The Availability of Sediment Phosphate to Algae

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Abstract

This study was undertaken to determine whether there is any relationship between the amount of phosphate extracted from a sample of sediment by chemical means, and the growth rate of *Selenastrum capricornutum,* when the same sediment is used as the sole source of phosphate in a nutrient medium. It was found that variable amounts of phosphate were utilized by the algae when different types of sediments were used. The amount of phosphate consumed by the algae correlated significantly with the inorganic phosphate content of the sediment, measured chemically, and the amount of phosphate correlated significantly with the amount of phosphate extracted by the nitrilotriacetic acid (NTA) procedure. There was a non-linear relationship between algal available phosphate and inorganic phosphate; the available phosphate varied between 4% and 98% of the inorganic phosphate, depending on the type of sediment used. The relationship between NTA extracted phosphate and algal available phosphate was linear, even when different types of sediment were used. There were major differences in the amount of available phosphate in the sediment for different sampling times at the same point. The amount of available phosphate also varied at different points in an impoundment, sampled at the same time.

The results of this study indicate that the sediment-bound phosphate was a ready source of phosphate for growth. The presence of this bound phosphate in a dam may lead to algal blooms over a long period of time. This has major implications for dam management and eutrophication control, of dams containing sediment-bound phosphate.

Introduction

Eutrophication may be defined as the enrichment of a water body by plant nutrients. Orthophosphate is one of the important plant nutrients involved in the eutrophication process and it was suggested that measures to control eutrophication should be directed at the removal of phosphate from effluents (Toerien, 1977). We have established that a major portion (>80%) of the total phosphate content of a stream could be bound to the suspended sediment and in this way be transported to an impoundment. Some of the phosphate bound to the sediment will settle out with the coarser sediment particles. However, a major portion of the phosphate entering a water body may accumulate in the bottom sediments from which it can be eventually released (Stumm and Leckie, 1971; Golterman, 1973a, b; Emsley, 1977).

A portion of the phosphate bound to the finer sediment particles will stay suspended in the water column for extended periods. Some of the phosphate bound to sediment particles may become available for algal growth.

The general standards (Regional Standards for Industrial Effluents, 1962) for the discharge of industrial effluents proclaimed in terms of the Water Act (Act 54 of 1956) contain no standard for phosphate. It is a recognised shortcoming of the existing standards. The introduction of a standard for phosphate is at present being considered by the Department of Water Affairs. Such an introduction, requiring a lower level of phosphate than at present found in watercourses, will have financial implications, the severity of which will be governed by the standard set.

In view of the above, it has become necessary to obtain information on how much phosphate is bound to and transported by sediment. It is also necessary to determine to what extent the bound phosphate may become available for algal growth, when the level of soluble phosphate is reduced to growth limiting levels.

It has been customary to determine the amount of algal available phosphate bound to sediment by chemical procedures, such as dilute acid extractions. Relatively few attempts at measuring the availability of sediment phosphate to algae have been made by using algae in bioassays (Porcella, Kumagai and Middlebrooks, 1970; Sagher, Harris and Armstrong, 1975; Cowen and Lee, 1976; Lee, Rast and Jones, 1978). Contradictory results have been obtained. This study was therefore undertaken, to determine what proportion of the sediment bound phosphate might be biologically available and to what extent the biologically available phosphate could be estimated by means of chemical methods.

Materials and Methods

Sediments

A total of 15 sediment samples were collected on three occasions at the following five Department of Water Affairs' registered sampling stations: C9R02 — 003 (B3), C9R02 — 006 (B6), C9R02 — 009 (B9) in Bloemhof Dam, C3R01 — 003 (S3) in Spitskop Dam and C9R01 — 001 (V1), in the Vaalharts Weir (Figure 1). Bloemhof Dam and the Vaalharts Weir are situated in the Vaal River catchment whilst the Spitskop Dam lies in the Harts River catchment.

Detailed data on the chemical quality of the overlying water at each of these stations can be obtained from the Department of Water Affairs Data Bank.

All three impoundments are turbid (Bruwer and Claassens, 1978) and shallow (Burke, 1977). Means of Monthly Secchi Disc readings taken over a year in 1978 were 0,9 m, 0,6 m, and 0,4 m respectively for Bloemhof Dam, Spitskop Dam and Vaalharts Weir. The mean depths were 5,6 m, 2,8 m and 3,0 m respectively.

Bottom sediments were collected with a Birge-Ekman grab and stored in glass bottles for between five and seven days until they could be transported to the laboratory. The samples were freeze dried in stainless steel trays. The dry sediments were ground with a tungsten-blade analytical mill, until they passed through a 1 mm sieve. The pulverized samples were stored in glass bottles until analyzed.

Bioassays

The availability of phosphate associated with sediment to algae was determined by supplying a test algal with sediment as its only source of phosphate in BG — 11 nutrient medium. BG — 11 was prepared as described by Stanier, Kunisawa, Mandel and Cohen-Bazire, (1971), with the omission of phosphate.

Selenastrum capricornutum was used as the test organism (Toerien, Huang, Radimsky, Pearson and Scherfig, 1971). Sediment was supplied at a rate of 0,1 g/50 cm^3 of nutrient medium.

The bioassays were done in 50 cm^3 batch cultures in 100 cm^3 conical flasks under specified light conditions (Toerien *et al.*, 1971). The cultures were aerated by air which was passed through concentrated sulphuric acid, activated charcoal, water and cotton wool consecutively. Each bioassay was done in

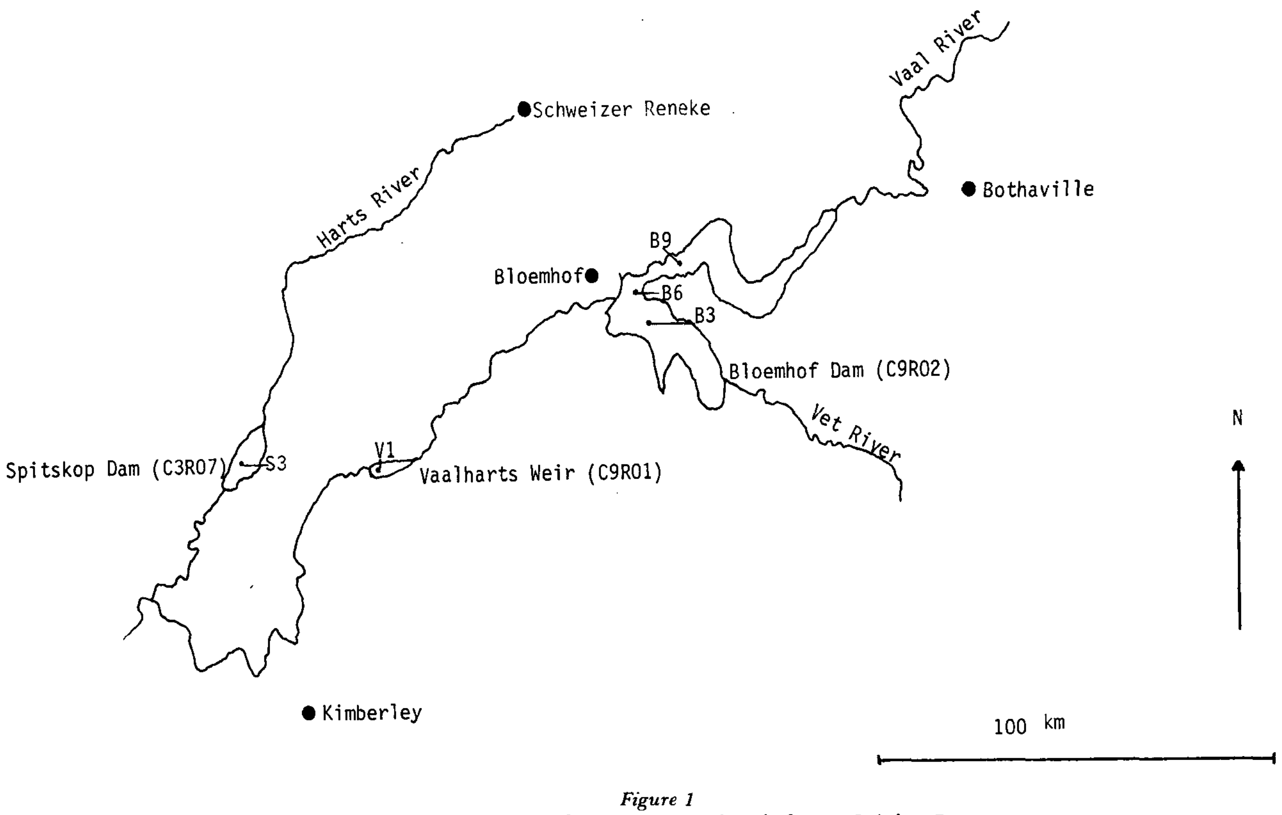

Figure 1
A map showing the sampling stations on Bloemhof Dam, Spitskop Dam and Vaalharts Weir

triplicate. The algae were grown for 21 d after inoculation to ensure that steady state conditions were reached and that growth was limited by the availability of sediment phosphate in the cultures. This period was decided upon after preliminary experimental work had shown that steady state conditions were reached after 14 d in all cases. This is also in accord with the findings by Toerien *et al.* (1971) for *Selenastrum capricornutum.*

Algal biomass was estimated by an adaption of the Walkley-Black method (Jackson, 1958) for determination of organic carbon (Grobler and Davies, 1979).

Chemical Analyses

The sediment samples were analysed for: cation exchange capacity (CEC) (Loveday, 1974); total phosphate (TP); inorganic phosphate (IP) and organic phosphate (OP) (Aspilla, Agemian and Chau, 1974). The dilute hydrochloric acid — dilute fluoride extractable phosphate (Bray-2-P) (Jackson, 1958), nitrilotriacetic acid extractable phosphate (NTA-P) (Golterman, 1976), Kjeldahl nitrogen (TKN) (Grobler, 1976) and organic carbon (OC) (Jackson, 1958) content of the sediments were also determined.

Statistical Methods

Means of algal available phosphate content of the different sediments were compared for statistical differences by analyses of variance using the F-test. The F-value, coefficient of variation (CV) and least significant differences, according to the Student-Newman-Keuls (SNK) procedure, were calculated with the aid of the computer program P/BLKOV. Multiple linear regressions were calculated with the aid of program P/MLREG and linear regression with the aid of program P/REPOL. The documentation of all the computer programs used is available at the Biometrics section of the Department of Agricultural Technical Services.

TABLE 1
CATION EXCHANGE CAPACITY (CEC); ORGANIC CARBON (OC); KJELDAHL NITROGEN (TKN) AS N; TOTAL PHOSPHATE (TP) AS P; INORGANIC PHOSPHATE (IP) AS P; ORGANIC PHOSPHATE (OP) AS P; NITRILOTRIACETIC ACID EXTRACTABLE PHOSPHATE (NTA-P) AS P AND PHOSPHATE EXTRACTABLE BY BRAY-REAGENT (BRAY-2-P) AS P FOR THE SEDIMENT SAMPLES USED IN THE ALGAL BIOASSAYS

Station and date collected		mmol/kg CEC	% OC	mg/kg TKN	TP	IP	OP	NTA-P	Bray-2-P
VI	1/78	43,1	0,61	950	392	237	55	24,6	1,3
	2/78	32,3	0,60	932	305	235	70	19,2	1,1
	3/78	42,9	0,60	850	296	248	48	18,6	1,4
B3	1/78	6,7	0,25	340	98	85	13	6,0	22,3
	2/78	11,0	0,45	700	185	130	55	26,4	27,6
	3/78	8,3	0,12	275	125	105	20	12,0	25,8
B6	1/78	50,4	0,62	1 420	498	394	104	49,5	16,0
	2/78	41,9	0,54	1 440	500	375	125	60,0	17,2
	3/78	55,0	0,67	1 500	475	373	102	62,4	14,2
B9	1/78	41,8	1,53	2 160	540	405	169	54,6	17,5
	2/78	39,0	0,79	1 572	510	330	130	55,8	17,6
	3/78	50,8	0,81	1 300	694	395	299	61,8	17,6
S3	1/78	38,9	1,33	1 470	660	505	155	28,8	22,6
	2/78	36,2	2,12	1 660	690	500	190	24,6	21,7
	3/78	40,4	2,44	1 300	568	410	158	22,8	17,9

TABLE 2
THE INTERRELATIONSHIP BETWEEN SEDIMENT PROPERTIES REPRESENTED BY A CORRELATION MATRIX

	CEC	OC	TKN	TP	IP	OP	NTA-P	BRAY-2-P
CEC								
OC	0,34							
TKN	0,73**	0,61*						
TP	0,73**	0,70**	0,85**					
IP	0,76**	0,71**	0,89**	0,97**				
OP	0,59*	0,59*	0,70**	0,91**	0,78**			
NTA-P	0,70**	0,04	0,72**	0,61*	0,57*	0,60*		
BRAY-2-P	−0,47	0,12	−0,02	0,08	0,03	0,16	0,04	

**Indicates that the correlation coefficients are significant at the 1% test level
* Indicates significance at the 5% test level

Results

Sediments

The values for the chemical properties for the B3 samples, with the exception of Bray-2-P were lower than for the rest of the samples. Values for the chemical properties of the V1 samples seemed to be between those for B3 and the rest of the samples. Therefore the sediments used in this study covered a wide range of chemical properties, especially as far as the phosphate fractions were concerned, and provided a suitable range to investigate the possible relationships between algal available P and chemically determined phosphate fractions in the sediments.

The interrelationship between the chemical properties of the sediments are given in the form of a correlation matrix in Table 2. The main feature of this matrix was the high occurrence of significant correlations between the chemical properties of the sediments. The exception was Bray-2-P which was not significantly correlated with any of the other chemical properties and OC which was not significantly correlated with CEC and with NTA-P. These interrelationships between sediment chemical properties, including the phosphate fractions, ruled out the consideration of a multiple regression approach to define the relationship between algal available phosphate and chemically determined sediment phosphate fractions.

Algal Available Phosphate

The algal available phosphate contents of the samples were calculated from the algal biomass produced in the bioassays and the phosphate yield coefficient of 805 mg suspended solids per mg P for *S. capricornutum* (Toerien *et al.*, 1971). The algal biomass was estimated from algal OC determinations using a relationship of biomass to OC of 2,18, experimentally determined by Grobler and Davies (1979). This ratio was in close agreement with the value of 2,04 to 2,17 for the same organism as reported by Goldman (1972). The algal available phosphate values, determined from triplicate bioassays, are given in Table 3. Striking differences were noticed between mean algal available phosphate values for the different sediment samples. The means were compared for significant differences by analysis or variance using the F-test. The calculated F-value, CV and the means, ranked in decreasing order, are given in Table 4.

TABLE 3
ALGAL AVAILABLE PHOSPHATE CALCULATED FROM A YIELD COEFFICIENT OF 805 MG BIOMASS PER MG PHOSPHATE AS P AND THE RELATIONSHIP BETWEEN ALGAL ORGANIC CARBON AND ALGAL BIOMASS

Sample Station and date collected		Algal available phosphate as P in mg/kg: Replicates 1	2	3	Means
V1	1/78	157,4	157,4	157,4	157,4
	2/78	196,6	155,7	157,6	170,0
	3/78	157,6	161,7	170,1	163,1
B3	1/78	1,2	7,2	1,2	3,2
	2/78	100,2	100,2	92,1	97,5
	3/78	25,2	21,1	21,1	22,5
B6	1/78	325,0	312,9	321,1	319,7
	2/78	343,8	347,9	345,7	345,8
	3/78	360,3	368,9		364,6
B9	1/78	285,8	285,8	288,0	286,5
	2/78	320,4	320,4		320,4
	3/78	323,9	313,9	328,0	321,9
S3	1/78	170,6	211,6	150,3	177,5
	2/78	200,4	202,6	196,6	199,9
	3/78	95,6	107,8	107,8	103,7

The means not significantly different from each other at the 5% test level compared by the SNK-procedure for least significant differences, have been underlined. An F-value of 307 indicated highly significant differences between the mean algal available phosphate contents of the sediment samples. A CV of 5,7% indicated little variation within groups, suggesting that three replicates per sediment sample were sufficient. The sediments from stations B6 and B9 in Bloemhof Dam had the

TABLE 4
MEAN ALGAL AVAILABLE PHOSPHATE VALUES AS P RANKED IN DECREASING ORDER. MEANS NOT SIGNIFICANTLY DIFFERENT FROM EACH OTHER ARE UNDERLINED. THE F-VALUE (F) AND COEFFICIENT VARIATION (CV) ARE ALSO GIVEN

F = 307**
CV = 5,7%

Means ranked in decreasing order of magnitude

B6 – 3/78	B6 – 2/78	B9 – 3/78	B9 – 2/78	B6 – 1/78	B9 – 1/78	S3 – 2/78	
364,6	345,8	321,9	320,4	319,7	286,5	199,9	
S3 – 1/78	**V1 – 2/78**	**V1 – 3/78**	**V1 – 1/78**	**S3 – 3/78**	**B3 – 2/78**	**B3 – 3/78**	**B3 – 1/78**
177,5	170,0	163,1	157,4	103,7	97,5	22,5	3,2

**Indicates that the means are significantly different at the 1% test level highest algal available phosphate contents, followed by sediments from stations S3 and V1 in Spitskop Dam and Vaalharts Weir respectively. Sediments from station B3 in Bloemhof Dam had the lowest mean algal available phosphate content. Sediment from station S3 in Spitskop Dam had the highest content of TP, OP and IP (Table 1) but this did not apply to mean algal available phosphate content. This suggested that the sediments in Spitskop Dam, originating in the catchment of the Harts River might be significantly different from the rest of the sediments obtained from Bloemhof Dam and Vaalharts Weir, both originating in the Vaal River catchment. For this reason the Spitskop Dam sediment results were excluded from the rest of the sediments for the interpretation of the relationships between algal available phosphate content of sediments and other sediment properties.

Significant differences also occurred between mean algal phosphate contents of sediment samples taken at the same station at different times, for example, the sediment sampled during March 1978 (3/78) at station B6 had a significantly higher algal available phosphate content than the sediment sampled during February 1978 (2/78) at the same station which again was significantly higher than the sediment sampled during January 1978 (1/78).

Lee (1973) mentioned that care should be taken with the interpretation of results obtained by bioassays under laboratory conditions since the nutrient medium might influence the availability of an element. To determine whether the nutrient medium used in this study could extract sediment phosphate and so make it more available to algae than would otherwise be the case, extractions, using the same ratio of nutrient medium to sediment employed in the bioassays, were done by shaking the mixture for 24 h on a mechanical shaker. The sediment phosphate extracted by the nutrient medium was determined in the clear filtrate after filtration of the mixture. The algal available phosphate content and the sediment phosphate extracted by the nutrient medium are given in Table 5.

TABLE 5
PHOSPHATE AS P EXTRACTABLE BY THE NUTRIENT MEDIUM (BG — 11) MINUS PHOSPHATE AND ALGAL AVAILABLE PHOSPHATE (ALGAL P) IN SEDIMENT SAMPLES

Station and date sampled		BG — 11 (mg P/kg)	Algal P (mg P/kg)
V1	1/78	2,5	157,4
	2/78	0,7	170,0
	3/78	0,6	163,1
B3	1/78	0,2	3,2
	2/78	1,0	97,5
	3/78	0,4	22,5
B6	1/78	0,7	319,7
	2/78	0,7	345,8
	3/78	0,3	364,6
B9	1/78	1,4	286,5
	2/78	1,2	320,4
	3/78	1,2	321,9
S3	1/78	1,3	177,5
	2/78	1,1	199,9
	3/78	0,8	103,7

The amounts of phosphate that could be extracted by the nutrient medium appeared in most cases to be only a fraction of a percent of the algal available phosphate. Therefore the nutrient medium used in this study did not influence the availability of sediment phosphate to algae.

Relationships between Available and Chemically Extractable Phosphate

The relationships between algal available phosphate and chemically determined phosphate fractions were investigated by linear regression between the mean algal available phosphate contents of the sediments and the chemical phosphate fractions. The sediment samples used in this study originated from two catchments which could have yielded two completely different types of sediment. Therefore the regression analyses were done by considering all the samples together and then only the sediments originating in the Vaal River catchment, excluding the S3 sediments originating in the Harts River catchment. The Harts River catchment sediments were not considered on their own because only three samples were collected. The regression equations, where algal available phosphate was always the dependent variable and the chemically determined phosphate fractions the independent variable, are given in Table 6.

Significant correlations were found between algal available phosphate and TP, IP, OP and NTA-P. Bray-2-P was not significantly correlated with algal available phosphate, whether all the sediments or only the sediments from the Vaal River catchment were considered. Considering the samples originating in the Vaal River catchment separately for regression purposes, the correlation coefficient (r) between algal available phosphate and TP increased from $r = 0,67$ to $r = 0,93$, for IP from $r = 0,67$ to $r = 0,97$ and for OP from $r = 0,58$ to $r = 0,72$. The correlation coefficient between algal available phosphate and NTA-P remained constant at $r = 0,95$ whether all samples were considered or only Vaal River catchment samples. This indicated a major difference between the results of the chemical determinations, placing TP, IP and OP determinations in a group where the relationships between phosphate determined chemically and algal available phosphate change for different types of sediment. On the other hand, NTA-P seemed to be more generally related to algal available phosphate, as indicated by a constant correlation coefficient when both cases were considered. Because of the highly significant correlations between TP, IP and OP (Table 2), only the relationship with the highest correlation coefficient, that is between algal available phosphate and IP, will be further discussed.

The regression lines of algal available phosphate and sediment IP indicate that the samples from the Harts River catchment formed a distinctive group on their own, (Figure 2) and when included in the regression equation resulted in a rather poor fit of the regression line. Omission of these results resulted in a good fit of the regression line to the remaining data. Figure 3 was obtained in a similar way for algal available phosphate and NTA-P. The inclusion or exclusion of the sediment originating in the Harts River catchment in the calculation of the regression equation had no real influence on the regression line obtained and no improvement in the fit of the regression line was observed. This confirmed earlier observations that NTA-P seemed to be a more generally applicable measure of algal available phosphate than IP, although the latter resulted in a higher correlation coefficient, $r = 0,97$ as compared with $r = 0,95$, when used on samples originating from one catchment.

TABLE 6
LINEAR REGRESSION EQUATIONS AND CORRELATION COEFFICIENTS GIVING THE RELATIONSHIP BETWEEN ALGAL AVAILABLE PHOSPHATE (Y) AND SEDIMENT PHOSPHATE FRACTIONS (X). BOTH CASES WHERE ALL SEDIMENT SAMPLES WERE CONSIDERED (NUMBER OF SAMPLES = 15) AND WHERE ONLY THE SEDIMENT SAMPLES FROM THE VAAL RIVER CATCHMENT WERE CONSIDERED (NUMBER OF SAMPLES = 12) ARE GIVEN

Number of samples considered	P fractions	Regression equation	Correlation coefficient (r)
15	TP	Y = 34,7 + 0,39 X	0,67**
12		Y = −28,7 + 0,65 X	0,93**
15	IP	Y = 19,8 + 0,58 X	0,67**
12		Y = −71,9 + 1,02 X	0,97**
15	OP	Y = 102 + 0,90 X	0,58*
12		Y = 97,8 + 1,18 X	0,72**
15	NTA-P	Y = 5,6 + 5,64 X	0,95**
12		Y = −0,13 + 5,71 X	0,95**
15	BRAY-2-P	Y = 243 −2,46 X	−0,18
12		Y = 247 −2,15 X	−0,15

**Indicates significance at the 1% test level. The absence of an asterisk indicates that the value is not significant at the 5% test level.

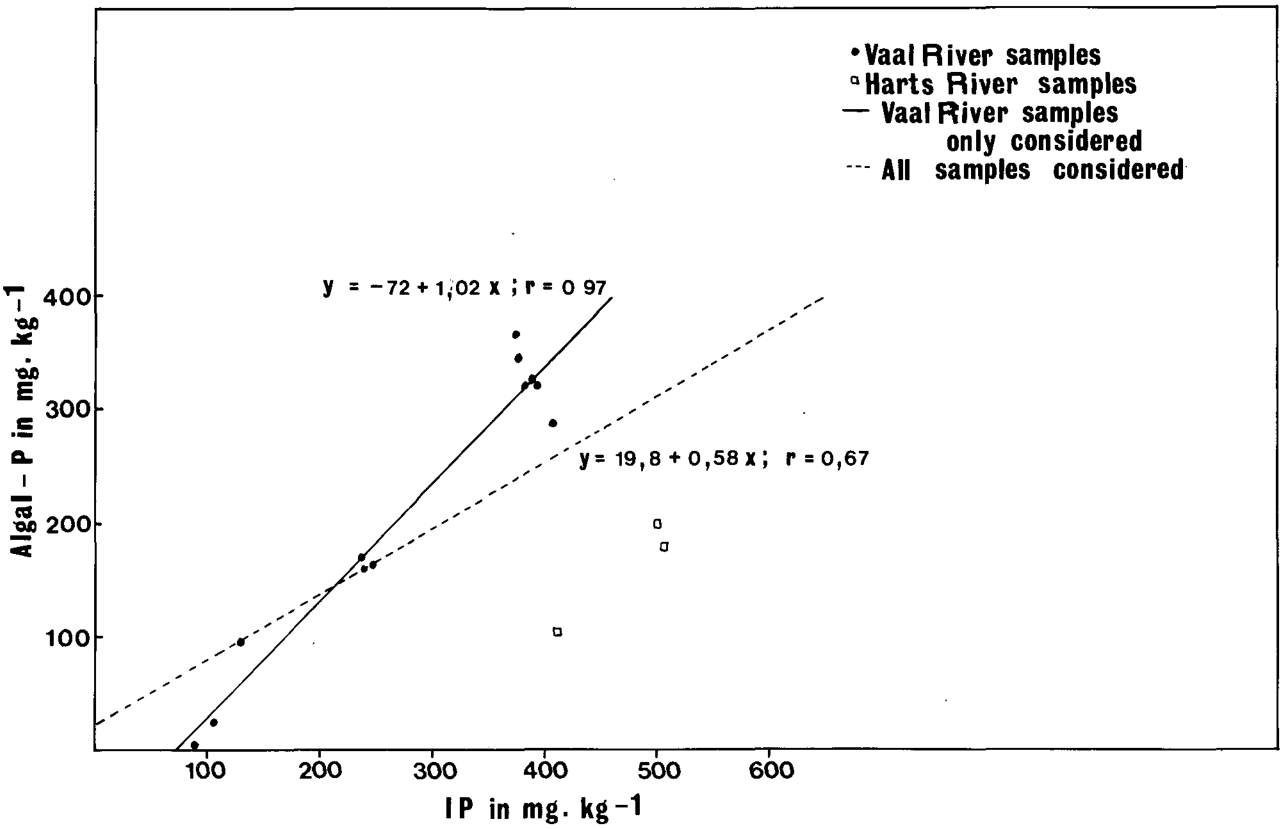

Figure 2
Relationship between algal available phosphate (algal-P) and IP in sediment samples. The regression lines for both cases, where all samples and only samples from the Vaal River catchment were considered, are given

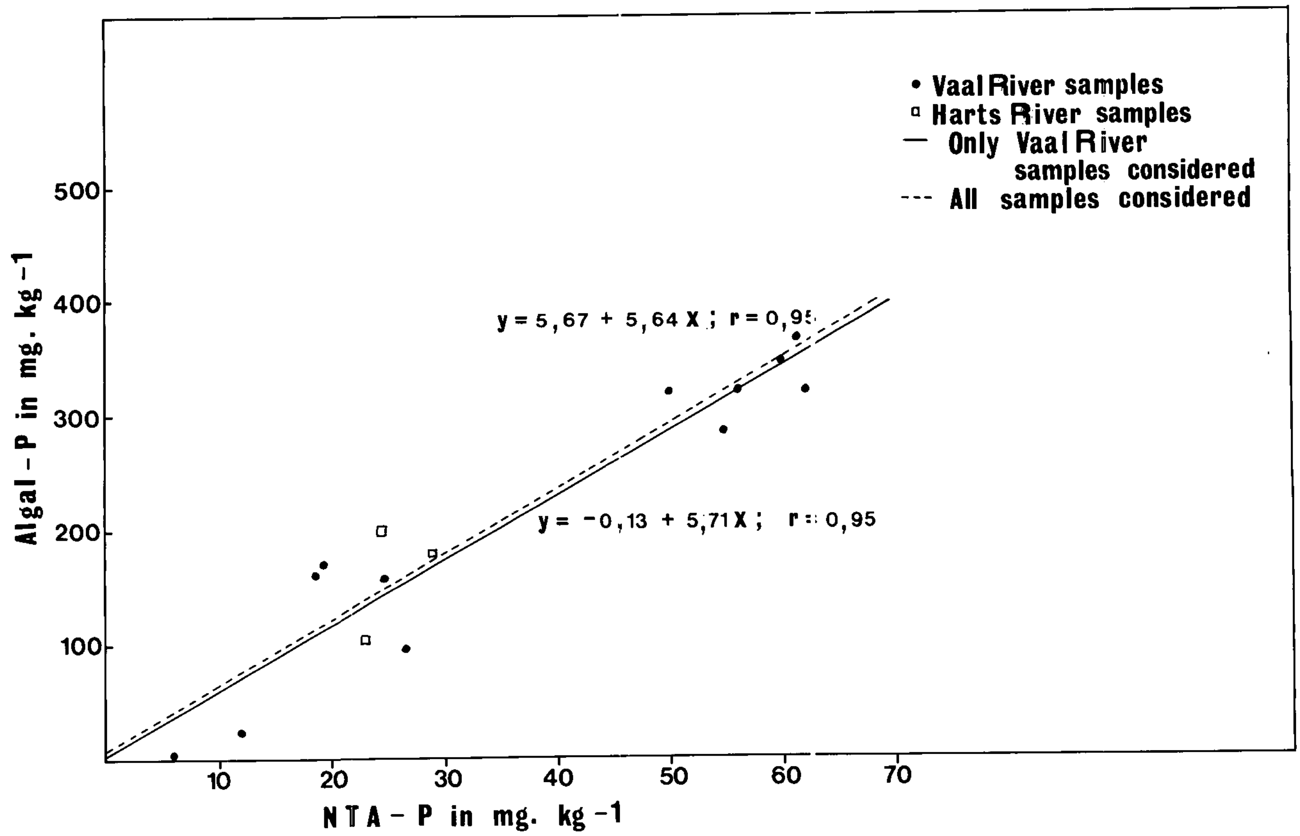

Figure 3
Relationship between algal available phosphate (algal-P) and NTA-P in sediment samples. The regression lines for both cases, where all samples and only samples from the Vaal River catchment were considered, are given

Linearity of Response

The mean algal available phosphate values obtained for the different sediment samples, given in Table 3, were expressed as percentages of IP and NTA-P and are given together with the sediment phosphate fractions in Table 7. The correlations between algal available phosphate as a percentage of IP and NTA-P and each of IP and NTA-P were calculated and are also given in Table 7. For IP, only the sediments originating in the Vaal River catchment were considered and for NTA-P, all samples were considered as discussed earlier. Algal available phosphate changed from between 4% and 98% of IP but were never higher than the IP values. Algal available phosphate seemed, on average, to be between 5 and 6 times more than NTA-P as indicated by algal available phosphate being between 55% and 885% of NTA-P. It was noted that the availability of IP to algae seemed to increase with increased IP content of the sediment samples originating in the Vaal River catchment. The highly significant correlation coefficient, of r = 0,87, between algal available phosphate as a percentage of IP and IP itself, indicated a non-linear relationship between these two phosphate fractions. The lack of a significant correlation between algal available phosphate as percentage of NTA-P and NTA-P itself indicated that there was no reason to believe that the relationship between these two phosphate fractions might not be linear. Insufficient data was available to warrant any further investigation into the non-linear relationship between algal available phosphate and IP.

Discussion

This study has shown that *S. capricornutum* was able to obtain phosphate from sediments for its growth requirements. The determination of algal available phosphate using bioassays and *S. capricornutum* as test organism, is a tedious procedure. It allows the analysis of only a limited number of samples and periods lasting up to one month are required for a single set of results. Chemical extractions offer a number of advantages, the most important being that they are rapid and a large number of samples can be analysed in a short period. If a good relationship between algal available phosphate, determined by bioassays, and a sediment phosphate fraction, determined by a chemical extraction, could be found, then chemical extraction could be used as a measure of algal available phosphate. Remarkably good relationships between algal available phosphate and IP and NTA-P, were found. No relationship between algal available phosphate and Bray-2-P could be found in contrast to the results of Porcella, Kumagai and Middlebrooks (1970). This difference can probably be explained by the fact that different types of sediments were used by us. Golterman (1976) found that NTA-P was equal to algal available phosphate in the sediments used by him. The results obtained in this study indicated that algal available phosphate changed from between 50% and 900% of NTA-P. Again the differences could be related to differences in sediment types and test organism used and possibly to differences in experimental procedures followed. Golterman (1976) had his sediments cast in solid agar blocks which might have restricted physical contact between sediment and the algae, and therefore may account for the differences found.

The fitting of highly significant linear regression lines to the experimental data is no guarantee that the relationship is actually linear. A linear relationship between algal available phosphate and IP or NTA-P means that algal available phosphate as a percentage of either IP or NTA-P must be the same for high and low IP or NTA-P values. Any significant relationship between algal available phosphate as a percentage of IP or NTA-P and IP or NTA-P itself, indicates a significant deviation from linearity of response. The use of IP as an estimate of algal available phosphate suffers from the shortcoming that the relationship seems to be different for different types of sediment and that the relationship might not be linear.

Part of the phosphate associated with bottom sediments is available to algae. The fact that these sediments were found in shallow impoundments, in which a certain amount of resuspension of bottom sediments takes place, might have a major influence on the reaction of these impoundments to phosphate enrichment. Other than in deep water systems where the bottom sediment acts as a sink for phosphate entering the system, the bottom sediment in shallow systems could act as a reservoir and source of phosphate. This would have made major implications on predictions about the response of these systems to phosphate enrichment as well as on the management of shallow water bodies to minimize the detrimental effects of eutrophication because of phosphate enrichment. The fact that significant differences were found in the algal available phosphate content of the sediments from different stations in a single impoundment and also between sediments from the same station taken at different times complicates the above issues.

Conclusions

1. Part of the phosphate associated with bottom sediment samples was available to *S. capricornutum*.

2. Algal available phosphate was highly significantly correlated with IP and NTA-P.

3. Discrepancies between the findings of this study and other published work were observed for the relationship between algal available phosphate and NTA-P. The relationship between algal available phosphate and IP proved to be non-linear and also not to be generally applicable. Therefore, not one of the above methods can be recommended at this stage to replace bioassays as a measure of algal available phosphate before further evaluation including a wider range of sediment types and sediment phosphate concentrations have been carried out.

TABLE 7
ALGAL AVAILABLE PHOSPHATE (ALGAL P) EXPRESSED AS PERCENTAGES OF SEDIMENT IP AND NTA-P VALUES. THE CORRELATION BETWEEN ALGAL AVAILABLE PHOSPHATE AND EACH SEDIMENT PHOSPHATE FRACTION ARE ALSO GIVEN

Station and date sampled		IP mg/kg	ALGAL-P AS %	NTA-P mg/kg	ALGAL-P AS %
V1	1/78	237	66	24,6	638
	2/78	235	72	19,2	885
	3/78	248	66	18,6	876
B3	1/78	85	4	6,0	55
	2/78	130	75	26,4	367
	3/78	105	21	12,0	183
B6	1/78	394	81	49,5	635
	2/78	375	92	60,0	577
	3/78	373	98	62,4	585
B9	1/78	405	71	54,6	526
	2/78	380	84	55,8	573
	3/78	395	82	61,8	523
S3	1/78	505	35	28,8	618
	2/78	500	40	24,6	813
	3/78	410	25	22,8	456
Correlation		r = 0,87**		r = 0,20	

**Indicates that the correlation is significant at the 1% test level.

4. The phosphate associated with bottom sediment can be available to algae in shallow water bodies, where resuspension of bottom sediments into the water body takes place. This will have serious implications concerning the prediction of the possible effects of phosphate enrichment on these water bodies and on the management of these water bodies to minimize the disadvantages of eutrophication because of phosphate enrichment.

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