

MICROBIOLOGICAL ASPECTS OF PHOSPHATE SOLUBILIZATION

Mervyn W. Thenabadu

Introduction

The chemical state of elements on the outer surface of the earth is to a great extent the consequence of activities of living organisms. Profound changes have occurred in the earth's atmosphere since life began. Various steps in the cyclic turnover of some elements are brought about by various organisms. The combined existence of any particular group of organisms in the biosphere depends on chemical transformations brought about by others; and the break in the cycle at any point would preclude all life. All the major elements essential for life, like C, N, S and P are transformed in a cyclic manner. The relatively enormous catalytic power of micro-organisms contributes to the major role they play in the chemical transformation on the earth's surface.

The phosphorus cycle

Phosphorus is not an abundant component of the ecosphere. Its availability is further restricted by its tendency to precipitate in the presence of cations like calcium, magnesium and ferric iron in neutral to alkaline pH range. There are reservoirs of this element in marine and other aquatic sediments where it is cycled substantially, though slowly. The actively cycled reservoirs of phosphorus are the dissolved phosphate in soils and water, and that in living and dead organic matter. Phosphate rock like apatite is a largely inert reservoir.

Much of the earth's supply of phosphate occurs as insoluble compounds of Ca, Fe and Al. Therefore, the availability of phosphate for terrestrial forms of life depends on the continued solubilization of insoluble phosphates; a process in which micro organisms play an important role. While their acidic metabolic products (organic, nitric and sulfuric) solubilize the phosphates of calcium, their production of H_2S dissolves ferric phosphates.

From a chemical point of view the phosphorus cycle is a simple cycle, because in living organisms this element occurs in the +5 valence state, whether as free PO_4^{3-} ions or as organic phosphorus constituents of the cells.

Most organic phosphate compounds cannot be absorbed into living cells. Phosphorus requirements are therefore met by the uptake of the phosphate ions. Much of the earth's supply of the element exists as insoluble salts of C, Fe or Al. Fresh water contains only trace amounts. It becomes available to animals only after it is concentrated by the phytoplankton. Thus phosphorus could be a limiting factor for the growth of many organisms inspite of the rapid functioning of the phosphorus cycle, and the relative abundance of phosphates in soils and rocks.

The availability of phosphates for the terrestrial forms of life depends on the continued solubilization of insoluble phosphates, a process in which micro-organisms play a key role. Acidic metabolic products (organic, nitric and sulfuric acids) solubilize the phosphate of insoluble phosphates like $C_3(PO_4)_2$ and H_2S produced by micro-organism, dissolves ferric phosphates.

Solubilization of inorganic phosphorus by micro-organisms

Insoluble inorganic phosphates like apatite are unavailable to plants. However, several micro-organisms are capable of solubilizing these rocks have been reported. The majority of these are bacteria and fungi which, when grown on media with insoluble phosphate like apatite as the sole supply of phosphorus they assimilate the element while also making a large proportion of it soluble. Large amounts of the element which would be in excess of their own nutritional demands are released.

Organic acids and inorganic acids like sulfuric acid and nitric acid produced, are responsible for this solubilization. Chemoautotrophic organism oxidize ammonium and sulphur to produce nitric and sulphur acids.

These acids (organic and inorganic) convert $Ca_3(PO_4)_2$ to the di- and monobasic phosphates. The net result is an enhanced availability of phosphorus to the plants. The amounts of the element solubilized by heterotrophic organisms will depend on the carbohydrate oxidized and transformation will occur

only if the carbonaceous is converted to organic acids.

Phosphorus occupies a critical position in crop production as well as in the biology of soil.

The phosphorus transformation brought about by micro-organisms are:

1. Altering the solubility of inorganic components of phosphorus.
2. Mineralization of organic compounds and the subsequent release of orthophosphate.
3. Immobilization of soluble anionic P i.e. incorporation of the element into cell protoplasm analogous to that of nitrogen.
4. Oxidation or reduction of inorganic phosphorus compounds.

Mineralization and immobilization of phosphorus by micro-organisms is particularly important in the phosphorus cycle. The availability of the element is governed by the continual interplay of these two processes.

Insoluble phosphates can be solubilized by microbial reactions without an intermediate step of acid formation. Thus, compounds like ferric or aluminium phosphates can liberate their phosphate under appropriate/suitable conditions.

Bacteria that produce hydrogen sulphide are capable of this phenomenon, because the latter reactions with ferric phosphate to yield ferrous sulphide; and liberate the phosphate. Phosphate from the ferric and aluminium compounds are also released under anaerobic conditions.

The microbial cycling of P for the most part does not alter the oxidation state of the phosphorus transformation. Most mediated by micro-organisms could be viewed as a one of transformation inorganic to organic phosphate, or as a transfer of phosphate from an insoluble, immobilized form to a soluble or mobile compound.

Although PO_4 is not normally reduced by micro-organisms, it appears that some micro-organisms are capable of utilizing phosphate as a terminal electron acceptor, under appropriate environmental conditions. It would only serve as a terminal electron acceptor in

the absence of oxygen, or ions like sulphate and nitrate. The product of this reduction is invariably phosphine(PH_3), can also ignite giving rise to the "Ghostly" light phenomena, seen in marshes in the night.

The omnipresence of micro-organism through out the biosphere is a consequence of their ready dissemination by wind and water. They exist in surface water, on ocean floors over continental shelves and in the top few inches of soil. The top 6 inches of fertile soil could contain approximately 2 tons of fungi and bacteria per acre.

The principle of microbial infallibility was postulated by Gale in 1952. The turnover of the elements, that compose living organisms, constitute the cycles of matter. Since, all organisms participate in various steps of these cyclic conversions, the contribution of micro-organisms is particularly important, both quantitatively and qualitatively.

The large number of phosphate dissolving micro-organisms in soil are especially abundant in the root zone, or the rhizosphere. They enhance phosphate assimilation by higher plants due to their biochemical activities.

Mycorrhizae and phosphorus availability

Recently there has been considerable interest in the possible increase in availability of organic phosphorus to plants due to infection of their roots by mycorrhizae. It has been postulated that the greater uptake of this element in phosphorus deficient soils by plant is association with ectomycorrhizae and endomycorrhizae. Increased uptake may be due to the increased phosphate activity of the mycorrhizae plants in addition to the increase in root surface and increased volume of soil explored by radiating hyphae.

There is an inverse relationship between soil P supply and the development of mycorrhizala. Increasing phosphorus supply decreases the percentage of root length converted to mycorrhizals.

It has been shown that the VA mycorrhizae could increase the yield of plants growing in phosphorus deficient soil by increasing the uptake of phosphorus from sources of low solubility inoculation of soil with fungi; could be of considerable economic importance, particularly when dealing with soils having high soil

phosphorus fixation capacities or soils which have been fumigated. Inoculation with VAM's might increase the effectiveness of low-cost rock powder fertilizers.

The concentration of phosphate in the soil solution may not be uniform through out the soil. Roots of some crop plants, and perhaps some rhizosphere bacteria probably secrete acids into the soil solution

which are capable of increasing the solubility of phosphates in the solid phase in their immediate neighborhood. This could affect some forms of phosphate more than others.

Phosphate ion concentration in the vicinity of decomposable organic matter, is likely to be higher than in the rest of the soil. It will also be higher, if the decomposition is rapid.