Heavy Metal Contamination in the Soils Collected From Al-Muthanna Storage Site

Hisham M. Jawad Al Sharaa¹, Abdul Hameed M. Jawad Al Obaid² and Abdul Razzak T. Ziboon³

¹,³Geomatics Eng. Div. Civil Eng. Dept. University of Technology, Baghdad, Iraq
²Environmental Research Center, University of Technology, Baghdad, Iraq

Abstract. This paper introduces the hazard contamination in the storage area site using geomatics analysis technique. The contamination level of four primary heavy metal concentrations (Cu, Zn, Pb and Cd) of soils evaluated, analyzed and compared to the background reference points. Results indicate that copper level exceeds the permitted level by (1050) times, for zinc by (16000) times over the permitted level on the surrounding isolation protection on the north-west Wall, very high Contamination spot activity of lead was found in Destruction zone about (1350) times over the background level and there is no activity detected for the cadmium in the storage area site.

1. Introduction

The Iraqi past chemical program was destroyed by the military operations or destructed by the UNSCOM teams during the early 90s. Both operations lead to a large number of heavy metal remnants. The quantities of hazardous materials, incomplete destructed materials and toxic chemicals were sealed in two well-protected bunkers. Al-Muthanna has been used as the key facility for production of chemical weapons in Iraq last century. It locate 90 km northwest of Baghdad as shown in Fig. 1 (a and b). According to the Security Council Resolution 678 (1991). Iraq accepted to declare and destroy its weapon of mass destruction (WMD) program.

Al Muthanna State Establishment (MSE) production facilities were converted to destroy the chemical agents and the precursors under the supervision united nation special commission (UNSCOM). Due to the high-risk and the lack of appropriate destruction technology, the UNSCOM has select two bunkers to secure and isolate the remnants resulted from the destruction process from the population.

Iraq declared the contents of two bunkers according to the Chemical Weapons Convention (CWC) in June 2009 and committed to submit the destruction plan to the Technical Secretariat [1], [2]. The contaminated area was investigated and analyzed by using the integration of Geospatial Information Systems and statistical software, to evaluate the heavy metal contamination in the storage site zone.

2. Al-Muthanna storage site description

Al-Muthanna storage site, located 90 km North West of Baghdad on Tigris river arm between Samara and Fallujah. The geographical coordinates are (33°52’26.6”N 43°50’30.3”E) shown in Figure 1b. The site was Iraq’s main chemical weapons research, development, and production facility [1]. It is located in Salah Al-din Governorate. This facility covering an area of 1 km², the site operated continuously from 1983 to 1991 to produce thousands of tons of precursor’s chemical agents and from 1994 until now used to store securely the remnants of the last project. The site was bombed heavily during the
Gulf war. From 1992 to 1994 the UNSCOM Group operated at this site to eliminate remaining precursor materials, equipment’s, and destroy production plants or burn remaining chemical agents [1].

The storage was semi-underground structures covered with a protective layer of concrete. They resembled a truncated pyramid.

![Al-Muthanna storage site](image1.jpg)

**Figure 1.** Al-Muthanna storage site

3. Materials and methods

In this paper, a total of 300 soil samples were analyzed by using GC mass spectrometer procedure. The soil samples data used in this paper were collected in 2015. The bunkers area (850 m *1000 m) divided as grid into 30 sectors (196 m* 163 m) as major sectors then each sector divided into ten minor sectors the sampling method depends on Two levels of soil samples, surface soil samples and samples from 50 cm depth were averaged, the minor sub-grid also averaged. Finally, each grid represented by one sample point for final statistical analysis. The background level is defined from samples located within about 1 km north and south from storages site. The contamination level of the main heavy metal chemical compound has detected and evaluated (Copper Cu, Zinc Zn, Lead Pb and Cadmium Cd), from the soil samples of the site, surrounding areas have investigated and compared to the selected reference points. The average results for the two depth layers have been combined to give us major perspicacity for soil contamination in Al-Muthanna storage site. The output digital map layer includes contours for Al-Muthanna storage zone maps were created by additive interpolation method of the geographical information system using the integration between ArcGIS 10.4 and golden surfer.

With ArcMap and Surfer spatial analysis extension and, DATA of subareas values can be imported to Geospatial through grid cells. These grid cells which have been classified in various ways and different colors are chosen for each class; the colors represent the progression of values for specified data. It is achieved after the raster themes are converted into a shapefile, which includes contaminations concentrations and information that represents subgrade characteristics. 3D mountain range plot and 2D contour have been created as a result for the evaluation stage. Data are interpolated by kriging method to introduce a continuous surface as a visual display by using spatial interpolation which is the process of using points with known values to estimate values at other unknown points. Kriging is a well-established method of spatial interpolation. It was created for geochemical data processing to estimate the most likely distribution of gold based on samples from boreholes. Kriging is based on the assumption of the continuous spatial distribution of numeric data in environmental geochemistry. The use of kriging is correct when the data density is sufficient with respect to the heterogeneity of the spatial distribution of the geochemical parameters. In geospatial statistical analysis, spatial interpolation of these points can be applied to create a raster surface with estimations made for all raster cells [2].
4. Results and discussion
The analysis of contamination activity levels of the main four heavy metals has detected and evaluated (Copper Cu, Zinc Zn, Lead Pb and Cadmium Cd) in the soils from different locations of the site, indicates a relatively asymmetrical distribution tainting slightly towards higher concentration. However, the activity level of Cu in the soil samples' exhibit higher variability and ranged between 3-42 ppm with an average value of 6.08 ppm. Similarity, it is observed that the activity level of Zn in the soil samples of the study area also exhibits large variability and ranged between 4.2-407 ppm with average values of 36.46 ppm, as for the Pb, it can see high concentration spot around 34 ppm with zone average 6.63 ppm and there is no activity for the cadmium in the storage area site. Whereas, the concentration level of Cu and Pb in the soil samples was above the reference background levels taken about 1 km away from the study site as shown in table 1. The obtained values of the copper level exceeds the permitted level by (1050) times over the background level, for zinc by (16000) times over the permitted level on the surrounding isolation protection on the north-west wall, very high contamination spot activity of lead was found in destruction zone about (1350) times over the background level and there is no activity detected for the cadmium in the storage area site. As shown in Figures 2, 3 and 4 as contour and mountain range plots that represent the concentration percentage over the background reference. This approach used to recognize that the contaminant and overall distribution, particularly higher concentrations due to hot spots are important parameters for demonstrating that the cleanup is very necessary to precisely achieve. Thus, it is necessary to have an overall understanding for the contaminant distribution to make this determination on hot spots acceptability. Many difficulties can be faced in this approach, one of them is the large numbers of samples are required to adequately characterize the upper tail of the distribution.

| Table 1. Statistical summary for heavy metals soil samples |
|---------------------------------------------------------|
| Cu ppm | Zn ppm | Pb ppm |
| Avg.   | 6.08   | 36.463333 | 6.653333 |
| Max.   | 42     | 407      | 34      |
| Min.   | 3      | 4.2      | 1.3     |
| Reference point | 3.15 | 2.4 | 2.25 |

Figure 2. Copper contamination contour and ‘mountain range’ 3D plot
5. Conclusions
In this paper the contamination of Al Muthanna storage site has been investigated. The results shows that the heavy metals concentration of Cu, Zn and Pb in the soil exceed the normal limits, while there is no significant contamination by the Cd. It’s clear that this site has suffered from the contamination due to the past chemical weapons program activities and the destruction of the chemicals and precursors related to this program. Severe contaminated hot spots were observed as follows:
- Cu hotspot near the storage bunkers exceed the reference values by 1050%
- Zn hot spot around the protective soil wall exceed the reference value by 16000% that might result from the contaminated soil that removed from bunkers in 2013 to the northwest protection wall.
- Pb hotspot near the destruction area exceed the reference value by 1350%
Due to these circumstances it’s essential to take the following action:
- Urgent action plan for decontamination
- Long term monitoring for the nearby water recourses.
- The agriculture activates should be moved out of the site by at least 1 km as recommended by the UN handover protocol.
- Medical examination for the nearby villages.
- More investigation and analysis for the other expected dangerous chemicals.
References

[1] Al Muthanna Chemical Weapons Complex Iraq’s Chemical Warfare Program – Annex.
[2] Abdol Razak T Z, Abdul Hameed M J A, Hisham M J Al-Sharaa 2014 Cobalt-60 And Cesium-137 Soil Contamination In Al Tuwaitha Nuclear Site Using GIS Technique Eng. &Tech. Journal 32 3209-3215.
[3] Muthanna / Samarra 2015- Iraq Special Weapons Facilities Report 2015 Fas.org Retrieved.