# Soil and Groundwater Contamination Based on Geological and Hydrogeological Investigation

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**Abstract**

*Water and environment are different things but they have a close relation each other. One of area in Indonesia Site 'X' (confidential site) has rapid development and many industries have built up their business here. The main issue is about the condition of soil and groundwater in this area are become contaminated in their waste disposal which is near with the resident area. Purposed of the study is to know how deep and extent the level of contamination in soil and groundwater. The investigations are using soil assessment, monitoring well installation, and aquifer testing. The soil assessment is using standard traditional drilling such as split spoon for subsurface drilling and sampling. Split spoon logging technique is more detail and provide good sampling for vertical or angle soil boring. Angle soil boring was done to know the detail soil sampling data near the resident area. Based on geological data, there are twelve soils boring (ten soils boring and two monitoring wells). The soil investigation observed as very fine grained to depths the recorded water table with coarser fine grained soil as depth. The indication of pure solvent was observed in three central location soil boring based on soil sampling. The PID (Photo-Ionization Detector) reading indicate that the soil sampling >1,000 ppm and with evident of solvent/hydrocarbon odour was indicating as impacted samples. Based on hydrogeology data, there are eleven monitoring wells (two the newest MW and nine the existing MW). This research area has shallow aquifer system at depths 8.0-10.0 meter below groundwater surface as an unconfined aquifer layer. The monitoring well installation was observed five impacted monitoring wells. From one to five well, there is one well can looks clearly the sheen and has strong solvent based on laboratory in one monitoring well.Based on the data analysis, discovered that the research area was impacted. The collected data bring us to the next step that the research area should be remediated to make our environment clean or decreasing the level of contamination concentrate. Additionally, soil and groundwater contaminant levels have likely eliminated the previous remedial alternative suggestion of slow release oxygen and along with the soil geological conditions and severely reducing groundwater conditions, will make all remedial efforts challenging.*

Keywords : *soil assessment; aquifer, contamination, environment, geology, hydrogeology, Indonesia.*

## INTRODUCTION

Groundwater is renewable natural resources which have important things for various purposes. The development of groundwater in some sectors brings the consequences for using the groundwater as much as possible without causing any impact on the environment.

However, rapid development has many impacts to groundwater condition which increase along years. This

E-ISSN : 2579 - 3136

investigation is supposed to increase our understanding about contaminant mass and the geological and hydrogeological profile. In other hand, it also improves understanding of the hydrogeological conditions and the variability of groundwater hydraulic conductivity especially related to contaminant transport. Therefore, Site X is feasible to do the research to know the causes and the solution for groundwater contamination.

## LITERATURE REVIEW

Site X is a manufacturing industry that located in Java Island, Indonesia. This site is undeveloped, not in use and is easily identified with an open excavation pit of approximately 2 m deep. The laboratory analysis showed that the exposed soils contained petroleum hydrocarbons, volatile and semi-volatile organic compounds, polycyclic aromatic hydrocarbons and metals.

According to the Geology Map of The Jakarta and Kepulauan Seribu Quadrangle, Jawa (Sheets No. 1209-4-,1210-1) scale of 1: 100,000 (Turkandi, 1992), by the Geological Research and Development Center the site is underlain by:

- Young river deposit (Qa): sand, mud, gravel, and cobble
- Unit of Conglomeratic and Tuffaceous Sandstone (Qav): Tuffaceous sandstone, conglomerate, tuff and breccia

According to the Hydrogeology Map, the research area is likely to occur in two significant aquifers:

- A shallow unconfined (phreatic) aquifer used for domestic purposes, either as the sole source of water or as a supplement to other sources of water such as municipal water; and
- An upper confined aquifer used for industrial purposes.

The shallow aquifer system consists of Pleistocene-aged marine and non-marine sediments to a typical depth of about 40 m. The horizontal hydraulic conductivity (K) of a number of the sand layers throughout the basin, regardless of which aquifer horizon they were from, have been found to be between about 0.1 m/day and 40 m/day (Yong et al., 1995; Schmidt et al., 1990).

## METHODOLOGY

### Geological Analysis

This stage is geological observation in detail. The activity are documentation of geological data along the track, description of soil, sketches of borehole log, photographs, PID (Photo-Ionization Detector) reading, and soil sampling. Placement of 12 new soil bores including two 45° angled soil bores and two monitoring wells in the Site X were determined based on the soil impacts and groundwater dissolved plumes detected in the previous investigations conducted between 2012 and 2016.

Soil samples for logging, screening and sampling were collected from a mechanically driven split–spoon sampler of 0.5 m in length. Samples were collected continuously until the terminal boring depth.

Approximately 200 g of soil sample from each split spoon sampler was transferred into zip-lock bags for screening of volatile organic contaminants and logging, and 130 g of samples were transferred to sampling jars provided by the laboratory for laboratory analysis. Soil profiles of each of the soil bores were logged using Unified Soil Classification System (USCS) by Geologists including soil physical properties such as lithology, grain size, grading, colour, texture, moisture and plasticity. Samples were visually inspected for noticeable odors or

E-ISSN : 2579 - 3136

discernible staining of the potential contamination.

## Hydrogeology Analysis

*Groundwater Sampling and Aquifer Testing*

Subsequent to the installation of monitoring wells and prior to sampling, wells were developed repeatedly using Teflon bailers to remove sediments and other foreign fines inside the wells and to surge the external filter pack. This ensured that the groundwater inside the monitoring wells was in equilibrium with the surrounding groundwater system.

Two methods of groundwater sampling were employed:

i) Manual sampling with Teflon bailers at the newly installed wells (MW-X10 and MW-X11); and

ii) Sampling at intervals with polyethylene diffusion bag (PDB) samplers at the newly installed wells and two existing wells (MW-X6 and MW-X7).

*Groundwater sampling with Teflon bailers*

Groundwater purging and sampling with bailers was conducted on five days after well completion and development. Prior to the commencement of groundwater sampling, the two newly installed wells. Subsequently, wells were purged of three well volumes (3 x Лr2h, where r is the radius of the well volume and h is the thickness of water column) to ensure that any stagnant water was removed and to ensure samples collected were representative of groundwater in the formation. A monitoring well was considered to be adequately developed or purged once the three well volumes of groundwater were removed, and physical-chemical parameters which include temperature, pH, electrical conductivity, redox potential and dissolved oxygen (DO) stabilized.

*Groundwater sampling with PDB samplers*

To attempt determination of the possible stratification of contaminant concentrations within the vertical water column, groundwater sampling at intervals using polyethylene diffusion bag (PDB) samplers were deployed for the two newly.

Once deployed into the well, the PDB samplers remained in place for two weeks, prior to removal to ensure that the deionized water in the bag had reached chemical equilibrium with the surrounding groundwater contaminants. Two weeks is the minimum recommended timeframe from the supplier to allow equilibrium conditions to establish in the PDB samplers and the monitoring well after installation. After removal from the well, the water in the samples were drained into appropriate sample containers and sent to the laboratory for analysis.

## The RESULT & ANALYSIS

**Geology**

Based on the soil boring activities, the subsurface geological profile it the Area of Interest at the base of the excavated area comprises of fairly consistent geological soil conditions. From the near surface to approximately 10 m bgs, soils consisted of silty clay to clayey silt. Generally, there was little physical difference between those two descriptions based on field visual observations. Below approximately 10 m bgs, the silty clay to clayey silt quickly graded into saprolitic clayey to silty sand in the south west portion of the area of interest (SG-X8 and MW-X11) and sandy silt to the north east (MW-X10 and SG-X10) prior to grading into the saprolitic clayey to silty sand. This saprolitic clayey to silty sand becomes harder with depth and was described as partially weathered volcanic tuff rock near the terminus of several of the borings.

In summary, fine grained soils dominate the geologic sequence to depths proximal to the average groundwater elevation. From there, the presence of fine grained sands with associated silts and clays present qualities of highly weathered rock material likely creates higher transmissivity with depth. In several of the borings, the material became less weathered and associated contaminant levels (Figure 2) declined rapidly as the lower soils graded into the clayey or silty sand to partially weathered rock possibly, demonstrating a flushing effect due to the likelihood of higher transmissivities of these soils.

**Hydrogeology**

During drilling, the groundwater levels in the soil bores were first noticed between 7.5 m – 10.0 m bgs. These depths approximate the changes in soils that are likely more transmissive or water bearing however, it is not certain that this is a function of these soils or just the measured water level as the well void was filling to the eventual static level. After development, the static groundwater levels in the monitoring wells within the Site X stabilized at levels between 7.340 m and 8.920 m bToW. There is a possibility of semi-confining conditions created by the clayey silt to silty clays at and above the typical groundwater elevations. This is based on soil moisture observations within these soils at depth, observations of initial water strike and the observed depths of possibly confining soils. Note, no hydrostratigraphs or diagnostic plottings were completed as part of this evaluation.

Groundwater to the depth of 15 m is the primary aquifer used for domestic water consumption in Jakarta and nearby provinces. This is consistent to what has been observed in the neighbouring community area where the well intake levels lie within the same shallow water table of the Site X. Similarly, this layer is expected to form a locally significant aquifer which is believed to be unconfined or partially confined. With the limited supply of municipal water, this aquifer is considered the main source of water for domestic and potable use in the neighbouring community area.

At the Site X, the groundwater flow direction was inferred to flow towards the north-easterly direction with a groundwater gradient of 0.04 (Figure 3 shows the direction of groundwater flow). Based on the observation of the soil properties, hydraulic conductivity and the gradient of groundwater at the area, the velocity of groundwater is anticipated between 38.4 m/year and 435.2 m/year which is considered slow to moderate.

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## CONLUSION

Primary findings include the increase in known soil contaminant concentrations and extent, increased groundwater concentrations and reducing the notion of numerous variations in geologic soil conditions that would affect the fate and transport of the contaminants.

There is now an increased likelihood of a soil remediation requirement due to the number of regulatory exceedances and the greater extent of elevated soil contamination levels. Additionally, soil and groundwater contaminant levels have likely eliminated the previous remedial alternative suggestion of slow release oxygen and along with the soil geological conditions and severely reducing groundwater conditions, will make all remedial efforts challenging.

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## APPENDICES



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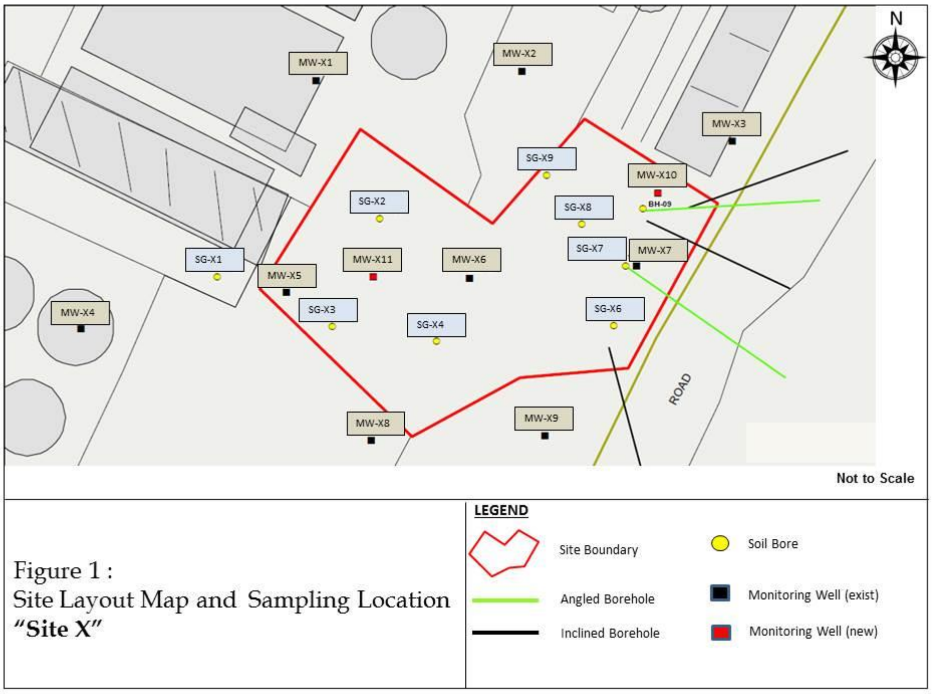


**Figure 1.** Site Layout Map and Sampling Location "Site X"

**Table 1.** PID Reading

| | PID Readings (ppm) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Up-gradient | In the impacted area | | | | | | Cross-gradient | | Angled Soil Bores at the Boundary | |
| Depth (m) | SG-X1 | SG-X3 | SG-X2 | SG-X4 | SG-X8 | MW-X10 | MW-X11 | SG-X9 | SG-X6 | SG-X10 | SG-X7 |
| 0.0 - 0.5 | | | | | | | | | | | |
| 0.5 - 1.0 | 80.6 | | | | | | | | | | |
| 1.0 - 1.5 | 296.1 | | | | | | | | | | |
| 1.5 - 2.0 | 12.1 | | | | | | | | | | |
| 0.0 m bgs | 115.2 | Base of excavation pit | | | | | | | | | |
| 0.0 - 0.5 | 28.6 | 21.8 | 202 | 80 | 137 | | 13.9 | 33 | 31.4 | 35.2 | 17.3 |
| 0.5 - 1.0 | 18.3 | 70.7 | 45.8 | 177 | 615 | 1,743 | 16.4 | 1,015 | 17.6 | 117.6 | 14.8 |
| 1.0 - 1.5 | 47.6 | 790 | 1,247 | >15,000 | >15,000 | >15,000 | 15.4 | 1,015 | 9.2 | 461.6 | 10.6 |
| 1.5 - 2.0 | 376.0 | 440 | 1,337 | >15,000 | >15,000 | >15,000 | 726 | 2,102 | 9.2 | >15,000 | 13.3 |
| 2.0 - 2.5 | 83.6 | 1,805 | 4,626 | >15,000 | >15,000 | 11,400 | 4,072 | 89.8 | 7 | 4,993 | 18.8 |
| 2.5 - 3.0 | 24.5 | 14,962 | 2,580 | >15,000 | >15,000 | 1,500 | >15,000 | 1,156 | 1.4 | 2,224 | 12.5 |
| 3.0 - 3.5 | 77.7 | 4,320 | 1,280 | >15,000 | >15,000 | >15,000 | >15,000 | 930 | 0 | 841 | 13.5 |
| 3.5 - 4.0 | 69.1 | 11,690 | 2,586 | >15,000 | 8,000 | >15,000 | >15,000 | 1,270 | 6.1 | 122.7 | 18.3 |
| 4.0 - 4.5 | 30.1 | 8,780 | 1,285 | >15,000 | 13,800 | >15,000 | >15,000 | 834 | 1.4 | 435 | 19.2 |
| 4.5 - 5.0 | 41.3 | 14,084 | 2,304 | 4,500 | 3,600 | >15,000 | >10,000 | 658 | 1.7 | 508 | 10.8 |
| 5.0 - 5.5 | 24.9 | >10,000 | 1,097 | 6,900 | 14,400 | >15,000 | >15,000 | 404 | 1.9 | 945 | 11.7 |
| 5.5 - 6.0 | 17 | >10,000 | 376 | 6,400 | 10,300 | >15,000 | >15,000 | 68.1 | 5 | 650 | 5.3 |
| 6.0 - 6.5 | 8.8 | >10,000 | 798 | 7,000 | >15,000 | >15,000 | >15,000 | 113 | 1.3 | 244 | 20 |
| 6.5 - 7.0 | 31.3 | >10,000 | 766 | >15,000 | >15,000 | >15,000 | >15,000 | 23.8 | 8.2 | 178 | 17.7 |
| 7.0 - 7.5 | 39.3 | >10,000 | 960 | 601 | >15,000 | >15,000 | >15,000 | 29.6 | 2.1 | 113 | 10.1 |
| 7.5 - 8.0 | 27.8 | 1,852 | >15,000 | 570 | >15,000 | >15,000 | >15,000 | 180 | 3.1 | 89.2 | 9.8 |
| 8.0 - 8.5 | 24.1 | >10,000 | >15,000 | 913 | 8,380 | >15,000 | >15,000 | 193 | 1.1 | 119.2 | 17.0 |
| 8.5 - 9.0 | 12.7 | 833 | >15,000 | 3,500 | 8,200 | >15,000 | >15,000 | 52.3 | 5.2 | 190 | 11.3 |
| 9.0 - 9.5 | | 1,201 | >15,000 | 515 | >15,000 | >15,000 | 1,200 | 30.5 | 5.7 | 450 | 6.9 |
| 9.5 - 10.0 | | 2,051 | >15,000 | 1,964 | 6,224 | 8,200 | 6,139 | 16.2 | 4.2 | 208 | 17.4 |
| 10.0 - 10.5 | | 2,753 | 1,216 | 1,100 | 1,100 | | >10,000 | | 4 | 350 | 7.2 |
| 10.5 - 11.0 | | 411 | 773 | 590 | 1,907 | 13,200 | 1,745 | | 7.1 | 431 | 10.8 |
| 11.0 - 11.5 | | 452 | 203 | 580 | 630 | 3,200 | | | | 104.6 | 15.7 |
| 11.5 - 12.0 | | 316 | | 219 | 400 | 440 | 560 | | | 410.4 | 29.7 |
| 12.0 - 12.5 | | | | | 376 | 110 | 1,000 | | | 745 | 5.3 |
| 12.5 - 13.0 | | | | | | | 143 | | | 367.5 | 22.2 |
| 13.0 - 13.5 | | | | | | | | | | 285.2 | 12 |
| 13.5 - 14.0 | | | | | | | | | | 355.2 | 13.2 |
| 14.0 - 14.5 | | | | | | | | | | 460 | 22.7 |
| 14.5 - 15.0 | | | | | | | | | | 413 | 19.1 |
| 15.0 - 15.5 | | | | | | | | | | | 11.7 |
| 15.5 - 16.0 | | | | | | | | | | | 360 |
| 16.0 - 16.5 | | | | | | | | | | | 35.6 |

Notes:
[illegible] is 2 m on a higher elevation than other soil bores
Impacted samples with PID readings between >1,000 ppm - >15,000 and with evident of solvent/hydrocarbon odor
19 soil samples selected for laboratory analysis



E-ISSN : 2579 - 3136

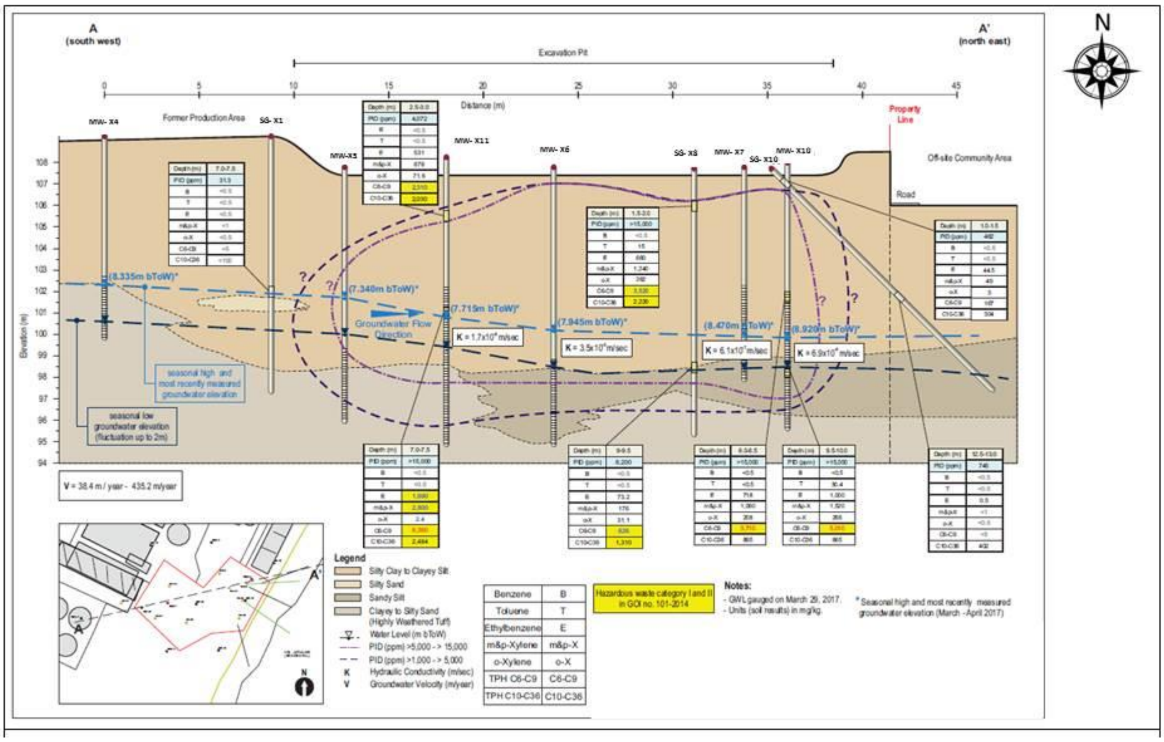

**Figure 2.** Geological Cross Section A-A' in the Site X

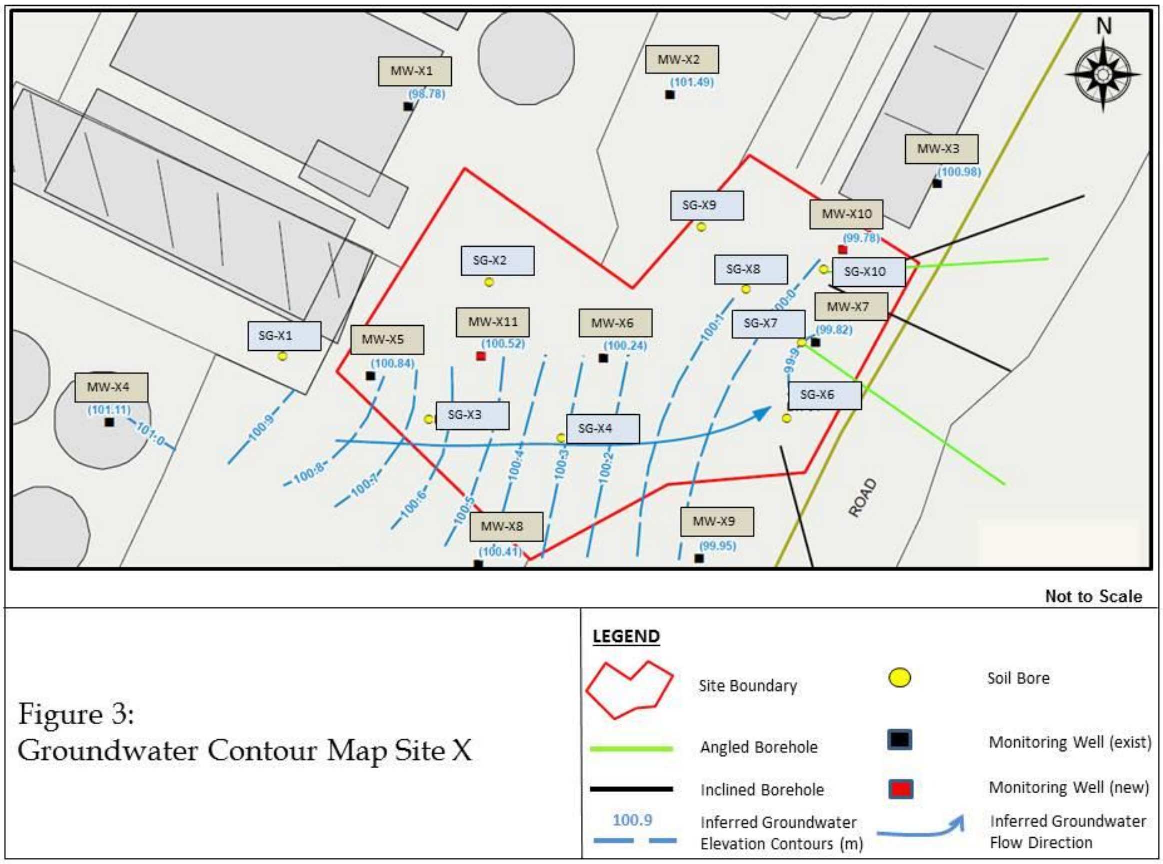


**Figure 3.** Groundwater Contour Map "Site X"



E-ISSN : 2579 - 3136

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