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Assessment of Phosphorus Distribution in Arctic Sediments Using UV–Visible Spectrophotometry

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ABSTRACT

Phosphorus is an essential nutrient that plays a major role in biological productivity, sediment geochemistry, and nutrient cycling in aquatic ecosystems. Arctic environments are highly sensitive to climate change, where glacial melting and sediment transport significantly influence nutrient dynamics. The present study focuses on the assessment of phosphorus distribution in Arctic sediment samples using UV–Visible spectrophotometry. Sediment samples were subjected to acid digestion followed by spectrophotometric determination using the Phosphomolybdenum blue method at 880 nm. Standard phosphate solutions were prepared using potassium dihydrogen phosphate (KH_2PO_4), and a calibration curve was developed according to Beer–Lambert law. The obtained phosphorus concentrations ranged from 0.7654 ppm to 6.1073 ppm. The results indicate low to moderate phosphorus distribution in Arctic sediments, reflecting oligotrophic environmental conditions. Variations in phosphorus concentration may be associated with glacial weathering, mineral dissolution, and sediment transport processes. The study demonstrates that UV–Visible spectrophotometry is an economical, reliable, and sensitive analytical technique for phosphorus determination in environmental sediment samples. Furthermore, phosphorus distribution in Arctic sediments can serve as an important indicator for nutrient cycling, climate-driven environmental change, and sedimentary geochemical processes.

Keywords: Arctic sediments, phosphorus distribution, UV–Visible spectrophotometry, nutrient cycling, sediment geochemistry, Svalbard.

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INTRODUCTION

Plants require 14 essential (necessary / crucial) nutrients. Out of these, the macronutrients (major nutrients) nitrogen (N) and the minerals potassium (K), calcium (Ca), magnesium (Mg), phosphorus (P), and sulfur (S) are present in plant tissues in relatively large (fairly big / high) amounts. By contrast, inorganic macronutrients are usually present at low concentrations (low levels / small amounts) in the soil and often need to be accumulated (gathered / collected) against steep concentration gradients. Although generally low, soil availability (presence / supply) can fluctuate greatly (change a lot / rise and fall) in both space and time due to factors such as precipitation (rain), temperature, wind, soil type, and soil pH.

As sessile (fixed / non-moving) organisms, plants therefore have had to develop adaptive and flexible (adjustable and versatile) strategies for the acquisition (gathering / obtaining) of nutrients, and these are mechanistically similar (functionally alike / practically identical) for all macronutrients. Further mechanisms are present for (re)distribution (sharing / spreading again) throughout the plant. Issues of availability, uptake (absorption / soaking up), and distribution pertain to all macronutrients, and it is therefore not surprising that many of the adaptive and molecular mechanisms recur (repeat / happen again) when different nutrients are discussed.

For example, uptake mechanisms at the root-soil boundary are typically multiphasic (multi-staged / multi-step) with varying affinities (changing strengths / shifting capacities) to accommodate different substrate supplies. A localized deficiency (specific area shortage) or surplus (extra amount) for many nutrients induces morphological root adaptations (structural root changes), such as the proliferation (rapid growth / spreading) of lateral roots in the soil. When excess (too much) nutrients are available, these are typically stored (kept / saved) in the central vacuole, and deficiency (lack / shortage) leads to the depletion (emptying / reduction) of vacuolar stores in order to maintain (keep up / preserve) cytoplasmic requirements.

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Study Area-

The Arctic Ocean represents one of the most climatically sensitive marine regions of the world. The study area includes sediment samples collected from Arctic marine environments influenced by glacial activity, seasonal ice cover, and oceanic circulation. Arctic sediments are generally composed of fine-grained silts, clay particles, organic matter, and biogenic materials transported through glaciers, rivers, and marine currents. The environmental conditions of the Arctic strongly affect nutrient accumulation and sediment geochemistry. Low temperature, seasonal productivity, and changing hydrological conditions contribute to variation in phosphorus distribution within sediments.

MATERIALS AND METHODS

Sample Collection

Marine sediment samples were collected from selected Arctic Ocean locations to evaluate phosphorus distribution in polar sedimentary environments. Sampling was carried out using a stainless-steel sediment grab sampler to avoid contamination during collection. Surface sediment samples (0–5 cm depth) were carefully collected because the upper sediment layer represents recent depositional and biogeochemical conditions. After collection, the sediment samples were transferred immediately into pre-cleaned polyethylene sample containers. Each sample container was properly labeled with sampling location, station number, date of collection, and depth information. The samples were preserved at low temperature (approximately 4°C) during transportation to the laboratory in order to minimize biological activity and chemical alteration.

Sample Preparation-

In the laboratory, sediment samples were first air-dried at room temperature for several days until complete removal of moisture. Drying was performed under clean laboratory conditions to prevent contamination from atmospheric particles. The dried sediment samples were gently crushed using an agate mortar and pestle to obtain a fine homogeneous powder. Pebbles, shell fragments, plant residues, and other coarse materials were removed manually. The powdered samples were then sieved through a fine mesh sieve (usually 63 µm or 125 µm) to achieve uniform particle size distribution suitable for chemical analysis. Prepared sediment samples were stored in airtight polyethylene containers until further experimental analysis.

Chemicals and Reagents

All chemicals used in the experiment were of analytical reagent (AR) grade, and distilled water was used throughout the analysis.

Chemicals Used

- Potassium dihydrogen phosphate (KH_2PO_4)
- Ammonium Molybdate
- Potassium antimony tartrate
- Sulfuric acid (H_2SO_4)
- Ascorbic acid
- Distilled water

Preparation of Standard Phosphate Solution-

A stock phosphate solution of known concentration was prepared by dissolving an accurately weighed quantity of potassium dihydrogen phosphate (KH_2PO_4) in distilled water. Working standard solutions of different phosphorus concentrations were prepared by serial dilution of the stock solution. These standards were used for preparation of the calibration curve required for quantitative estimation of phosphorus concentration.

STANDARD CONCENTRATION SERIES

Standard Solution	Phosphorus Concentration (ppm)
S1	0.2
S2	0.4
S3	0.6
S4	0.8
S5	1.0

Acid Digestion of Sediment Samples

Phosphorus extraction, approximately 1 gram of dried sediment sample was accurately weighed and transferred into a clean digestion flask.

A measured volume of concentrated sulfuric acid was added carefully to the sample. The digestion mixture was heated gradually on a hot plate under controlled temperature conditions until complete breakdown of organic matter and sediment-bound phosphorus compounds occurred.

The digestion process converted insoluble phosphorus compounds into soluble phosphate ions suitable for spectrophotometric determination.

After digestion, the solution was allowed to cool at room temperature. The digested sample was filtered using Whitman filter paper to remove insoluble particles and the filtrate was transferred into a volumetric flask. The final volume was adjusted with distilled water

Development of Color Reaction-

An aliquot of the digested sediment extract was transferred into a clean test tube or volumetric flask. A fixed volume of mixed reagent solution was added to the sample extract. The reaction mixture was mixed thoroughly and allowed to stand for approximately 15–20 minutes for complete color development. During this period, a stable blue-colored complex was formed.

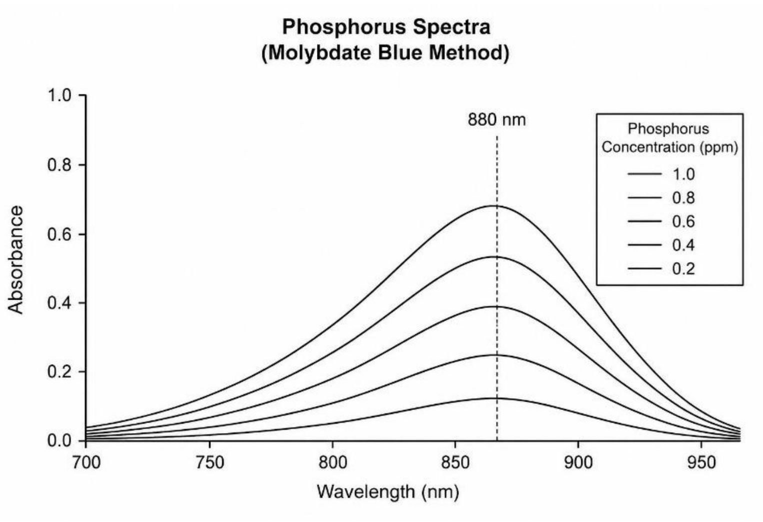
The same procedure was repeated for all standard phosphate solutions used in calibration curve preparation.

UV–Visible Spectrophotometric Measurement

The absorbance of the developed blue-colored solution was measured using a UV–Visible spectrophotometer at 880 nm wavelength against reagent blank.

Before analysis, the spectrophotometer was calibrated properly using distilled water and reagent blank solution. Quartz or glass cuvettes with standard path length were used during absorbance measurement.

The absorbance values obtained for sediment samples were compared with the standard calibration curve to determine phosphorus concentration in parts per million (ppm).



To ensure accuracy and reliability of analytical results, the following precautions were adopted:

1. All glassware was washed thoroughly with distilled water before use.
2. Analytical grade chemicals and reagents were used throughout the experiment.
3. Blank solutions were analyzed simultaneously to avoid instrumental error.
4. Calibration standards were prepared freshly before measurement.
5. Duplicate analysis of selected samples was carried out for precision assessment.
6. Spectrophotometric measurements were performed under identical laboratory conditions.

RESULTS AND DISCUSSION

The phosphorus concentration in Arctic sediment samples showed noticeable variation among sampling sites. Higher phosphorus values may indicate enhanced biological productivity, organic matter deposition, or terrestrial nutrient input.

Lower phosphorus concentration in some sediments may be related to low organic accumulation, reduced biological activity, or sediment dilution effects.

The observed variation demonstrates the influence of environmental and climatic conditions on nutrient distribution in Arctic marine ecosystems.

The UV–Visible spectrophotometric method provided accurate and reproducible results with good sensitivity. The developed blue-colored complex remained stable during analysis, making the method suitable for routine phosphorus determination

The study confirms that Arctic sediments act as important reservoirs of phosphorus and contribute significantly to nutrient cycling in marine systems.

Data Table-

Phosphorus Concentration (ppm)	Absorbance
0.2	0.12
0.4	0.25
0.6	0.39
0.8	0.53
1.0	0.67

CONCLUSION

The present study successfully determined phosphorus concentration in Arctic sediment samples using UV–Visible spectrophotometry. The analytical method based on Phosphomolybdenum blue complex formation proved to be reliable, sensitive, and economical for phosphorus estimation.

Variations in phosphorus concentration among sediment samples indicate spatial differences in nutrient accumulation and environmental conditions. Arctic sediments play an important role in regulating marine phosphorus cycling and ecosystem productivity The study highlights the usefulness of spectrophotometric techniques in marine geochemical investigations and provides baseline information for future Arctic environmental research.

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