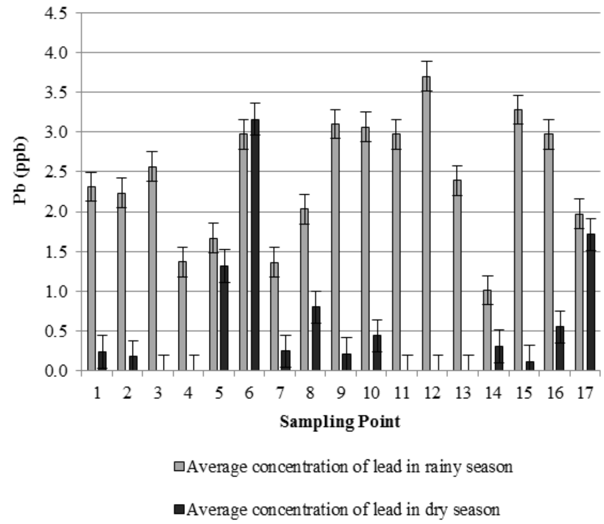

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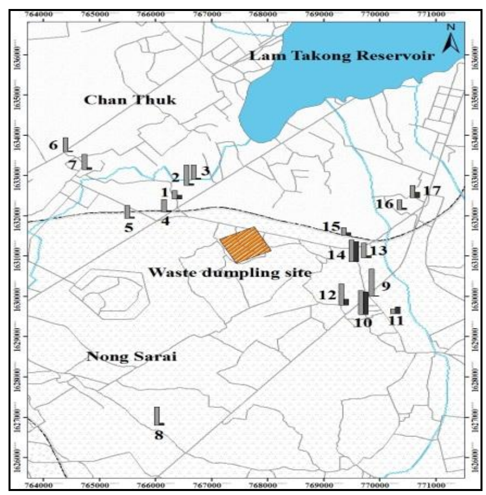
Fig. 2: Average lead concentrations of each sampling point between rainy and dry seasons. (a) Seasonal variations of lead concentrations, (b) Average concentration of lead in rainy and dry seasons



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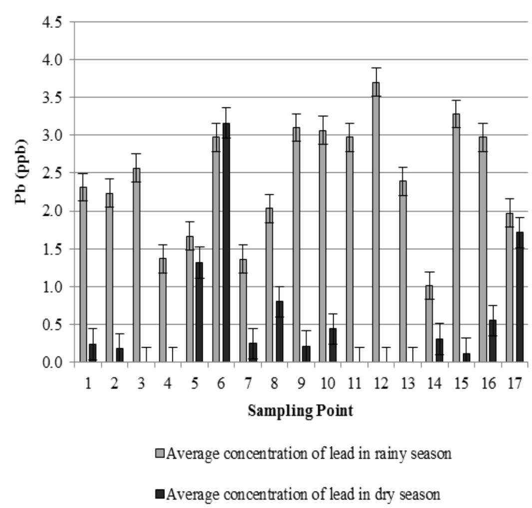
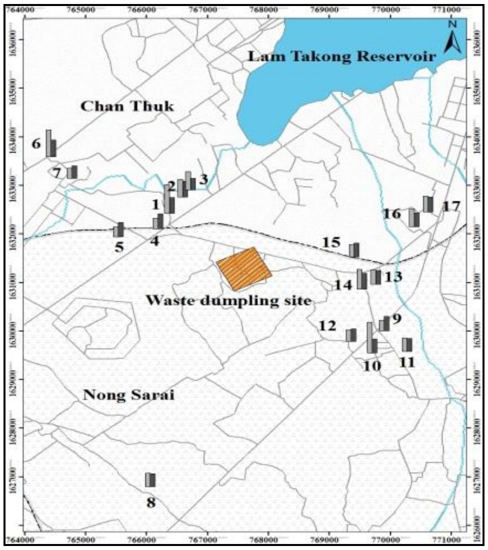


(b)

Fig. 3: Average nickel concentrations of each sampling point between rainy and dry seasons. (a) Seasonal variations of nickel concentrations, (b) Average concentrations of nickel in rainy and dry seasons



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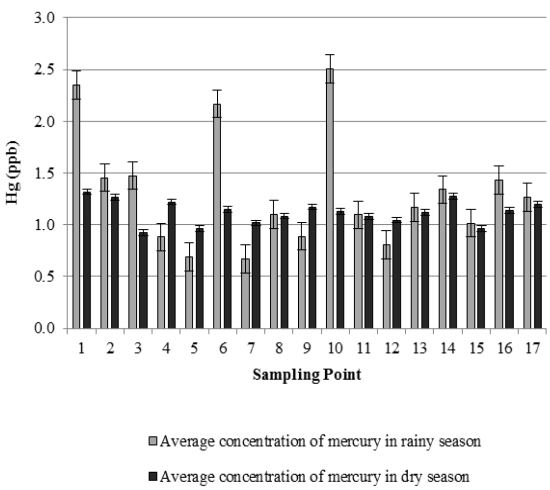

(b)

Fig. 4: Average mercury concentrations of each sampling point between rainy and dry seasons. (a) Seasonal variations of mercury concentrations, (b) Average concentrations of mercury in rainy and dry seasons

The analysis of groundwater direction in the study area showed that groundwater flows from higher water level in the northwest to the lower level in the southeast. If the dumping site causes contamination to groundwater, the wells in the east to southeast are at risk. The contaminations may seep through soil and discharge into the small stream located to the east and may cause contamination in the reservoir downstream.

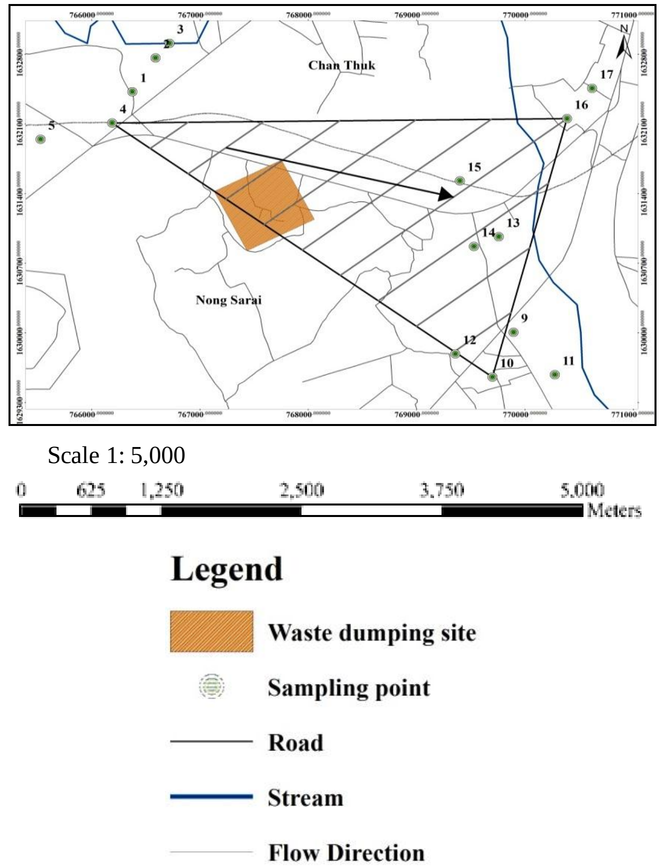

Fig. 5: Groundwater direction

IV. Conclusion

Rainfall had potential to influence the average concentrations of lead, nickel, and mercury in groundwater in the study area. Groundwater samples obtained during rainy season clearly showed higher levels of lead, nickel, and mercury than those found in dry season. Cadmium was not detected. Location of the waste dumping site posed environmental and health risk to the wells nearby, especially the wells located in the east and southeast direction of the site. The reservoir is subjected to contamination in the long-term if groundwater is contaminated from leachate of the dump site.

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