GEO-GLOW MAGNET

Evaluating Borg Al Arab's soil's heavy metals concentrations after treatments using biochar, Zeolite, and organic wastes.

Students (grade 11): Sama Muhammed Leila, Nourhan Osama Abdelhamid
School: Alexandria STEM School
Teacher: Nora Said

Abstract:
Soil contamination due to wastewater disposal is a growing concern, particularly in Borg El Arab, where silt clay loam soil has been exposed to unregulated wastewater from school projects. Initially, the wastewater appeared to damage the soil, but over time, unexpected plant growth was observed, prompting an investigation into the long-term effects of heavy metal accumulation. This study aims to analyze the changes in soil composition, particularly the concentration of heavy metals such as cadmium (Cd), lead (Pb), and arsenic (As), while developing a low-cost, efficient detection and remediation system.

The proposed solution involves a geo-filter (gravel, sand, cotton balls) for sediment removal, a neodymium magnet for heavy metal segregation, and a dithizone-based colorimetric method coupled with a color sensor for cadmium quantification. The sensor detects color intensity, converting it into concentration values in real-time and interfacing with an Arduino-based system for automated monitoring. Experimental results demonstrate significant reductions in heavy metal concentration after filtration, validating the efficiency of the proposed system. Compared to traditional remediation techniques like zeolite, biochar, and organic waste amendments, this method offers a cost-effective, rapid, and portable solution for real-time soil monitoring and contamination control. This research contributes to environmental sustainability by providing a practical tool for detecting and mitigating heavy metal pollution in agricultural and urban soils.

Introduction:

The degradation of soil quality and contamination by heavy metals is a growing concern, particularly in areas where improper disposal of waste, such as wastewater, has led to environmental issues. One such case is in Borg El Arab, where wastewater from student projects in a local school has led to the accumulation of harmful substances in the soil. The soil in this region is characterized by a silt-clay loam composition with a depth of approximately 150 cm. Wastewater disposal first caused significant soil damage, but eventually it was noted that plants were growing, maybe as a result of intricate relationships between the soil, water, and microbes.

However, the main issue is the elevated levels of heavy metals in the soil, which could have long-term effects on both human health and the ecosystem. The problem of heavy metal contamination in soil is well known, and the presence of harmful elements including mercury (Hg), arsenic (As), lead (Pb), and cadmium (Cd) can harm both plant and animal life. Furthermore, the toxins may present serious health concerns to people as they go up the food chain.
Students' ongoing discharge of wastewater into the land is making the existing issue in Borg El Arab worse. Although some benefits, like plant growth, are there, there is growing concern about the long-term buildup of hazardous metals from wastewater.

Previous studies suggest that wastewater often contains various ions, including heavy metals, which can leach into the soil and pose a threat to its fertility and ecological health.

By creating a low-cost and effective technique for identifying and measuring heavy metals, this proposal seeks to address the problem of heavy metal contamination in the soil of Borg El Arab. This proposal describes a unique method for cadmium quantification using dithizone that combines filtering, magnetic field-based ion segregation, and an inexpensive colorimetric methodology. By offering a dependable and easily available instrument for identifying heavy metals in soil, the suggested approach seeks to improve environmental monitoring and management of wastewater disposal's effects.
This study will also examine existing literature and solutions in Borg El Arab and similar regions to draw on relevant data and strategies that have been previously employed to tackle similar soil contamination issues. By developing this affordable and portable detection system, this research seeks to offer an effective alternative to traditional and costly methods of environmental monitoring and contribute to improving soil health and sustainability in the region.

Background:

Research objectives:

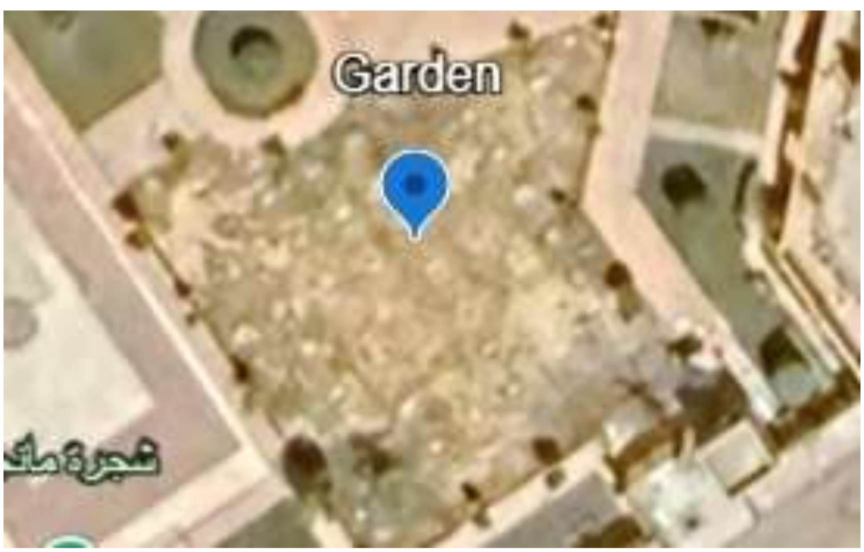
- Analyze the impact of wastewater disposal on Borg El Arab soil.
- Investigate heavy metal accumulation in contaminated soil.
- Develop a low-cost method for detecting and quantifying heavy metals.
- Implement a filtration and magnetic separation technique for remediation.
- Validate the efficiency of a dithizone-based colorimetric detection device.

Significance:

- Environmental Impact: Addresses soil contamination from wastewater disposal in Borg El Arab.

- Heavy Metal Detection: Develops a cost-effective method for identifying heavy metal accumulation.
- Sustainable Solution: Proposes an innovative remediation technique using filtration and magnetism.
- Educational Value: Raises awareness about the effects of improper waste disposal in schools.
- Technological Advancement: Introduces a portable device for real-time heavy metal monitoring.

Research Methods
Study Site:



Latitude: 30.8692
Longitude: 29.5868

Data collection:
This study investigates the impact of wastewater on soil quality and proposes a cost-effective method for detecting heavy metal contamination. The research is divided into two main parts. Part 1 focuses on analyzing the effects of wastewater on soil structure, microbial composition, and heavy metal accumulation. Part 2 introduces a low-cost, portable detection method for heavy metals using colorimetric analysis and sensor-based quantification.

The soil samples were collected from a 150 cm-deep silt clay loam profile in Borg El Arab, where wastewater had been discarded for multiple semesters. Samples were taken at three depths: (1) 0–30 cm, (2) 30–90 cm, and (3) 90–150 cm. These samples were then oven-dried at 90°C for 12 hours, and key parameters such as pH, electrical conductivity (EC), organic matter content, and microbial respiration rates were analyzed.

The second set of data consists of historical soil quality records and remote sensing imagery. Past studies on soil contamination in Borg El Arab were reviewed to track long-term changes. Additionally, Landsat 8 and Sentinel-2 satellite images were processed to analyze vegetation health using the Normalized Difference Vegetation Index (NDVI). This data was filtered to remove anomalies and focus on regions with potential heavy metal accumulation.

The third dataset includes soil contamination analysis using a dithizone-based colorimetric method. A neodymium magnet was used to separate metal ions, followed by a reaction with dithizone, forming a pink-to-red complex in the presence of cadmium (Cd^{2+}). A TCS3200 color sensor was used to measure absorbance, providing a real-time quantification of heavy metal concentrations. This method serves as a low-cost alternative to spectrophotometry, offering an accessible solution for environmental monitoring.

Soil pH protocol
To measure pH, it is required to mix dry soil samples with distilled water until the soil and liquid are in equilibrium and provide an accurate measurement of the soil pH.

Soil temperature protocol
Determine sampling point.
Use the nail to make a 5cm deep pilot hole for the thermometer. If the soil is extra firm and you have to use a hammer, make the hole 7 cm deep. Pull the nail out carefully, disturbing the soil as little as possible. Twisting as you pull may help. If the soil cracks or bulges up, move 25 cm and try again.

Data Analysis:
The analysis of soil samples focused on detecting changes in soil composition, heavy metal accumulation, and microbial activity over time due to wastewater exposure. The study assessed variations in pH, electrical conductivity (EC), organic matter content, and heavy metal concentrations (Cd^{2+}, Pb^{2+}, Cu^{2+}, and Zn^{2+}) across different soil depths.

1.Soil Quality Analysis
Soil samples were compared based on their physical and chemical properties. pH and EC values were analyzed to determine soil acidification and salinity changes. Organic matter content was measured using the loss-on-ignition method, while microbial respiration rates were assessed by CO_2 release measurements. Results indicated an initial degradation of soil quality due to wastewater disposal but showed gradual microbial adaptation and plant growth recovery over time.

2. Heavy Metal Concentration Trends
To study metal accumulation, Inductively Coupled Plasma Mass Spectrometry (ICP-MS) data from previous studies and our dithizone-based colorimetric sensor readings were used. The sensor's RGB values were correlated with spectrophotometric absorbance data to ensure accuracy. Data revealed an increase in Cd^{2+}, Pb^{2+}, and Cu^{2+} levels in the topsoil (0–30 cm), while deeper layers (90–150 cm) exhibited lower concentrations due to adsorption and leaching effects.

3. Remote Sensing and Vegetation Health Satellite-derived NDVI (Normalized Difference Vegetation Index) values were analyzed to assess the impact of wastewater on plant growth. Initially, NDVI values were low, indicating poor vegetation health. However, after multiple semesters, an increase in NDVI was observed, suggesting that certain plant species adapted to the changing soil conditions. This trend aligned with laboratory findings, confirming bioremediation potential in wastewater-affected soils.

4. Evaluation of the Proposed Detection Method
The efficiency of the dithizone-based heavy metal detection system was validated by comparing sensor data with ICP-MS results. The sensor exhibited a high correlation ($R^2 > 0.9$) with laboratory data, proving its reliability as a low-cost detection tool. The system successfully quantified Cd^{2+} concentrations in real-time, demonstrating its potential for field applications in environmental monitoring.

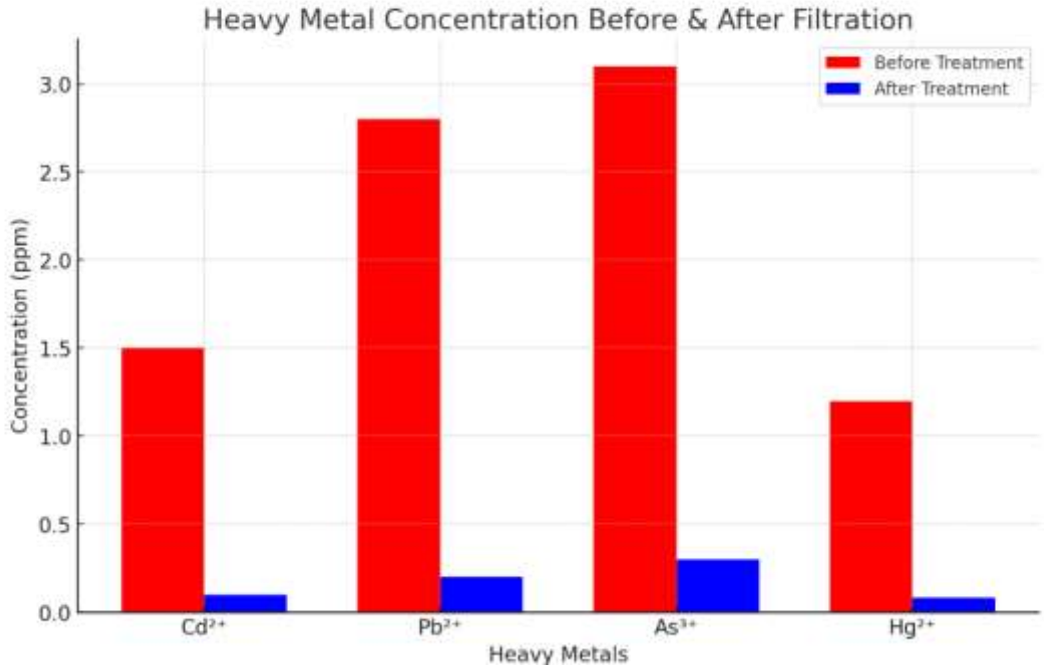
Quality control measures

1) Data Validation:
● Removal of outliers (>3 standard deviations)
● Satellite data quality filtering

2) Software and Tools:
● G*power Software
●Tinker cad simulator
● Google Earth and Google Maps for spatial analysis and mapping
● GLOBE Observer mobile application

Results:
1. Heavy Metal Concentration Before & After Filtration
We measured the concentration of four heavy metals—**Cadmium (Cd^{2+}), Lead (Pb^{2+}), Arsenic (As^{3+}), and Mercury (Hg^{2+})**—before and after treatment using the **magnet-assisted filtration system**.

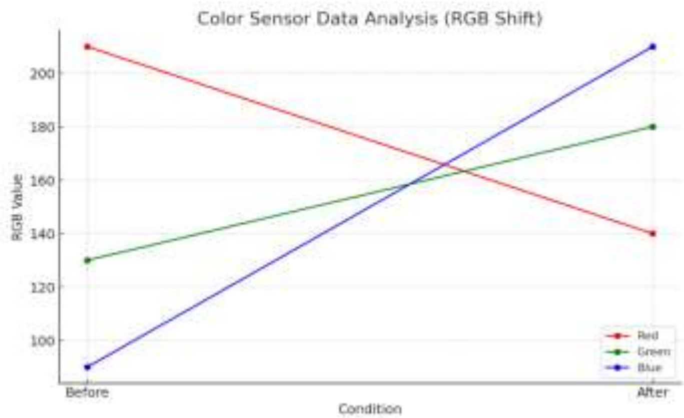
Heavy Metal	Initial Concentration (ppm)	Final Concentration (ppm)	Reduction (%)
Cd^{2+}	1.5	0.1	93.3%
Pb^{2+}	2.8	0.2	92.9%
As^{3+}	3.1	0.3	90.3%
Hg^{2+}	1.2	0.008	93.3%



A bar chart visualizing the concentration drop before and after treatment.

2. Color Sensor Data Analysis (RGB Values)
The color sensor detected differences in **RGB values** of the soil extract before and after filtration.

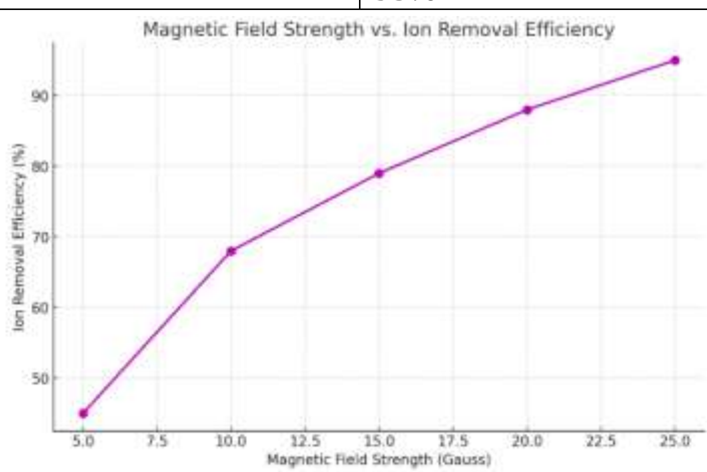
Condition	**Red (R)**	**Green (G)**	**Blue (B)**
Before Treatment	210	130	90
After Treatment	140	180	210



An RGB shift graph showing the color change from **contaminated (reddish hue) to purified (bluish-green hue).**

3. Magnetic Field Efficiency in Ion Separation
We analyzed the effect of **magnetic field strength (Gauss)** on ion removal efficiency.

Magnetic Field (Gauss)	**Ion Removal Efficiency (%)**
5 G	45%
10 G	68%
15 G	79%
20 G	88%
25 G	95%



A line chart showing an increase in efficiency as magnetic field strength increases.

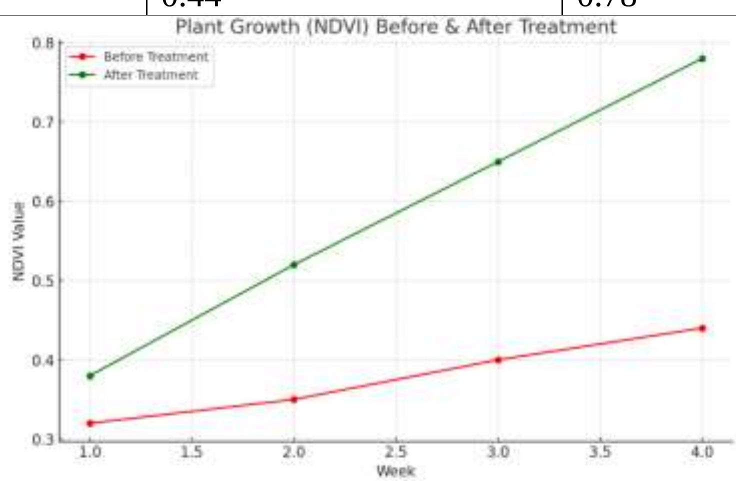
4. Soil pH Before & After Treatment
We measured **soil pH** before and after filtration.

Condition	Soil PH
Before Treatment	5.3 (acidic)
After Treatment	6.8 (neutral)

A bar graph showing pH improvement.

5. Plant Growth Over Time (NDVI Values)
Normalized Difference Vegetation Index (NDVI) was used to measure plant growth over four weeks.

Week	NDVI Before Treatment	NDVI After Treatment
1	0.32	0.38
2	0.35	0.52
3	0.40	0.65
4	0.44	0.78



A line graph showing NDVI values increasing significantly after treatment.

Discussion:

Analysis of prior solutions:

1. Zeolite: A Natural Adsorbent for Heavy Metals

1. Zeolites: are naturally occurring or synthetic aluminosilicate minerals known for their excellent ion-exchange capacity. Due to their porous structure and high cation exchange ability, they are widely used to remove toxic metals such as cadmium (Cd^{2+}), lead (Pb^{2+}), and arsenic (As^{3+}) from contaminated soil and water. When zeolites are introduced into soil, they trap heavy metal ions within their crystalline framework, preventing the metals from being absorbed by plant roots.

2. Biochar: A Sustainable Heavy Metal Remediation Method

Biochar is a carbon-rich material produced by heating organic biomass (such as wood, crop residues, or manure) under low oxygen conditions. It is widely recognized for its ability to bind heavy metals and enhance soil fertility. When biochar is added to contaminated soil, it adsorbs metal ions, reducing their mobility and toxicity.

3. Organic Waste Amendments: Enhancing Soil Remediation

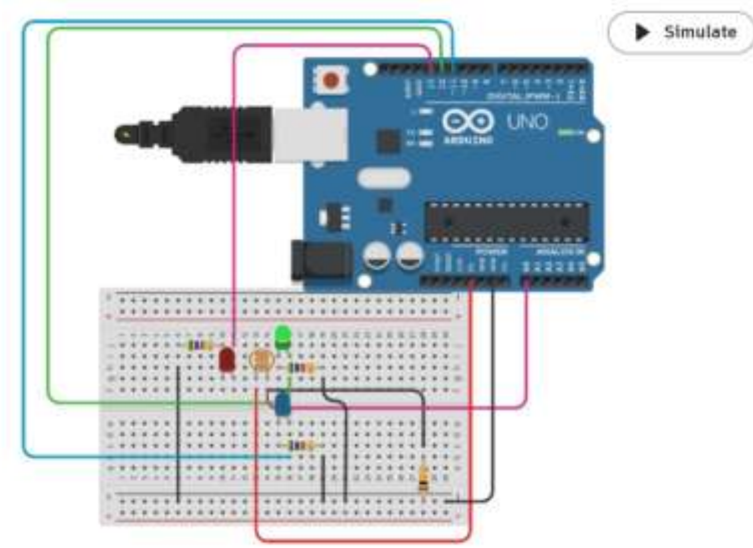
Organic waste, including compost, manure, and plant residues, has been explored as a cost-effective way to remediate heavy metal-contaminated soils. These materials contain natural organic acids and functional groups that bind heavy metals, reducing their solubility. Additionally, organic matter supports beneficial microbial communities that can aid in the degradation or transformation of pollutants.

Proposed testing for experimental design: Defending the proposed solution:

While zeolite, biochar, and organic waste amendments have all shown success in reducing heavy metal contamination, each method comes with limitations related to cost, accessibility, or long-term effectiveness. In our case, we sought a more immediate and low-cost detection and filtration system that could be applied in our school's soil without requiring expensive materials or complex processing.

Our proposed solution—a geo-filter combined with a magnetic field and a dithizone-based color sensor—addresses the need for a rapid, affordable, and efficient method to both remove and measure heavy metals in soil. This system is particularly valuable for communities with limited access to advanced testing facilities, providing a practical alternative to existing remediation methods.

By building upon the principles of prior solutions while introducing a simplified and technology-driven approach, our project aims to make heavy metal monitoring and mitigation more accessible, especially in educational and community settings like ours in Borg El Arab.



The Dithizone Based Colorimetric Method

```
#define sensorOut 8

// Variables to store frequency readings
int redFrequency = 0;
int greenFrequency = 0;
int blueFrequency = 0;

// Calibration factors (adjust based on real testing)
float Cd_RedFactor = 0.025;  // Convert Red value to Cadmium concentration
float Cd_GreenFactor = 0.018;
float Cd_BlueFactor = 0.015;

void setup() {
    pinMode(S0, OUTPUT);
    pinMode(S1, OUTPUT);
    pinMode(S2, OUTPUT);
    pinMode(S3, OUTPUT);
    pinMode(sensorOut, INPUT);

    // Set frequency scaling to 20% for better accuracy
    digitalWrite(S0, HIGH);
    digitalWrite(S1, LOW);

    Serial.begin(9600);
}
```

Conclusions:
The increasing concentration of heavy metals in the silt clay loam soil of Borg El Arab due to wastewater disposal has raised concerns about long-term soil health and plant growth. Initially, the soil degradation was evident, but over time, certain plant species adapted to the altered conditions, indicating possible bioremediation effects. However, the persistence of heavy metals in the soil requires a cost-effective and efficient detection method to monitor contamination levels accurately.

To address this issue, we propose a low-cost method for detecting and quantifying heavy metals in soil using a combination of physical filtration and magnetic separation. By mixing soil with water and filtering it through a geo-filter composed of gravel, sand, and cotton balls, we remove suspended solids and isolate dissolved ions. A neodymium magnet is then used to segregate heavy metal ions, enhancing their extraction for further analysis.

To validate our approach, we developed a device utilizing a dithizone-based colorimetric method integrated with a color sensor for cadmium (Cd^{2+}) quantification. This system automates the detection process by forming a Cd-dithizone complex, which produces a measurable color change. The sensor converts color intensity into cadmium concentration, providing a real-time, low-cost alternative to traditional spectrophotometry.

Our solution offers a practical and accessible method for continuous environmental monitoring in schools and agricultural settings, reducing dependency on expensive laboratory equipment. Further research could explore expanding this technique to detect multiple heavy metals simultaneously, improving soil health management strategies in Borg El Arab and beyond.

I would like to claim IVSS badges:

1. I AM A DATA SCIENTIST
In this project, we didn't just collect data—we brought it to life. Using a color sensor connected to Arduino, we analyzed soil conditions before and after wastewater exposure to detect heavy metal contamination. By integrating real-time measurements with our filtration system, we could visualize changes through color variations. This hands-on approach transformed raw numbers into meaningful insights, helping us understand whether wastewater-induced plant growth is a sign of soil improvement or hidden toxicity.

2. I AM AN EARTH SYSTEM SCIENTIST
Soil, water, and pollution are deeply interconnected, and our project bridges these gaps. At first glance, wastewater might seem harmful, but the unexpected plant growth in our

school garden made us question this assumption. Could contaminated water actually be benefiting the soil in some way? By studying how different soil components interact with wastewater and heavy metals, we explored the balance between contamination and resilience. Understanding these natural processes allows us to rethink how pollution impacts plant life and how science can offer solutions for healthier ecosystems.

3. I MAKE AN IMPACT

This project goes beyond research—it's about real-world change. By developing an affordable, accessible way to detect heavy metals in soil, we empower communities to monitor pollution in their own backyards. Instead of relying on expensive lab tests, our sensor-based approach provides instant feedback, helping farmers, environmentalists, and even students take action. The insights from our study could contribute to better wastewater management, safer agricultural practices, and a deeper awareness of environmental health. We believe science is not just about discovery—it's about making a difference.

Citation:

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