Human Health Risk Assessment of Contaminated Land

Devon Great Consols Mine Consultancy Report

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Consultancy Report

Environmental Management

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1. Introduction

As per (Palumbo-Roe and Klinck, 2007), during the 1800s, when Southwest England dominated the world's Copper (Cu) mining sector, one of the most prosperous Cu producers was the Devon Great Consols Mine, located in the Tavistock district on the east bank of the river Tamar. During the 1870s, it was claimed that six mines in the Callington and Tavistock area, notably Devon Great Consols, produced half of the world's Arsenic (As). The mining operations ceased in 1930 and the Devon Great Consols Mine became an abandoned copper-arsenic mine and the home to the highest quantities of As, Cu, Sn, and W in the Tamar watershed.

According to a soil geochemical assessment conducted by the British Geological Survey, approximately 60% of the sites in the 920 km^2 Tamar watershed in SW England had total soil (As) values above the Soil Guideline Value (SGV) of 20 mg/kg for residential land use, it would be evident to say that there are still threats to the ecosystem from the significant legacy of arsenic contamination left by this facility. Hence this consultancy report is based on a field visit to the Great Devon Consols Mine prepared for West Devon Borough Council. It is a human health risk assessment based on analysis of the presence and levels of contaminants in both the old and new heaps of the mine along with the impact on the surrounding environment of the area.

2. Aims And Objectives:

- To perform the human health risk assessment posed by soils and tailings at the mine.
- To understand the geographical and environmental features of the mine.
- To determine the presence and level of contaminants in the soil.
- To analyse the associated environmental impact of the contaminants on the area's vegetation and biodiversity.

3. Study Area:

Geolocation: 50.53762121943572, -4.221089557115973

Fig 1: Study Area Maps. (Created by Author using Digimaps)

4. Methodology Adopted:

To identify and analyse the contamination in the soil, the following methodology was followed:

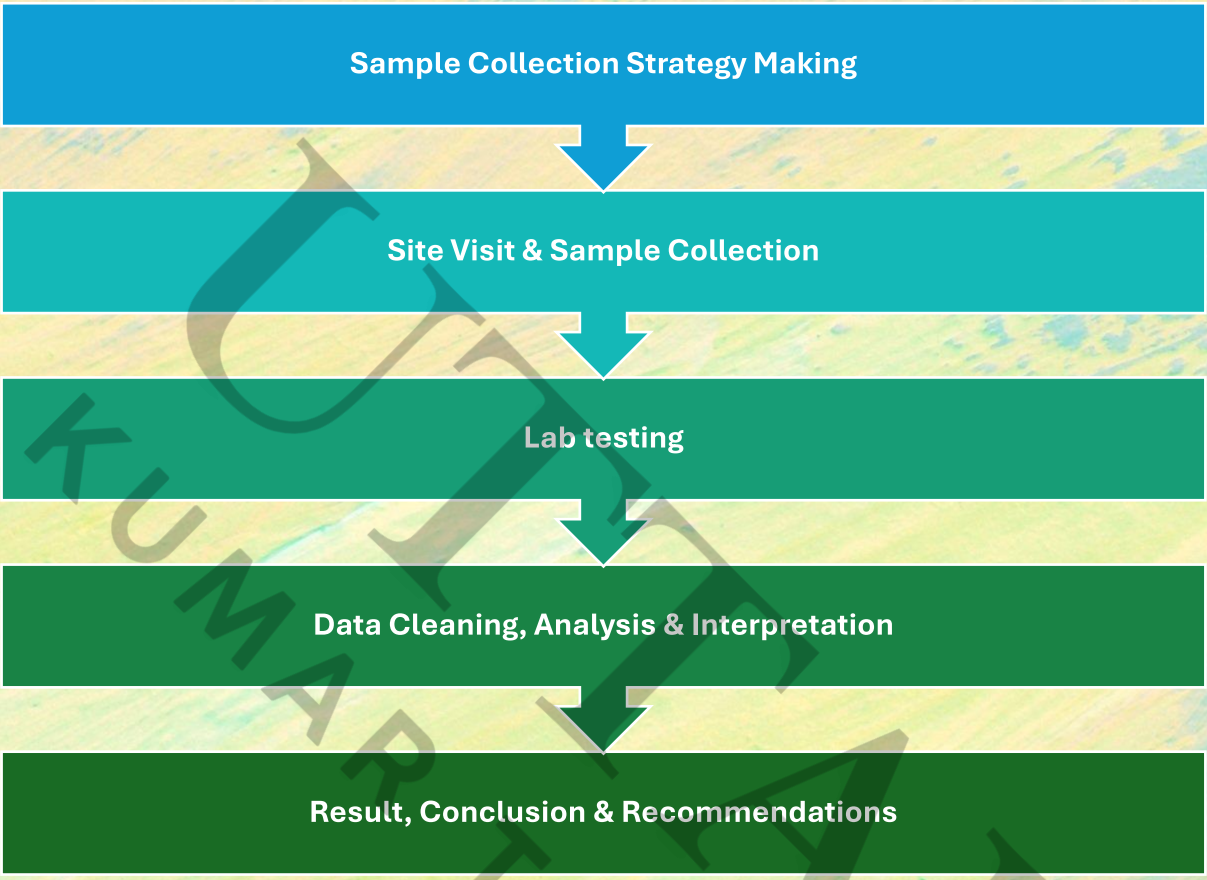
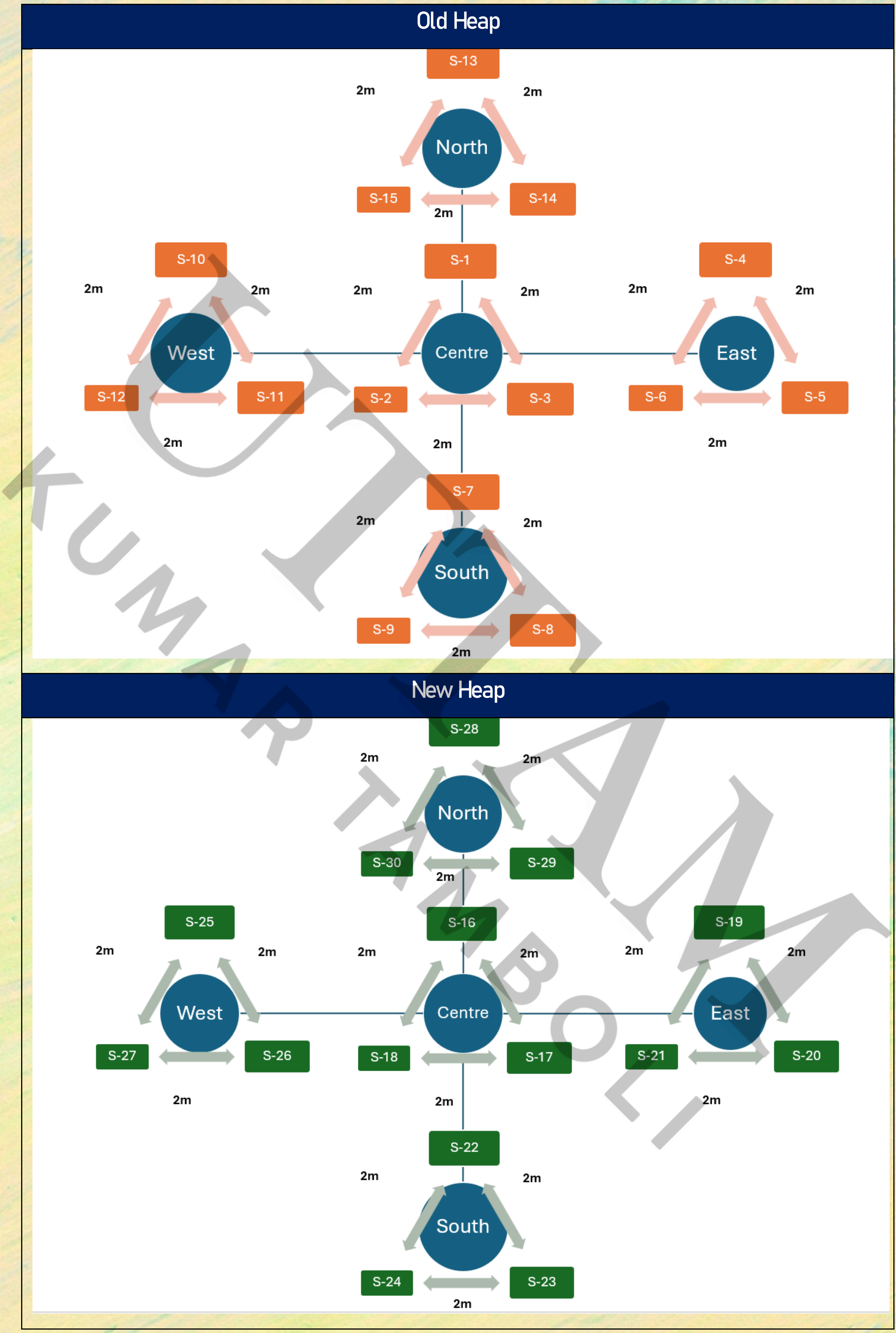


Fig 2: Flowchart of Methodology

4.1. Sample Collection Strategy Making:

Considering the study area, available time and resources, a sample size of 30 was finalized. These samples were distributed equally in both the soil heaps (5 each). In each heap, samples were decided to be collected in all five directions. (Centre, North, South, East, West). Moreover, in each sample site, 3 samples were finalized to be collected in a triangular arrangement with all the points being 2 meters apart from each other shown in Fig 3.


Old Heap

New Heap

Fig 3: Soil Sample Collection Strategy

4.2. Site Visit and Sample Collection:

The study area was visited on 9th April 2024. Photographs of the site were taken; preliminary analysis was done, and soil samples were collected in prelabelled plastic bags using a hand trowel. The following GIS map shows the locations of soil samples in both the heaps.

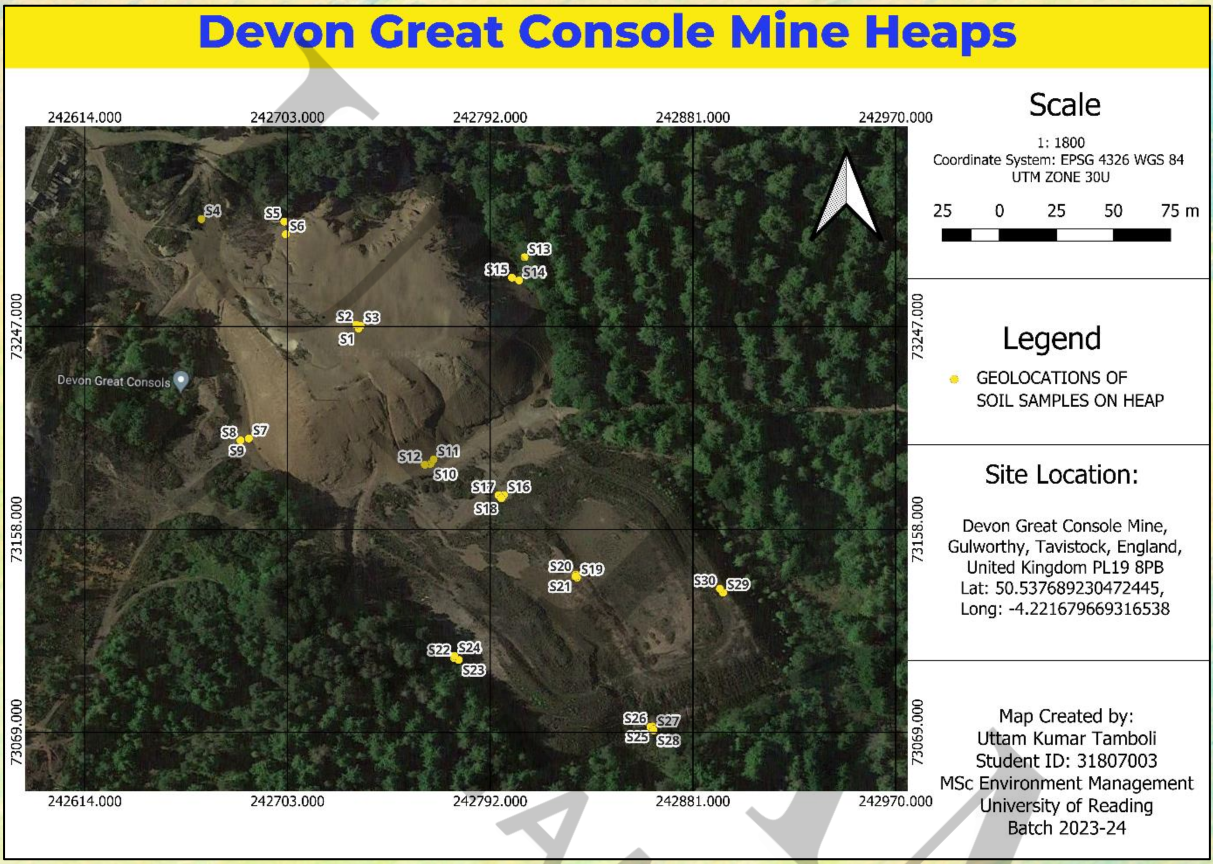


Fig 4: GIS Map of Soil Sample Collection locations in the study area. (Created by Author)

4.3. Lab Testing:

Due to the limited time and resources, only pXRF (portable X-ray fluorescence) testing and soil texture testing were performed in the soil samples.

4.3.1. pXRF Testing:

All 30 soil samples were taken to the lab and were subjected to pXRF testing. Thermo Scientific XL3T 950 He GOLDD+ series 61850 equipment model was used to perform the test. Different X-ray signals were emitted by the sample components when they were exposed to X-rays from the equipment. By monitoring these emissions with the previously calibrated pXRF, each element's presence and concentration were determined. This process created a detailed profile of the components that make up the soil.

4.3.2. Soil Texture Testing:

All the samples were subjected to soil texture testing by Hand with a standard soil texturing procedure using a Mansell colour chart. (University of Georgia, 2016)

4.4. Data Cleaning, Analysis & Interpretation:

The results of the pXRF test were provided in an Excel sheet by the technician of SAGES, University of Reading which was then cleaned, analysed, and interpreted using Minitab Statistical Software. In addition to it, the soil texture data was also studied and interpreted accordingly.

4.5. Results, Conclusion & Recommendation:

Based on the desktop study, site visit, lab results and data interpretations, appropriate conclusions were drawn, and recommendations were proposed for future works.

5. Site Visit & Lab Testing Photographs:

The buildings and ground within the area contain very high levels of arsenic contamination. Additionally there are unprotected drops and unstable structures.

For your safety, please keep to defined pathways. Children should be closely supervised at all times.

This site is a scheduled monument. It is a criminal offence to damage or disturb any of the structures o surrounding ground.

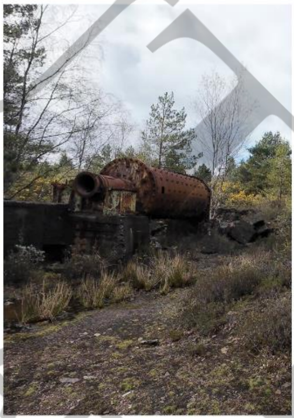


Fig 5: pXRF Testing and Hand soil texture using Munsell Colour Chart

6. Result & Discussion:

6.1. Soil Texture Results:

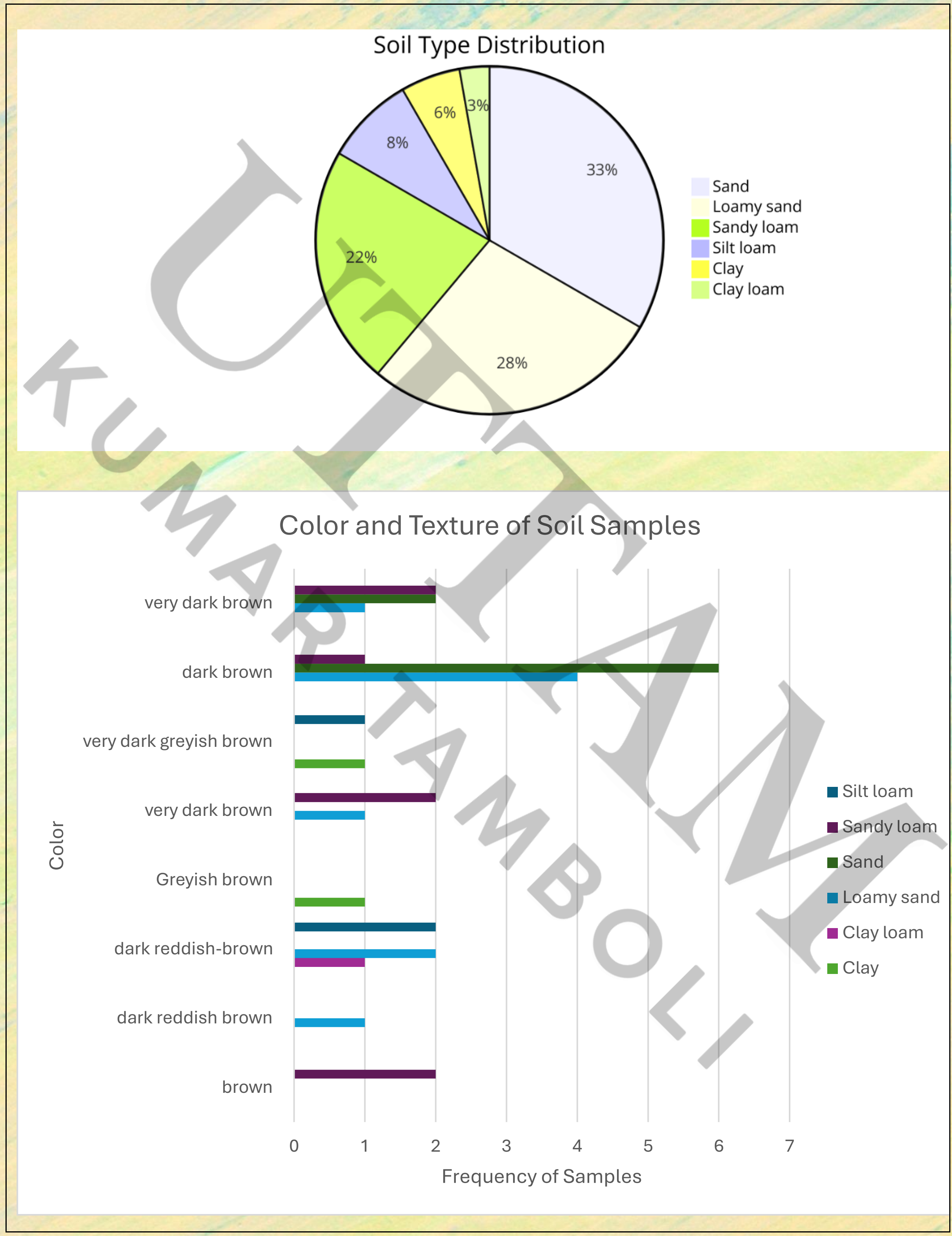


Fig 6: Soil Texture Graphs of samples.

The graph in Fig 6 gives a concise visual description of the soil types found in the thirty samples. In addition to highlighting the relative rarity of clay and silt loam types, this distribution shows how dominant sandy soils are in the dataset. With twelve samples or the greatest portion, sand is the most common form of soil. The significant occurrence of Loamy Sand is indicated by the 10 samples that follow. A moderate occurrence is indicated by the presence of sandy loam in 8 samples. Only three samples each of silt loam and clay indicate how uncommon they are. Lastly, there is only one sample of clay loam, making it the rarest. Check Table 2 of the appendix for the datasheet.

6.2. PXRF Test Results:

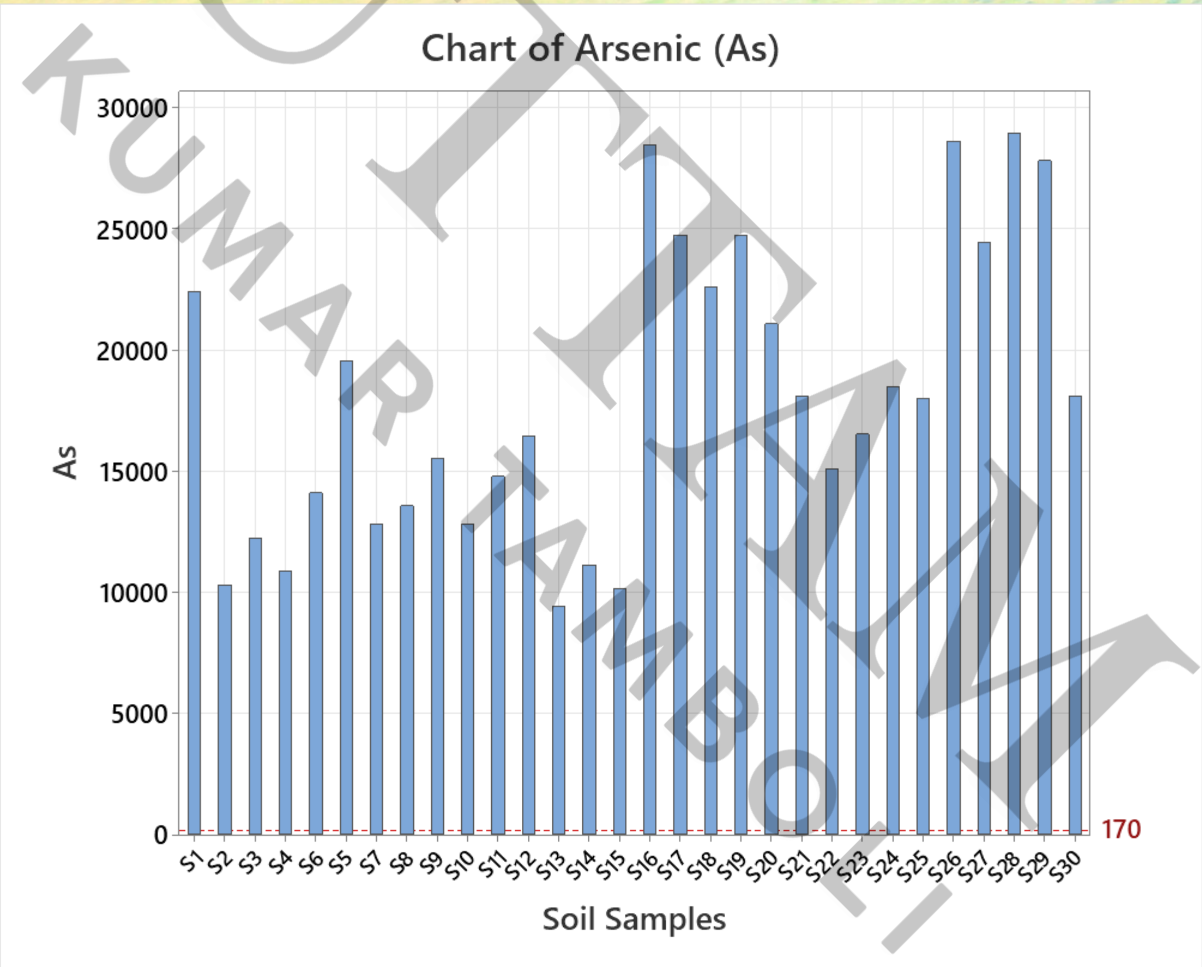


Fig 7: Concentration of Arsenic Contamination in soil samples.

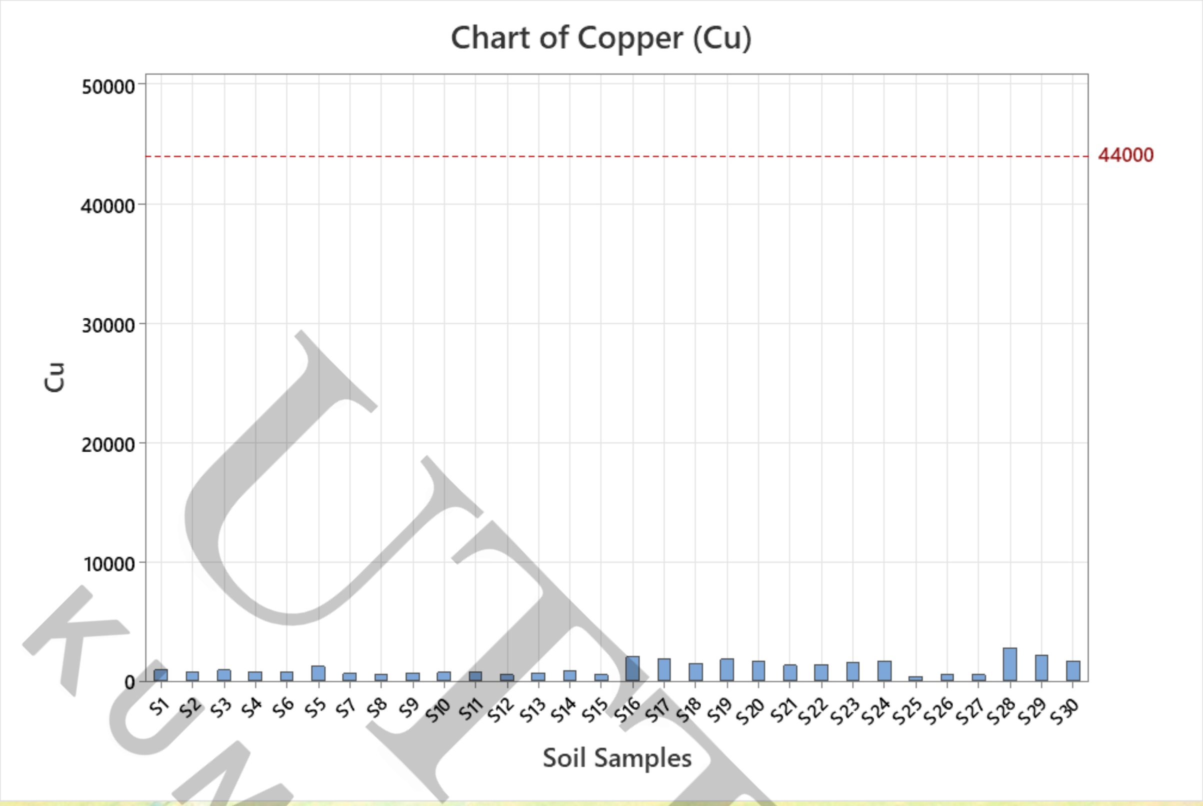


Fig 8: Concentration of Copper Contamination in soil samples.

For the assessment of the level of contamination, the Public Open Space (POSpark) of the S4UL category was used from the generic assessment criteria for human health Risk Assessment Comparison (Environment Agency, 2024). Out of all the metals detected in the pXRF test, arsenic was above the safety limit of 170 mg/kg which is extremely high in all 30 soil samples ranging from 9413.53 to 28921.26 mg/kg (Refer to Fig 7). Apart from this, as copper was mined before Arsenic, its presence is distinctively visible in all samples, but they are very low considering the limiting value (Refer to Fig 8). All the other metals were either below the level of detection or were extremely below the safety limit. (Refer to Table 3 in the appendix for the datasheet).

Source	Pathway	Receptor	Potential Impact
Mine tailings and spoil heaps	Water runoff	Local water bodies, Local community population, aquatic, ecosystem, wildlife, vegetation	Contamination of aquatic environments

	Soil deposition	Local soil	Accumulation of heavy metals in soil
Abandoned mine shafts and leftover machinery	Groundwater	Local community population, vegetation	Contamination of drinking water with arsenic and other metals of higher concentration
	Air (dust)	Local community population, aquatic, ecosystem, wildlife, vegetation	Respiratory issues due to inhalation of dust

Table 1: Source- Pathway, Linkage and Receptors

Table 1 evidently explains the source pathway and receptor linkages in the study area which will be beneficial in restoration and remediation practices in future projects.

7. Recommendations:

The following recommendations are suggested for in-depth contamination analysis, and the environmental and human impact of the Devon Great Consols mine:

7.1. Bio accessibility testing:

Though, pXRF is a good test for understanding the composition of soil and detecting the level of contaminants, understanding the bioaccessibility of contaminants is paramount in understanding their impact on the environment, human health, and the entire biodiversity. It can be done in the form of a human health risk assessment with the help of vitro gastrointestinal extraction tests like the Physiologically Based Extraction Test (PBET). (Zingaretti and Baciocchi, 2021)

7.2. Ecotoxicological Studies:

Ecotoxicological Research will help determine how pollutants affect the local flora and wildlife by testing the effects of toxins seeping into water bodies of the vicinity. (Chapman, Dave, and Murimboh, 2010)

7.3. Vegetation Surveys:

Vegetation Surveys evaluate the effects on vegetation to comprehend how metals bioaccumulate and how they affect the health of plants and the quality of the soil. Hence it will be crucial for the Great Devon Consols mine (Panda and Dhal, 2015)

7.4. Water Sample Testing:

Comprehensive testing of water quality and level of contamination should be performed in the study area. This is also emphasized in (NERC, 2005) where it was performed using ICP-AES and colorimetric analysis.

7.5. Testing Chromium:

In pXRF test results, the variant of Chromium was not mentioned which makes it difficult to determine its value with the safety limits from the selected assessment criteria which provides different safety limits for Cr III and Cr VI. As the values were significantly closer to the safety limits of Cr VI and are more toxic than Cr III, a specific test for that is recommended. (U.S. Environmental Protection Agency, 2016). (Check Fig 9 in the appendix for the graph)

8. Conclusion:

In conclusion, the Devon Great Consols Mine's Human Health Risk Assessment has brought to light major concerns about arsenic levels that considerably surpass safety criteria and endanger both human health and nearby ecosystems. Even though copper concentrations were discovered to be below allowable bounds, extensive and immediate remediation measures are required due to the ongoing arsenic pollution. To gain a deeper understanding of the behaviours and effects of the contaminants, this report promotes the use of more advanced investigative techniques, such as ecotoxicological investigations and bio-accessibility testing. To alleviate the environmental and health concerns connected with the mine's legacy and ensure a safer future for both the surrounding people and the ecosystem, these findings must inform remediation methods.

9. References:

Chapman, E., Dave, G., & Murimboh, J., 2010. Ecotoxicological risk assessment of undisturbed metal contaminated soil at two remote lighthouse sites. Ecotoxicology and Environmental Safety, 73(5), pp.961-969. Available at: https://doi.org/10.1016/j.ecoenv.2010.02.014 [Accessed 14 April 2024].

Environment Agency, 2024. Appendix D SCR - Appendix G - Human Health Generic Assessment Criteria. [pdf] Available at: https://consult.environment-agency.gov.uk/psc/ct13-9nd-concept-life-sciences-integrated-discover/supporting_documents/Appendix%20D%20SCR%20%20Appendix%20G%20%20Human%20Health%20Generic%20Assessment%20Criteria.pdf [Accessed 14 May 2024].

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Panda, S. & Dhal, N., 2015. Assessment of Heavy Metal Contamination of Soils and Plants in and around Open Cast Mines of Sukinda, India. Asian Journal of Environmental Science, 10, pp.76-82. Available at: https://doi.org/10.15740/HAS/AJES/10.1/76-82 [Accessed 14 April 2024].

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University of Georgia, 2016. Understanding Munsell Soil Color Notations. [pdf] Available at: https://soils.uga.edu/files/2016/08/Munsell.pdf [Accessed 14 April 2024].

Zingaretti, D. and Baciocchi, R., 2021. Different Approaches for Incorporating Bioaccessibility of Inorganics in Human Health Risk Assessment of Contaminated Soils. Applied Sciences, 11(7), 3005. Available at: https://www.mdpi.com/2076-3417/11/7/3005 [Accessed 14 April 2024].

10. Appendix:

Sample No.	Type of soil	Colour Chart Specification
1.	Sand	7.5 YR, dark brown 3/4
2.	Sand	7.5 YR, dark brown 3/2
3.	Sand	7.5 YR, very dark brown 2.5/2
4.	Loamy sand	7.5 YR, dark brown 3/3
5.	Sand	7.5 YR, very dark brown 2.5/3
6.	Sand	7.5 YR, dark brown 3/3
7.	Sandy loam	7.5 YR, very dark brown 2.5/3
8.	Loamy sand	7.5 YR, dark brown 3/4
9.	Sand	7.5 YR, dark brown, 3.5/4
10.	Loamy sand	7.5 YR, very dark brown 3.5/3
11.	Sandy loam	7.5 YR, dark brown 3/4
12.	Sand	7.5 YR, dark brown 3/4
13.	Sand	7.5 YR, dark brown, 3/3
14.	Loamy sand	7.5 YR, dark brown 3/4
15.	Loamy sand	7.5 YR, dark brown 3/4
16.	Sandy loam	7.5 YR, very dark brown 2.5/3
17.	Sandy loam	10 YR, very dark brown 2/2
18.	Loamy sand	10 YR, very dark brown 2/2

19.	Silt loam	5 YR, dark reddish-brown 3/3
20.	Clay loam	5 YR, dark Reddish-brown 3/3
21.	Silt loam	5 YR, dark reddish-brown 2.5/2
22.	Loamy sand	5 YR, dark reddish brown 2.5/2
23.	Loamy sand	5 YR, dark reddish-brown 2.5/2
24.	Loamy sand	5 YR, dark reddish-brown 2.5/2
25.	Sandy loam	10 YR, brown 5/3
26.	Clay	10 YR, Greyish brown 5/2
27.	Sandy loam	10 YR, brown, 4/3
28.	Clay	10 YR, very dark greyish brown 3/4
29.	Silt loam	10 YR, very dark greyish brown 3/2
30.	Sandy loam	10 YR, very dark brown 2/2

Table 2: Distribution of Soil Texture of Samples prepared using Mansell colour chart. (University of Georgia, 2016) Here YR = Yellow Red

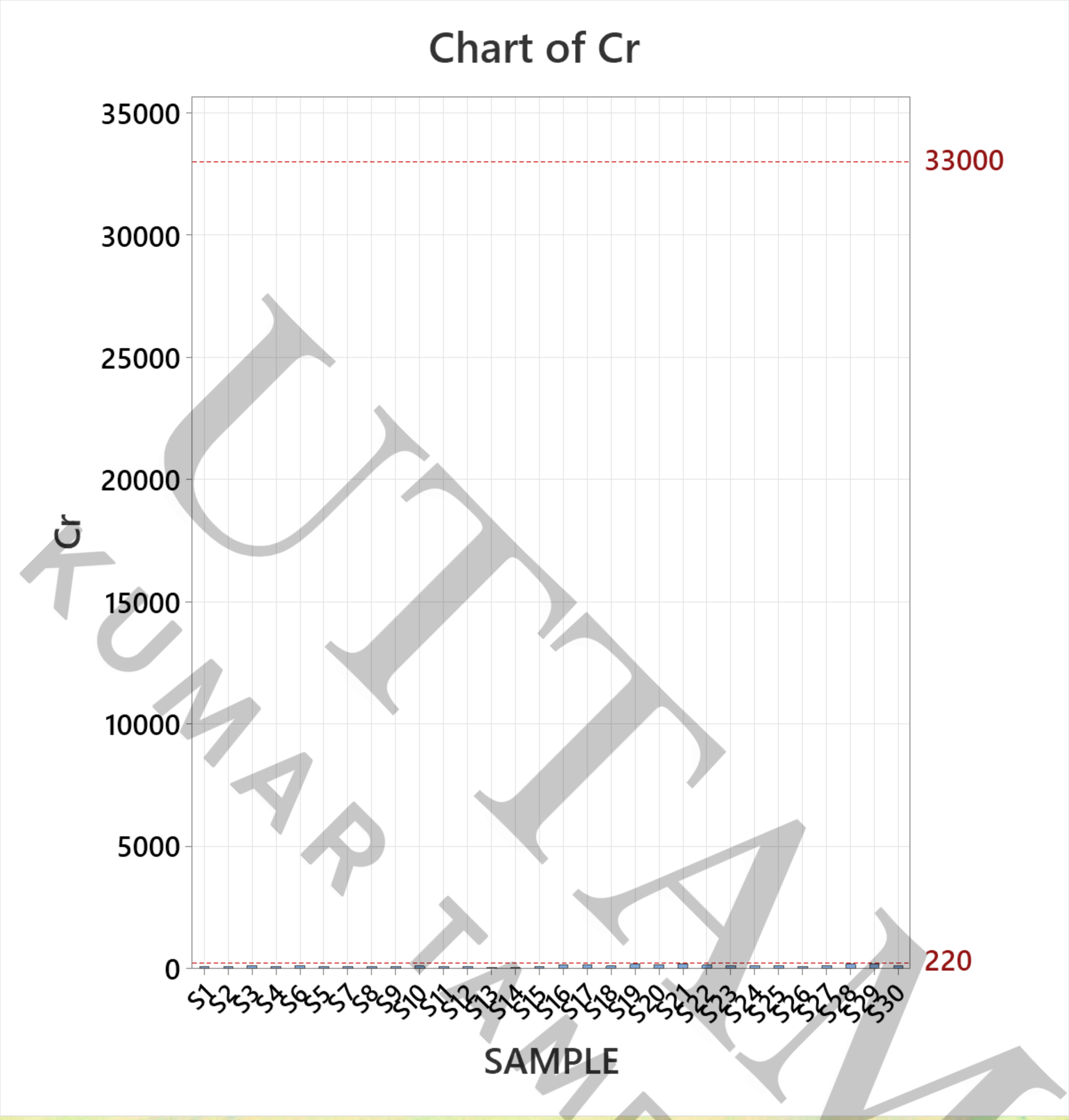

Fig 9: Graph of Chromium Contamination concentrations in soil samples.

SAMPLE	As	Cu	Cr
S1	22389.18	918.81	89.36
S2	10314.88	743.76	108.68
S3	12211.63	905.07	127.62
S4	10853.67	745.94	94.93
S6	14104.56	736.74	129.12
S5	19536.05	1221.91	106.38
S7	12805.79	615.23	107.1
S8	13579.25	520.84	94.81
S9	15528.22	672.4	101.06
S10	12830.56	706.91	113.97
S11	14778.96	781.64	93.73
S12	16439.98	528.48	100.6
S13	9413.53	678.97	72.6
S14	11128.61	822.59	70.42
S15	10156.54	526.22	93.34
S16	28436.85	2030.72	155.34
S17	24747.33	1892.27	146.41
S18	22607.81	1463.98	119.1
S19	24705.29	1836.84	194.65

S20	21088.35	1678.07	158.72
S21	18071.25	1299.44	192.3
S22	15106.22	1344.3	147.44
S23	16516.09	1544.04	131.27
S24	18460.63	1695.74	138.29
S25	17994.71	389.31	129.05
S26	28599.32	590.67	103.46
S27	24439.25	510.49	137.35
S28	28921.26	2749.47	184.17
S29	27815.5	2142.57	217.31
S30	18091.68	1661.11	134.11

Table 3: pXRF Datasheet of values of As, Cu and Cr contamination