

Determination of Phosphate Content in Agricultural Soil by UV–Visible Spectrophotometric Method

Sunita Pati¹, Maryappa Sonawale², Yashwant Gaikwad³, Vitthal Shivankar⁴, Aamod Thakkar⁵

¹ Student, P.G. Department of Chemistry, Veer Wajekar College, Phunde, Uran

^{2,3} Assistant Professor, Department of Chemistry, Veer Wajekar College, Phunde, Uran

⁴ Principal, Raosaheb Ramrao Patil Mahavidyalaya, Savlaj, Tal. Tasgaon, Dist. Sangli, Maharashtra

⁵ I/C Principal, Veer Wajekar College, Phunde, Uran

Abstract: *Phosphorus is an essential macronutrient required for plant growth, metabolic activities, energy transfer, and crop productivity. However, excessive phosphate accumulation in agricultural soils due to uncontrolled fertilizer application, domestic waste disposal, and agricultural runoff may lead to environmental pollution and eutrophication of nearby water bodies. Therefore, quantitative determination of phosphate concentration in soil has become highly important for sustainable agricultural management and environmental monitoring.*

The present study focuses on the determination of phosphate content in agricultural soil samples collected from different crop cultivation areas using the UV–Visible spectrophotometric method. The phosphate estimation was carried out through the formation of phosphomolybdenum blue complex using ammonium molybdate and stannous chloride reagents. The absorbance of the developed blue-colored complex was measured at 690 nm using a UV–Visible spectrophotometer.

A calibration curve was prepared using standard potassium dihydrogen phosphate solutions in the concentration range of 0.5–3.0 mg/L, which exhibited good linearity and accuracy. Different soil samples collected from sugarcane, onion, and wheat farms were analyzed and compared. Among all the samples, the sugarcane farm soil showed the highest phosphate concentration due to extensive use of phosphate fertilizers and irrigation practices, whereas wheat farm soil exhibited comparatively lower phosphate content.

The study demonstrates that the UV–Visible spectrophotometric method is simple, accurate, sensitive, cost-effective, and suitable for routine determination of phosphate levels in agricultural soils. Continuous monitoring of phosphate concentration is necessary to maintain soil fertility, improve agricultural productivity, and reduce environmental pollution.

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

I. INTRODUCTION

1.1 Soil as an Important Natural Resource

Soil is one of the most important natural resources that supports life on Earth by serving as a medium for plant growth and by supplying essential nutrients, minerals, water, gases, and microorganisms necessary for agricultural productivity and ecological balance. Scientifically, soil is defined as the weathered superficial layer of the Earth's crust formed



through physical, chemical, and biological weathering processes over long geological periods. It is a dynamic system composed of mineral matter, organic matter, water, air, and living organisms. The interaction among these components determines soil fertility, nutrient availability, and overall environmental quality.

1.2 Importance of Phosphorus in Soil

Phosphorus is an essential macronutrient required for proper plant growth and development. It plays a significant role in various biochemical and physiological processes including energy transfer reactions, photosynthesis, cell division, root development, flowering, seed formation, DNA and RNA synthesis, and ATP production. In soil, phosphorus mainly exists in the form of phosphate compounds because elemental phosphorus is highly reactive and does not occur freely in nature. Adequate phosphate concentration in soil is therefore essential for maintaining soil fertility and crop productivity.

1.3 Environmental Significance of Phosphate

Although phosphate is vital for plant growth, excessive phosphate concentration in soil and water can cause serious environmental problems. High phosphate levels may result from excessive fertilizer application, agricultural runoff, domestic sewage discharge, industrial effluents, decomposition of organic matter, and contamination from human and animal wastes. Elevated phosphate concentration in water bodies can lead to eutrophication, which results in excessive algal growth, reduction in dissolved oxygen levels, fish mortality, ecological imbalance, and deterioration of water quality. Therefore, regular monitoring of phosphate levels in agricultural soils is important for environmental protection and sustainable agricultural practices.

1.4 Spectrophotometric Determination of Phosphate

Several analytical methods such as gravimetric methods, titrimetric methods, atomic absorption spectroscopy, ion chromatography, colorimetric methods, and UV-Visible spectrophotometry have been developed for phosphate determination. Among these techniques, UV-Visible spectrophotometry is widely preferred due to its simplicity, sensitivity, rapid analysis, cost-effectiveness, and good accuracy. In spectrophotometric analysis, phosphate reacts with ammonium molybdate under acidic conditions to form a phosphomolybdate complex, which is subsequently reduced by stannous chloride to produce a blue-colored complex. The intensity of the blue color is directly proportional to the phosphate concentration present in the sample.

1.5 Aim and Objectives of the Study

The main aim of the present study is to determine the phosphate content in agricultural soil samples using UV-Visible spectrophotometric analysis. The objectives of the study include collection of soil samples from different agricultural fields, preparation of standard phosphate solutions and calibration curves, estimation of phosphate concentration spectrophotometrically, comparison of phosphate levels among different soil samples, and evaluation of the environmental and agricultural significance of phosphate concentration.

II. LITERATURE REVIEW

Several researchers have investigated the importance of phosphorus in soil fertility and environmental chemistry. Weier (1973) reported that soil is a complex environmental system consisting of minerals, organic matter, water, air, and living organisms. Chaube and Gupta (1983) explained that phosphorus is the eleventh most abundant element in the Earth's crust and generally occurs in phosphate form. Murphy and Riley (1962) developed a widely accepted colorimetric method for phosphate estimation based on phosphomolybdate blue complex formation. Sharpley et al. (2001) reported that phosphorus transport through agricultural runoff significantly contributes to eutrophication in aquatic systems. Recent environmental studies emphasize continuous monitoring of phosphate levels in soil and water to maintain environmental sustainability and agricultural productivity.



III. PRINCIPLE OF SPECTROPHOTOMETRIC METHOD

Spectrophotometry is an analytical technique used to measure the amount of light absorbed by a chemical substance. According to Beer–Lambert’s law, the amount of light absorbed is directly proportional to the concentration of the absorbing species present in solution. In phosphate determination, phosphate ions react with ammonium molybdate under acidic conditions to form a phosphomolybdate complex. This complex is then reduced by stannous chloride to produce a blue-colored compound known as molybdenum blue. The absorbance of the developed blue color is measured at 690 nm using a UV–Visible spectrophotometer. The intensity of the blue color is directly proportional to the phosphate concentration present in the soil sample.

IV . MATERIALS AND METHODS

4.1 Soil Samples Collected

Different agricultural soil samples were collected from various locations for phosphate determination. The collected samples included sugarcane farm soil from Pune District, sugarcane farm soil from Satara District, onion farm soil from Pune District, and wheat farm soil from Pune District. These samples were selected to compare phosphate concentration in soils cultivated with different crops and from different agricultural regions.

4.2 Instruments Used

The instruments used in the present study included a UV–Visible spectrophotometer for absorbance measurements, an analytical balance for accurate weighing of chemicals and soil samples, standard laboratory glassware for solution preparation, and filtration apparatus for separation of soil extracts.

4.3 Chemicals Used

The chemicals used for phosphate estimation included sulphuric acid, perchloric acid, sodium hydroxide solution, ammonium molybdate solution, stannous chloride solution, standard potassium dihydrogen phosphate solution, and phenolphthalein indicator. All chemicals used were of analytical reagent grade and prepared using distilled water.

4.4 Preparation of Solutions

The standard phosphate solution was prepared by dissolving 4.388 g of dried potassium hydrogen phosphate in distilled water and diluting the solution to one liter. Further dilutions were made to prepare working standard solutions of different concentrations. Ammonium molybdate solution was prepared by dissolving ammonium molybdate in distilled water followed by mixing with dilute sulphuric acid. Stannous chloride solution was prepared by dissolving 0.5 g of stannous chloride in concentrated hydrochloric acid and diluting the solution with distilled water.

V. EXPERIMENTAL PROCEDURE

About 1 g of air-dried soil sample was transferred into a flask and mixed with 200 mL of sulphuric acid solution. The suspension was shaken continuously for 30 minutes to extract phosphate from the soil sample. The resulting mixture was filtered through Whatman filter paper to obtain a clear filtrate. Approximately 25 mL of the filtrate was evaporated to dryness, and the residue obtained was dissolved in perchloric acid. Distilled water and phenolphthalein indicator were then added to the solution, followed by titration against sodium hydroxide solution. After neutralization, ammonium molybdate solution and stannous chloride solution were added, resulting in the development of a blue-colored complex. The absorbance of the developed blue color was measured at 690 nm using a UV–Visible spectrophotometer for phosphate determination.



VI.. CALIBRATION CURVE AND STANDARD DATA

Standard Phosphate Solution Data

Concentration (mg/L)	Absorbance
0.00	0.000
0.50	0.230
1.00	0.386
1.50	0.580
2.00	0.759
2.50	0.831
3.00	1.172

The calibration curve showed good linearity between concentration and absorbance.

VII. OBSERVATIONS AND RESULTS

Absorbance of Soil Samples

Sample	Absorbance
Sugarcane Farm (Pune)	1.169
Sugarcane Farm (Satara)	0.980
Onion Farm (Pune)	0.632
Wheat Farm (Pune)	0.285

Phosphate Concentration Calculation

The phosphate concentration was calculated using:

$$PO_4\text{-P (mg/L)} = Ps \times V / 1000 \times W$$

Where:

- Ps = phosphate estimated in suspension
- V = total volume of suspension
- W = weight of soil sample

Final Phosphate Concentration

Sample	Phosphate Concentration
Sugarcane Farm (Pune)	0.029 mg/L
Sugarcane Farm (Satara)	0.024 mg/L
Onion Farm (Pune)	0.015 mg/L
Wheat Farm (Pune)	0.007 mg/L

VIII. DISCUSSION

The results clearly indicate variation in phosphate concentration among different agricultural soil samples.

The sugarcane farm soil from Pune exhibited the highest phosphate concentration. This may be attributed to:

- Heavy use of phosphate fertilizers
- Intensive agricultural practices
- Irrigation using underground water
- Accumulation of agricultural runoff

The wheat farm soil showed the lowest phosphate concentration because wheat cultivation generally requires comparatively lower fertilizer input.



The phosphate concentration in onion farm soil was moderate due to balanced fertilizer application and mixed irrigation sources.

The findings indicate that agricultural activities significantly influence phosphate levels in soil.

Excessive phosphate accumulation may:

- Alter soil chemistry
- Affect microbial activity
- Increase risk of eutrophication
- Reduce environmental sustainability

Hence, continuous monitoring and controlled fertilizer usage are necessary.

IX. ADVANTAGES OF SPECTROPHOTOMETRIC METHOD

The UV–Visible spectrophotometric method offers several advantages:

- Simple and easy operation
- Rapid analysis
- High sensitivity
- Good precision and accuracy
- Low cost
- Suitable for routine analysis
- Minimal instrumentation requirements

Therefore, it is highly suitable for phosphate estimation in agricultural laboratories.

X. ENVIRONMENTAL SIGNIFICANCE

Phosphorus management is important not only for crop production but also for environmental protection.

Excess phosphate may enter nearby rivers, lakes, and reservoirs through runoff and cause eutrophication.

Environmental consequences include:

- Algal bloom formation
- Oxygen depletion
- Fish mortality
- Water pollution
- Ecological imbalance

Proper fertilizer management practices should therefore be adopted.

XI. CONCLUSION

The present study successfully demonstrated the determination of phosphate content in agricultural soil samples using the UV–Visible spectrophotometric method.

The developed method proved to be simple, sensitive, reliable, accurate, and cost-effective for phosphate estimation.

Among the analyzed samples, sugarcane farm soil exhibited the highest phosphate concentration due to excessive fertilizer usage and irrigation practices, whereas wheat farm soil contained comparatively lower phosphate concentration.



The study confirms that agricultural activities strongly influence soil phosphate levels and emphasizes the importance of continuous monitoring for maintaining soil quality and preventing environmental pollution.

The spectrophotometric method can therefore be effectively employed for routine phosphate analysis in soil and environmental laboratories.

XII. FUTURE SCOPE

Future research may focus on:

1. Seasonal variation in soil phosphate levels.
2. Comparative analysis using advanced analytical techniques.
3. Correlation between fertilizer usage and phosphate accumulation.
4. Monitoring of phosphate transport through agricultural runoff.
5. Development of rapid field-based phosphate sensors.
6. Environmental impact assessment of phosphate pollution.

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