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Analysis and Quantification of Characteristics of Soil from Agricultural Fields and Ground Water Samples

Chandan Arundi B R
PG Student, Department of Civil Engineering
Bapuji Institute of Engineering and Technology,
Davanagere, Karnataka, India

Praveen Kumar G B
Assistant Professor, Department of Civil Engineering
Bapuji Institute of Engineering and Technology,
Davanagere, Karnataka, India

***Abstract*: Soil and groundwater in agriculture land is the major concern to get quality crops and more crop yield. This soil and groundwater may contaminate through the emission of industrial waste, sewage discharge, application of soil fertilizer and pesticides. In this study we collected three samples from agriculture land around Davangere, to determine the heavy metal in the soil using atomic absorption spectrophotometer. We also analyzed the fertility of the soil and physico-chemical parameters of the groundwater including heavy metals. The results of the study shows that heavy metals found in the soil is less than permissible limit and heavy metals in the groundwater is absent. Nitrogen in the soil is less than permissible limit. Phosphorous in soil is more than permissible limit. Potassium of soil sample1 is less than the permissible limit. To improve the soil fertility, NPK must be balanced. The pH of both soil and groundwater have to be balanced and heavy metal contamination must be prevented. Both soil and groundwater quality must be monitored regularly to obtain more crop yield and to maintain good soil health.**

***Keywords*: Soil, Groundwater, Heavy metal, Atomic Absorption Spectrophotometer.**

I. INTRODUCTION

A. SOIL: Soil is the top layer of Earth’s crust, made up of organic and inorganic materials. Usually, it contains about 45% mineral particles, 5% organic matter, and 20-30% each of water and air. The pedosphere, or Earth's soil layer, has four main functions: it acts as a medium for plant growth, stores, supplies, and filters water, influences the climate, and provides habitats for many organisms. Soil isn’t just mineral particles; it also has air, water, decomposing organic material, and various living beings. It interacts with the lithosphere, hydrosphere, atmosphere, and biosphere, making it vital to Earth's ecosystem. However, soil can be polluted by heavy metals and metalloids from sources like industrial emissions, mine tailings, waste disposal, leaded gasoline and paints, fertilizers, animal waste, sewage sludge, wastewater discharge, coal residues, pesticides, petrochemical spills, and atmospheric fallout. Toxic metals such as lead (Pb), chromium (Cr), zinc (Zn), cadmium (Cd), copper (Cu), iron (Fe), and nickel (Ni) are a broad group of inorganic hazards. These metals naturally exist in soil, but human activity and geological processes can increase their levels, which may harm plants and animals.

B. GROUNDWATER: All human activities, whether in agriculture, industry, or daily living, use of groundwater is increased. Unfortunately, excessive use, poor management, and pollution have gravely impacted our water resources, particularly groundwater. The issue of groundwater contamination has escalated, primarily due to pollutants like arsenic, nitrate, fluoride, and heavy metals. These harmful substances render water unsafe for drinking and can lead to significant health problems. The heavy metals concerning in groundwater include Arsenic (As), Cadmium (Cd), Lead (Pb), and Chromium (Cr). Contamination from toxic metals in agricultural groundwater is an urgent environmental problem, as these substances can arise from agricultural activities—such as fertilizer and pesticide use as well as from industrial waste. When these metals enter the environment, they can build up in the soil and eventually infiltrate groundwater supplies.

C. ATOMIC ABSORPTION SPECTROPHOTOMETER: An atomic absorption spectrophotometer is an analytical device designed to quantify specific elements in a sample by analyzing the light absorption characteristics of individual atoms. The technique requires converting the sample into free atoms and directing light of specific wavelengths through them. The degree of light absorbed is proportional to the concentration of the element being measured.

a. Principle: The sample is drawn into the flame where it undergoes atomization. A beam of light passes through the flame and is directed into a monochromator, ultimately reaching a detector that quantifies the light absorption by the atomized element in the flame. The energy absorbed at a specific wavelength in the flame correlates with the concentration of the element in the sample, but this can hold true only within a certain range of concentrations.

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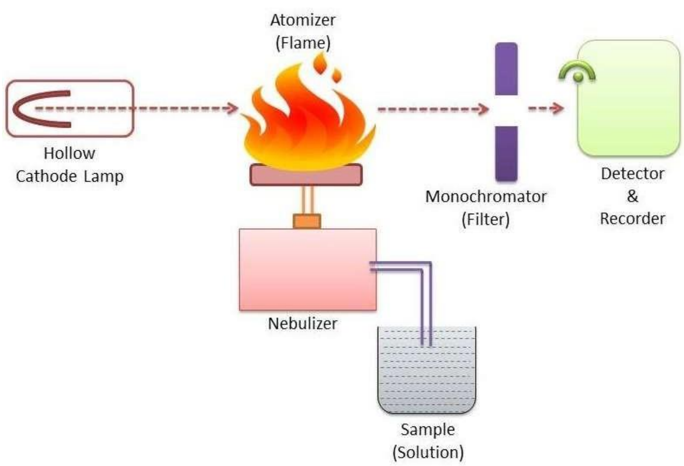

Fig. 1: Schematic diagram of an AAS

D. STUDY AREA

Soil and groundwater samples were collected in three different agricultural land around Davanagere. They are Mittlakatte, Shiramagondanahalli and Avaragolla villages.

E. OBJECTIVES

1. To collect the sample from various places around Davanagere.
2. Analysis of physico-chemical parameters of groundwater including toxic chemicals (heavy metals).
3. Analyse the fertility status of soil.
4. To compare the analysed groundwater concentration with the permissible limits set by regulatory agencies (IS 10500:2012).

II. MATERIALS AND METHODOLOGY

A. SAMPLE COLLECTION: Soil samples provide insights into nutrient levels, fertility, and potential risks from toxic substances. Similarly, groundwater samples are critical for evaluating drinking water safety, irrigation suitability, and pollution levels. Adhering to established protocols, utilizing suitable instruments, and employing preservation techniques during the sample collection process are crucial for guaranteeing that the samples accurately reflect field conditions. Consequently, obtaining soil and groundwater samples serves as a fundamental aspect of environmental monitoring, agricultural studies, and pollution evaluation, ensuring that the data gathered genuinely mirrors real-life scenarios.

a. Procedure for Surface Soil Sampling

1. Traverse through the entire field and study the field features like gravelliness, slope, soil colour etc. Observe for salinity / alkanity patches, water logged conditions etc.
2. Demarcate the field/entire land approximately into several uniform subplots or portions each of which must be sampled separately.
3. In each subplot, in zig-zag path collect samples from 15-20 spots randomly.
4. In standing crop, collect the sample between rows.
5. At each spot, remove the surface litter or leaves, small stones, gravels, pebbles, roots etc., and collect small quantity of sample from surface to plough layer depth (0-20 cm) from 15 to 20 spots.

In "V" shaped furrow 2 cm thick slice of soil from surface to bottom is taken carefully.

- 0 to 20 cm

6. Combine the soil samples gathered from various locations into one bucket to create a composite sample.
7. In order to reduce the sample size & to get desired quantity of sample, follow the procedure of quartering. Pour the entire soil into a piece of clean polythene sheet or cloth, mix thoroughly and remove pebbles, stones and roots. Divide into four equal parts. Reject the two opposite quarters. Mix the remaining two portions and repeat the procedure 3 or 4 times till you get 0.5 to 1 Kg soil.
8. Transfer the sample to clean polythene bag or cloth bag and put one label inside and tie another label outside.
9. Air dry the sample in shade for 4 to 5 days if the soils are moist or wet before putting them into clean sample containers.
10. The samples were mix, gently homogenized and sieved through 2-mm-mesh sieve.

B. SOIL TESTING: Soil testing is a scientific approach aimed at examining the physical, chemical, and biological attributes of soil. This process is essential for assessing soil fertility, identifying contamination levels, and evaluating the soil's applicability for agricultural, industrial, or environmental uses.

a) Material Required

Soil sample, plastic bag, shovel, 2 mm sieve, beakers, electronic balance, hot plate, measuring cylinder, funnel, Whatman filter paper No. 42, distilled water.

b) Chemical Required

35% HCL, 70% high purity HNO_3, standard solutions

c) Instrument Required

Atomic Absorption Spectrophotometer

d) Sample Digestion

1. Acid Digestion Process: To prepare the solid soil sample for analysis, it needs to be transformed into a liquid solution. Begin by accurately weighing a specific amount of dried soil and placing it into a digestion tube.
2. Addition of Acids: Introduce strong acids, such as concentrated nitric acid (HNO_3), and possibly hydrochloric acid (HCl) as well.
3. Heating the Mixture: Heat the combination to at least 95 °C to decompose the soil's mineral structure and dissolve the targeted elements. This step might require

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refluxing and repeating certain procedures until all brown fumes, which signify incomplete digestion, are eliminated.

4. Dilution of the Solution: Once the mixture has cooled, dilute the processed sample with ultra-pure water to reach a determined volume in a volumetric flask.

e) Instrument Analysis

1. Prepare calibration standards: Prepare solutions that contain established concentrations of the target element, ensuring that the acid matrix matches that of the digested sample to avoid inconsistencies.
2. Analyze samples: Inject the prepared standard solutions alongside the digested soil samples into the AAS (Atomic Absorption Spectroscopy) instrument, which typically operates using a flame.
3. Measure absorbance: The instrument measures the amount of light absorbed by the atoms in the sample at a specific wavelength, which reveals the concentration of the element.

f) Data Interpretation

1. Create a calibration curve by plotting the absorbance values of the known standards against their respective concentrations.
2. To determine the concentration of the target component in the unknown soil sample, consult the calibration curve.

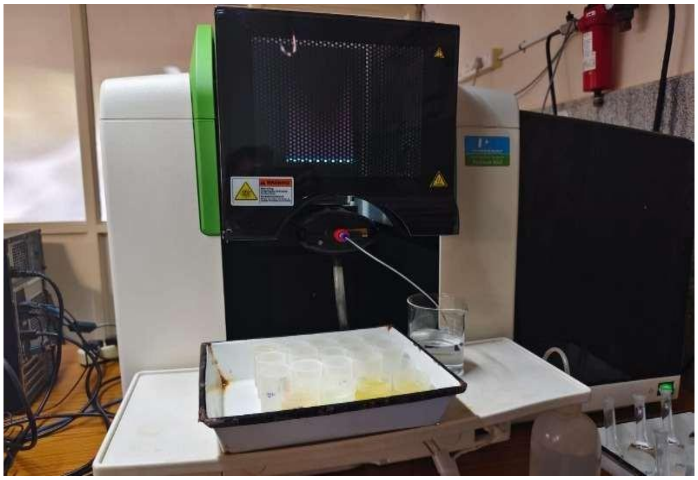

Fig. 2: Soil and Groundwater testing in A.A.S

C. GROUNDWATER TESTING

a. Instrument Calibration

Before conducting sample analysis, it's crucial to calibrate the AAS instrument using a series of standard solutions to determine the relationship between absorbance and concentration.

1) Prepare standard solutions: Create a set of standard solutions that contain the target metal at different known concentrations (for example, 0, 0.25, 0.5, and 1 ppm) by diluting a stock solution.
2) Zero the instrument: Start the AAS instrument by aspirating a blank solution, which should consist of all necessary reagents but without the analyte.
3) Analyze the standards: Introduce each of the prepared standard solutions into the AAS instrument.
4) Construct a calibration curve: Graph the absorbance readings obtained from the standards against their respective known concentrations to generate a calibration curve. Many contemporary AAS instruments can automate this process.

b. Analysis and Quantification

1. Sample introduction: Introduce the prepared groundwater sample into the atomizer of the AAS instrument, where it will be converted into a vapor.
2. Measurement of absorbance: The hollow-cathode lamp produces light at a particular wavelength that matches the metal being analysed. Metal atoms within the sample take in this light, and a detector measures the decrease in light intensity.
3. Determining concentration: By utilizing the calibration curve, the instrument assesses the sample's absorbance reading to compute the concentration of the metal present.

Fig. 3: Grundwater testing in Lab

III. RESULTS AND DISCUSSION

A. SOIL SAMPLE RESULTS

a. Parameters Tested in Soil

1. pH: It plays a crucial role in nutrient availability, microbial activity, and overall plant growth.
2. Electrical Conductivity: This measures the amount of dissolved salts in the soil, which can have an impact on plant health.

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3. Nutrients: Key nutrients encompass macronutrients such as nitrogen (N), phosphorus (P), and potassium (K), along with micronutrients including zinc, iron, and boron.
4. Heavy Metals: The presence of harmful metals such as lead, cadmium, chromium, and nickel.

Table 1: Soil Sample Results

SL. NO.	Parameters	Unit	Permissible limit	S1 Result	S2 Result	S3 Result
1	pH	-	6.5-7.5	7.88	7.40	6.44
2	E.C	dS/m	1-2	0.16	0.42	0.10
3	Organic Carbon (OC)	Percent	0.5-0.75	0.85	1.38	0.28
4	Nitrogen (N)	Kg/hectare	280-560	122.30	78.40	128.57
5	Phosphorus (P_2O_5)	Kg/hectare	22.9-56.33	131.82	95.49	114.18
6	Potassium (K_2O)	Kg/hectare	141-336	134.26	489.35	381.83
7	Iron (Fe)	PPM	4-9	11.85	40.72	34.05
8	Manganese (Mn)	PPM	2-4	14.91	19.23	33.02
9	Zinc (Zn)	PPM	0.6-1	3.25	1.08	14.02
10	Copper (Cu)	PPM	0.2-0.3	1.56	1.08	3.95
11	Calcium (Ca)	PPM	600-1000	110	1163.12	181.25
12	Magnesium (Mg)	PPM	100-500	1217.50	2430.00	1407.50
13	Boron (B)	PPM	>0.50	0.03	0.10	0.07
14	Lead (Pb)	PPM	600 (WHO)	2.70	1.58	1.05
15	Chromium (Cr)	PPM	50 (WHO)	0.11	0.00	0.03
16	Cadmium (Cd)	PPM	100 (WHO)	0.07	0.19	0.05
17	Nickel (Ni)	PPM	75 (WHO)	0.99	2.87	0.46

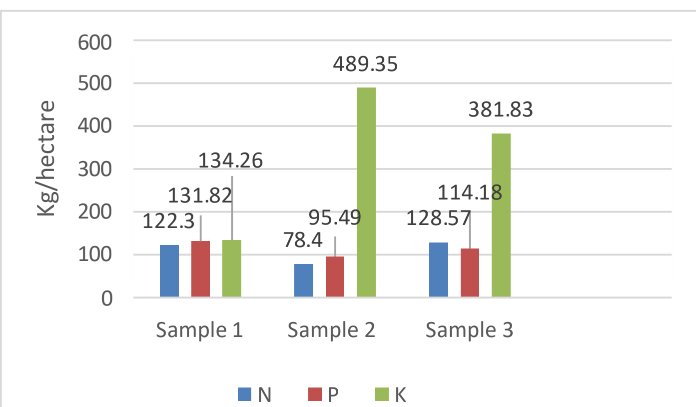

Fig. 4: Graph showing N.P.K values for Soil Sample

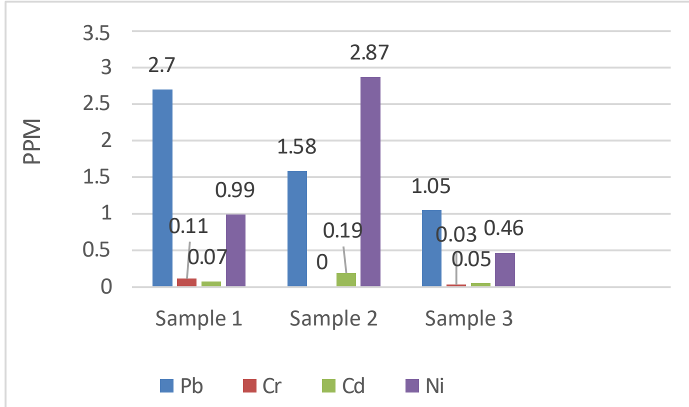

Fig. 5: Graph showing heavy metal values for Soil Sample

B. GROUNDWATER SAMPLE RESULTS

a. Parameters Tested in Groundwater

1. pH: Indicates the level of acidity or alkalinity in the water, which influences the availability of nutrients.
2. Total Dissolved Solids (TDS): It pertains to the overall quantity of both organic and inorganic materials that are dissolved in the water.
3. Nutrients: Includes essential elements like iron and zinc that are vital for the growth of plants.
4. Hardness: Refers to the overall hardness of water, including the calcium and magnesium hardness.
5. Heavy Metals: Contains harmful metals like cadmium, chromium, lead and nickel which can build up in plants and soil.

Table 2: Groundwater Sample Results

SL. NO.	Parameters	Unit	Permissible Limit-IS10500	S1 Result	S2 Result	S3 Result
1	pH	-	6.5-8.5	8.0	7.42	6.95
2	TDS	PPM	500-2000	356	403	849
3	Iron (Fe)	PPM	0.1-1.0	0.008	0.007	0.020
4	Manganese (Mn)	PPM	0.1-0.3	0.005	0.002	0.009
5	Zinc (Zn)	PPM	1-5	0.008	0.015	0.035
6	Copper (Cu)	PPM	<0.05	0.000	0.000	0.000
7	Calcium (Ca)	mg/l	80-200	49.6	44.8	163.2
8	Magnesium (Mg)	mg/l	40-100	28.08	43.05	119.80
9	Total hardness	mg/l	300-1000	184	204	664
10	Chloride (Cl)	mg/l	300-1000	55.98	33.98	265.91
11	Lead (Pb)	PPM	<0.01	0.00	0.00	0.00
12	Chromium (Cr)	PPM	<0.05	0.00	0.00	0.00
13	Cadmium (Cd)	PPM	<0.003	0.00	0.00	0.00
14	Nickel (Ni)	PPM	<0.02	0.00	0.01	0.01

IV. CONCLUSION

- In soil sample 1 and 2, pH values were observed as 7.88 and 7.40. These numbers were above the permissible limit 6.5-7.5, hence gypsum of 1-2 quintal per acre is used to reduce the pH.
- In soil sample 2 organic carbon is observed as 1.38%, so FYM of 10 ton/acre is applied to reduce within the range of 0.5-0.75%.
- In all the soil sample nitrogen values were less than the limit of 280-560 kg/hectare, hence it is recommended to increase nitrogen-based fertilizer such as urea which contains 46% of nitrogen.
- Phosphorus is used for root development at the time of harvesting, in all the soil samples it is more than the range of 22.9-56.33 kg/hectare, hence it is advised to reduce the amount of DAP fertilizer which contain 46% of phosphorous.
- In soil sample 1 potassium is observed as 134.26 Kg/hectare, which is lower than the limit of 141-336 Kg/hectare. So, it is necessary to use MOP fertilizer about 150 g/plant which contain 60% of potassium.
- For all the soil samples boron is less than permissible limit (>0.50 ppm) hence borax of 15g/plant is used to increase the boron.
- For agriculture soil presence of heavy metal is not good. If any toxic metal is present, it is necessary to take some precaution such as creating drainage, using FYM and to avoid irrigation of crops by contaminated water.
- For groundwater sample 1 pH is more, to reduce that certain measures are used in irrigation such that groundwater should be mixed with channel water, gypsum is mixed in farm pond which is used for irrigation and by adopting softeners.
- In all groundwater sample heavy metals are absent, it indicates that it is suitable for growing crops.
- Revitalizing soil starts with the removal of weeds, decaying plants, and leftover roots, as these can be breeding grounds for pests or diseases and hinder decomposition.
- Conducting a soil test is essential to assess pH levels and nutrient deficiencies, providing insight into the specific amendments needed.
- Using a garden fork to loosen compacted soil can enhance air circulation and facilitate root growth. To boost soil fertility, incorporating organic materials like compost, aged manure, and leaf mold is highly effective.
- Based on soil testing results, nitrogen can be replenished with blood meal or composted manure, phosphorus with bone meal, and potassium can be added using wood ash or kelp meal.
- Enhancing soil health can also be achieved by composting kitchen scraps, including fruit peels and coffee grounds.
- Implementing crop rotation or allowing the soil to rest with cover crops can help prevent nutrient depletion and naturally renew soil vitality.

V. SCOPE FOR FUTURE WORK

- Improving soil fertility (N, P, K, boron balance).
- Sustainable pH management in soil and water.
- Preventing heavy metal contamination in soil and water.
- Long-term monitoring of soil and groundwater quality.

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