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THE USEFULNESS OF POLYETHYLENE BAGS IN EXPERIMENTS FOR WATER ENRICHMENT WITH INORGANIC COMPOUNDS **

ABSTRACT: A 6-day in situ water exposure in open 40-l polyethylene bags did not show physico-chemical deformations of the lake habitat. Phytoplankton production in bags was almost 50% lower in comparison with open lake water. Phytoplankton biomass and contribution of algal groups examined approximated in both environments. Six-hour (100 ml bottles, 40-l bags) and 6-day (40 l bags) enrichment experiments (in P, N or P and N together) were conducted. The ^{14}C assimilation by phytoplankton in variously enriched water depended on the duration of exposure in situ and the kind of enrichment.

KEY WORDS: Lake, enrichment experiment, nutrients, phytoplankton, primary production.

1. INTRODUCTION

In studies on the influence of inorganic compounds on primary production processes, which decide about the rate of eutrophication of aquatic environments, different types of laboratory and in situ experiments enriching the water with nutrients were used. In these experiments, after adding a specific amount and proportion of nutrients, the algae (natural community or cultures) react by an adequate increase of ^{14}C assimilation rate, biomass increment, changes in composition and also the photosynthetic activity, thus indicating the limiting influence of these nutrients in a natural environment. These experiments are one of the methods for predicting the

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eutrophication rate of waters. An extensive literature review on enrichment experiments is given by Woroniecka (1976).

The enrichment experiments, the object of which are algal monocultures (Skulberg 1964, 1975, Smayda 1964, 1974), frequently provide inadequate results for natural water bodies, because of the different physiological and ecological properties of natural plankton communities and laboratory cultures of algae. From the ecological point of view the best experiments are those where examined is the reaction to enrichment with inorganic compounds of whole water ecosystems from producers through successive levels of consumers (Zdanowski et al. 1975, Schindler 1977, de Noyelles and O'Brien 1978).

Undoubtedly such experiments provide the most reliable information on the effect of changes in the fertility of aquatic environment as they concern all trophic levels. However, they require at least few years for observations and are extremely time-consuming, which is difficult in many cases because of the increasing rate of eutrophication processes.

Studies on factors limiting the primary production in water bodies on the basis of enrichment experiments in situ, where plankton community is the object, although some characters of experimental conditions are preserved, seem to provide results reliable from the point of reaction of producers of a given ecosystem. This is also the opinion of Schelske et al. (1972), Schelske and Rothman (1974), O'Brien and de Noyelles (1976).

But there are some technical problems and the fundamental question is how big a fragment of natural environment can be isolated, and for how long, to have similar biological processes to those in open water. Kuiper (1977a, 1977b), Parsons et al. (1977) in a marine environment and Lund (1972) in an inland environment have used polyethylene bags of a volume of several tens of tons of water, containing a natural pelagic community of organisms with representatives of all or almost all trophic levels, and exposed them for at least 30 days. Whereas Takahashi et al. (1975), Ostrofsky and Duthie (1975), Crane and Sommerfeld (1976) have used smaller polyethylene bags of a volume of several thousand litres and exposed them in situ also for 30 days.

These studies have confirmed that the processes in open water and in limnocorrals used are similar. But such big corrals used for a longer time are very expensive and time-consuming. Frequently a faster and cheaper estimation of the limiting effect of nutrients on production providing sufficiently reliable results is of greater significance.

The aim of the present paper has been an estimation of usefulness of smaller plastic enclosures, not exceeding 40 l capacity and exposed for several days. The experiments were carried out in two lakes of Masurian Lakeland, in the strongly eutrophic Lake Jorzec (A – 0.41 km^2, z max 11.6, $\bar{z}$ 5.5 m, dimictic) and moderately eutrophic Lake Głębokie (A – 0.46 km^2, z max 34.3 m, $\bar{z}$ 11.8 m, dimictic) (Woroniecka-de Wachter 1983).

2. EXPERIMENTS AND METHODS

Lake water with natural phytoplankton was isolated in open polyethylene bags of a volume 40 l and in closed glass bottles of a volume 100 ml. Both bottles and bags were filled with water sampled at the depth 0.5 – 1.0 m and exposed during short (6 hours) and longer intervals (3 and 6 – 7 days) in a natural lake habitat.

Polyethylene bags, 25 cm in diameter and 150 cm long, on a metal construction, floated freely on lake surface, protruding some 20 cm above the water level (Fig. 1). The open bags allowed for free exchange of gases with the atmosphere, a similar course of temperature changes, and infiltration of solar radiation in plastic enclosures.

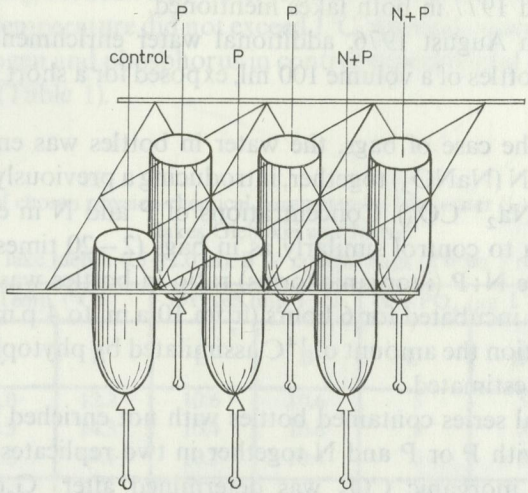


Fig. 1. Diagram of a single set of polyethylene bags (volume 40 l, diameter 25 cm, height 150 cm) used in lake water enrichment experiments with P and P and N

The experimental series had three sets of bags (6 in each set). In each set there was one control bag (not enriched lake water). In other bags phosphorus (KH_2PO_4) was added, simple or in combination with nitrogen ($NaNO_3$). The enrichment variants were: only phosphorus, only nitrogen or a combination of both. Each experimental variant had three replicates. Concentrations of P-PO_4 in experimental bags increased 2 – 20 times as compared with the not enriched control, whereas N – NO_3 – 3 – 6 times.

The N : P (inorganic forms) ratio in control and variants enriched with both nutrients ranged between 10 and 16, i.e., was balanced considering the algal demand for nutrients (W o r o n i e c k a 1976); in variants with the addition of phosphorus only it was always less than 10 (8.0 – 1.6).

During the experiment the reaction of phytoplankton to enrichment with given nutrients was measured. Changes in the rate of ^{14}C assimilation by phytoplankton in variously enriched water were measured by the method of light and dark bottles – technical details are described in W o r o n i e c k a-d e W a c h t e r (1983).

As the diameter of bags was small the bottles were incubated in water directly neighbouring with bags.

The measurements were made three times: in the first stage of the experiment – 6 hours after enriching the water with inorganic compounds, in the second stage – after 3 days of the experiments, and in the final stage – after 6 or 7 days of the experiment.

During all experiments changes in water temperature were analysed as well as concentration of dissolved O_2, $P-PO_4$, $N-NO_3$ in open lake water outside the bags and also in experimental not enriched bags (control) and those enriched with P and N. The losses in phosphorus and inorganic nitrogen in the water isolated in the bags were made up to the given level.

Experiments in bags were carried out in the spring (May, June) and summer (August) of 1976 and 1977 in both lakes mentioned.

In both lakes, in August 1976, additional water enrichment experiments were conducted in glass bottles of a volume 100 ml, exposed for a short time (6 hours) in the lake habitat.

Similarly as in the case of bags, the water in bottles was enriched only with P (KH_2PO_4) or P and N ($NaNO_3$) together, introducing a previously marked solution of sodium carbonate ($Na_2{}^{14}CO_3$). Concentrations of P and N in experimental bottles increased in relation to control similarly as in bags (2–20 times $P-PO_4$ and 3–6 times $N-NO_3$). The N:P (inorganic forms) ratio in bottles was similar as in bags.

The bottles were incubated for 6 hours (from 10 a.m. to 4 p.m.) in situ in the lake and after the incubation the amount of ^{14}C assimilated by phytoplankton in variously enriched water was estimated.

The experimental series contained bottles with not enriched lake water (control) and that enriched with P or P and N together in two replicates.

Total dissolved inorganic CO_2 was determined after Golterman and Clymo (1969) titrating water samples 0.05 n HCl in the presence of Tashiro indicator.

In the lake and in not enriched bags the phytoplankton composition and biomass were estimated in water samples of a volume 100 ml fixed with Lugol solution (JKJ) and 1 ml 4% formalin. Phytoplankton was analysed under an inverted microscope. Time of plankton sedimentation in sedimentation chambers was about 20 hours for a 5 ml sample. The volume of particular taxa was calculated by comparing algal cells to geometric figures. The biomass was calculated assuming 1 mm^3 as 1 mg.

Measurements of water temperature (°C) and concentration of dissolved oxygen (mg $O_2 \cdot l^{-1}$) in lake water at the depth of 0.5–1.0 m were made using oxygen and thermic electrodes model 2110–00 Automatic Multirange Analyzer Delta Scientific.

$P-PO_4$ as SRP (soluble reactive phosphorus) was determined colorimetrically by molibdenian method, where tin dichloride was the reducing agent (Golterman and Clymo 1969), with an accuracy 0.001 mg $\cdot l^{-1}$. Nitrates were also determined colorimetrically utilising the ability of these compounds to form phenol nitro derivatives with phenoldisulphonic acid, which turn yellow in alkaline solution (Just and Hermanowicz 1965); method accuracy 0.01 mg $\cdot l^{-1}$.

3. RESULTS

3.1. POLYETHYLENE BAGS AND OPEN LAKE WATER – DIFFERENCES AND SIMILARITIES OF BIOLOGICAL PROCESSES

Altogether seven experiments were conducted in two lakes in both years of investigations (1976, 1977). Because of the similar character of biological processes examined in the same vegetation seasons (Figs. 2, 3) the results of four experiments are presented.

During the 6-day incubation of bags in situ, in both lakes, no significant differences were observed in temperature, concentrations of dissolved oxygen and concentration of $N-NO_3$, $P-PO_4$, between lake water isolated in bags (control) and free lake water. The differences in temperature did not exceed 1°C, whereas concentrations of dissolved O_2, inorganic nitrogen and phosphorus in control experimental bags and in lake water were very similar (Table 1).

Table 1. Comparison of chosen physico-chemical parameters of lake water (L) and in control bags (B), in lakes Głębokie and Jorzec

L – lake (depth 0.5–1.0 m), B – control bags ($\bar{x}$ from 3 replicates)

Lake, date		Temp. (°C)		Oxygen ($mg \cdot l^{-1}$)		$P-PO_4$ ($\mu g \cdot l^{-1}$)		$N-NO_3$ ($mg \cdot l^{-1}$)	
		L	B	L	B	L	B	L	B
Głębokie	12	12.0	12.2	10.6	10.6	5	5	0.08	0.08
May	15	14.5	14.3	10.4	10.6	8	8	0.08	0.08
1977	19	14.2	14.5	10.2	10.4	5	5	0.05	0.05
Jorzec	5	10.0	10.0	10.0	10.0	5	5	1.20	1.20
May	8	7.0	7.2	10.0	10.0	5	5	1.24	1.32
1977	11	7.5	7.8	9.8	10.0	5	5	1.20	1.30
Głębokie	23	16.0	16.1	–	–	5	5	0.08	0.08
June	26	22.0	22.0	–	–	5	5	0.08	0.08
1976	29	23.0	22.8	–	–	5	5	0.08	0.08
Głębokie	11	19.5	19.8	–	–	5	5	0.10	0.10
August	13	17.0	17.2	–	–	7	5	0.08	0.08
1976	16	18.2	18.0	–	–	7	5	0.08	0.08
Jorzec	18	18.0	18.0	–	–	10	10	0.07	0.07
August	21	17.0	17.2	–	–	5	5	0.07	0.07
1976	24	18.8	19.0	–	–	10	10	0.07	0.07
Głębokie	11	23.0	23.0	11.9	11.9	5	5	0.08	0.08
August	15	21.0	21.2	10.8	11.0	5	8	0.08	0.08
1977	17	20.0	20.5	10.0	10.5	5	5	0.08	0.08
Jorzec	4	19.5	19.5	17.8	17.8	5	5	0.12	0.12
August	7	20.0	20.5	17.6	18.0	5	5	0.10	0.10
1977	10	21.0	21.2	16.0	16.2	3	3	0.08	0.08

Although there were no significant physico-chemical differences, phytoplankton production in control bags (not enriched) had a permanently lower rate as compared with that in open lake water in both lakes and in all experimental periods (Figs. 2 A, 3 A). The amount of ^{14}C assimilated by phytoplankton in bags was 30–75% lower than that assimilated in open lake water. However, the increase and decrease of production rate in successive experimental periods were always synchronized in bags and in lake and reflected the changes in the intensity of solar radiation (W o r o n i e c k a - d e W a c h t e r 1983).

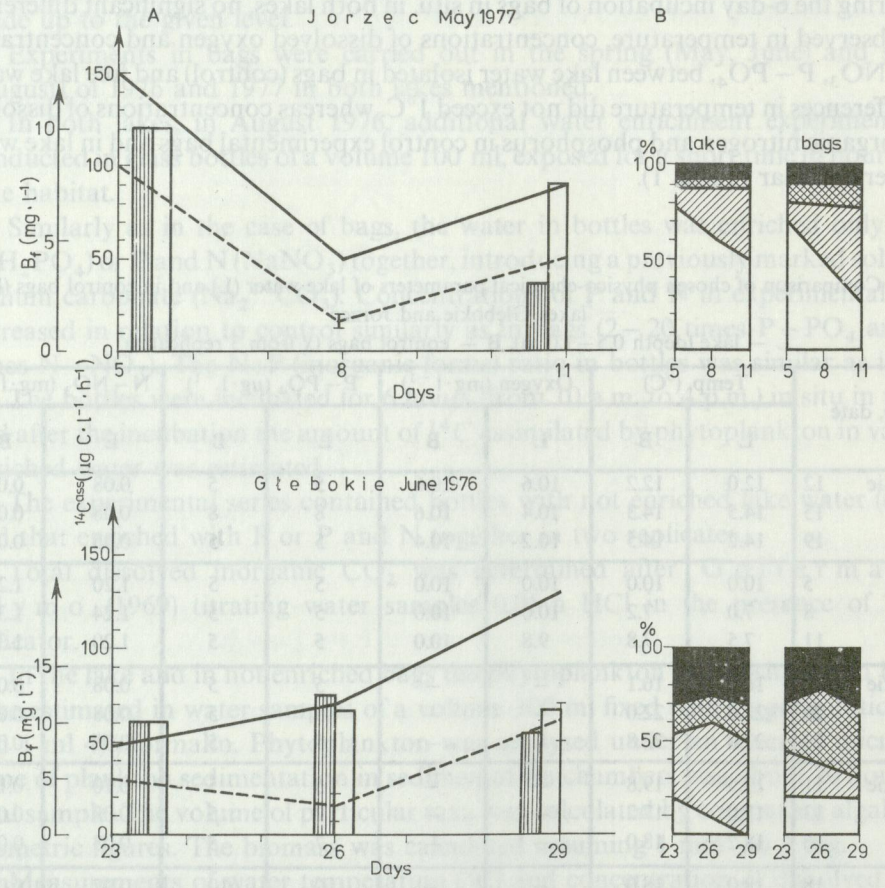
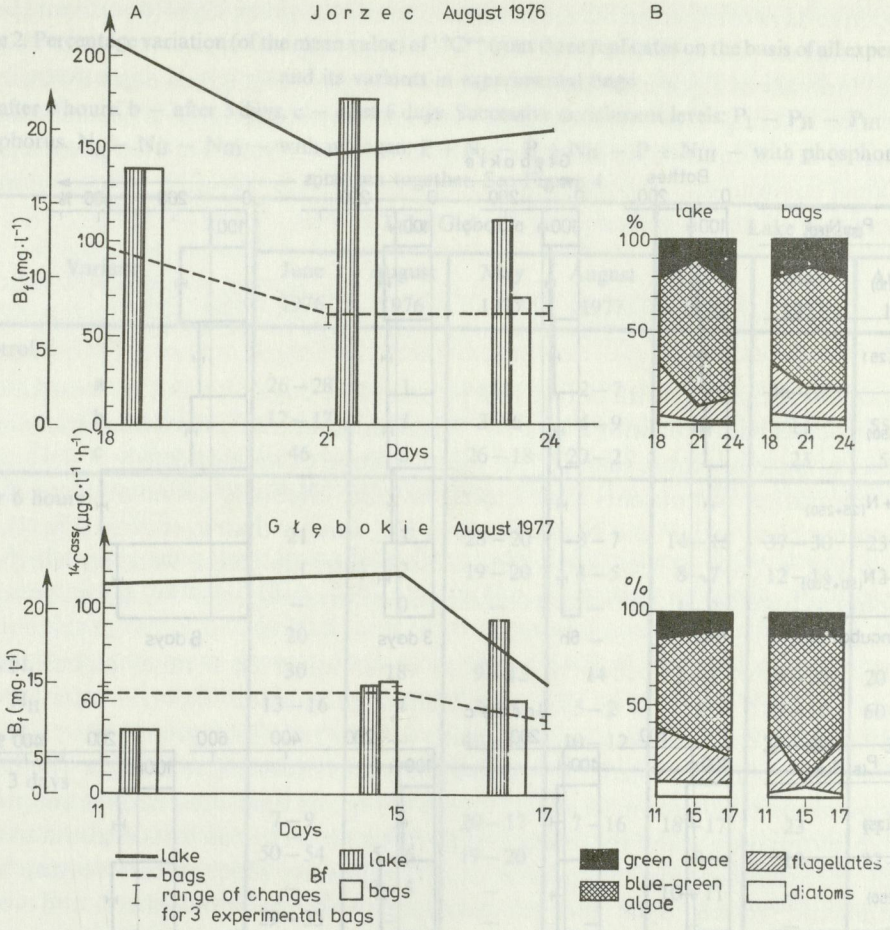


Fig. 2. Changes in phytoplankton photosynthesis ($^{14}C^{ass}$ $\mu g\ C \cdot l^{-1} \cdot h^{-1}$) and total biomass of algae (B_f wet weight $mg \cdot l^{-1}$) – A and changes in percentage of algal groups in their total biomass – B in open water and control (not enriched) experimental bags in Lake Jorzec and Lake Głębokie – in spring
For explanations see Figure 3

Analysis of changes of algal biomass in control bags in consecutive days of experiments did not show any consistent difference in comparison with open lake water. The biomass was both 40% lower and 130% higher than that recorded in open



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lake water; the direction of changes during each experiment were generally synchronized (Figs. 2 A, 3 A).

The percentage of algal groups examined: diatoms, flagellates, blue-green algae and green algae, in their total biomass was similar in bags and in open lake water, showing also synchronized changes during each experiment (Figs. 2 B, 3 B).

In the spring phytoplankton community in Lake Jorzec diatoms (*Asterionella formosa* Hassall, *Fragilaria crotonensis* Kitton) dominated, although, both in bags and in lake, their percentage in total biomass decreased from 80 to 25%, whereas the percentage of flagellates (dominant genus *Rhodomonas* sp.) increased in both phytoplankton communities from 10 to 50% (Fig. 2 B).

In spring, in Lake Głębokie, no significant changes were observed as regards the contribution of algal groups examined to both phytoplankton communities. But in

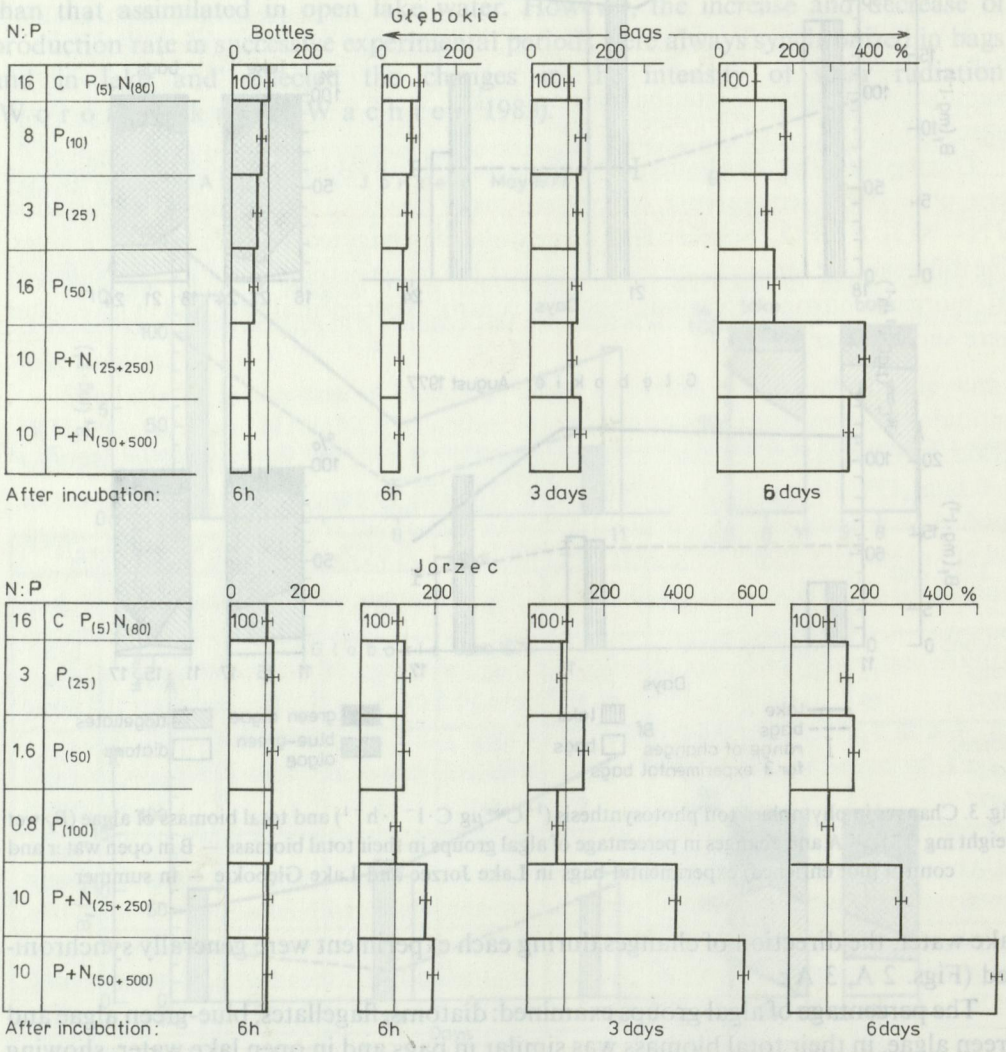

Fig. 4. Phytoplankton production (expressed as the percent of the control) in experimental vessels variously enriched with P or P and N ($\mu g \cdot l^{-1}$) in lakes Głębokie and Jorzec (August 1976)
100 ml bottles were exposed for 6 hours, polyethylene bags of a volume of 40 l were exposed for 6 hours, 3 and 6 days. C – control = 100%

Table 2. Percentage variation (of the mean value) of $^{14}C^{ass}$ from three replicates on the basis of all experiments and its variants in experimental bags

a – after 6 hours, b – after 3 days, c – after 6 days. Successive enrichment levels: $P_I - P_{II} - P_{III}$ – with phosphorus, $N_I - N_{II} - N_{III}$ – with nitrogen, $P + N_I - P + N_{II} - P + N_{III}$ – with phosphorus and nitrogen together. See Figure 4

Variant	Lake Głębokie				Lake Jorzec		
	June 1976	August 1976	May 1977	August 1977	August 1976	May 1977	August 1977
Control							
a	26–28	1	11	2–7	7	36–27	0
b	12–17	1	3–6	4–9	10	11	55–48
c	46	3	26–18	20–2	1	23	5–10
After 6 hours							
P_I	21	3	28–20	8–7	14–15	37–30	23–50
P_{II}	1	2	19–20	4–5	8–7	12–14	42–50
P_{III}	–	0	–	–	1–2	–	–
N	20	–	–	–	–	–	–
$P + N_I$	30	18	9–12	14	3–4	14–29	20–40
$P + N_{II}$	13–16	4	3–5	5–2	6	13–10	60–80
$P + N_{III}$	–	–	41–13	10–12	–	22–28	25
After 3 days							
P_I	7–9	2	20–17	7–16	18–17	23	11–30
P_{II}	50–54	5–6	19–20	14	8	19	22–25
P_{III}	–	3–5	–	–	10–11	–	–
N	29–33	–	–	–	–	–	–
$P + N_I$	4	11	6	27–25	10–2	8	17–24
$P + N_{II}$	42–43	1	1	10–7	4	17	9–18
$P + N_{III}$	–	–	18–23	14–13	–	22	13
After 6 days							
P_I	23–24	23–25	5–16	4–6	16	45	6–8
P_{II}	15	4–6	24–42	12–3	12	15	11
P_{III}	–	3–5	–	–	10–11	–	–
N	80	–	–	–	–	–	–
$P + N_I$	4	1	5	31–16	8	19	25–43
$P + N_{II}$	12	11	0	29–16	22–21	24	35–19
$P + N_{III}$	–	–	27–32	9	–	24	0

consecutive days of experiments the contribution of blue-green algae (dominant species *Aphanizomenon flos-aque* (L.) Ralfs) and green algae (*Sphaerocystis schroederi* Chod.) to total biomass of algae increased. In summer (August) blue-green algae (*Microcystis aeruginosa* Kutzing) and dinoflagellates (*Ceratium hirundinella* (O. F. Müller) Bergh) dominated in communities of planktonic algae. The contribution of blue-green algae in both algal communities examined approximated and was 40–75% of total biomass, whereas that of dinoflagellates was 20–40% (Fig. 3 B).

3.2. THE EFFECT OF TIME OF EXPOSURE ON ENRICHMENT AND THE ESTIMATION OF VARIATION OF RESULTS

Both in experiments with bottles and polyethylene bags, after 6-hour incubation of water enriched with P or with P and N, ^{14}C assimilation rate increased slightly, in the majority of cases not more than 20% of values in control, independently of the amount and composition of nutrients added; even in Lake Głębokie assimilation of ^{14}C in variants enriched with P and N together was 50% smaller than in control (Fig. 4). Still, after 3 and 6 days of exposure, almost each time the bags were enriched with phosphorus together with nitrogen or with phosphorus only, the ^{14}C assimilation rate increased rapidly.

Phytoplankton production in enriched water was even 6 times higher than in control in both lakes (Fig. 4). This highest production increase was in bags simultaneously enriched with both nutrients at their ratio (inorganic forms) equalling 10. The experiment described shows that a short time exposure, regardless whether the phytoplankton is isolated in small and closed or big and open vessels, does not provide reliable information about the reaction of phytoplankton to nutrients introduced. Such results are available only after several days of exposure, which in turn require bigger experimental vessels open for gas exchange with the atmosphere and regular enrichment with adequate doses of nutrients.

The variation of results was determined for each variant of experiment in bags (Table 2). The repeatability of results was satisfactory, although for technical reasons the repeats in each variant had to be limited to three (bags) or two (bottles). The value of variation in experimental bags was most frequently 15–45% of the mean and no essential differences due to either various enrichment or duration of experiment were observed. The extreme values of variation in case of bags enriched with phosphorus only, was from 0 to ±52%, and in case of bags enriched with the two nutrients, P and N, from 0 to ±70%.

4. DISCUSSION

The experiments in situ try to preserve the conditions closest to those in the natural aquatic habitat in order to transfer fully the results of experiments into natural conditions.

The use of different kinds of experimental vessels makes it necessary to analyse the degree of deformation of aquatic habitat by partial isolation.

Comparison of physico-chemical and biological parameters of water isolated in open polyethlyne bags of a volume 40 l and that in the lake did not show any differences in the course of temperature, concentration of dissolved oxygen and basic inorganic compounds $P-PO_4$ and $N-NO_3$. These results confirm those obtained by other authors (Goldman 1962, Ostrofsky and Duthie 1975, Takahashi et al. 1975, Crane and Sommerfeld 1976) in other kinds of open experimental vessels.

However, phytoplankton production in bags was always some 50% lower as compared to lake water. In general, these changes were fully synchronized in both types of habitat: experimental and natural. Constant reduction of photosynthetic activity of algae in bags could be the result of penetration of solar radiation through bag "walls" up to 25% of visible light (Goldman 1962, Takahashi et al. 1975), but first of all – of the insufficient water mixing in bags (Verduin 1969, Bender and Jordan 1970).

At the same time there was a lack directional deformations in the development of phytoplankton biomass (Fig. 2 A) and in the percentage of main phytoplankton components (diatoms, flagellates, blue-green algae and green algae) (Fig. 2 B), also the same dominants were present, indicating thus a lack of essential differences in the development of phytoplankton communities in bags and in lake water.

Although absolute values of photosynthetic activity of algae isolated in bags are difficult to transfer into natural conditions, this kind of open vessels can be used in enrichment experiments as they maintain a similar to natural conditions direction and character of photosynthetic activity, maintaining simultaneously a similar or identical phytoplankton composition and biomass. Therefore, bags deform quantitatively the production processes without changing qualitatively the composition of algal communities and their functions.

An analysis of changes in ^{14}C assimilation by phytoplankton after 6 hours of incubation in small closed vessels (bottles) and in open big bags did not show any significant differences in the algal production rate in any of the lakes, independently of the enrichment variant and concentration of the inorganic compound added. The slight production increase in Lake Jorzec after enrichment with P or P and N by some 10% above control values could be an accidental result due to sensitivity of measuring method rather than to stimulation of production by adding the nutrients. In Lake Głębokie the inhibition was almost 50% below control values.

Lack of phytoplankton reaction after enriching it with P or P and N, after 6 hours of incubation, independently of the kind of vessel applied, and on the other hand, rapid and greatly variable reactions observed after 3 and 6 days of exposure in bags, indicate that only few day observation of phytoplankton reaction allows to draw correct conclusions about the limiting effect of P and N on phytoplankton production. Results of these experiments are in favour of a 6-day enrichment in polyethylene bags and suggest a careful interpretation of results after 6-hour exposure of enriched water, both

in bottles and in bags. Similar conclusions have been reached also by Gerhart and Likens (1975), O'Brien and de Noyelles (1976), Ignatiades (1977).

Short-lasting enrichment experiments are supposed to provide quick information about nutrient limiting the phytoplankton growth. The frequently observed here and in other cases lack of algal reaction to enrichment may be caused by a too short time necessary for adaptation of algae to new food conditions or by cutting-off from processes of regeneration the inorganic compounds, which are an important source of nutrients for phytoplankton under natural conditions (O'Brien and de Noyelles 1976, Ignatiades 1977, Ejsmont-Karabin 1983). The addition to experimental vessels of a large concentration of inorganic compounds and other manipulations with water with phytoplankton may also cause for a short time an inhibition of biological processes (Holm-Hansen 1969, Gerhart and Likens 1975).

The interpretation of lack of phytoplankton reaction to enrichment with nutrients, after 6-hour incubation in situ, as presented here, is in favour of few day experiments, which automatically require the use of bigger open vessels.

The analysis of variation of results obtained from three repeats of each experimental variant in bags shows a variation between 15 and 45% of mean value (Table 2). The fluctuations are not disectional, i.e., are not connected with the duration of exposure or kind of enrichment. Thus, this type of experiments provides a sufficient repeatability of results.

5. SUMMARY

The object of the research has been an estimation of usefulness of 40 l open polyethylene bags in experimental investigations in situ on the phytoplankton reaction to lake water enrichment with nutrients. The studies were conducted in two eutrophic lakes: Głębokie and Jorzec – Masurian Lakeland (Fig. 1). Assimilation of carbon ^{14}C was estimated as well as phytoplankton composition and biomass. Physico-chemical and biological properties of lake water in bags and in open water were compared (Table 1).

No permanent qualitative deformations were found, only the photosynthetic activity of algae in bags was constantly lower (down to 50%) as compared with lake water. But the biomass and composition of algal communities and directions of photosynthetic changes in bags and in lake were similar and synchronized (Figs. 2, 3). Reduction of photosynthetic activity of algae in bags was probably caused by the fact that water did not mix there and by 25% light reduction.

Studies on the effect of time of exposure in small closed vessels (100 ml bottles) and in big open vessels (40 l bags) on enrichment displayed a proper phytoplankton reaction after at least few day exposure in experimental bags (Fig. 4). After 6-hour exposure in situ of enriched phytoplankton, in bags and in bottles, there was either no reaction to enrichment or production inhibition or a slight production increase (Fig. 4). These results indicate the uselessness of short-lasting enrichment experiments in estimations of the limiting effect of nutrients in eutrophic waters.

An average variation (per cent of the mean) was estimated for all experimental variants (Table 2): 15 – 45%; thus there is a sufficient repeatability of results obtained in experimental bags.

6. POLISH SUMMARY

Celem pracy była ocena użyteczności 40-litrowych otwartych polietylenowych worków dla badań eksperymentalnych in situ nad reakcją fitoplanktonu na wzbogacenie wody jeziornej w związki pokarmowe. Badania przeprowadzono w 2 eutroficznych jeziorach Głębokim i Jorzcu – Pojezierze Mazurskie (rys. 1). Oceniono asymilację węgla ^{14}C, skład i biomasę fitoplanktonu. Porównano właściwości fizyczno-chemiczne i biologiczne (tab. 1) wody jeziornej umieszczonej w workach i wody otwartej.

Nie wykazano trwałych odkształceń jakościowych, jedynie aktywność fotosyntetyczna glonów w workach była stale niższa (do 50%) w porównaniu z wodą jeziorną. Jednakże biomasa, skład zespołów glonów oraz kierunki zmian fotosyntezy w workach i w jeziorze były podobne i zsynchronizowane (rys. 2, 3). Redukcja aktywności fotosyntetycznej glonów w workach była prawdopodobnie wynikiem braku mieszania wody w tych naczyniach oraz 25% redukcji naświetlenia.

Badanie wpływu czasu ekspozycji w małych naczyniach zamkniętych (100-ml butelki) i dużych naczyniach otwartych (40-l worki) na efekt wzbogacania wykazało prawidłową reakcję fitoplanktonu po co najmniej parudniowej ekspozycji w workach eksperymentalnych (rys. 4). Po 6-godzinnej ekspozycji in situ wzbogaconego fitoplanktonu zarówno w workach jak i butelkach obserwowano bądź brak reakcji na wzbogacenie, bądź inhibicję produkcji lub jej niewielki wzrost (rys. 4). Wyniki te wskazują na nieprzydatność krótkotrwałych eksperymentów ze wzbogacaniem do oceny limitującego działania związków biofilnych w wodach eutroficznych.

Przeciętne odchylenie procentowe od średniej ocenione dla wszystkich wariantów doświadczenia (tab. 2) wynosi 15–45%, co wskazuje na dostateczną powtarzalność wyników otrzymanych w workach eksperymentalnych.

7. REFERENCES

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