An Assessment on Hounslow Heath Heavy Metal Contaminated Land Soil Quality and a Recommendation of a Primary School Location Chosen

Han Zhang
China Electronic System Technology CO., LTD., Beijing, China
hhzldm@163.com

Abstract. This report will deal with the following aspects of Hounslow Heath contaminated land potential soil issues such as heavy metal containment. Meanwhile, it will give a recommendation on primary school location chosen in this region after comprehensive assessments. Firstly, backgrounds of contaminated land and Hounslow Heath will be briefly introduced, then the significances of those two factors will be identified, which includes the risk of reusing contaminated land and the difference between Hounslow Heath and other habitats. By telling the significances, the purpose of this part in the report is to discuss the value of Hounslow Heath, which is recognized as contaminated land because of historical landfill. In order to reuse this site, the contaminated land assessment is necessary under risk assessment regulation. After then, an analysis of Hounslow Heath, sampling points and methodology used will be presented, followed by data analysis, results will be motioned for further discussion.

1. Introduction
“Contaminated land” was recognized as a major issue in modern development for at least 30 years. And it was first reported on “Contaminated land” in 1990 by the Government’s House of Commons Environment Select Committee. [1] The specific land and its groundwater were used for industrial or waste disposal should be considered as contaminated land. A contaminated land like Hounslow Heath needs unacceptable risks assessment before re-usage. That is the major reason for doing soil assessment in this report before setting a primary school in Hounslow Heath. [2] Issues in contaminated land such as waste disposal include toxic or hazardous waste; water pollution; regeneration and decommissioning of derelict land and industrial site; they also affect the socio-economic and political landscape. In this report, based on the same journal from Hester’s, there are two major factors need to be considered in assessment: soil and water quality. [2]

1.1. A briefly introduce of Hounslow Heath and its significance
Hounslow heath is located in Southwestern London, were near one of the biggest airports, Heathrow airport. It is bounded by roads and River Crane. (Figure 1) Postcode areas: Hounslow, TW3 and TW4
Hounslow Heath has won award for conservation management excellence. It is a place full of excellent historical value with a written record going back to Norman times. The most important habitat in Hounslow Heath is lowland heathland, one of rare habitats in the UK, where a high conservation important place mixture of heathland, grassland, is squares of scour, and ranges of uncovered ground.

Hounslow Heath is a territory has more than 3000 hectares and holds lots of species. It is designed as nature reserve. [3]

Figure 1. The map of Hounslow Heath location.

Figure 2. The map of Hounslow Heath Nature Reserve. There are pond, heathland, wood, scrubland, meadow and wetland. [3]
It can be seen from the figure above, there are several habitats includes the pond, heathland, wood, scrubland, meadow, and wetland in Hounslow Heath. The most valuable habitat in Hounslow Heath is large scale heathland, which covers 5% of London’s heathland. Hounslow Heath is also labeled as the National BAP habitat. It is one of the biodiversity conservation habitats under the UK Biodiversity Action Plan (UK BAP). [4]

Besides, Hounslow Heath is also used by tourism, public open space, and education. For example bird watching and outdoor gym. It also won a Green Flag Award, which means it is a good example of managing habitat in a sustainable way. [5]

The first mentionable use of the Hounslow Heath was in the year of 1800. It was first acquired by the government as a military training shooting range by the time, and later during World War One, it was militarily elevated into a critical nexus of the aerial defense in London. The heath military usage was completely terminated by the year of 1948. Followed by the World War Two gravel extraction, the heath was then used for landfill purposes in the 60s for about a decade, though the usage as a gravel extraction site was again implemented to the heath in the 80s. Gravel extraction was not the only purpose of existence for the Hounslow heath in the 80s, wherein 1985 due to the expected awareness on environmental issues the heath also served the purpose as wildlife conservation and recreation site. Though less prioritized compared to other users in the past, the site has been also used as a golf course since 1977 until the current time. The most recent event of Hounslow heath would be the declaration as a natural reserve of the country. [6]

Thus, from the information above, the significant of Hounslow Heath is an important habitat and it was a contaminated land needed potential risk assessment before reuse it for building a primary school.

2. Aim and Objectives
To assess the potential risk of heavy metal contamination on the intended use of Hounslow Heath as a primary school location.

2.1. Objectives
- determine the nature and distribution of heavy metal contaminated across Hounslow Heath
  - identify the pathway from “potential source” to “receptor” and the relationship within
  - identify the risk by assessing the levels of hazard and exposure
- make the recommendations as to the most suitable location for a primary school plan

3. Methodology
Literature review on the previous studies, such as Chin report on Hounslow Heath [1]. It will help to understand the major problems (the aim of this report, and the objectives to achieve the aiming step by step), sampling design, and results in analysis for making a final decision. An example is reading the history of land use will help identify the contamination of the land. In other words, research on historical land use in landfill or industrial usage will help identify the soil pollution area in Hounslow Heath.
Figure 3. A flow chart shows methodology used in this report.

In the process of the completion of this report, a single direction procedure has been taken to reach the result. (Figure 3) The first part would be the problem formulation, making a strategy about sample collection and analysis. In the sampling session, they are two steps: data collection, then laboratory analysis. After data collection and processing, data analysis will be done by statistics. Then in the discussion session, the risk assessment will be divided into two parts: hazard and exposure. Finally, a decision of locating a primary school in Hounslow Heath will be made.

3.1. Sampling Collection

There were 3 parts in-field sampling processes: soil samples collection, water samples collection and OPAL soil survey. 100 systematic sampling locations were designed in sampling collection, 80 auger soil samples were taken, 10 OPAL soil samples were done, and meanwhile, 10 water samples were taken from boreholes and surface water bodies.

Figure 4. The map of sampling points. 4 groups of soil samples collection, one groups of OPAL soil sampling- blue points; and one group of water sample collection- red triangles.
All groups were followed by a square grid pattern sampling on GPS (see Appendix I), the soil collection groups use a list of materials below (See session 3.2) to dug holes to collect soil samples then brought them back to the lab. At the same time, the actual GPS grid codes were recorded. To take a viable and valid sample, not only one sample point is enough. It has to be done by taking 3 points of the sample site and mix the soil to get a valid sample. [7] Besides, physical soil quality was done when doing sample collection. (Such as soil smell, soil color, and soil texture)

3.2. Materials used in the field sampling
A GPS an OPAL soil survey guider
- Record sheet a bottom of water
- An auger (figure 5) Plastic bags
- Soil sample bags with marked labels

![Figure 5. The method of using an auger.](image)

3.3. Laboratory analysis and data analysis
Two parts of laboratory analysis were processed, includes water quality and soil quality. Physical soil quality (e.g. pH) and chemical soil quality (e.g. heavy metal contamination) were surveyed. Pb, Zn, Ni, Cu are metals that were investigated in this report. The reason for researching pH is based on the importance it holds in the potential for soil leach. Furthermore, it affects the solubility of heavy metals in soil. In the soil with a pH index within the range of neutral and weak alkaline (6.5~ 8.5), the Pb within the soil mainly exists in stable states such as strong organic fraction and Fe-Mn oxidation state. The ion exchange rate should basically under 2 percent, which indicates low harm from the number; while when the pH index is lower than 6.5, the Pb over ion exchange rate would increase significantly and could be over 8% when the pH index was 4.5. Thus, it is essential to keep the pH index of the soil within the range of 6.5~8.5 in order to reduce the harmful effects that occurred due to Pb. [8]

![Figure 6. The chart of correlation between Pb ion exchange rate (W) and soil pH. Form this chart, it can be seen, acid or high alkaline soil will make Pb more active than it in normal environment.](image)

*Base on the research mentioned above, soil pH checking will be necessary when dealing with the collected data.*
Regard on water samples, it is similar to OPAL physical soil samples. Both of them will confirm the soil sample's result on the other side.

3.4. Dealing with data uncertainties
After all, samples were collected, and all data was retrieved from the laboratory test, uncertainties were considered when designing the survey, including the difference between plan samples collected grid point and actual samples collection points. There are varied reasons lead to this consequence, such as no access to designed points in bush depth.
- Remove all outliers;
- Realize the duplicates
- Conform record GIS grid code on the map to find the real sample location map rather than trust the very first automatic output sampling map
- Always consider other factors will include results, for example, a small scale human actives.

3.5. The way to do a risk assessment and give a recommendation
The necessity of doing risk assessment in European countries is a kind of “common sense” before doing any decision, including any issue link with the environment. To do risk assessment in this report, there are 3 factors need to be considered: known information (landfill, military site and burned airport); potential heavy metal pollutant and hazards (birth defects, cardiovascular problems, carcinogenic, respiratory-related diseases and ecosystem effect) [9]

The method of assessing heavy metal used GIS to see hotspot, where re-usage should be avoided.

![Risk Assessment Diagram]

**Figure 7.** The schematic figure shows the method risk assessment works in this report.

Legislation should be considered when giving a recommendation on the primary school location chosen. Soil Guideline Values (SGVs) is the legislation this report followed. It is published by DEFRA and the Environmental Agency. It was used to identify the significant possibility of significant harm (SPOSH); evaluate the long-term risks to human health from contaminated soil and screening tools for the quantitative assessment of land contamination. Low, Medium and High consequences were quantitatively assessed using SGVs +/- half a standard deviation. As figure 7 shows, following the SGVs standard, the level of risk can be identified by it.

The limitations are:
1. Short term exposures not accounted for;
2. Risks of explosions, injury & contamination of water not taken into account. [10]
4. Results
Firstly, the data points map is shown below, the actual data points did not evenly distribute in the Hounslow Heath area. However, it still covered almost the whole area.

![Maps of original and actual data points](image1)

**Figure 8.** The maps of original data points and actual data points

According to Dai, besides Pb, pH effect on Calcium content, which effects on soil texture and its leachability directly. [8] From figure 9, the correlation between pH and Ca content was done, the higher pH (alkaline) come with more Ca (with 60% confidence). On the other hand, higher pH sites will have higher soil leachability (figure 10).

![Correlation chart between pH and Calcium](image2)

**Figure 9.** The correlation chart between pH and Ca, Y=0.98x-2.94, possibility is 60%
Figure 10. The GIS map of pH distribution and the hotspot map of soil leachability

From two maps above, the hotspot of high soil leachability located on northwest corner and southwest area in Hounslow Heath.

Figure 11. The map of Lead (Pb) distribution and its hazard.

Figure 11 is an example to show the result of Pb distribution and the way its hazard level is present on a map. From the right-hand map, a hotspot of high hazard sites are marked on a map. Other heavy metal results can be seen in Appendix II. In figure 12, the risk level of Pb in Hounslow Heath each sample site is displayed. Green area means low risk (safe to use), yellow means not good, red means dangerous.
It can be seen from the maps above, the red zone is not suitable for usage. Thus the location of the school will neither be northwest corner and southwest area nor middle part of north Hounslow Heath.

5. Literature Review and Discussion

5.1. Literature review on basic but helpful information on heavy metal damage and landfill history

Heavy metal in the soil is difficult to extract, long-lasting, and high toxicity. It is serious when it is absorbed into crops and further into the food chain. It is also possible for heavy metals to mix into the water or the air, which will severely threaten the health of mankind and the cycle within nature. Thus, managing rivers and soil polluted by heavy metals have always been an essential and difficult problem for the industries to solve. [11]
Pb will enter human inner circulatory system and blood, this action affects the nervous system and damage the brain. Children are even more sensitive than adults, Pb will impede their growth. Meanwhile, Cd is harmful to human health, a very famous epidemiological case in Japan called “Itai Itai” disease, which is caused by large scale cadmium poisoning. [12]

Generally, a heavy metal pollutants from source point where industrial emission point is or landfill from underground. In Hounslow Heath, the major source is historical landfill. Pathways help pollutant carrying to receptors, they can be nature (groundwater running flow) or human activities (soil remove from one site to another site, such as building the foundation. [13] In this case, building a primary school must avoid heavy soil polluted areas.

![Figure 14. A scheme of pathway between pollutant source and receptors](image)

To research pollutant source in Hounslow Heath, its landfill history should be known. The figure 15 shows the period in 1966 to 1988. The scale, age of landfill site links well with soil pollutant contamination.

![Figure 15. The map of Hounslow Heath landfill history](image)
5.2. Literature review on related regulations

Part 2A of the 1990 Environmental Protection Act

System for identifying and remediating statutorily defined contaminated land. The Education (School Premises) Regulation 2012 Part IV

Cites “Every part of a school building and the land provided for a school shall be such that the health, safety, and welfare of the occupants in aspects other than those referred to in paragraph (1) are reasonably assured”

5.3. Environmental Permitting Regulations

In the case of Remediation needed before construction

Building regulations

The requirement of reasonable precaution to avoid danger to health and safety caused by contaminants in the ground to be covered by buildings and associated ground.

5.4. The Education Act 1996/2002

Non-statutory advice on how to meet the regulations

Advice on standards for school premises

5.5. The discussion of results and school location options

Three Options of School Location

Three Locations, and Best Location selected based on the following criteria: hazard levels based on heavy metal distribution, access points, surrounding environment and transportation points. As is shown in figure 16, the three optional locations were chosen to follow heavy metal risk levels, stay in the low-risk area while avoiding the high risk of Pb and Cd. Then making a decision of those three options, the multi-criteria analysis was used, results shown in figure 17. It includes Access, transport provision, the safety of surroundings, low/medium hazard to human health, potential for resource sharing with the Heathland School (surrounding resource) and environment (SSSI, heathland).

|                      | Option 1 | Option 2 | Option 3 |
|----------------------|----------|----------|----------|
| Access               | ✓        | ✓        | ✓        |
| Transport provision  | ✓        | ✓        | ✓        |
| Safety of surroundings| ✓        | ×        | ✓        |
| Low/medium hazard to human health | ✓ | × | × |
| Potential for resource sharing with The Heathland School | ✓ | × | × |
| Preservation of SSSI | ✓        | ✓        | ×        |

Figure 16. Three options of school location

Figure 17. The option criteria matrix
6. Appendix

6.1. Appendix I

Figure 18. The map of plumbum (Pb) distribution and its hazard

Figure 19. The map of admium (Cd) distribution and its hazard

Figure 20. The map of Arsenic (As) distribution and its hazard
Figure 21. The map of Copper (Cu) distribution and its hazard

Figure 22. The map of Nickel (Ni) distribution and its hazard

Figure 23. The map of Zinc (Zn) distribution and its hazard
6.2. Appendix II

Table 1. Tables of duplicates in field and lab

|          | Ca  | Ni  | Cu  | Zn  | Pb  | Crd | As  |
|----------|-----|-----|-----|-----|-----|-----|-----|
| Average  |     |     |     |     |     |     |     |
| difference| 6211.00 | 24.43 | 13.09 | 101.46 | 116.01 | N/A | N/A |
| between   | duplicates| | | | | | |
| Average   |     |     |     |     |     |     |     |
| percent   | 160%| 72% | 23% | 43% | 33% | N/A | N/A |
| differences| of the | duplicates| | | | | |

Field Duplicates

|          | Ca  | Ni  | Cu  | Zn  | Pb  | Crd | As  |
|----------|-----|-----|-----|-----|-----|-----|-----|
| Average  |     |     |     |     |     |     |     |
| difference| 5215.27 | 1503.01 | 97.57 | 270.68 | 536.62 | N/A | N/A |
| between   | duplicates| | | | | | |
| Average   |     |     |     |     |     |     |     |
| percent   | 7630%| 38% | 25% | 72% | 253%| N/A | N/A |
| differences| of the | duplicates| | | | | |

Table 2. OPAL soil data

| #   | pH (12) Field | pH lab | Ca    |
|-----|---------------|--------|-------|
| 11  | 4.0           | 6.5    | 11973.63 |
| 22  | 4.0           | 5.7    | 5133.44  |
| 24  | 5.0           | 5.2    | 2477.05  |
| 37  | 4.0           | 5.4    | 3950.24  |
| 41  | 4.0           | 5.4    | 5128.83  |
| 48  | 4.0           | 6.1    | 7087.95  |
| 47  | 5.0           | 5.9    | 6514.1   |
| 60  | 5.0           | 6.0    | 4957.02  |
| 66  | 5.5           | 6.7    | 22778.33 |
| 68  | 4.5           | 6.2    | 15470.65 |
### Table 3. The water sample results

| Sample No. | Description       | Water Type      | Easting | Northing | pH  | Temperature | As      | Ca      | Cd      | Cu      | Ni      | Pb      | Zn      |
|------------|-------------------|-----------------|---------|----------|-----|-------------|---------|---------|---------|---------|---------|---------|---------|
| 1          | Stanines Road     | Surface Water   | 511362  | 174600   | 8.36| 4.9         | NV      | 145.46  | 0.05    | 0.05    | 0.05    | 0.05    | 0.05    |
| 2          | Corner River      | Surface Water   | 511164  | 174533   | 7.30| 8.5         | NV      | 167.09  | 0.05    | 0.05    | 0.05    | NV      | 0.05    |
| 3          | Northwest Ground  | Surface Water   | 511783  | 174582   | 6.27| 1.7         | NV      | 15.80   | 0.05    | 0.05    | NV      | 0.05    | 0.05    |
| 4          | Southeast Ground  | Ground Water    | 512162  | 174524   | 6.50| 9.3         | NV      | 319.53  | 0.05    | 0.05    | 0.05    | 0.05    | 0.05    |
| 5          | Northeast Ground  | Ground Water    | 512543  | 174485   | 6.79| 10.4        | NV      | 326.75  | 0.05    | 0.05    | NV      | 0.05    | 0.05    |
| 6          | Southeast Ground  | Ground Water    | 512726  | 174149   | 7.02| 11.7        | NV      | 509.15  | 0.05    | 0.05    | 0.05    | 0.05    | 0.05    |
| 7          | Central West      | Ground Water    | 512344  | 174098   | 7.01| 10.6        | NV      | 605.69  | NV      | NV      | NV      | NV      | 0.05    |
| 8          | Bridge River      | Surface Water   | 511978  | 173843   | 7.54| 4.1         | NV      | 207.40  | 0.05    | 0.05    | 0.05    | 0.05    | 0.05    |
| 9          | Polluted Pool     | Surface Water   | 511356  | 174628   | 7.21| 6.0         | NV      | 536.45  | 0.05    | 0.05    | 0.05    | 0.05    | 0.05    |

Note: Not Valid (NV) cus the RSD higher than 10

Option 1 is the east corner of Heath, which is a low-risk area for both Pb and Cd contamination. Meanwhile, it is located near a local resident, car park and bus station, also on the boundary of Heath, the area with the lowest distribute on heath habitat.

#### 6.3. Remediation Techniques

Compare the final soil pollution data map with the map in Chin report, 1995. [1] We can see the concentration of heavy metal pollutants reduced, especially in the middle part of Hounslow Heath. What we can believe it is a result of natural cleaning and soil leach. If the primary school will built-in Hounslow Heath, there should be a plan to avoid further soil pollution. There are only two ways in Hounslow Heath to solve this issue. First, reduce pollution source, reducing actives below: removal soil, excavation and landfill, degradation, bioremediation, chemical, and thermal destruction, extraction. However, there is still natural power such as soil washing by rainfall, groundwater flowing, these natural events also will do unwanted pollutant travel. [14] Thus another method is cutting the pathway down by using some artificial process: In-ground barriers, surface covers, plant vegetation, solicitation and stabilization, and groundwater pumping.

To sum up, this report aims to assess the unwanted risk produced by heavy metal contamination which may negatively influence future intended use of Hounslow Heath as a primary school location. It achieved the objectives of 3 points. Firstly, the nature and distribution of heavy metal contaminated throughout the Hounslow Heath have been determined. Secondly, the pathway linking the “potential source” and the “receptor” has been acknowledged and discussed the interrelation between these two. Thirdly, the risk has been assessed. This resulted in the decision of the relatively best location for a primary school.

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