

# ON ASSIMILATION AND REGENERATION OF PHOSPHORUS IN TWO DIFFERENT ENVIRONMENTS

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## ABSTRACT

Samples of water collected from marine and estuarine environments were inoculated with phytoplankton organisms. The rates of regeneration of phosphorus were measured under laboratory conditions from phytoplankton decomposing in the dark. The observations were carried out for a period of five months and the changes were recorded between 15th and 60th day after darkening the system. Maximum recorded rate of regeneration was  $0.094 \mu\text{g-at PO}_4\text{-P/l/d}^1$ . The marine sample was found to be more efficient than the estuarine sample in their phosphorus regeneration capacity. Mineralization was almost complete after 100 days indicating that it may cease after that period as it is dependant on the components of plankton which almost get exhausted within that time. After 150 days, about 70% of the phosphorus was observed in dissolved inorganic state.

## INTRODUCTION

Nutrients are known to limit or enhance organic production in almost all types of aquatic environments (Redfield *et. al*, 1963). The exchange of nutrients between sea water and algae is a cyclic process divided into two phases (1) assimilation and (2) regeneration. Assimilation implies the process during which elements are withdrawn from the water as a result of photosynthesis of algae and regeneration means replacement of these elements in the sea water due to decomposition of organic matter.

Phosphorus occurs in all living organisms in the form of organic compounds. As a result of decay and decomposition it is liberated into the water as dissolved substances, which on

oxidation presumably by bacterial action, is released as phosphate in ionic form (Redfield *et. al*, 1963). In the process of regeneration, particulate phosphorus from the algal cells and detritus (including animal matter) is oxidised into inorganic phosphate. The intermediate stage during the process is dissolved organic phosphorus.

Measurements on the rate of regeneration of phosphorus and nitrogen were made earlier (Cooper, 1935; von Brand and Rakestraw, 1937; Grill and Richards, 1964). Reddy and Sankaranarayanan (1972) reported on the regeneration of phosphate from estuarine sediments, and recently, Rajendran and Venugopalan (1974) on the role of microbial flora in the regeneration of

nutrients. Cooper (1935) observed in the laboratory that about half of the total organic matter of the decomposing plankton appears in a soluble form on the first day. The present work is a laboratory experiment on assimilation and regeneration of phosphorus by the phytoplankton organisms in marine and estuarine environments.

#### METHODS

About 100 litres of water collected from marine ( $S=33.48\%$ ) and estuarine ( $S=26.21\%$ ) regions around Cochin were kept separately in glass tanks after passing it through a No. 20 (Ca 0.08 mm aperture) bolting nylon so as to remove zooplankton animals and larger particles. Plankton samples were also collected from these stations simultaneously in duplicate by towing a No. 25 plankton net (Ca 0.065 mm aperture). A part of each sample was transferred to the respective tank, and the rest was kept for qualitative analysis. The chlorophyll *a* concentration determined by the method given by UNESCO (1966) was taken as a measure of phytoplankton biomass in the environments. From the towed samples, plankton cells were identified and counted. After inoculation, the samples were kept in sunlight for a period of forty days and the nutrient concentrations were estimated on the 1st, 15th and 40th day. After 40 days of incubation, samples were kept in the dark and from this subsamples were drawn every morning between 9 and 9.30 a. m., for a period of ten days and then on alternate days upto the 20th day. Thereafter, the routine was changed to 5-day intervals upto the 50th day and then every tenth day till the 150th day. Analysis on the samples

included dissolved inorganic phosphate (DIP), total phosphorus (TP) and total dissolved phosphorus (TDP), following the methods described by Strickland and Parsons (1968). The concentration of particulate phosphorus (PP) was calculated by the difference between TP and TDP while dissolved organic phosphorus (DOP) was calculated from TDP and DIP by difference.

#### RESULTS

The following major organisms were recorded in the samples. Diatoms: *Skeletonema* sp., *Coscinodiscus* sp., *Planktoniella* sp., *Ditylum* sp., *Tricentrum* sp., *Pleurosigma* sp., *Fragillaria* sp., *Biddulphia* sp., *Navicula* sp., *Asterionella* sp., *Bacillaria* sp., and *Lauderia* sp.

*Cyanophyceae*: *Oscillatoria* sp. and *Trichodesmium* sp. were found in the marine samples.

*Dinoflagellates*: *Peridinium* sp., *Ceratium* sp. and *Diplopsalis* sp. were abundant in the estuarine samples. Filamentous algae such as *Spirogyra* sp. (*Chlorophyceae*), *Nitzschia* sp. and *Bacteriastrum* sp. (*Bacillariophyceae*) were also abundant in both the samples. Marine environment showed an abundance of only limited groups against the estuarine samples having a larger number of these groups.

The chlorophyll *a* content of the marine sample was 5.77 mg/m<sup>3</sup> and that of estuarine sample 4.89 mg/m<sup>3</sup>. The DIP concentrations at the time of collection were 4.67 and 2.88 µg-at PO<sub>4</sub>-P/l respectively, in marine and estuarine samples. After the inoculation of plankton, while in sunlight, the DIP

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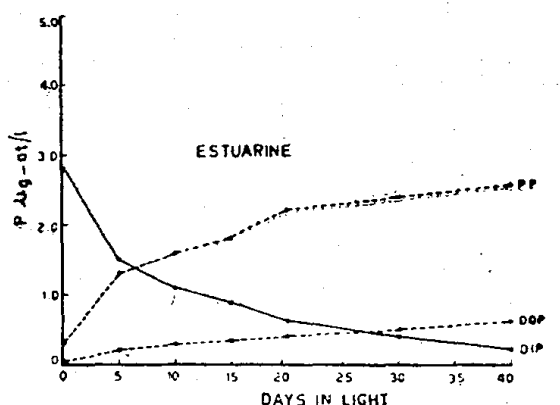
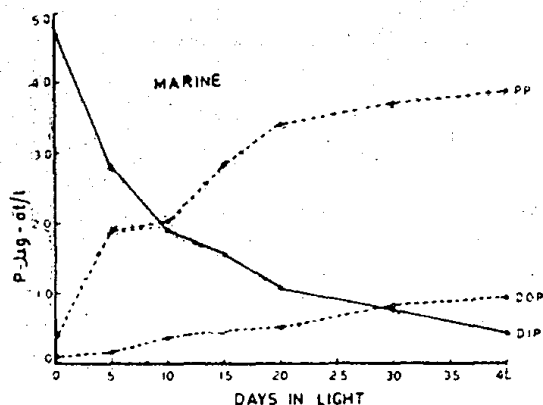


Fig. 1 & 2 Changes in the concentration of the different fractions of phosphorus during 40 days in sun light.

concentration dropped in both the samples and after 15 days it was 1.62 and 0.92  $\mu\text{g-at/l}$  respectively, and on the 40th day it was 0.47 and 0.26  $\mu\text{g-at/l}$  (Figs. 1 & 2). The DOP and PP concentrations on these days were 0.91, 0.61 and 3.80, 2.54  $\mu\text{g-at/l}$ , respectively.

The tank was kept in the dark by covering it with a thick black cloth on 15th November, 1973 and during the first 5 days the DIP concentration showed a gradual decrease while the DOP showed a slight increase (Figs. 3 & 4). The PP remained almost unchanged (with slight increase till the 5th day). From the 6th day onwards the trend changed and a marked increase in the concentration of DIP was observed. The rate of transformation was well marked in the marine samples on these days and on an average the rate of regeneration between the 5th and the 10th day in the marine sample was  $0.094 \mu\text{g at PO}_4\text{-P/l/d}^{-1}$  while in the estuarine sample between 13th and 25th day it was  $0.09 \mu\text{g-at PO}_4\text{-P/l/d}^{-1}$  (Figs. 5

& 6). In both the samples, the mineralization was noticeable between 15th and 60th day with a peak on the 20th day. After 100 days the rate of transformation was very slow and uniform. After 150 days in the marine sample, 72% of the phosphorus was in DIP form, 20% as PP form and the rest as DOP. In the estuarine sample the percentage of these components were 67%, 24% and 9% respectively (Table I).

#### DISCUSSION

In sunlight a rapid decrease in the concentration of DIP in the system occurred because of assimilation. However, regeneration was also going on simultaneously and the former process seems to dominate the latter. The results are in conformity with the earlier observation of Pratt (1950) in fertilized sea water. The decrease in the concentration of DIP and a slight increase of DOP during the first 5 days in the dark clearly indicate that the process of assimilation dominates over regeneration. This possibly suggest that some of the planktonic groups are cap-

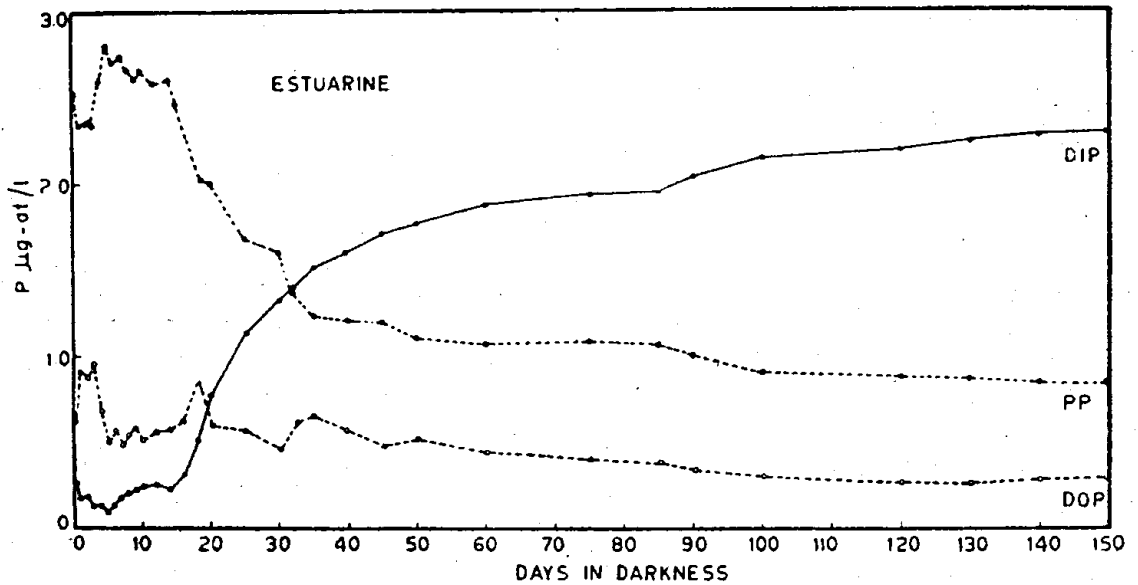
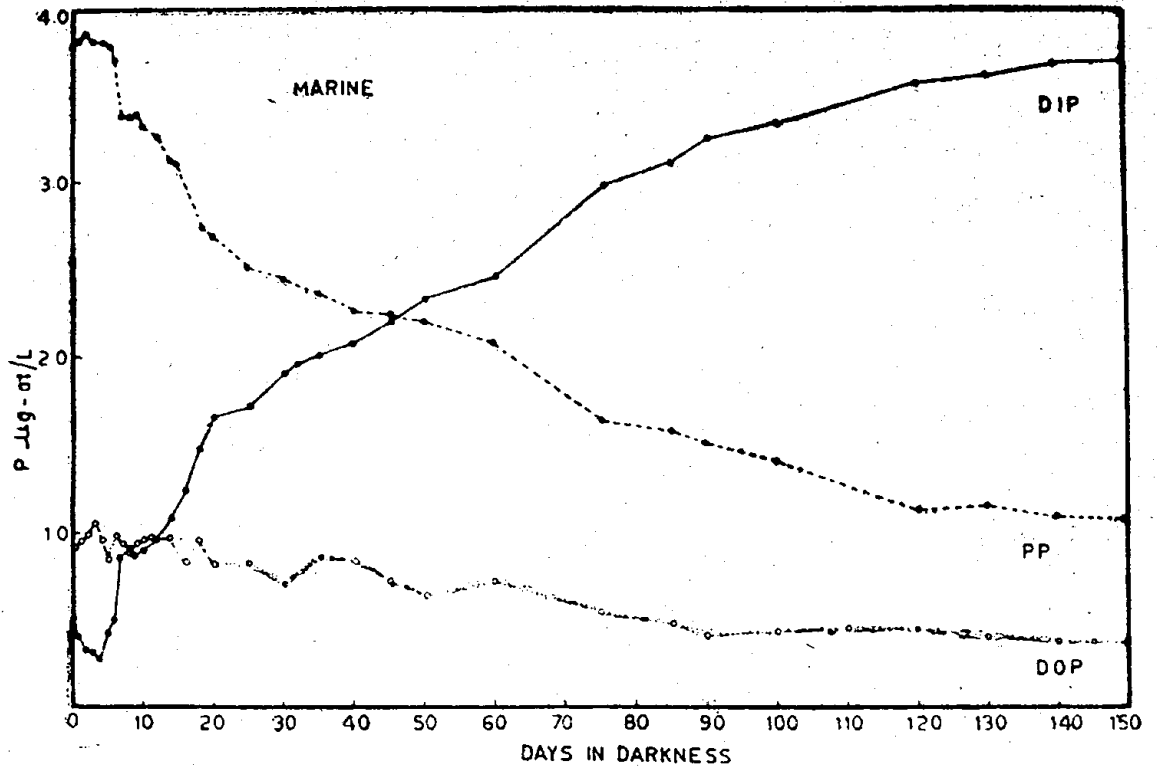


Fig. 3 & 4 Changes in the concentrations of the different fractions of phosphorus 150 days in darkness.

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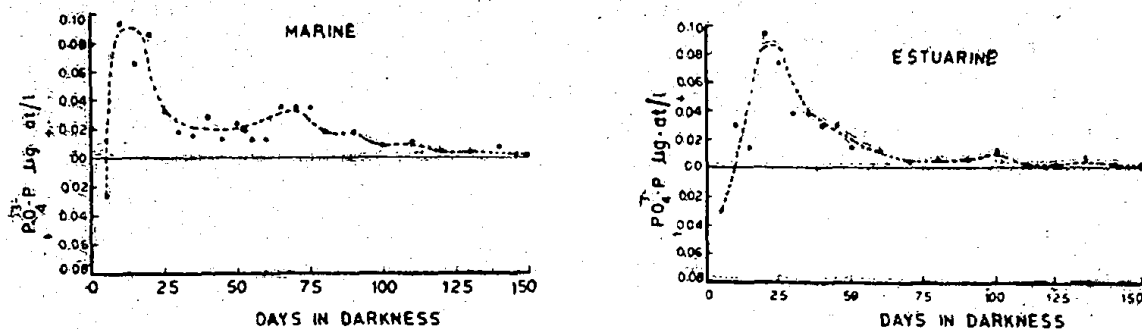


Fig. 5 & 6 Rate of assimilation and regeneration of phosphorus in darkness.

able of assimilating inorganic nutrients even in complete darkness. Ketchum (1939) reported phosphate assimilation in the dark by *Phaeodactylum tricor- nutum* in relation to phosphate deficiency

and nitrate concentration. Hays and Phillips (1958) found that bacteria in freshwater cultures convert the added radiophosphate rapidly into dissolved organic compounds. Thus the decrease

TABLE I  
Percentage of the three fractions of phosphorus in darkness

Days	Marine			Estuarine		
	DIP	DOP	PP	DIP	DOP	PP
1	9	18	73	8	18	74
5	8	16	76	3	15	82
10	18	18	64	6	16	78
15	24	16	60	9	19	72
20	32	16	52	23	18	59
25	35	16	49	34	17	49
30	37	15	48	39	13	48
35	38	17	45	45	19	36
45	43	14	43	50	14	36
50	45	13	42	52	15	33
60	48	12	40	56	12	32
75	58	10	32	58	10	32
90	63	8	29	60	10	30
100	64	8	28	64	9	27
120	68	9	23	65	8	27
130	69	8	23	66	8	26
140	71	8	21	66	9	25
150	72	8	20	67	9	24

in DIP and a simultaneous increase in DOP may largely be due to the action of the microbial flora as the PP remains almost unchanged in both the samples. A significant increase in the concentration of DIP from the 6th day onwards indicates the autolytic decomposition of planktonic population following a critical nutrient minimum. Such an autolytic release of DIP and DOP was observed by Hoffman (1956) from dead diatoms. Goldberg *et. al* (1951) observed that much of the phosphate accumulated by diatoms during the exponential growth was only loosely bound and could easily be washed from the cells, and following nutrient exhaustion, the excess cellular phosphorus was leached into the solution.

The rate of regeneration was well marked from 7th to 75th day, which agrees with the observation of Cooper (1935) who reported the maximum phosphate regenerative activity from the 55th day onwards. Thus a greater portion of the nutrients, if not the major ones, was remineralized in both the samples during these periods. The fluctuations observed after the first maximum may be due to the autolytic decomposition of some of the diatoms which seems slightly stable because of siliceous covering. The percentage of nutrients after 150 days in the system compares well with the general nature of phosphorus fractions in the surface waters of the ocean where normally about two-thirds of the total phosphorus content appears in inorganic form while the rest is organic.

As far as the efficiency of mineralization is concerned, the marine sample,

which initially contained a higher concentration of DIP and chlorophyll, was slightly more efficient than the estuarine sample. The values observed here agree with those of Bruce and Hood (1959), who found that approximately 60% of the phosphorus from dead diatoms were converted into inorganic phosphate by autolytic process. Pratt (1950) observed the rate of phosphorus regeneration in fertilized sea water to be about  $0.13 \mu\text{g-at PO}_4\text{-P/l/d}^{-1}$ . As compared to this rate, in the present experiment the process was relatively slow even though the trend was almost similar. The difference thus observed might have been either caused by the composition of plankton or by the initial phosphorus content of the medium (Ryther and Guillard, 1959).

The changes recorded in the experimental tanks may represent the period that may be required for a complete regeneration of phosphorus in marine and estuarine environments, where, in the euphotic zone, the phytoplankton assimilate phosphorus and through various trophic levels it is distributed to all depths as a result of death and decay and by up and down movements of the detrital particles, the fixed phosphorus is released to the medium by autolysis as inorganic phosphate which again comes up to the surface layers by mixing processes.

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