The spatial and temporal distribution of nitrogen and phosphorus in mangrove fringed creek waters and sediments were investigated with a view to determine the variability of phosphorus speciation in water column as well as in sediments. General hydrographic features and sediment characteristics were also investigated to ascertain the influence of these factors on phosphorus speciation. Monthly observations were made during the period December 1999 to December 2000. Three mangrove-fringed creeks around Cochin estuary were selected according to plant density. Station 1 was located near the terminus of a 5-7 feet wide canal. It is about 1km distant from adjoining estuarine water body. Station 2, represented a carefully preserved mangrove habitat inside the premises of Kerala Agricultural University campus. Station 3, Aroor is located on the southern part of Cochin estuary while Station 1 and Station 2 were located in an island in Cochin estuary.

Surface water and sediment cores to a depth of 20cm were collected at monthly intervals. Without much of compaction sediment cores were taken out from the corer and fractionated into five layers at depths 2cm, 4cm, 6cm, 10cm and 20cm. General hydrographic features were noted. Surface and core sediments were analysed for basic sediment characteristics as well as for total elemental concentrations of carbon, nitrogen and phosphorus. Phosphorus fractionations were carried out by sequential extraction with chelating compounds.

The annual mean values of salinity, recorded a minimum of $11.28 \times 10^{-3}$ at Station 3 and maximum of $18.41 \times 10^{-3}$ at Station 2. Station R recorded a mean salinity
value of $11.26 \times 10^{-3}$. High salinity values at Station 1 and Station 2 indicated that no real flushing took place at two Stations according to the tidal dynamics of the estuary. On the other hand Station 3 exhibited salinities that were similar to Station R. Remarkably higher salinities at Station 1 and Station 2 during pre-monsoon might be due to isolation of the head of the creek from near shores. The isolation resulted in low fresh water discharge, in turn a maximum salinity regime found at the head of the creek. Low pH values were recorded at Station 3, while all other stations recorded alkaline pH values. During pre-monsoon season Station 1 also exhibited a low pH, probably due to microbial activity in surface waters. Water temperatures were found to vary within normally expected ranges at all the stations. The lowest annual mean value of 29.1°C recorded at Station 1, 29.5°C at Station 2, and 30.2°C at Station 3. A clear seasonal variation was found at all three stations. As expected, the maximum temperature was recorded during pre-monsoon at all stations. Suspended sediments associated with river influx and plant litter may contribute to the large amount of TSS at the creek waters under study area. The maximum concentrations of TSS varied between 150.13mgL$^{-1}$ and 360.80mgL$^{-1}$ at the three mangrove-fringed creek waters as against the 88.41mgL$^{-1}$, the maximum TSS concentration exhibited at Station R. The annual mean POC concentrations at three mangrove-fringed Stations were found to be 7.19mgL$^{-1}$, 6.85mgL$^{-1}$, and 5.06mgL$^{-1}$ respectively. At Station R an annual mean value of 4.19mgL$^{-1}$ was recorded. Bacterial density, phytoplankton productivity as well as the presence of fine sediment in particulate matter resulted in an elevated concentration of POC in mangrove creek waters.

Uptake by trees and microorganisms and by sorption on to the sediment matrix considerably reduces nitrate concentrations in mangrove forests, which in turn make it an effective sink for nutrients. Significantly higher concentrations of nitrate-N were recorded at Station R than the mangrove fringed creek waters. A general trend of nitrite nitrogen distribution showed minimum values during pre-monsoon at Station 1 and Station 2. The maximum value recorded at Station 1 during monsoon and during pre-monsoon at Station 3 might be due to the bacterial activity in surface water. The annual mean ammonium concentrations recorded at Stations 1, 2, 3 and R were 13.28μmolL$^{-1}$, 32.90μmolL$^{-1}$, 11.54μmolL$^{-1}$, and 14.11μmolL$^{-1}$ respectively. Remarkably high concentration at Station 2, may be due to the localized regeneration from sediments.
The N:P ratio at mangrove-fringed creek waters were varied between 1.36 and 5.70 and Station R showed an annual mean value of 4.48. The significantly lowered ratio at Station 1 and Station 2 could be due to an enhanced concentration of DIP. The above ratios suggest that the mangrove-fringed creeks of Cochin estuary represent an anthropogenically altered ecosystem.

The annual mean values of DIP showed a variation from 1.51 µmol L\(^{-1}\) (Station 3) to 10.70 µmol L\(^{-1}\) (Station 2). Station R recorded an annual mean value of 2.07 µmol L\(^{-1}\). Remarkably higher concentration of DIP was found during monsoon at Station 1 and decrease of the same occurred during post-monsoon at Station 1. The relationship between seasonal pattern of phosphate in water and flux of phosphate from sediments is an evidence for the regeneration of benthic phosphate affects water column DIP concentrations. The high concentration of DIP at Station 2, during pre-monsoon may be as a result of the evapotranspiration. The DIP concentrations recorded at Station 3 and Station R were similar during the study period. The DOP concentrations in surface waters showed a variation from 0.01 µmolL\(^{-1}\) at Station 3 to 11.96 µmolL\(^{-1}\) at Station 1. The minimum and maximum DOP concentrations recorded at Station R were 0.13 µmolL\(^{-1}\) and 3.23 µmolL\(^{-1}\) respectively.

Particulate phosphorus concentration found to vary between 0.49 µmolL\(^{-1}\) at Station 2 and 55.40 µmolL\(^{-1}\) at Station 2 in creek waters. However at Station R, PP concentrations varied from 0.58 µmolL\(^{-1}\) to 8.40 µmolL\(^{-1}\). Seasonal variations showed maximum concentrations of PP during monsoon at all Stations except at Station R, where maximum concentration was found during pre-monsoon. The distributions of particulate phosphorus depend on the suspended sediment brought in by the river discharge and not on the particulate matter formed during the estuarine mixing. Low concentrations of TP were observed during post-monsoon at all Stations. The annual mean concentrations of TP showed maximum value at Station 2 and a minimum value at Station R. TP concentrations indicated phosphorus loading in the water column of mangrove creeks (Station 1 and Station 2) than Station 3 and estuarine reference Station. Station 1 recorded relatively higher TP concentration during monsoon and pre-monsoon. Phosphorus may enter a water body through the inflows, precipitation, dry fallout and from the sediments, and it may be removed by sedimentation and through the outflow.
Concentrations of nitrate, nitrite and ammonium showed significant difference between Stations (ANOVA). Significantly higher concentrations of nitrate and nitrite were recorded at Station R, while Station 2, recorded higher concentrations of ammonium. Contrary to the inorganic nitrogen species, DIP and DOP concentrations exhibited significantly higher concentrations at Stations 1 and 2 than at Stations 3 and R. At the mangrove creek waters, TSS concentrations showed significant positive correlations with POC, DIP, TP, PP and ammonium concentrations, while no such correlations could be observed at Station R. Correlation analysis of ammonium with other parameters showed significant positive correlation with TSS, DIP, PP and TP. However, dissolved ammonium levels were found to be negatively correlated with dissolved oxygen.

Analysis of relative composition of each form of phosphorus revealed that the PP concentrations were greater than DIP concentrations which in turn was greater than DOP at all stations except at Station 1; where phosphorus was partitioned into about 34.5% PP, 48.4% DIP and 17.1% DOP. The observed high percentage of DIP at Station 1 during the present study may be resulted from the high fraction of iron bound phosphate in the sediment. Anderson and Jensen (1992) have shown that Fe-bound P, when present in significant proportions in the sediment, may be a major source for internal P loading in shallow, eutrophic lakes, just as it may be in deeper, stratified lakes. At Station 2 the relative composition of each form of phosphorus observed were 51.4% PP, 39.3% DIP and 10.5% DOP while Station 3, recorded the percentage composition of PP, DIP and DOP as 65.4%, 21.2% and 13.4% respectively. The reference Station gave a composition with 61.3% PP, 26.7% DIP and 21% DOP. Differences in speciation of phosphorus in water column among the studied area can be ascribed to local characteristics, such as extent of fresh water input, land run-off, tidal amplitude and productivity of biota.

Textural studies indicated the nature of surface sediment to be sandy mud, sandy silt and muddy sand at Stations 1, 2 and 3 respectively. The well-developed mangroves at Station 1 and Station 2 support the root system of mangroves, which has a dense grid of vertical pneumatophores and arial roots. This structure traps floating detritus and reduces tidal flow, eventually creating conditions where suspended clay and silt particles settle, whereas the lack of vegetation as well as tidal influence and impact of waves remove finer fractions (silt + clay) of the sediment.
The mean moisture percentages recorded higher values at Station 1 and Station 2. The spatial and seasonal variation in moisture content could be attributed to the variation of organic matter and grain size of the sediment. Generally, higher pH values were observed at Station 1 and Station 2, while lower pH values were recorded at Station 3. Minimum pH values were recorded during pre-monsoon or post-monsoon at all Stations and maximum values were recorded during monsoon season.

The concentrations of TOC in surface sediments of Station 1 and Station 2 were very high when compared with that of Station 3. The prevalent hydrodynamics at Station 1 and Station 2 and the presence of well-developed mangrove roots retained fine fraction of surface sediment. The results indicate that Station 1 and Station 2 were composed of organic rich surface sediment, capable of trapping nutrients. Similarly TN concentrations, recorded a minimum of 0.97 mg g\(^{-1}\) at Station 3 and maximum concentration of 4.90 mg g\(^{-1}\) was recorded at Station 2. The seasonal variation of TN concentration showed maximum concentrations during pre-monsoon and minimum concentrations during monsoon at all Stations. The seasonal variations may be attributed to the variation in TOC concentrations as well as with the adsorbed ammonium present in the sediment, since exchangeable ammonium was found to be positively correlated with TN concentrations. The concentrations of TP recorded were similar at Station 1 and Station 2, varied from 1.12 mg g\(^{-1}\) to 2.10 mg g\(^{-1}\) but sediments of Station 3 were significantly lower, ranging from 0.49 mg g\(^{-1}\) to 0.80 mg g\(^{-1}\). Remarkable spatial variation with higher values at first two Stations might be attributed to different hydrodynamic regime. Station 3 was marked by the overbearing of coarse fraction, which inhibits accumulation of phosphorus in sediments. The maximum salinity at Station 2 may cause precipitation of dissolved phosphorus and hence a maximum concentration was recorded during pre-monsoon. The cycling of phosphorus in the studied area is highly dynamic at least at first two Stations, where the sediments act as an efficient sink for phosphorus as far as an aerobic environment prevailed.

The exchangeable inorganic nutrient concentrations were found to be low in other mangrove ecosystem due to plant intake and solubility of these in surface water. Exchangeable ammonium concentrations in surface sediments varied between 0.08 μmol g\(^{-1}\) (Station 3) and 0.84 μmol g\(^{-1}\) (Station 1 and Station 2), while
exchangeable nitrate concentration ranged between 3.29 nmol g\(^{-1}\) (Station 3) to 64.31 nmol g\(^{-1}\) (Station 1). A regular tidal incursion at Station 3 may remove ammonium from the sediment as it is soluble in water. Seasonal variations were found with comparatively higher values during pre-monsoon and post monsoon at Station 1 and Station 2.

The C/N ratios of surface sediments were ranged between 16.57 and 35.32 at all Stations. However at Station 2, surface sediments exhibited a C/N variation of 16.57 and 28.18, which indicated an origin of mangrove detritus at this site. The high C/N ratios observed at Station 1 and Station 3, during the present investigation may be attributed to the accumulated organic carbon at Station 1, and humic derived nitrogenous organic matter (biogenic origin) at Station 3. Relatively lower ratios observed at Station 2, indicate a mangrove detrital origin. The mangrove detritus were associated with the tight coupling between microbial mineralization and assimilation in organic sediments of the studied mangrove area.

The low N:P ratios (1.50 to 3.27) observed in the study area were due to comparatively high concentration of TP. N:P ratio can be taken as an index of the extent of extraneous influence on a productive water body, since the nitrogen if produced is autochthonous, variation in N:P depend on phosphorus which is mostly external. These ratios observed during the present study indicated an abiotic origin of phosphorus in the mangrove fringed creek sediments.

The C/P ratios varied between 34.68 (Station 2, monsoon) and 68.00 (Station 2, post-monsoon). The observed C/P ratio revealed that the accumulated phosphorus load in creek waters could be reduced by the mangrove plants and associated micro-organisms. However to arrive at the cause of deviation from Redfield stoichiometry requires more information on the kind of litter produced in this area, and also on the influence of microbes on carbon, nitrogen and phosphorus dynamics in this particular ecosystem. Outwelling of mangrove litter significantly influences sediment concentrations of TOC, TN and stoichiometric ratios of C:N:P (Alongi, 1990).

Grain size analysis of core sediments recorded similar observation as that of surface grain size analysis at all Stations except in 4-6 cm layer at Station 1 and in 10-20 cm layer at Station 2. The major textural facies in sediment core at Station 1 was sandy mud with a mud layer at 4-6 cm interval. However sediment core at Station 2 was predominantly composed of sandy mud sediment with an
intercalation of 10 cm thick muddy sand was recorded at a depth of about 10 cm from the surface. According to Flach and Heip (1996), a homogeneous distribution pattern of grain size in the vertical column of sediment suggests a constant mixture by bioturbation effects.

The moisture percentage in sediment cores varied between 29.40% (Station 3) and 61.76% (Station 2). Generally moisture percentage decreased down the core at all Stations. The moisture percentage showed a significant positive correlation with organic carbon. The annual mean values of moisture showed identical percentage at Station 1 and Station 2 due to the similar textural attributes at these stations, while less moisture percentage were recorded at Station 3, due to predominant muddy sand nature of the sediment. Seasonal variation in pH values in core sediments recorded the maximum values during monsoon while minimum values were recorded during pre-monsoon at Station 1 and 2. However a remarkable decrease was noticed beyond 10 cm depth at the same Stations. All other depths showed an increase in pH values with an increase in depth during all three seasons. The three mangrove locations showed pH values as that of an alkaline nature of sediment up to 20 cm of depth with an exceptions during pre-monsoon at Station 1 and Station 3. The annual variation of pH values in core sediments showed a general increase down the core at all Stations indicated an alkaline condition in sediment till 20 cm of depth.

TOC concentration in the sediment cores varied between as low as 10.62 mg g\(^{-1}\) (Station 3) and as high as 140.23 mg g\(^{-1}\) (Station 1). Remarkably higher TOC concentrations were observed at Station 1 and Station 2 compared with Station 3. Generally highest values of TOC observed at the top and lowest contents recorded at 20-30 cm layer may be attributed to the particles loosened and suspended by the wave action during inundation of the forest and flushed into the creek and deposit as a silt layer on the sediment surface. Litterfall in the forest floor accounted for about 45% of the total detritus in a mangrove area. However subsurface increases in TOC concentration were found only at Station 1 and Station 2, suggesting an accumulation of organic carbon in subsurface sediment. Higher values of TN concentrations were recorded during all seasons at Station 1 and Station 2 than at Station 3. Nitrogen fixation by cyanobacteria and heterotrophic bacteria which are abundant on all inhabitable surfaces in mangrove ecosystem, mineralization processes associated with the ammonium assimilation
by microphyto benthos and plants, the production of mucopoly saccharide exudates by bacteria and their incorporation into humic compounds enhance the TN concentrations in surface sediment. Also TN correlated positively with TOC and negatively with sediment C/N ratio at 0-2 and 2-4 cm depth. This indicated that decrease in C:N ratio was mainly due to the increased organic nitrogen in the sediment. It is possible that the increase in TN and thus decrease in C/N ratio in the sediment may be partly attributed to the increase of chlorophyll-containing labile materials.

The minimum and maximum values of exchangeable nitrate recorded were 2.71 μmol g⁻¹ (Station 3) and 90.67 μmol g⁻¹ (Station 2) respectively. Comparatively higher values were recorded at Station 1 and Station 2 than at Station 3. A general pattern of exchangeable nitrate concentrations, with an increase in sub-surface sediment followed by a gradual decrease down the core was noticed at all Stations except at Station 3. Active growth of plants might cause the decrease of this nutrient with depth. Alternatively tidal incursions can also remove nitrate at Station 3 where tidal influence is maximum.

The ammonium concentrations varied between 0.08 μmol g⁻¹ (Station 3) and 0.84 μmol g⁻¹ (Station 1). Higher ammonium concentrations were noticed at Station 2 than other Stations may be attributed to high organic carbon and clay as they provide greater surface area for adsorption of the cations. Annual variation in depth pattern showed an increase in exchangeable ammonium concentrations with an increase in depth at Station 1 and Station 2. The ammonium concentration increases with depth in the anaerobic soil, indicating denitrification beyond rhizospheres.

TP concentrations were similar at Stations 1 and 2. The overall picture of the annual variation followed the general pattern of decreasing phosphorus concentration with increasing depths at Station 1 and Station 3, except at 10-20 cm depth at Station 1. Associated with the high silt and clay percentage, a significantly high concentration of TP was recorded at the first two stations. The present observation indicated the sediments at Station 1 and Station 2 were better nutrient sinks than at Station 3 due to its ability to immobilize phosphorus in an oxidised sediment-water interface. TP concentrations were high in surface and subsurface sediments indicated the contribution of below ground roots in maintaining oxidised surface sediment. The oxidative reactions would limit the desorption of phosphate
into overlying water, since most of the phosphorus being bound to non-reactive metals, particularly as iron and manganese oxyhydroxides.

The C/N ratios recorded at Station 1 and 3 were remarkably higher than at the other two Stations. C/N ratio varied from 19.09 (2-4cm) to 36.16 (10-20cm), 15.61 (4-6cm) to 38.33 (10-20cm), and 10.48 (4-6cm) to 56.62 (10-20cm) at Station 1, Station 2 and Station 3 respectively. Annual variations in depth profile showed a general pattern of a sub-surface decrease followed by a remarkable increase beyond 10 cm depth at all stations. The fringing mangrove Station 1, have high C:N ratios indicating an accumulation of carbon relative to nitrogen; this carbon probably originates from debris washed on to strand lines. The C/N ratio fluctuated during monsoon season when fresh water discharge was greater and this indicated that besides mangroves and associated biota, terrigenous organic matter brought in by fresh water discharge continuously added detritus to the mangrove ecosystem also varied the stoichiometric ratios at these sites. N:P ratios in core sediments showed a gradual decrease down the core may be attributed to the decrease of TN, since only TN concentrations showed a significant decrease with increasing depth (App.16). The highest N:P ratios were observed in surface/ subsurface sediment at all Stations, where TN concentrations showed significantly higher values. The value of N/P ratio ranged between 0.82 and 4.47 and were far below the N:P ratio of planktons, indicating the abiogenic nature of phosphorus in the studied area.

The minimum and maximum C/P ratios observed in sediment cores were 25.67 (Station 3) and 83.22 (Station 2) respectively. Generally a sub-surface increase in C/P ratios was observed at Station 1 and Station 3. The decrease in C/P ratios beyond 10cm depth may be associated with minimum concentrations of TOC in this layer. The high organic carbon as well as relatively high C/P ratio observed at Station 1 and 3 indicted that a major portion of the phosphorus in sediment undergoes bacterial mineralisation. Further more it was also established that mangrove leaf litter found to harbour a large population of bacteria that appear to be highly productive.

Fractionation of phosphorus was carried out using the EDTA method (Golterman, 1996). The study on vertical variation of phosphorus fractions in sediments indicated that the variation of phosphorus forms with depth was susceptible to multifactor influences such as sedimentary environment, early
diagenesis, grain sizes and anthropogenic activities. Depth profiles of P fraction were examined to provide information on P diagenesis as a function of various storage forms.

Sum of phosphorus fractions were similar at Station 1 (1482 μg g⁻¹ - 1855 μg g⁻¹) and at Station 2 (1361 μg g⁻¹ - 1792 μg g⁻¹) but concentration were lower at Station 3 (483 μg g⁻¹ - 741 μg g⁻¹). It reflects large spatial difference of phosphorus due to different geographical and geomorphological locations. These results indicate the occurrence of trapping mechanism for phosphorus in the mangrove ecosystem. The denser vegetation seen at Station 1 and Station 2 (as compared to Station 3) facilitates trapping of sediment and nutrients discharged to these creeks from nearby systems. It appears that very high phosphate adsorption capacity exist in the sediments of Station 1 and Station 2 in accordance with the amount of iron bound phosphorus fraction while the major fraction obtained at Station 3 was organically bound phosphorus and calcium-bound inorganic phosphorus.

The W-IP concentrations recorded a general increase down the core may be attributed to the elevated phosphate levels in interstitial water of the sediment. Desorption of phosphorus into pore water may be attributed to the anaerobic conditions prevail in the bottom layers of the sediment. Unlike W-IP, WOP fraction showed a general decrease with increasing depth. The Fe-IP fraction showed general decrease down the core at these Stations except at Station 2, where a subsurface maximum was recorded. Seasonal variations in Fe-IP were found at three stations with maximum during post-monsoon and minimum recorded during pre-monsoon at all three Stations. The Fe:P ratio in sediments found to vary from 9.08 (Station 3) to 14.26 (Station 1). Thus, based on Fe:P ratios, the sediments had a high capacity for binding phosphate to iron. Unlike the inorganic fraction, the concentrations of Fe-OP were similar during three seasons other than the exceptionally higher values at Station 2. The concentrations of Ca-IP showed an erratic behavior down the core at Station 1 and Station 2. The overall picture of the annual variation followed the general pattern at Station 3 with decreasing concentration down the core. Variation of Ca-IP in the study area confirmed the influence of sediment texture in its distribution. Ca-OP concentration showed a decrease with the increase in depth except at 6-10 cm depth. The Ac-OP fraction exhibited a general decrease in concentration down the core. A reversal of this trend was observed at depths beyond 10 cm at Station 1 and 6-10 cm depth at
Station 2. The Ac-OP fraction mainly consisted of fresh organic matter, which decreases with increasing depth. The exceptionally high values recorded at 6-10cm depth at Station 2 may be due to occasional presence of root particles in sediment core. Alk-OP generally decreases down the core except at Station 2 where a subsurface increase was found. NaOH, extract the humic bound phosphates and poly phosphates associated with bacteria. Therefore the general decrease down the core may be attributed to the decrease in bacterial biomass with increase in sediment depth. Generally ROP concentration showed a decrease down the core. However the ROP fraction found to concentrate in subsurface sediment at Station 2 and Station 3.

The speciation of phosphorus in the mangrove ecosystems showed preferences of one form of phosphorus or the other with changing salinity. At Station 1, Fe-IP fractions were observed as the abundant fraction of phosphorus at all depths and ranged between 345.68μg·g⁻¹ and 495.36μg·g⁻¹. W-OP recorded a minimum with values ranging between 7.18μg·g⁻¹ and 13.28μg·g⁻¹. Other major fractions found were Ca-IP (246.35μg·g⁻¹ and 362.04μg·g⁻¹) and Alk-OP (263.98μg·g⁻¹ to 372.89μg·g⁻¹). All other fractions gave intermediate values to those of W-OP and Alk-OP.

Similar to Station 1, Station 2 core sediments also were generally composed of Fe-IP as the major fraction at all depths except at 6-10 and 10-20 cm depths. Fe-IP at this Station ranged between 282.63μg·g⁻¹ and 477.99μg·g⁻¹. W-OP recorded minimum concentrations (4.75μg·g⁻¹ to 8.90μg·g⁻¹). Other major fractions at this site were Ca-IP, which ranged from 266.66μg·g⁻¹ to 442.21μg·g⁻¹ and Alk-OP, which ranged from 237.74μg·g⁻¹ to 301.48μg·g⁻¹.

Fractionation of sediment cores at Station 3 gave an entirely different pattern from that of Station 1 and Station 2. The major fraction at this site was Alk-OP. This fraction showed a variation from 133.42μg·g⁻¹ to 183.94μg·g⁻¹. The minimum concentration fraction was also different from the other two Stations. Here W-IP showed minimum concentration at this site, which varied from 1.70μg·g⁻¹ to 7.08μg·g⁻¹. The other major fractions obtained were Fe-IP (52.41 to 102.76μg·g⁻¹) Ca-OP (50.61 to 99.15μg·g⁻¹) and Ac-OP (69.10 to 93.63μg·g⁻¹). It was reported that the added excess DIP was efficiently taken up by the sediment particles and primarily retrieved in the easily exchangeable and iron bound fractions and the mangrove sediment was thus found to act as a phosphorus sink. Thus Stations 1
and 2 sediments which comprise majority of Fe-IP fractions may act as a phosphorus sink.

It has been established that sediment characteristics could serve as the basis to assume phosphorus species in sediments and ultimately predict potential rates of internal phosphorus loading. The water exchangeable fraction showed significant positive correlation with percentage of silt, clay, and TOC concentrations in 0-2 and 2-4 cm layers. The Fe-bound phosphorus was found as, positively correlated with percentages of silt, clay, organic carbon and iron content at all depths except 6-10 cm layer. No significant correlation was exhibited by Ca-bound phosphorus at 0-2, 2-4, and 10-20 cm layers. This fraction showed negative relationship with total organic carbon, iron content and in some depths, with percentage of clay. Correlation analysis showed that a similar mechanism governed the phosphorus speciation at 0-2 and 2-4 cm layers. These layers remain oxygenated layers at all seasons. The 4-6, 6-10 and 10-20 cm layers may become anoxic and this could influence the amount of different species of phosphorus present. The concentrations of different fractions indicated a trapping mechanism operating for phosphorus in the mangrove ecosystem. At Station 1 and Station 2, denser vegetation was seen compared to Station 3, which facilitates trapping of nutrients discharged to this creek from nearby systems. Also, Station 1 and Station 2 appear to be the sites with high sedimentation. Therefore the causes of chemical differences among the first two Stations and the third Station can ascribe to sedimentation, through which the system can act as a sink of suspended matter. Fabre et al., (1999) found that the difference in the major form of phosphorus at different mangrove sites in French Guiana were due to the sedimentation pattern at each sites and also the ability of these sites to function as a sink for suspended matter. Influences of biotic processes like bioturbation, plant uptake and transpiration and root zone decomposition are some factors which affect the mobilization of P in wetlands. The order of abundance of each fraction at various depths gave an indication of bioturbation in the studied area. At Stations 1 and 2, the order of abundance was similar in the first three layers, which indicated bioturbation at this site, while Station 3 showed different order of abundance in these layers. The statistical ANOVA carried out between station, fraction and depth, showed significant difference in concentrations of phosphorus exist between Station, and between fraction and not between depths. Among fractions, Fe-IP
fractions recorded significantly higher concentrations followed by Ca-IP concentrations and Alk-OP concentrations.

REFERENCES

