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Heavy Metal Contamination in Shallow Groundwater in the Illegal Landfill Area, Eastern Thailand

Sorrawit Thammajai and Schradh Saenton

***Abstract*—A shallow groundwater sampling scheme was conducted for a site located nearby the illegal landfill, eastern Thailand. The site was consisted of several soil pits which were subsequently filled by unidentified industrial wastes for an unknown duration. This preliminary investigation includes groundwater samplings and chemical analyses. Groundwater flow direction is mainly from north to south where the illegal landfill is clearly located on the groundwater flow pathways and this could pose a potential threat for groundwater contamination. Seven heavy metals are iron, lead, manganese, copper, zinc, nickel, and cadmium. Most metal are in the Thai Government's regulated standards except for Mn and Pb for wells located near the landfill. Future work will include more detailed investigation and modeling to predict the extent and advance of contamination.**

***Keywords*—groundwater, contamination, heavy metals, aquifers, Thailand**

I. Introduction

Chachoengsao Province is located in the Eastern part of Thailand and is a part of Bang Pakong River basin which it is economically important in terms of industrial and agriculture production in eastern region of Thailand. However, the outcomes of these activities have adversely affected the environment especially groundwater. Recently, groundwater contamination were discovered and reported in shallow groundwater supply wells in Nongnae sub-district, Phanom Sarakam district, Chachoengsao province see Fig. 1. Initial investigations were conducted by both local and central government agencies such as Department of Groundwater Resources (DGR), Department of Pollution Control (PCD), Department of Industrial Works (DIW), and Department of Environmental Quality Promotion (DEQP). It was found that unidentified and unknown quantities of industrial wastes have been illegally dumped into several abandoned and unlined soil pits during the past 10-15 years [1].

The above illegal actions became evident as unacceptably high concentrations of volatile and semi-volatile organic compounds (VOCs) and heavy metals from wastes were discovered in groundwater wells nearby. Despite several government agencies participated site investigation, their sampling schemes were uncoordinated and sampled locations were unsystematic.

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Consequently, the hydrogeological characteristics especially groundwater flow velocities and directions and the extent of contaminant plume are still not known. As a result, effective site assessment cannot be performed and remediation scheme cannot be proposed because the sites have not been fully characterized. A more systematic sampling scenario, complete chemical analyses, and the use of mathematical models should help characterize the sites and better assess the extent of groundwater contamination and suggest possible remediation or monitoring scheme.

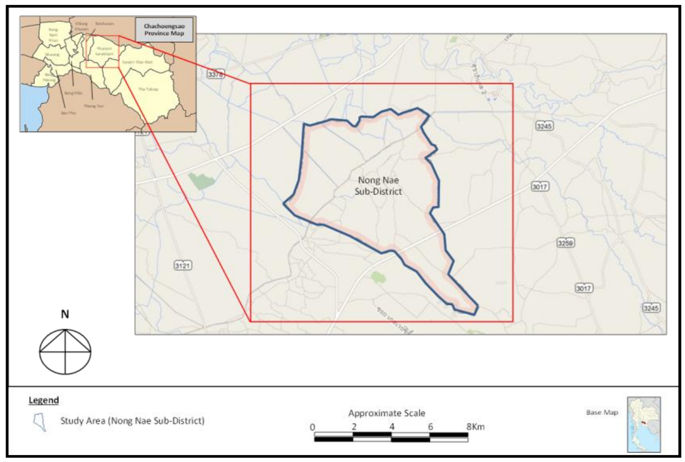

Figure 1. Nong Nae Sub-District, Phanom Sarakam district Chachoengsao province (modified from www.Map.google.com).

The above illegal actions became evident as unacceptably high concentrations of volatile and semi-volatile organic compounds (VOCs) and heavy metals from wastes were discovered in groundwater wells nearby. Despite several government agencies participated site investigation, their sampling schemes were uncoordinated and sampled locations were unsystematic. Consequently, the hydrogeological characteristics especially groundwater flow velocities and directions and the extent of contaminant plume are still not known. As a result, effective site assessment cannot be performed and remediation scheme cannot be proposed because the sites have not been fully characterized. A more systematic sampling scenario, complete chemical analyses, and the use of mathematical models should help characterize the sites and better assess the extent of groundwater contamination and suggest possible remediation or monitoring scheme.

The purpose of this study is to delineate the extent of shallow groundwater contamination in illegal landfill areas, and to predict the movement and dispersion of pollutants in contaminated aquifers. It is expected that the results of contamination investigation can be used to assess the site so that proper action(s) can be implemented to avoid unwanted

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consequences and the developed groundwater flow and contaminant transport model can be used to predict contamination dispersion in the future.

II. Site Information

A. *Hydrogeology*

The Department of Mineral Resources [2-5] mapped groundwater occurrence of Chachoengsao and Chonburi provinces at a scale of 1:100,000. The map illustrated the types of aquifers, groundwater quality, and groundwater quantity. From the groundwater availability map of Chachoengsao and Chonburi provinces, it can be seen that the groundwater in the some part of study area occurs in an unconsolidated aquifer that is the flood plain aquifer (Qfd) which is composed of gravel, sand, silt, and clay and its thickness ranges from 15 to 60 meters. Its yield is less than 5 m^3/hr. The groundwater generally has total dissolved solids content less than 500 mg/L.

Klueabthong [6] studied hydrogeology of Bang Khla Royal Development Project in order to determine its groundwater resources potential in Bang Khla District, Chachoengsao province which is a part of Bang Pakong river basin. Its hydrogeologic units can be divided into 3 units including clay unit, sand unit, and shale interbeded sandstone unit which have transmissivity in the range of from 0.252 to 2.232 m^2/d, storage coefficient in the range of 8.7×10^{-3} to 1.41×10^{-2}, and hydraulic conductivity in the range of 3.07×10^{-3} to 0.02 m/d. Groundwater recharge has been estimated using two methods: hydrologic budget method, and a combination of Geographic Information System database and permeability testing method. The results show that recharge estimated from hydrologic budget method is 18,988 m^3/yr (7.43% of the average annual rainfall) whereas the other method gave recharge estimate of 16,642.7 m^3/yr (6.52% of the average annual rainfall).

Udomsilp [7] conducted groundwater potential assessment of the Bang Pakong River Basin (Figs. 2-3) based on a complex, three-dimensional regional groundwater flow model. The uncertainty of the model was quantified using Monte Carlo technique. The water budget calculation gave the total in-flow or out-flows of the basin of 120.7 Mm^3/yr with an uncertainty of ±40.8 Mm^3/yr. High uncertainty arises from the uncertainty in parameter values of the model especially the riverbed and general-head conductance. A map showing areas or locations associated with high uncertainty in head measurements was also produced from Monte Carlo analysis. It was recommended that uncertainty analysis in groundwater flow modeling should be performed on a routine basis so that a statistically reliable bracket of groundwater potential or safe yield at some confidence interval.

B. *Groundwater Contamination*

Department of Groundwater Resources [8] conducted detailed study of groundwater exploration and potential assessment in Bang Pakong River Basin. A large number of deep and shallow groundwater samples were taken throughout the basin and analyzed for agrochemicals and microbes. Several areas affected from agricultural activities were delineated and closely monitored.

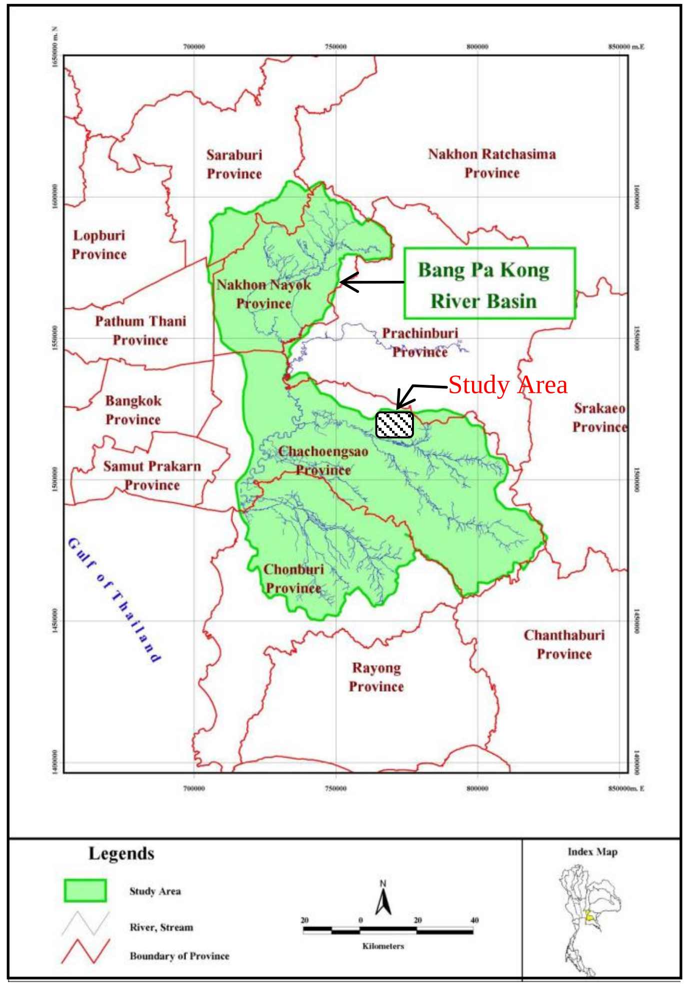

Figure 2. Boundary of the Bang Pakong river basin.

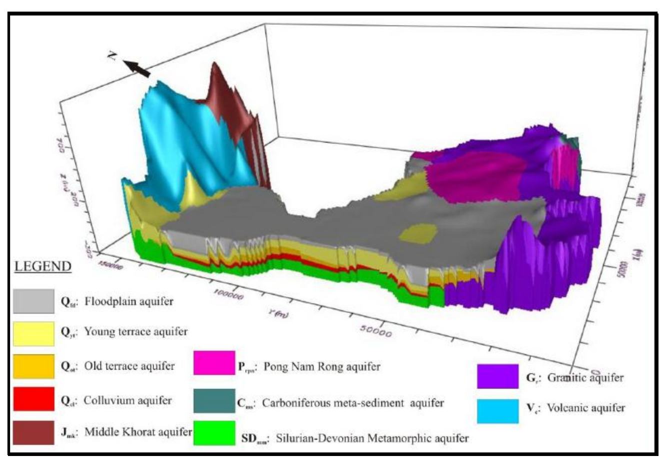

Figure 3. Hydrostratigraphic units of the Bang Pakong river basin [7].

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Department of Groundwater Resources [9] constructed a groundwater contamination risk map of Chonburi and Rayong provinces using GIS technology. This study showed that parts of the shallow aquifers of both provinces were vulnerable and susceptible to contamination from both industrial activities and poorly managed landfills. Twenty representative groundwater samples were taken and analyzed for heavy metals and volatile organic compounds. Advective transport modeling showed the possibility of leakage of contaminants outside the source zone boundaries and the site must be monitored closely.

Department of Pollution Control [11] and Department of Groundwater Resources [9], Department of Industrial Works [10] and Department of Environmental Quality Promotion [1] conducted preliminary surveys to assess the contamination in shallow groundwater within and nearby illegal landfill areas. A number of groundwater samples were taken and analyzed for heavy metals, volatile and semi-volatile organic compounds. Although large database of groundwater quality was obtained, the hydrogeologic investigation was not completed. Consequently, the number of contaminant sources is still not known, and the plume size, shape, and movement has yet to be understood.

III. Methods

This research focuses on groundwater sampling for chemical analyses, and characterization of groundwater flow pattern of the shallow aquifers in illegal landfill areas located in Tambon Nongnae, Phanom Sarakam district, Chachoengsao province. The study area lies within the Central Plain of Bang Pakong river basin.

Groundwater level measurement and metal content from 47 representative observation wells (Fig. 4) that are evenly distributed over the targeted area were conducted. Groundwater samples) will also be taken and sent to the certified laboratories for heavy metal analyses (Fe, Pb, Mn, Cu, Zn, Cd, and Ni) based on AWWA-2005 ICP-OES method.

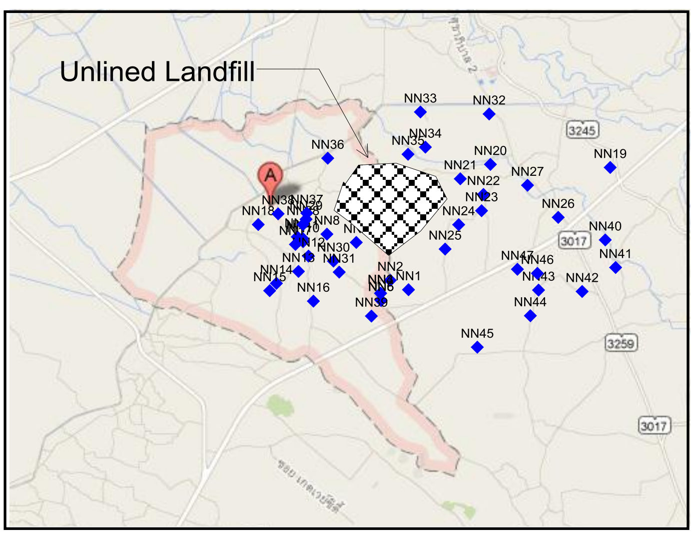

Figure 4. Groundwaer sampling locations (NN1-NN47) around the unlined (illegal) landfill which was used to be a soil pit (approximately 50 acres).

IV. Results and Discussion

Based on the groundwater level measurement within the affected area, it was found that shallow groundwater generally flows southward (Fig. 5). The flow paths (red arrows) clearly intersect the dumpsite which could potentially pick up contaminants (both volatile organic compounds and heavy metals) along the way toward domestic (and regularly used water) wells.

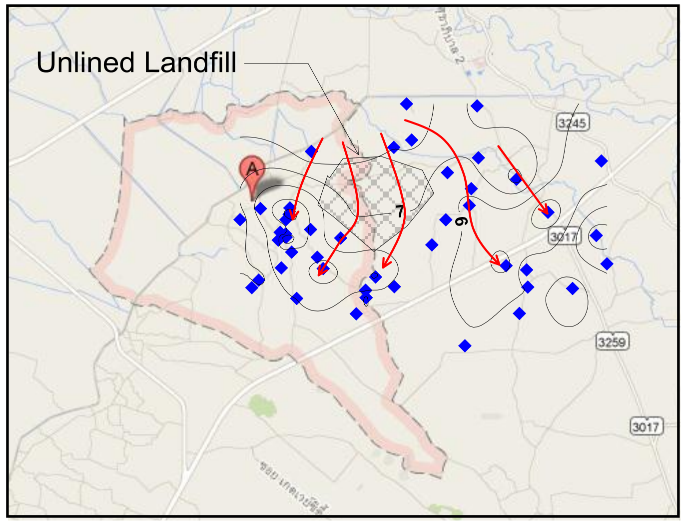

Figure 5. Shallow groundwaer flow direction.

Groundwater quality data indicates pH of the solution is within the range of 7-9 where the electrical conductivity is rather high (250-1500 µS/cm). The oxidation-reduction potential (ORP or Eh) is between -150 to 250 mV suggesting that the groundwater is either slightly reduced or oxidized. The metal contents were shown in Table I. Cadmium was not detected in any sample while lead, copper, and nickel were occasionally found in some samples. Iron, manganese, and zinc were most frequently found in the domestic groundwater wells. Most of the wells surrounding the landfill were contaminated and some of them (especially, manganese) exceed Thai Government's regulated standards. An on-going work is conducted to continuously monitor groundwater quality of the affected area. Selenium, arsenic, and mercury will also be measured and analyzed. Groundwater modeling and contaminant transport simulation will also be setup to quantitatively assess the site's environmental impact.

Acknowledgment

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TABLE I. GROUNDWATER QUALITY FROM 47 OBSERVATION WELLS. RED NUMBERS DESIGNATE VALUES EXCEEDING THAI REGULATED STANDARDS.

Well	UTM-E	UTM-N	Fe	Pb	Mn	Cu	Zn	Cd	Ni
NN1	755,294	1,511,271	0.14	-	3.52	-	-	-	-
NN2	754,778	1,511,537	0.64	-	1.42	-	0.02	-	-
NN3	754,502	1,511,170	2.00	-	2.55	-	-	-	-
NN4	754,505	1,511,171	1.62	0.02	2.08	-	-	-	-
NN5	754,516	1,510,970	1.26	0.11	1.63	-	0.03	-	0.01
NN6	754,519	1,510,970	1.24	0.09	2.01	-	-	-	-
NN7	753,817	1,512,608	1.91	0.01	2.53	0.01	-	-	-
NN8	752,988	1,512,842	3.97	-	0.43	0.03	0.02	-	0.01
NN9	752,151	1,512,765	1.20	-	0.26	0.04	0.06	-	0.01
NN10	752,314	1,512,629	0.13	-	2.92	0.02	0.01	-	-
NN11	752,302	1,512,720	1.69	0.01	0.37	0.04	0.02	-	-
NN12	752,467	1,512,221	0.02	0.01	0.38	0.10	0.08	-	-
NN13	752,183	1,511,788	3.16	-	0.18	0.02	0.02	-	-
NN14	751,560	1,511,451	0.23	-	0.45	0.02	0.03	-	-
NN15	751,370	1,511,244	1.16	-	0.04	0.01	0.01	-	-
NN16	752,605	1,510,948	0.10	-	0.06	0.02	0.01	-	-
NN17	752,098	1,512,551	0.02	-	0.06	-	0.02	-	-
NN18	751,046	1,513,113	0.61	-	3.84	-	0.03	-	-
NN19	760,995	1,514,726	2.49	-	2.16	-	0.04	-	-
NN20	757,609	1,514,813	0.04	-	0.06	-	-	-	-
NN21	756,757	1,514,406	0.04	-	0.03	-	-	-	-
NN22	757,412	1,513,964	0.05	-	0.04	-	0.01	-	-
NN23	757,359	1,513,504	0.09	-	0.04	-	0.02	-	-
NN24	756,712	1,513,109	0.05	-	0.06	-	0.01	-	-
NN25	756,328	1,512,420	4.36	0.02	2.28	-	-	-	-
NN26	759,525	1,513,316	0.07	-	0.04	-	0.01	-	-
NN27	758,658	1,514,223	0.05	-	0.05	-	0.01	-	-
NN28	752,311	1,513,114	0.03	-	0.11	-	0.01	-	-
NN29	752,398	1,513,262	1.84	0.01	0.15	0.02	0.03	-	-
NN30	753,172	1,512,080	0.14	-	0.05	-	0.05	-	-
NN31	753,335	1,511,768	0.08	-	0.12	-	0.02	-	-
NN32	757,573	1,516,238	6.26	0.01	0.22	-	0.02	-	-
NN33	755,630	1,516,294	0.47	-	0.05	-	0.02	-	-
NN34	755,771	1,515,301	9.82	0.01	0.36	-	0.01	-	-
NN35	755,280	1,515,099	1.15	-	0.04	-	0.01	-	-
NN36	753,011	1,514,987	2.51	-	0.31	-	0.02	-	-
NN37	752,419	1,513,435	0.06	-	0.05	0.01	0.02	-	0.02
NN38	751,608	1,513,416	0.07	-	1.26	0.01	0.10	-	0.02
NN39	754,245	1,510,526	0.10	-	0.09	0.01	0.03	-	-
NN40	760,855	1,512,678	1.71	0.01	2.03	-	0.02	-	-
NN41	761,148	1,511,899	2.44	0.01	0.24	0.05	0.02	-	-
NN42	760,202	1,511,221	0.04	-	0.03	-	0.01	-	-
NN43	758,969	1,511,260	0.05	-	0.02	-	0.01	-	-
NN44	758,738	1,510,536	0.05	-	0.10	-	0.01	-	-
NN45	757,238	1,509,647	7.44	-	0.66	0.01	0.03	-	-
NN46	758,936	1,511,733	2.98	-	3.50	-	0.02	-	-
NN47	758,372	1,511,849	0.05	-	0.02	0.02	0.06	-	-
		Minimum	0.020	0.010	0.020	0.010	0.010	-	0.010
		Maximum	9.820	0.110	3.840	0.100	0.100	-	0.020
		Average	1.396	0.035	1.131	0.023	0.020	-	0.005
		S.D.	2.083	0.034	1.063	0.022	0.020	-	0.005

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