Resuspension and Diffusive Flux of Nitrogen and Phosphorus in a Hypereutrophic Lake


ABSTRACT

Bottom sediments in shallow lakes can play a major role in releasing nutrients to the overlying water column during wind induced sediment resuspension or by constant flux due to diffusion. Internal nutrient loads due to these processes may be equal to or higher than external loads. Laboratory and field experiments were conducted on Lake Apopka, a shallow, hypereutrophic subtropical lake located in central Florida. Ammonium (NH$_4^+$) and soluble reactive P (SRP) flux during sediment resuspension were measured under laboratory conditions using intact sediment cores. Ammonium N and SRP flux due to resuspension were assessed using in situ porewater concentrations. Average diffusive fluxes of NH$_4^+$ from sediment to the overlying water was estimated to be 25 mg NH$_4^+$ N m$^{-2}$ d$^{-1}$ and 1 mg P m$^{-1}$ d$^{-1}$. Resuspension fluxes of NH$_4^+$ and SRP were higher than diffusive fluxes. Soluble reactive P profiles of porewater showed distinct profile differentiation, with the surface 0 to 8 cm sediment depth acting as a P-depletion zone, and the underlying sediment displaying steep gradients in porewater SRP. These results suggest that dissolved NH$_4^+$ and SRP transport from the surface 8 cm of sediment was due to sediment resuspension, while below this depth, upward mobility of NH$_4^+$ and SRP was regulated by diffusion. Although dissolved N and P flux is upwards (from sediment to water column), during extended periods (annual cycle) the lake is functioning as a net sink for N and P by transforming inorganic pools of nutrients into organic forms and depositing them on the sediment surface.

In shallow lakes, dissolved oxygen of the water column remains relatively high due to: (i) a low density of oxygen consuming organisms, (ii) photosynthetic oxygen production by algae, and (iii) wind-induced mixing in the water column. While oxygen demand in the water column may be low, it is much greater in the bottom sediments, especially those with high organic matter content and microbial activity. These conditions result in development of an oxidized sediment–water interface (Howeler and Bouldin, 1971). With quiescent conditions, flux of dissolved nutrients from sediment to the overlying water column largely depends on concentration gradients established across the sediment–water interface (Berner, 1980; Reddy et al., 1976). However, both the surface–oxidized sediment layer and the concentration gradients at the sediment–water interface are often disrupted by wind-induced resuspension of surface sediment or bioturbation.

Resuspension of unconsolidated surface sediments in shallow lakes during periods of heavy wind can result in high levels of turbidity and nutrients in the overlying water. These conditions can significantly affect light penetration and influence algal productivity. The effect of wind-induced resuspension on algal growth has been documented in marine, estuarine, and lacustrine systems (Mehta and Parthenides, 1975; Wolanski et al., 1988; Hawley and Lesht, 1992; Sondergaard et al., 1992).

During sediment resuspension, NH$_4^+$ released upon desorption can be rapidly oxidized to NO$_3^-$ or assimilated by plankton. Similarly, desorbed P can be assimilated by plankton, undergo precipitation with Ca minerals; or become involved in ligand exchange with ferric oxyhydroxide minerals contained in suspended sediments (Anderson, 1975; Lijkemla, 1977; Moore et al., 1991). In calcareous sediments, increased pH of the overlying water column decreased net P flux from sediments as a result of sorption and coprecipitation with calcite (Gunatilaka, 1982). High pH conditions of the water column can also increase the loss of NH$_4^+$-N due to volatilization (Bouldin et al., 1974).

Wind-induced mixing of surface sediment can increase nutrient exchange across the sediment-water interface (Anderson, 1974). The depth of the surface sediment layer involved in mixing with the overlying water column may be highly variable depending on shear stress and sediment structure (Lee, 1970). For shallow aquatic systems, the depth of surface sediment involved in resuspension was estimated to be about 10 cm (Tessenow, 1972; Schindler et al., 1977). Holdren and Armstrong (1980) measured increased SRP release from sediments when the water column was well mixed. Similarly, wind-induced sediment resuspension increased P release in other lakes (Ryding and Forsberg, 1977; Ahlgren, 1977). However, these studies were limited to lakes in temperate climates. Sediment resuspension was the major mechanism for cycling of NH$_4^+$ between the bottom sediment and the overlying water column in the transition zone of the Potomac River Estuary (Simon, 1988 a,b).

In Lake Apopka (81° 35' W. Long., 28° 35' N. Lat.), surface unconsolidated floc (UCF) sediments are 98% water and about 2% solids (dry weight basis) (Reddy and Graetz, 1990), thus offering a high potential for rapid resuspension during hydrodynamic events. The objectives of this study were to determine: (i) the rate of NH$_4^+$ and SRP release during sediment resuspension using simulated conditions, and (ii) the spatial and temporal variations in sediment porewater NH$_4^+$ and SRP. It was hypothesized that N and P release during sediment

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Abbreviations: SRP, soluble reactive P; UCF, unconsolidated floc; TKN, total Kjeldahl N; TP, total P; TSS, total suspended solids.
resuspension and diffusive flux from sediments are important sources to overlying water column in shallow lakes.

MATERIALS AND METHODS

Site Description

Lake Apopka is the largest lake (12.500 ha) in the Oklawaha River Basin with a mean depth of 2 m (Fig. 1). The lake is highly eutrophic with chlorophyll-a concentrations often exceeding 200 µg L⁻¹. Soils adjacent to this lake (formerly lake side marsh) are used intensively for vegetable production, and drainage from these areas is discharged into the lake (Reddy et al., 1982). Excessive nutrient loading during the past several decades has contributed to hypereutrophic conditions in the lake (USEPA, 1979).

Laboratory Sediment Resuspension Study

Six intact sediment cores were obtained from a station located in the center of the lake (Station F-6) (Fig. 1) on 20 July 1989, using a piston core sampler (Fisher et al., 1992). Three intact sediment cores overlaying with 30 cm of water were used as a control, while the second set of three cores was used to simulate resuspension of surface sediments. Sediment resuspension was generated in Plexiglas cylinders (6.35 cm i.d. and 60 cm long) by oscillating grids (Fig. 2), an experimental setup similar to that described by Wolanski et al. (1989). Using this apparatus, the surface 10 cm of sediment was resuspended into the water column for 1 h. During this period, water samples containing resuspended sediments were sampled at 0, 15, 30, and 60 min, and filtered through a 0.45-µm membrane filter. After 1 h, sediment resuspension was stopped, and suspended sediment particles were allowed to settle. During sediment settling, water samples were obtained after 1, 2, 4, 8, 12, and 24 h and analyzed for NH₄-N and SRP after filtration through a 0.45-µm membrane filter (Methods 351.2 and 365.1, EPA, 1983). Simultaneously, water samples were also obtained from control sediment-water columns.

Field Experiments

Water Sampling and Analysis

Water samples from the center lake station (Station F-6) were collected three times each week for 1 yr, and analyzed for total Kjeldahl N (TKN), total P (TP), and total suspended solids (TSS) using standard methods (USEPA 1983; APHA, 1985). Wind data were also collected by the St. Johns River Water Management District, Palatka, FL, at the center lake station at 15-min intervals.

Sediment Porewater Sampling and Analysis

Triplicate intact sediment cores were obtained from seven locations (Fig. 1 stations B-2, G-2, D-5, K-6, G-7, H-10, and D-11) on 12 Feb. 1988 to determine the spatial variation in porewater concentrations of NH₄-N and SRP. The porewater gradients of NH₄ and SRP allowed for the calculation of diffusive flux using Fick's first law of diffusion (Moore et al., 1991). To determine temporal variations, triplicate sediment cores were obtained quarterly from Station F-6 on 7 Oct. 1988 and 10 January, 10 April, and 10 July 1989, using a piston corer (Fisher et al., 1992). All sediment cores were then sectioned into 0 to 2, 2 to 4, 4 to 8, 8 to 12, 12 to 16, 16 to 20, 20 to 25, 25 to 30, 30 to 40, and 50 to 60-cm intervals and transferred into centrifuge tubes followed by purging with N₂ gas to maintain anaerobic conditions. Porewater was extracted by centrifuging the sediments at 4066 x g for 20 min., followed by filtration through a 0.45-µm membrane filter. Filtered solutions were analyzed for NH₄-N and SRP as described before.

RESULTS

Sediment Resuspension Effects

Resuspension of the surface 10-cm sediment into the overlying water for 1 h resulted in rapid release of soluble NH₄-N within the first 15 min (Fig. 3a). Ammonium concentration in the water column increased from 0.2 to 3.8 mg L⁻¹ during the initial 15 min, followed by minimal change during the remainder of the resuspension
period. Ammonium concentration of the water column remained relatively constant (3.5–3.8 mg L⁻¹) during 23 h of the settling period (Fig. 3c). Initial NH₄⁺ release rates during the sediment resuspension event were in the range of 67 to 85 mg m⁻² min⁻¹ (Table 1). Most of NH₄⁺ release occurred during the first 15-min interval, with little or no change during the remainder of the 45-min resuspension period. In sediment cores with no resuspension, diffusive flux of NH₄⁺ during a 24-h period resulted in no significant change in NH₄⁺ levels of the water column (Fig. 3b and 3d).

Three hours after the resuspension event was stopped, water column SRP levels increased from 7 to 26 µg P L⁻¹ (Fig. 4). Calculated P release rates during sediment resuspension ranged from 0.5 to 3.3 mg m⁻² h⁻¹ compared to −0.2 to 0.5 mg m⁻² h⁻¹ cores with no resuspension (Table 1).

**In Situ Water Chemistry**

Total suspended solid concentrations were in the range of 29 to 170 mg L⁻¹, while TKN and TP concentrations were 3 to 10 mg N L⁻¹ and 0.06 to 0.36 mg P L⁻¹, respectively (Fig. 5). In general, TKN, TP, and TSS

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**Fig. 2.** A schematic diagram of the sediment resuspension apparatus used in the study.

**Fig. 3.** Ammonium N released during and after sediment resuspension in laboratory conditions. (a) NH₄⁺ release during 1 h of resuspension, (b) NH₄⁺ release due to diffusion only (control sediment cores with no resuspension), (c) NH₄⁺ release after sediment resuspension was stopped, and (d) control sediment cores. Individual lines represent replicate cores.
Table 1. Ammonium (NH₄⁺)-N and soluble reactive P (SRP) release during sediment resuspension into the water column.

<table>
<thead>
<tr>
<th></th>
<th>NH₄⁺-N</th>
<th>SRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cores with sediment resuspension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core I</td>
<td>4030</td>
<td>-0.2</td>
</tr>
<tr>
<td>Core II</td>
<td>5080</td>
<td>1.1</td>
</tr>
<tr>
<td>Core III</td>
<td>4430</td>
<td>4.8</td>
</tr>
<tr>
<td>Cores with no sediment resuspension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core I</td>
<td>-48</td>
<td>0.4</td>
</tr>
<tr>
<td>Core II</td>
<td>5</td>
<td>-0.2</td>
</tr>
<tr>
<td>Core III</td>
<td>5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

showed similar seasonal trends, with significant relationships among these parameters ($P = 0.01$). No significant relationship was observed between TSS and either SRP or NH₄⁺-N (data not shown). Suspended solids averaged about 71 mg N g⁻¹ (dry solids) and 2.7 mg P g⁻¹, respectively, for the 1-yr period (Table 2). Results showed significant fluctuations in the concentrations of water quality parameters suggesting an influence from both external and internal nutrient loading. Due to sensor problems, reliable wind data were available for only 38 of the 173 sample dates. The maximum wind speed measured in the 6, 3, and 1-hr periods preceding sampling was not significantly correlated with TP and TKN ($P = 0.05$). The only significant correlation between wind speed and water quality parameters was between TSS and the maximum wind speed that occurred in the 6-h interval preceding sampling. Even so, wind speed explained only 11% of the variability in TSS. Water sampling typically occurred during mid-morning, a time period characterized by low wind velocities, while maximum wind speeds generally occurred in late afternoon. The close coupling of wind induced resuspension of bottom sediments and water quality in a system where nutrients are subject to rapid recycling may require more coordinated measurements of wind velocity and water quality.

**Dissolved Ammonium Nitrogen and Soluble Reactive Phosphorus in Sediment Porewater Spatial Variability Studies**

Ammonium-N concentration in the sediment porewater showed spatial variability, with concentrations ranging from 20 to 140 mg L⁻¹ at depths >30 cm (Fig. 6). Ammonium concentration in the surface layers was

![Fig. 4. Soluble reactive P released during and after sediment resuspension under laboratory conditions. (a) SRP release during 1 h of resuspension, (b) SRP release due to diffusion only (control sediment cores with no resuspension), (c) SRP release after sediment resuspension was stopped, and (d) control sediment cores. Individual lines represent replicate cores.](image)

![Fig. 5. Seasonal variability in total suspended solids (TSS), total N (TKN), and total P (TP) in Lake Apopka water column (Station F-6).](image)
Table 2. Average concentration of selected water quality parameters. Each value represents an average of 170 samples collected from station F-6 during 1989. SD = standard deviation.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Avg. ± SD</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total suspended solids</td>
<td>mg L⁻¹</td>
<td>78 ± 23</td>
<td>27</td>
<td>170</td>
</tr>
<tr>
<td>Total N</td>
<td>mg L⁻¹</td>
<td>5.3 ± 1.3</td>
<td>3.2</td>
<td>10.0</td>
</tr>
<tr>
<td>Total P</td>
<td>mg L⁻¹</td>
<td>0.20 ± 0.05</td>
<td>0.06</td>
<td>0.36</td>
</tr>
<tr>
<td>Total organic C</td>
<td>mg L⁻¹</td>
<td>28.2 ± 7.6</td>
<td>9.3</td>
<td>44.0</td>
</tr>
<tr>
<td>Total N⁺</td>
<td>mg g⁻¹</td>
<td>71 ± 20</td>
<td>36</td>
<td>151</td>
</tr>
<tr>
<td>Total P⁺</td>
<td>mg g⁻¹</td>
<td>2.7 ± 1.0</td>
<td>0.6</td>
<td>6.5</td>
</tr>
<tr>
<td>N/P ratio</td>
<td></td>
<td>28.2 ± 9.7</td>
<td>13.5</td>
<td>67.1</td>
</tr>
</tbody>
</table>

† Values represent concentration of N and P normalized to dry weight of suspended solids.

<5 mg L⁻¹ and showed less variability. Porewater NH₄⁺ concentration was lowest in the sediment cores obtained from G-2 and D-11, while highest concentrations were measured in the cores obtained from station G-7.

Ammonium-N profiles at all stations showed steep gradients from the sediment surface down to 20 cm depth, suggesting rapid interchange between the sediment and the overlying water column (Fig. 6). The calculated NH₄⁺ flux from the sediment to the water column ranged from 10 to 39 mg N m⁻² d⁻¹ and averaged 25 ± 11 mg N m⁻² d⁻¹ (Table 3).

The SRP levels in the surface sediment layers (0- to 8-cm) were low (12-26 μg L⁻¹) and were approximately in the same range as those found in the water column suggesting the effects of sediment resuspension and subsequent release into the water column (Fig. 7). Apparently the surface 8-cm sediments are resuspended into the water column more frequently, as suggested by depletion of SRP. Below the 8-cm depth, there was a steep gradient in SRP levels of the porewater as a function of depth. Phosphorus mobility from sediments below this depth is primarily associated with diffusive flux, as indicated by the porewater SRP gradients. Diffusive flux of P was in the range of 0.2 to 1.9 mg P m⁻² d⁻¹ and averaged 0.97 ± 0.59 mg P m⁻² d⁻¹ (Table 3). Low P flux was observed at stations G-2 and D-11, while high flux was observed at stations K-6 and G-7.

**Temporal Variability Studies**

Sediment porewater NH₄⁺ and SRP concentrations at Station F-6 were low in the surface layer and increased with depth (Fig. 8). Flux of NH₄⁺ (18.7 ± 5.6 mg m⁻² d⁻¹) (SRP 0.64 ± 0.16 mg m⁻² d⁻¹) were in the same range as reported for other stations in Lake Apopka (Table 4). Porewater SRP concentrations showed a clear break at 8-cm depth, suggesting the impact of possible sediment resuspension effects. Soluble reactive P concentrations in the 0- to 8-cm depth were in the range of 3 to 21 μg P L⁻¹, which are typical concentrations observed in the Lake Apopka water column. The SRP levels of the water column during the same sampling period were between 28 to 47 μg P L⁻¹.

![Fig. 6. Sediment porewater ammonium concentration at selected stations in Lake Apopka (12 Feb. 1988). Individual lines represent replicated cores.](image-url)
DISCUSSION

The results indicate that NH$_4^+$ release is rapid during resuspension events, with flux of up to 85 mg N m$^{-2}$ min$^{-1}$ as measured in laboratory conditions. Much of this flux was measured during the first 15 min of resuspension event. If we assume that there is one resuspension event per day, this flux is approximately three times greater than the diffusive flux. The flux of NH$_4^+$ during resuspension was primarily due to resuspension of the top 8-cm of sediment containing high concentrations of NH$_4^+$. However under field conditions, the amount of NH$_4^+$ released depends on periodicity of resuspension events, which is influenced by climatic conditions such as wind speed. Similar results were also observed by Simon (1988a,b) for the Potomac River Estuary.

Wind induced turbulence may also increase levels
Table 4. Seasonal variation in diffusive flux of ammonium (NH$_4^+$)-N and soluble P (SRP) as calculated from sediment porewater concentration gradients (n = 3 for each sampling period). SD = standard deviation.

<table>
<thead>
<tr>
<th>Sampling period</th>
<th>NH$_4^+$-N (mg m$^{-2}$ d$^{-1}$)</th>
<th>SRP (mg m$^{-3}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 Oct. 1988</td>
<td>18.0</td>
<td>0.7</td>
</tr>
<tr>
<td>10 Jan. 1989</td>
<td>15.8</td>
<td>0.6</td>
</tr>
<tr>
<td>10 Apr. 1989</td>
<td>14.1</td>
<td>0.5</td>
</tr>
<tr>
<td>20 July 1989</td>
<td>26.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Mean</td>
<td>23.8</td>
<td>0.6</td>
</tr>
<tr>
<td>SD</td>
<td>5.6</td>
<td>0.2</td>
</tr>
</tbody>
</table>

of dissolved nutrients in the water column. Therefore, decreased NH$_4^+$ concentration of the water column following resuspension may have been caused by nitrification of NH$_4^+$. In lakes, NO$_3^-$ will rapidly diffuse into bottom sediments where it is subjected to various NO$_3^-$ reductive processes (D'Angelo and Reddy, 1993).

A high degree of variability was observed in SRP release rates during sediment resuspension. The SRP flux during sediment resuspension measured in laboratory conditions was about 2 mg m$^{-2}$ h$^{-1}$. The chemical processes associated with P release by resuspended sediments in the water column are similar to those functioning within the sediment profile, except that resuspended sediments are interacting with an oxygenated water column containing a low concentration of SRP, typically <10 $\mu$g L$^{-1}$. As the particles are resuspended, SRP desorption occurs until a new equilibrium is reached. The equilibrium P concentration is regulated by many factors including: amount of sediment resuspended (total suspended solids concentration of the water), O$_2$ demand of the suspended sediment, SRP concentration of the water column before resuspension, ionic strength, pH, and sorptive characteristics of the sediment particles. Phosphorous flux due to sediment resuspension in 1 h was equivalent to about 2 d flux due to diffusion.

Ammonium N and SRP concentration profiles showed spatial variability, but little temporal variability, suggesting steady-state conditions in the sediment. The NH$_4^+$ diffusive flux from sediment to overlying water column was estimated to be 28 to 40 mg N m$^{-2}$ d$^{-1}$.

The porewater profiles of NH$_4^+$ and SRP at all stations had similar shapes and increased with depths (Fig. 6, 7, and 8). Ammonium concentrations steadily increased below the sediment-water interface. Ammonium-N production in surface sediments was higher than that released during resuspension, as suggested by steady concentration gradients with depth. These results suggest that NH$_4^+$ is steadily diffusing upwards, and that the shape of these profiles is similar to those found in flooded soils (Reddy et al., 1976), and lake and marine sediments (Klump and Martens, 1981).

Soluble reactive P profiles showed two distinct gradient zones. In the surface 8 cm, the porewater SRP concentration was approximately in the same range as that of the overlying water column suggesting that the surface 8-cm sediments are frequently resuspended during wind-driven resuspension, and the SRP released may be assimilated by active plankton in the water column. Soluble reactive P is supplied into the surface 0- to 8-cm depth by steady upward diffusive flux as suggested by sharp changes of the concentration gradients below the 8-cm depth. However, when sediment-water columns were incubated in the laboratory for periods of 1 to 12 mo (Moore et al., 1991), the surface 0- to 8-cm depletion zone disappeared as a result of organic P mineralization and absence of hydrodynamic events. The SRP profiles measured by Moore et al. (1991) showed development of concentration gradients initiating at the sediment-water interface. Sundby et al. (1992) also observed similar profiles in coastal marine sediments, where the P-depletion zone varied seasonally from a 5-cm depth in May to 10 to 15 cm in July. Below this region, SRP concentration increased steadily with depth. They attributed the increase in SRP at lower depth to reduction of iron oxides and mineralization of organic P.

In our study, the sediments were low in Fe and high in organic matter. Decomposition of organic matter and dissolution of phosphate minerals as a result of organic acid accumulation probably resulted in sharp increases in SRP (Moore et al., 1991). The dissolved concentrations of Ca, Mg, and Mn showed similar profiles as those observed for SRP (Moore et al., 1991). We concluded from these observations that dissolved NH$_4^+$ and SRP transport from the surface 8-cm sediment layer was due to release during sediment resuspension, while below the 8-cm sediment depth, upward mobility of dissolved NH$_4^+$ and SRP was governed by diffusion-related processes.

Results of this study show that NH$_4^+$ flux from bottom sediments potentially can increase water column NH$_4^+$ levels by 13 $\mu$g L$^{-1}$ d$^{-1}$. These calculations assume a 2-m water depth and that NH$_4^+$ released from sediments is uniformly mixed in the water column. This represents about 10% of the ambient NH$_4^+$-N (pool) present in the water column, suggesting incorporation of NH$_4^+$-N into particulate organic N. For example, resuspension of particulate N into the water column, followed by mineralization into NH$_4^+$ under aerobic water column conditions, can be one of the major sources of N to the water column (D'Angelo and Reddy, 1993).

Sediment porewater SRP gradients suggest that diffusive flux is the limiting step in P release into the water column. Low SRP in the surface 8-cm sediment layer suggests that P is either assimilated by active plankton in the surface layers or is released into the water during resuspension events (Fig. 7). Diffusive flux of SRP from bottom sediments can potentially increase water column P levels by 0.5 $\mu$g L$^{-1}$ d$^{-1}$ representing about 17% of the ambient SRP levels in the water column. Carrick et al. (1993) found that plankton mats, existing in close proximity to Lake Apokla sediments, are photosynthetically active and viable, suggesting that P released from bottom sediments can be readily assimilated by these organisms. It appears then that quasi-benthic algae are functioning as an active sink for P released from sediments.

The apparent importance of the diffusive flux of P to the water column has significant implications for lake reclamation. If external nutrient loads are curtailed, C and N fixation will continue to maintain plankton productivity until P limitation occurs in the system. This will result in deposition of planktonic matter with high C/P
and N/P ratios. At present, sediment accretion rates in Lake Apopka are approximately about 1 cm yr⁻¹ (Reddy and Graetz, 1990). Phosphorus load reduction associated with deposition of planktonic matter of high C/P ratios will create boundary layers at the sediment-water interface that may potentially function as a sink for P released from underlying sediment. In bottom UCF sediments (30-cm depth), about 20% of the total P is in the labile pool (Oliila et al., 1994). At the current rate of diffusive flux, this pool of P can potentially be mobilized from bottom sediment layers to surface layers in about 5 to 8 yr. Thus, if external loads are reduced, internal turnover may reduce P load from the bottom sediments, perhaps shifting Lake Apopka from hypereutrophic to a eutrophic condition.

CONCLUSIONS

Sediment resuspension and diffusive fluxes of NH₄ and SRP appear to be responsible for the development of the observed porewater concentration gradients in Lake Apopka. The SRP concentration of the porewater in the surface 8-cm sediment layer is approximately the same as the overlying water column. This may be due to disruption of the surface 8-cm sediment layer as a result of resuspension into the water column.

Average diffusive flux was estimated to be 25 mg NH₄-N m⁻² d⁻¹ and 1 mg P m⁻² d⁻¹. Although dissolved N and P flux is upwards (from sediment to water column), over extended periods (annual cycle) the lake is functioning as a net sink for N and P by transforming inorganic pools of nutrients into organic forms and depositing them at the sediment surface. The current hypereutrophic condition in Lake Apopka may be self-perpetuating. In the short term, reduction of external loading may not result in significant changes in the degree of eutrophication. After the external loads are curtailed, diffusive and resuspension flux from bottom sediments can potentially support the current trophic level of the lake until P limitation is created. Over a long period (several years), nutrient limitation may eventually occur in the lake as a result of reduction in nutrient supply from bottom sediments. Future reclamation techniques should aim at reducing labile pools of N and P in the sediment, which will reduce the rate of nutrient flux from bottom sediments as a result of diffusion and resuspension.

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