SOME OBSERVATIONS ON PHOSPHOROUS IN ATTERSEE, MONDSEE, AND FUSCHLSEE SEDIMENTS

A. GUNATILAKA

Introduction

Progressive enrichment of lakes with nutrients has led to serious eutrophication problems and it represents one of the central problems in pollution management. The pollution research carried out in last two decades clearly showes that increasing input of nutrients is the main cause of eutrophication. Due to larger residence time, nutrients in sediments are more stable than those in the water column.

GOLTERMAN (1966) showed that sediments can play a critical role in determining the trophic state of a lake. A study of sediments could help in understanding eutrophication processes taking place in the over lying water column and such knowledge will also help in drawing up programmes for lake management.

A preliminary investigation of sediment was carried out in Attersee - Mondsee - Fuschlsee lake-chain, in order to establish nutrient profiles in sediments. The main objective of this work was to find the state of

Phosphorous in these three lakes.

The early work of EINSELE (1936, 1938) and MORTIMER (1941, 1942) gave the indication that the phosphorous exchange at the sediment-water interface of lakes has been controlled by some physical (temperature) and chemical (oxidation-reduction) conditions and stressed the importance of redox-potential of the sediments in controlling phosphorous release to the water. BANOUB (1975) and KAMP-NIELSON (1975) proved that temperature and phosphorous release rates are directly related. However, recent work (PROCELLA et al. 1970; KAMP-NIELSON 1974, 1975 a and b; DAVIS et al. 1975) indicates that phosphorous will move into well-oxygenated water through surface mud that presumably has a high redox potential. It was shown that micro-organisms are responsible for this release and hence bacteria and algae considered to be important.

The biotic role of animals in this exchange processes seems to be significant. The work of EDWARDS (1958), TESSENOW (1964), DAVIS (1974 a and b), DAVIS et al. (1975), GALLEP et al. (1978) and GALLEP (1979) demonstrated the role of Chironomids and Oligocheats in nutrient release from sediments.

Materials and methods

Sediment samples were collected from deepest part of lakes (Attersee: 170 m Unterach, 100 m Weyregg - Mondsee: 65 m - Fuschlsee: 68 m), once in early Spring and again in late Autumn using a modified Kajak corer (NEWRKLA 1977). The water overlying the sediment was emptied carefully with a slow working suction pump under reduced pressure. The sediment cores were cut into 1 cm thick slices; slices from following depths were collected for further analysis: surface, 2, 3, 4, 5, 8, 10, 15, and 20 cm respectively. Duplicate samples were air dried for chemical analysis.

Sediment samples were ignited at 450°C in a muffle oven for 24 hrs; the difference in the weight at 105°C (for moisture determination) and the loss in weight after muffling was taken as the ignition weight loss and is expressed as percentage organic carbon.

Total phosphate was determined after persulphate oxidation (RAVEH et al. 1979). 100 mg sediment samples were mixed with 50 ml distilled, deionized water and 5 g Potassium persulphate in large boiling tubes. The tubes were covered with aluminium foil and autoclaved for two hours at 1,5 atm pressure. Phosphorous was determined by MURPHY and RILEY (1962) method STRICKLAND & PARSONS (1967). Inorganic phosphate was determined separately on muffled (450°C) samples, digested in the same manner. The difference between the total-P and inorganic-P fractions were taken as the organic-P content. In addition from the late Autumn series total nitrogen also was determined in order to establish C:P:N ratios. The same persulphate digestion was used here: after cooling 1 g Devardas alloy was added to each test tube to convert all the nitrates into ammonium. Nitrogen was determined as Ammonium using modified SOLORZANO (1969) method (SCHREINER (1976)).

Results:

A general description of the sediments is given in table 1 and nutrient analysis data are summarised in Tables 2 - 7.

The surface sediments in these three lakes show distinct differences in appearance. The colour of the spring surface sediment appeared to be paler than the autumn sediment. Lamination was observed in the first few cm of both Mondsee and Fuschlsee sediments with Mondsee sediments showing very clear striations. As the samples were taken at the maximum depth (point of highest sedimentation), the first few cm of the sediment (ca. 5-8 cm; see Table 1) were mixed with a small percentage of undecomposed vegetative material imported from the catchment. With depth, sediments become more compact and solid due to the presence of a higher percentage of fine clay. They also appered to be highly reduced. An increase in the negative redox potential was observed within the first cm of all three sediments and according to their respective redox profile, they could be arranged in the following descending order: Mondsee >Fuschlsee >Attersee (-120 to -480; +5 to -350 and +5 to -120 E_{Pt}mV respectively).

The surface sediments contained a higher percentage of water (60 - 85 %), which showed a gradual decrease with depth. However, there were no characteristic differences between the three sediment types. Loss in ignition at 450^{o}C which correspond to the organic carbon content of the sediment indicated a similar distribution pattern in all sediments. The organic carbon content decreases with depth with a conspicuous drop in the first 5 cm (for spring 20 - 36 %; Autumn 17 %). At depths below 5 cm it fluctuates within a narrow range. In Attersee, surface sediments appeared to contain a higher percentage of organic matter in Spring whereas Mondsee and Fuschlsee show a slight overall increase in Autumn.

Analytical data given in tables 2-7 show different levels of nutrient accumulation in sediments with Attersee showing a minimum. Total-P concentration is highest in Mondsee sediments (Spring 418-764; 533-705 in Autumn) which is approximately three times the concentration in Attersee (Spring 203-225; Autumn 206-311 microgramm/g). Fuschlsee has a slightly higher concentration (Autmn 258-336; Spring 273-317 microgramm/g) than Attersee. The general trend is decrease in concentration with depth, which is characteristic for all three lakes. In general, spring concentrations are slightly higher for Mondsee and Fuschlsee but they lie more or less within the same range as Attersee. Inorganic phosphorous concentrations show wide fluctuations either in vertical distribution or between the three sediment types. Organic phosphorous show similarities in distribution in all three lakes but there is a slight decrease in Autumn.

Total-Nitrogen (T-N: Kjeldahl-N + Ammonium + nitrate + + nitrite) values are available only for Autumn. The T-N content is fairly high in Mondsee (13,6 - 17 mg/g) and Fuschlsee (ca. 17 mg/g) surface sediments (first 5 cm) but the concentration is slightly lower in Attersee (9 - 12 mg/g). In vertical distribution of T-N, Mondsee and Fuschlsee show similarities (10 - 15 mg/g).

C:P ratio is lowest for Mondsee (127-249) while it is twice as much for Fuschlsee (261-467) and Attersee (269-409). The order of magnitude of C:N in Mondsee: 7,3-4,6; Fuschlsee: 8,1-4,2; Attersee: 5,5 - 10,6.

N:P ratio for Autumn show some interesting similarities and differences; it is similar in that it increases with depth but differs widely in magnitude (Mondsee 20-36; Attersee: 33-54; Fuschlsee: 42-78).

Discussion:

The exchange of P between bottom sediments and overlying water is important in the phosphorous budget of lakes

(STUMM & LEKIE 1971, IMBODEN 1974). Generally the lakes act as phosphate traps either by sedimentation of organic material, adsorption, or precipitation of inorganic phosphate (STRASKRABOVA et al. 1973, PROCHEZKOVA et al 1973).

In the Attersee-Mondsee-Fuschlsee lake - chain the phosphorous loading is considerably high; this can be seen from the following figures given by MÜLLER (1979),MOOG (1980).

Critical loading, real phosphorous-input and P-input as a percentage value of critical loading

	Critical loading	Real P-input (1978)	Percentage
Fuschlsee	1000	1250	125
Mondsee	9750	7240	74
Attersee	19740	10540	54
		(1979)	
Fuschlsee		-	-
Mondsee		10760	110
Attersee		13780	70

The phosphate thus brought enters either the food chain and is ultimately sedimented, or precipitated as inorganic phosphate. The inorganic binding of phosphorous usually ascribed to formation of minerals with Al, Fe, Ca or to adsorption or ion exchange, especially with clay minerals, metal oxides or metal hydroxides (STUMM& MORGAN 1970, GOLTERMAN 1976).

Lake sediments bear evidence to processes taking place in the overlying water column. Thus some of the processes outlined above are reflected by the physical and chemical characteristics of the sediments.

The sedimenting algal biomass contributes much to T-P, T-N and also in this case to the sediment colour. In meso-oligotrophic Attersee, the algal community is dominated by diatoms and hence surface sediments are pale grey in colour. In eutrophic Mondsee and Fuschlsee the major contribution to the algal biomass comes from Oscillatoria rubescens; the purple pigmet from it is responsible for highly coloured laminations. Distinct thicker lamination in Mondsee show comparatively higher sedimentation rates (Table 1). This has resulted in slightly higher carbon values: the overall Spring values are slightly higher than the Autumn values. The impact cf the high algal biomass is clearly indicated by comparatively high T-N values in Autumn samples of Mondsee and Fuschlsee (tables 5 - 7).

Both allochthonous and autochthonous material contribute to high sediment T-P values. High algal biomass and probably the loading from inputs contribute much to the high phosphate values in Mondsee and Fuschlsee. Attersee Autumn samples are from the more eutrophicated Weyregg-bay and hence may be the increased T-P values. In contrast the drop in concentration of T-P in superficial sediments of Mondsee and Fuschlsee indicate a positive P-flux to the hypolimnion. Organic-P does not show much variation but it is probable that oxygen consumption of the sedimented plankton exceeds the oxygen transfer from the overlying sediment and thus contributing towards an oxygen depletion.

The mean N P ratio for the first three cm of Mondsee, Attersee and Fuschlsee sediments are 20, 37 and 54 respectively.From the algal phosphorous ratio of 15:1 (from VOLLENWEIDER 1969), one could assume that allochthonous sedimentation exceeds by far the autochthonous sedimentation. However there seem to be a significant contribution to autuchthonous sedimentation in Mondsee.

In contrast to the overlying water, phosphorous content of the sediments in these lakes appear to be higher by atleast one order (tables 2 - 7); this implies that a large amount of nutrients are beeing buried in sediments. As this phosphorous could be released from sediments from time to time, it can play an important role in eutrophication processes.

The release of phosphate may result from:
1) increased temperature, 2) increase in pH, 3) change in redox conditions and 4) bioturbation.
Figure 1 summarizes the major phosphorous forms and transformation pathways (after SCAVIA 1979).

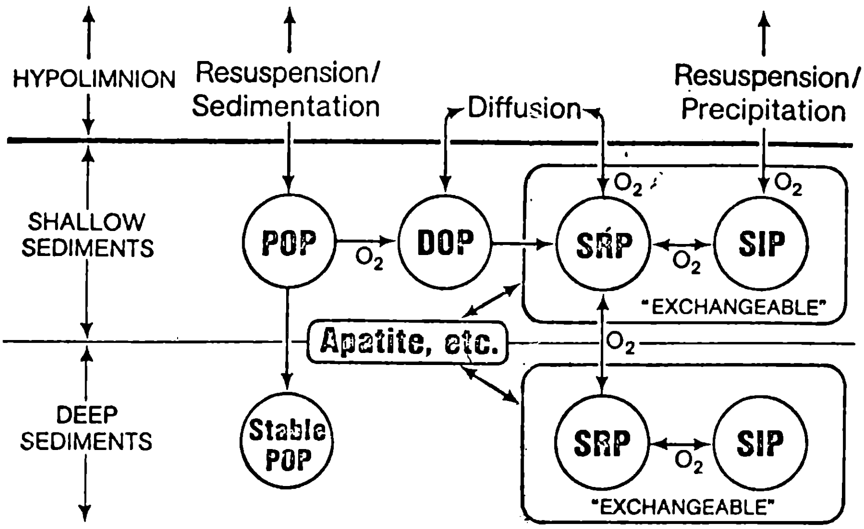

Figure 1. Suggested mechanism of phosphorus transformation and movement in the deep water/sediment zone. POP = particulate organic phosphorus, DOP = dissolved nonreactive phosphorus, SRP = soluble reactive phosphorus, SIP = sorbed inorganic phosphorus; arrows labeled with O_2 are affected by oxygen content.

An increase in temperature will tend to liberate some of the inorganically adsorbed phosphate. Also increased biological activity at a higher temperature, will aid in releasing phosphorous. The exchange processes are governed by diffusion coefficients a) within sediment, b) within water column, and c) sediment-water interface.

The pH of the sediment and the hypolimnetic water controls various precipitation and sorption processes. The inorganic binding of phosphate with Ca (II), Al (III), and Fe (III) is dependent on pH (STUMM & MORGAN 1970, KAMP-NIELSEN 1974 and LIJKLEMA (1977).

The oxigen concentration or redox-potentials of the water column and sediments are probably the most important criteria in determining the magnitude of the exchange of nutrients between the water column and sediments. Low oxygen and high phosphorous concentrations have been observed near lake bottoms in Mondsee (JAGSCH 1979) and Fuschlsee (HASLAUER 1979). They have also observed an increase of almost ten fold in total phosphate concentration in bottom waters (Mondsee: 40 microgramm/l at the surface, 300 at the bottom; Fuschlsee: 59 microgramm/l at the surface, 352 at the bottom) at the end of summer stagnation. The sediments taken in Autumn 1979 show that they were strongly reduced. (Low redox-potentials and traces of sulfide in overlying water, 0,28 - 0,31 m.mol/l; the scattered black patches in sediments probably due to FeS).

The oxidized microzone on the sediment surface suppresses P-release from lake sediments, although phosphorous does not move into overlying water under aerobic conditions. When the zone becomes reduced during anaerobic periods, such as seen in Mondsee and Fuschlsee during summer stagnation, phosphorous diffuses from the area of high concentration, the sediment, into the overlying water.

Phosphorous diffusing from the sediment to the hypolimnion may not be immediately available to the algae in the euphotic zone. Possibly a more direct source of P for summer algal growth is sediment in contact with the epilimnetic water. Because this area is oxygenated, it has a greater potential for diverse animal-sediment interactions which might faciliate nutrient regeneration.

The effects of benthic macroinvertebrates (chironomids, oligochaets) on the sediment-water exchange may be significant. The role of worm populations in preventing the build-up of organic matter and inducing nutrient cycling is very important.

They also increase oxygen penetration into the sediment and increase redox-potentials in the surface layers of mud (EWARDS 1958). BRINKHURST (1972) and WOOD (1975) using dye tracer, found that macroinvertebrates had a significant influence on the transport of solutes between the sediment and water column through pumping mechanisms. This would definitely result in accelerated diffusion rates.

We have no detailed information about chironimid and oligochaete populations in these three lakes but they are common members of the lake biots. From published work - EDWARDS (1958), TESSENOV (1964), BRINKHURST (1972), WOOD (1975), DAVIS (1974 a & b), DAVIS et al. (1975), GALLEP et al. (1978) and GALLEP (1979) - one could conclude that they play a positive role in the release of P from sediments as they are known to be important agents of bioturbation and effect sediment chemistry including redox and pH.

There is no doubt that the processes operating in the superficial sediments of lakes can significantly influence overlying water. BANNERMAN et al (1975) have estimated sediment-derived phosphorous loads of lake Ontario to be ten percent of the stream loads. BURNS & ROSS (1972) estimated the load of P from lake Erie sediments to be 137 % of the external load during the two critical sommer months when the hypolimnion of the central basin was anoxic. A similar oxygen depletion is observed both in Mondsee and Fuschlsee at the end of summer stagnation with a corresponding increase in P in the hypolimnion. This indicates that superficial sediments are playing an important role in the P-budget, especially in these two lakes.

Sediments act as a sink for phosphates (which become bound to Fe III-oxides), as long as the P-loading of the lake is small, and as long as dissolved O_2 prevails at the sediment-water interface. As soon as the loading exceeds a critical limit, a significant lowering of the redox intensity at the sediment-water interface results in a reversal of the feed-back mechanism of P-regulation; under anaerobic conditions, sediments release P-accumulated in earlier years. According to MÜLLER (1979), of the three lakes, only Attersee is under critical loading limits. However, this does not mean that one has to ignore the changes that are taking place in Mondsee and Fuschlsee. Precautions taken in time could prevent acceleration of eutrophication processes.

	Attersee	Mondsee	Fuschlsee
Water depth & sampling	170 m Unterach 15.04.1979	65 m 16.04.1979	68 m 17.04.1979
	100 m Weyregg 12.11.1979	56 m 13.11.1979	68 m 14.11.1979
Depth			
1 - 5	Yellowish-pale brown (spring) Brownish-grey (Autumn), mixed with organic debris of lower density; inhomogenous	Black fluffy (Spring) changed to purple greyish black in Autumn; lamination-clear alternating striations (0,5-0,7 cm thick); inhomogenous; mixed with vegetative matter; S^{2-}prs. in Autumn: 0,28 m.mol/l.	Black fluffy (Spring); purple greyish black in Autumn; less distinct lamination; fluffy material lighter in density up to 3 cm; inhomogenous; S^{2-}prs. in Autumn: 0,31 m.mol/l in surface water.
5 - 10	Inhomogenous; more silt and clay; grey colour; black patches: scattered; occasional vegetative litter	Black gyttja like sed. upto 8 cm; sed. below with more composed material - grey in colour	Dark grey sed. with finer constituency followed by black sediments
10 - 15	Light grey sed. with fine clay; Autumn colour changed to black.	Dark grey fine sediments; (darker than Fuschlsee).	Dark grey sediments; homogenous; well decomposed.

Table 1: Sediment description and physical charakteristics

Depth (cm)	T-P	% I-P	% O-P	% water content	% loss in ignition
1	234.4	87.3	12.7	72.13	8.54
2	236.2	83.8	16.2	56.32	7.49
3	215.5	86.5	13.5	50.63	6.76
4	209.6	87.9	12.1	52.28	6.90
5	201.3	66.4	33.6	47.18	6.87
8	167.5	87.8	12.2	44.56	6.68
10	204.1	74.1	25.9	42.52	5.66
15	195.1	71.0	29.0	47.62	6.71

Table 2: Phosphorous content in Attersee sediments. Sediments from Unterarch at 170 m depth taken on 26.4. 1979. Total phosphorous (T-P) in ug/g, inorganic phosphorous (I-P), organic phosphorous (O-P) as percentages. Weights expressed as per gram dry sediments (105^{o}C).

Depth (cm)	T-P	% I-P	% O-P	% water content	% loss in ignition
1	802.5	84.9	15.1	84.85	11.22
2	649.4	84.6	15.4	68.36	.23
3	589.7	76.9	23.1	61.39	8.96
4	438.1	55.3	44.7	58.56	4.98
5	403.4	68.2	31.8	64.27	7.20
8	309.2	73.6	26.4	79.06	6.39
10	337.2	77.9	22.3	56.77	5.51
15	275.6	82.6	17.4	52.48	7.12

Table 3: Phosphorous content in Mondsee sediments. Sediments taken at 65m depth on 26.4.1979. Total phosphorous (T-P) in ug/g, inorganic phosphorous (I-P), organic phosphorous (O-P) as percentages. Weights expressed as per gram dry sediments (105^{o}C).

Depth (cm)	T-P	% I-P	% O-P	% water content	% loss in ignition
1	305.1	86.9	13.1	87.31	10.90
2	258.3	84.8	15.2	82.63	9.45
3	336.4	75.0	25.0	81.82	7.52
4	272.6	80.9	19.1	80.60	7.55
5	267.4	83.7	16.3	69.45	8.39
8	240.6	75.9	24.1	64.43	8.14
10	213.1	83.7	16.3	53.53	6.88
15	158,3	82.9	17.1	50.91	6.96

Table 4: Phosphorous content in Fuschlsee sediments. Sediments taken at 68 m depth on 27.4.1979. Total phosphorous (T-P) in ug/g, inorganic phosphorous (I-P), O-P organic phosphorous as percentages. Weights expressed as per gram dry sediments (105^{o}C).

Depth (cm)	T-P	% I-P	% O-P	% water content	% loss in ignition	T-N
1	276.3	87.3	12.7	80.18	9.78	9.2
2	310.6	87.1	12.9	78.54	9.18	11.3
3	239.5	87.8	12.2	76.90	8.49	10.1
4	225.6	89.2	10.8	76.12	7.12	12.3
5	219.0	82.2	17.8	74.55	8.10	11.8
8	222.4	82.6	17.4	65.33	7.48	7.3
10	237.2	83.5	16.5	65.15	8.16	8.4
15	223.1	86.8	13.2	60.88	6.68	8.6
20	215.3	77.9	22.1	60.82	6.50	7.8

Table 5: Nutrient content in Attersee sediments. Sediments from Weyregg-bay at 100m depth taken on 14.11.1979. Total phosphorous (T-P) in ug/g, inorganic phosphorous (I-P), organic phosphorous as percentages and total nitrogen (T-N) in mg/g; expressed as weight per gram dry sediment (105^{o}C)

Depth (cm)	T -P	% I-P	% O-P	% water content	% loss in ignition	T-N
1	650.4	83.6	16.4	85.09	9.35	13.6
2	681.5	80.7	19.3	80.87	9.97	13.7
3	705.4	80.4	19.6	76.77	8.95	14.1
4	533.4	77.4	22.6	76.23	7.85	17.0
5	419.7	74.4	25.6	76.92	7.70	15.3
8	338.5	70.7	29.3	66.58	8.43	11.2
10	333.3	73.6	26.4	66.96	6.07	11.5
15	324.8	76.8	23.2	63.12	7.09	10.8
20	306.3	77.9	22.1	61.01	6.70	10.8

Table 6: Nutrient content in Mondsee sediments. Sediment from 65m depth taken on 14.11.1979. Total phosphorous (T-P) in ug/g, inorganic phosphorous (I-P), organic phosphorous (O-P) as percentages and total nitrogen (T-N) in mg/g; expressed as weight per gram dry sediment(105°C).

Depth (cm)	T-P	% I-P	% O-P	% water content	% ignition loss	T-N
1	293.3	84.5	15.5	80.90	9.78	16.9
2	304.0	84.4	15.6	66.96	9.18	15.8
3	317.5	85.7	14.3	63.67	8.49	16.8
4	273.3	86.8	13.2	60.45	7.12	16.9
5	268.2	88.1	11.9	62.89	8.10	14.4
8	252.9	88.3	11.7	59.86	7.48	14.1
10	239.5	86.4	13.6	59.87	8.16	10.1
15	192.4	87.2	12.8	57.19	6.68	10.4
20	139.1	84.5	15.5	55.92	6.50	10.9

Table - 7: Nutrient content in Fuschlsee sediments sediments from 68m depth taken on 15.11.1979. Total phosphorous (T-P) in ug/g, inorganic phosphorous (I-P), organic phosphorous (O-P) as percentages and total nitrogen (T-N) in mg/g; expressed as weight per gram dry sediments ($105^{\circ}C$).

References:

BANNERMANN, R. T., D. E. ARMSTRONG, R. F. HARRIS & G. C. HOLDEN (1975): Phosphorous uptake and release by lake Ontario sediments.- U.S. Environm. Protect. Ag., Corvallis, Oregon EPA-600/375006.

BANOUB, M. W. (1975): Verh. Internat. Verein. Limnol. 19: 1263-1271.

BRINKHURST, R. O. (1972): The role of sludge worms in eutrophication.- U.S. Environm. Protect. Ag., Corvallis, Oregon, EPA/R 3-72004.

BURNS, N. M. & C. ROSS (1972): Oxygen-nutrient relationships within the central basin of lake Erie.- in: "Nutrients in Natural Waters", H. E. ALLEN & J. R. KRAMER, Eds., Wiley & Sons, NY: 193p.

DAVIS, R. W., D. L. THURLOW & F. E. BREWSTER (1975): Verh. Internat. Verein. Limnol. 19: 1080-1087.

DAVIS, R. B. (1974 a): Limnol. Oceanogr. 19: 466-487.

-"- (1974 b): ibidem 19: 342-346.

EDWARDS, R. W. (1958): Ann. Appl. Biol. 46: 457-464.

EINSELE, W. (1936): Arch. Hydrobiol. 29: 664-686.

-"- (1941): Z. Fisch. 39: 407-488.

GALLEP, G. W., J. F. KITCHELL & S. M. BARTELL (1978): Verh. Internat. Verein. Limnol. 20: 458-465.

GALLEP, G. W. (1979): Ecology 60: 547-556.

GOLTERMAN, H. L. (1976): Influence of the mud on the chemistry of water in relation to productivity.- in: H. L. GOLTERMAN & R. S. CLYMO eds., Chemical environment in the aquatic habitat: 297-313.

GOLTERMAN, H. L. (1977): Sediments as a source of phosphate for algal growth.- in: Interaction between sediments and freshwater, Ed. H. L. Goltermann, Proc. Int. Sym. Amsterdam 1976: 286-293. Junk B. V. Publishers.

IMBODEN, D. M. (1974): Limnol. Oceanogr. 19: 297-304.

HASLAUER, J. (1979): Arb. Lab Weyregg 3: 53-67.

JAGSCH, A. (1979): Arb. Lab. Weyregg 3: 68-82.

KAMP-NIELSEN, L. (1974): Aroh. Hydrobiol 73: 218-237.

-"- (1975 a): Ecol. Model. 1: 153-160.

-"- (1975 b): Verh. Internat. Verein. Limnol. 19: 1057-1065.

LIJKLEMA, L. (1977): The role of iron in the exchange of phosphate between water and sediments.- in: Interactions between sediments and freshwater, Ed.: H. L. GOLTERMAN, Proc. Int. Sym. Amsterdam 1976: 313-317.

MORTIMER, C. H. (1941): J. Ecol. 29: 280-329.

-"- (1942): J. Ecol. 30: 147-201.

MÜLLER, G. (1979): Arb. Lab. Weyregg 3: 18-36.

NEWRKLA, P. (1977): Arb. Lab. Weyregg 2: 109-116.

PROCELLA, D. B., KUMAGAI, T. S. & MIDDLEBROOKS, E. J. (1970): J. San. Eng. Division; Proc. Amer. Soc. Civil Eng. 96: 911-926.

PROCHAZKOVA, L., V. STRASKRABOVA & J. POPOVSKY (1973): Hydrobiol. Stud. 2: 83-154.

RAVEH, A. & AUNNIMELECH (1979): Water Res. 13: 911-912.

SCAVIA, D. (1979): The use of ecological models of lakes in synthesizing available information and identifying research needs.- in: Perspectives on lake modeling, Ed. D. SCAVIA, Ann Arbor Science.

SCHEINER, D. (1976): Water. Res. 10: 31-36.

STRASKRABOVA, V., PROCHAZKOVA, L. & J. POPOVSKY (1973): Hydrobiol. Stud. 2: 316-348.

STRICKLAND, J. D. H. T. R. PARSONS (1967): Bull. Fish. Res. Bd. Can. 167: 310.

STUMM, W. & J. J. MORGAN (1970): Aquatic Chemistry - Wiley Int., NY, 583 p.

VOLLENWEIDER, R A. (1968): OECD Report DAS/CSI/ 68. 27

WOOD, L. W. (1975): Verh. Internat. Verein.Limnol. 19: 1530-1533.

Zeitschrift/Journal: Arbeiten aus dem Labor Weyregg

Jahr/Year: 1980

Band/Volume: 4_1980

Autor(en)/Author(s): Gunatilaka A.

Artikel/Article: SOME OBSERVATIONS ON PHOSPHOROUS IN ATTERSEE, MONDSEE, AND FUSCHLSEE SEDIMENTS 213-234