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Analysis of Phosphate Content in Agricultural Soil Samples Using UV–Visible Spectrophotometry

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Abstract: *Phosphorus is an essential macronutrient required for proper plant growth, development, and maintenance of soil fertility. However, excessive phosphate accumulation in soil can lead to serious environmental problems such as pollution and eutrophication of water bodies. The present study focused on the quantitative determination of phosphate in agricultural soil samples using UV–Visible spectrophotometric analysis. Soil samples were collected from sugarcane, onion, and wheat cultivation areas of Maharashtra for phosphate estimation. The analysis was carried out using the ammonium molybdate–stannous chloride colorimetric method, in which a blue-colored phosphomolybdate complex was formed and the absorbance was measured at 690 nm. Calibration standards in the concentration range of 0.5–3.0 mg/L obeyed Beer–Lambert's law, confirming the reliability of the analytical method. Among the analyzed samples, the highest phosphate concentration was observed in sugarcane farm soil from Pune (0.029 mg/L), whereas the lowest concentration was found in wheat farm soil (0.007 mg/L). The elevated phosphate levels observed in certain soil samples may be associated with excessive fertilizer application and agricultural runoff. The study confirms that UV–Visible spectrophotometry is an accurate, economical, sensitive, and reliable technique for phosphate analysis in agricultural soil samples.*

Keywords: Phosphate analysis, soil chemistry, UV–Visible spectrophotometry, environmental pollution, agricultural soil.

I. INTRODUCTION

Soil is a heterogeneous natural system composed of mineral matter, organic matter, water, air, and microorganisms. It plays an important role as a nutrient reservoir, a medium for plant growth, and a regulator of various environmental processes. Among the essential nutrients present in soil, phosphorus is considered an important plant macronutrient required for proper growth and development. Phosphorus participates in several biological and biochemical processes including ATP synthesis, photosynthesis, nucleic acid formation, cell division, and energy transfer reactions. In nature, phosphorus mainly occurs in the form of phosphate compounds due to its highly reactive nature.

Although phosphate is essential for plant productivity, excessive phosphate concentration may cause serious environmental problems such as eutrophication, algal bloom formation, depletion of dissolved oxygen in water bodies, soil nutrient imbalance, and ecological disturbances. Phosphate contamination may arise from both natural and anthropogenic sources. Natural sources include weathering of phosphate-containing rocks and decomposition of organic matter, whereas anthropogenic sources include excessive use of chemical fertilizers, sewage discharge, agricultural runoff, animal waste, industrial effluents, and domestic waste disposal.

UV–Visible spectrophotometry is widely used for phosphate determination because of its simplicity, sensitivity, and accuracy. Spectrophotometric analysis involves the measurement of absorption of electromagnetic radiation by

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chemical species. In this method, phosphate ions react with ammonium molybdate and stannous chloride to form a blue-colored phosphomolybdate complex. The intensity of the blue color formed is directly proportional to phosphate concentration according to Beer–Lambert's law:

where (A) represents absorbance, (\varepsilon) is molar absorptivity, (b) is the path length, and (c) is the concentration of the absorbing species. The maximum absorbance of the blue-colored complex was observed at 690 nm.

II. OBJECTIVES OF THE STUDY

The primary objective of the present study was to determine the phosphate concentration in agricultural soil samples and to analyze phosphate contamination using UV–Visible spectrophotometric analysis. The study also aimed to compare phosphate levels among different agricultural soils collected from various cultivation areas. In addition, an attempt was made to study the influence of fertilizer usage on soil phosphate concentration and to evaluate the environmental implications associated with phosphate accumulation in agricultural soils.

Materials and Methods

Different agricultural soil samples were collected from various cultivation areas for phosphate analysis. The collected samples included sugarcane soil from Pune (S1), sugarcane soil from Satara (S2), onion soil from Pune (S3), and wheat soil from Pune (S4). These samples were selected to compare phosphate concentrations in soils associated with different agricultural practices and crop types.

The chemicals used in the present investigation included sulphuric acid, perchloric acid, sodium hydroxide, ammonium molybdate, stannous chloride, potassium dihydrogen phosphate, and phenolphthalein indicator. All chemicals used were of analytical reagent grade and prepared using distilled water wherever necessary.

The analytical work was carried out using a UV–Visible spectrophotometer for absorbance measurements. Standard laboratory glassware and instruments such as volumetric flasks, pipettes, conical flasks, burettes, and Whatman filter paper No. 50 were used for solution preparation, filtration, and analytical procedures during phosphate estimation.

Experimental Procedure

For phosphate determination, approximately 1 g of air-dried soil sample was accurately weighed and transferred into a flask containing 200 mL of sulphuric acid solution. The resulting suspension was shaken continuously for 30 minutes to ensure proper extraction of phosphate from the soil sample. The mixture was then filtered through Whatman filter paper to obtain a clear filtrate.

About 25 mL of the filtrate was evaporated to dryness, and the residue obtained was dissolved in perchloric acid for digestion. After digestion, phenolphthalein indicator was added to the solution, and neutralization was carried out by titration using sodium hydroxide solution. Subsequently, ammonium molybdate reagent followed by stannous chloride solution was added, resulting in the formation of a blue-colored phosphomolybdate complex.

The intensity of the developed blue color was measured spectrophotometrically at 690 nm using a UV–Visible spectrophotometer, with distilled water used as the blank solution.

III. OBSERVATION TABLE

Standard Calibration Data

Concentration (mg/L)	Absorbance
0.0	0.000

0.5	0.230
1.0	0.386
1.5	0.580
2.0	0.759
2.5	0.831
3.0	1.172

IV. RESULTS

Phosphate Concentration in Soil Samples

Soil Sample	Absorbance	Phosphate Content
Sugarcane (Pune)	1.169	0.029 mg/L
Sugarcane (Satara)	0.980	0.024 mg/L
Onion (Pune)	0.632	0.015 mg/L
Wheat (Pune)	0.285	0.007 mg/L

V. DISCUSSION

Interpretation of Results

Among the analyzed soil samples, sugarcane soil showed the highest phosphate concentration. This may be attributed to intensive fertilizer application, irrigation with contaminated water, and accumulation of organic matter in agricultural fields. In contrast, wheat soil exhibited the lowest phosphate concentration, which may be due to comparatively lower fertilizer usage, shorter crop cycle, and reduced nutrient accumulation in the soil.

Elevated phosphate concentration in agricultural soils may have serious environmental implications, including alteration of soil nutrient balance, reduction in soil quality, contamination of nearby water bodies, and acceleration of eutrophication processes. Excess phosphate runoff into aquatic systems can promote excessive algal growth and depletion of dissolved oxygen, thereby disturbing ecological balance.

The UV–Visible spectrophotometric method used in the present study demonstrated good analytical performance with high sensitivity, linearity, precision, and reproducibility for phosphate determination. The ammonium molybdate–stannous chloride colorimetric method proved to be accurate and reliable for quantitative phosphate analysis in soil samples.

Conclusion

The present study confirmed that UV–Visible spectrophotometry is an effective technique for phosphate determination in agricultural soil samples. The ammonium molybdate–stannous chloride method showed satisfactory analytical accuracy and sensitivity. Among the analyzed samples, sugarcane farm soils contained comparatively higher phosphate concentrations, mainly due to extensive fertilizer application. Excess phosphate accumulation in soil is closely associated with agricultural activities and may lead to environmental pollution if not properly monitored. Therefore, continuous monitoring of soil phosphate concentration is essential for sustainable agriculture, proper soil fertility management, and environmental protection.

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