

EKOLOGIA POLSKA (Ekol. pol.)	36	3-4	459-470	1988
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IN SITU DECOMPOSITION OF *PHRAGMITES AUSTRALIS* TRIN. EX STEUDEL AND *TYPHA ANGUSTIFOLIA* L.

ABSTRACT: Decomposition of reed and cattail was measured in situ by standard net bag method. The rate of decomposition and release of nutrients, macroelements and heavy metals was analysed. The influence of nitrogen content and the N:P ratio on the process is suggested. The differences in decomposition rates and release of elements between plants or plant parts are presented and possible mechanisms of release are discussed in relation to particular element analysed.

KEY WORDS: Reed, cattail, decomposition, release, nutrients, heavy metals.

1. INTRODUCTION

Destruction of plant biomass produced in littoral zone and further mobilization of the elements is a function of many different factors. Mining and grazing activity of invertebrate fauna may to different degree destruct plant shoots (G ł o w a c k a et al. 1976). Grazing of fish and birds may also accelerate the circulation of matter accumulated in macrophyte biomass. In case of emergent macrophytes the mechanical factors like wind and wave action and ice cover movements are very important. They lead to break up of plant shoots and promote further decomposition. The relative importance of these factors in littoral of Lake Mikołajskie were listed and compared by P i e c z y ń s k a (1976).

When already dead and fallen to water plant detritus undergoes a number of biochemical and physicochemical processes it becomes food detritophagous animals and substratum for bacteria. Temperature and oxygen regime influence the breakdown of organic matter either to high molecular organic compounds (in low temperature and deficit of oxygen) or to simple, low molecular combinations or to carbon dioxide (in high temperature and access of oxygen) as showed by G o d s h a l k and W e t z e l (1978). Decomposition depends on species-specific factors like, for instance, the amount

of structural tissues in plant shoots (G o d s h a l k and W e t z e l 1978). The complexity of processes involved makes the measurements of decomposition rates hardly comparable and extremely sensitive to experimental conditions. That is probably the reason why different authors (S o l s k i 1962, P l a n t e r 1970, P i e c z y ń s k a 1972, M a s o n and B r y a n t 1975, H o w a r d - W i l l i a m s and H o w a r d - W i l l i a m s 1978, L a r s e n and S c h i e r u p 1981) obtained different decomposition and elution rates for emergent macrophyte detritus.

For present study two species of aquatic macrophytes were selected — reed (*Phragmites australis*) and cattail (*Typha angustifolia*) that are common in lake littoral in Polish lowland. The aim of the research was to measure the rate of decomposition and the release of mineral constituents out of plant detritus.

2. MATERIALS AND METHODS

Plant samples were taken from the littoral zone of Lake Gardyńskie, small (82.6 ha) eutrophic basin with well developed higher aquatic vegetation. According to F. Szajnowski (unpublished data) emergent macrophytes cover 38.7% of lake area. Reed and cattail for the experiment were collected from monospecific stands of an area not less than 200 m².

Freshly harvested plant shoots were cut into pieces about 25 cm long (leaves and stems of reed separately) weighed and placed in nylon net bags of the mesh size 2 × 2 mm. The total number of bags was 24. All bags were then attached to a string and submerged in littoral water at a depth of 0.5 m with no contact with the substratum. The preweighed fresh plant samples were also taken to the lab for analyses of water content and the initial concentration of the elements. Oxygen was not analysed regularly in the littoral water. Occasional checking showed that oxygen concentrations were close to saturation in the vicinity of experimental bags.

The experiment started on 26 of June. This data was arbitrarily taken as a compromise because some elements to be analysed (especially heavy metals — K u f e l 1978) have their maxima earlier than maximum biomass. The early beginning of the decomposition measurements can be also supported by the opinion of D a v i s and v a n d e r W a l k (1978) who described the process of senescence of several marsh species and found that some of them exhibited typical symptoms of dying back already during the vegetative season. *Carex atherodes* Spreng., for example, started to die back as soon as in May, two species of *Scirpus* — in July, and yellow tips of *Typha* leaves had appeared several weeks before the whole plant died back.

At irregular time intervals (about two weeks) two bags of each plant species were taken from littoral water to the lab. The plant detritus was gently washed in tap water and dried to constant weight at a temperature of 105°C. The following elements were analysed in so prepared material: organic matter, Ca, Na, K, N, P, Mn, Mo, Co, Cu, Pb, Cd. Organic matter was measured as a loss on ignition at 450°C. Nitrogen was analysed after standard Kjeldahl digestion and distillation, resulting ammonia determined by

Nessler method. Plant detritus for phosphorus and cation determinations was wet digested in a mixture of nitric and perchloric acids (4:1 v/v). The acid digest was diluted with distilled water. Phosphorus was analysed by molybdenum blue method using stannous chloride as a reducing agent. Calcium, sodium and potassium were determined with flame photometric method. Atomic absorption spectrophotometry was used to analyse manganese, molybdenum, cobalt, lead, copper and cadmium. All those elements were analysed in the graphite furnace of the Perkin-Elmer 305A spectrophotometer according to manufacturer's instructions. In case of very low concentrations, the metals were extracted in APDC/MIBK system and the organic phase with concentrated elements taken for analyses.

3. RESULTS AND DISCUSSION

The decomposition of plant material can be described (Fig. 1) by the exponential equation of the type: $y = ae^{-bx}$ where: y — dry weight of the sample, x — time, a and b — constants. Decomposition rate was highest for reed leaves and lowest for reed stems.

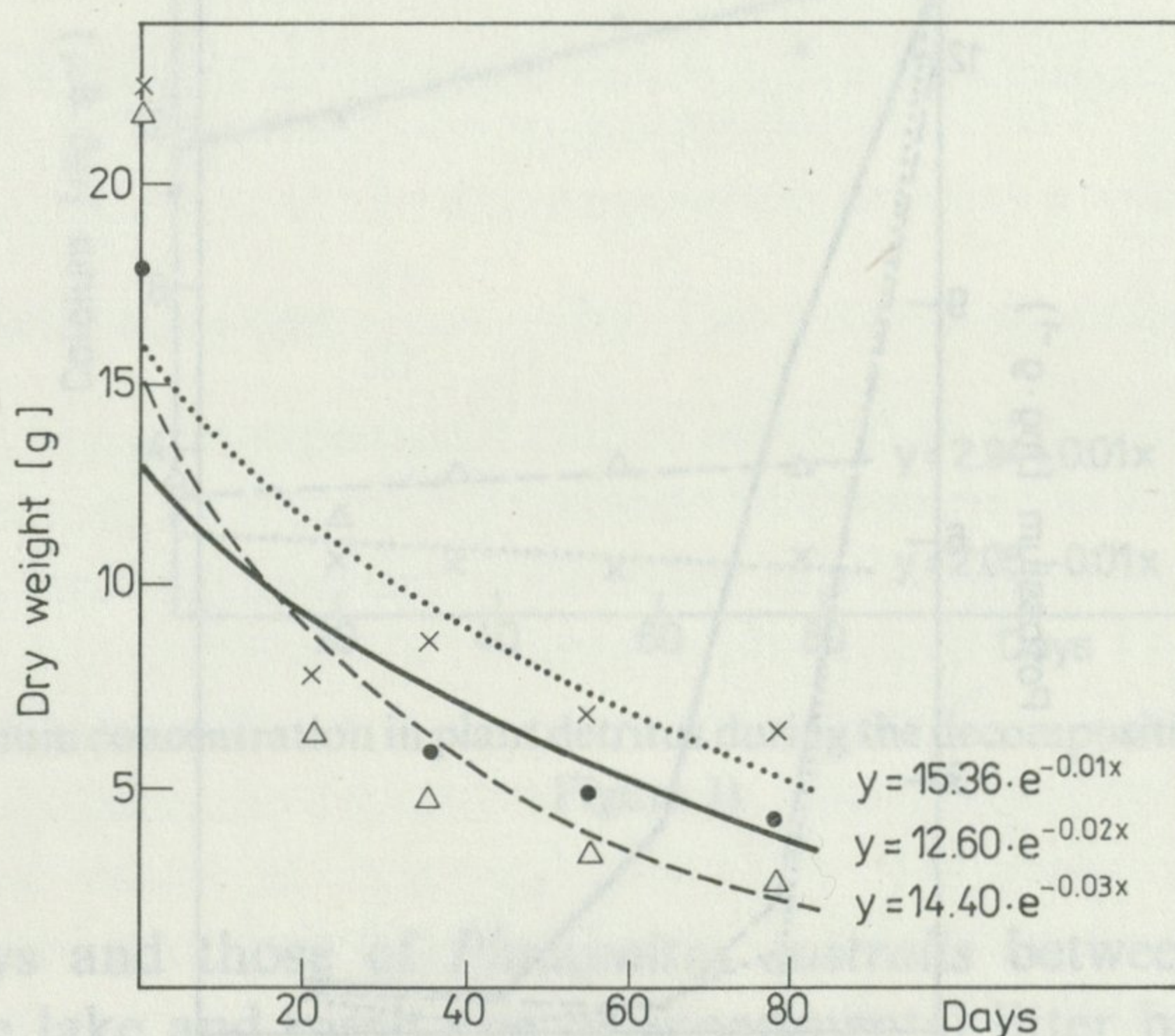


Fig. 1. Loss of plant material dry weight during the decomposition (solid line, points — cattail, dashed line, triangles — reed leaves, dotted line, crosses — reed stems)

Basing on the equations, the time of decomposition of 99% of initial plant sample was calculated. For cattail, reed leaves and reed stems it was 250, 140 and 298 days, respectively. These results are consistent with the data of P i e c z y ń s k a (1972) who reported the disappearance of 7% to over 50% of reed leaves in 10 days depending on the conditions of sample exposition. In littoral (0.5 m depth and plant samples placed on the sediment) 20% of P i e c z y ń s k a's (1972) initial material decomposed in the first 10 days of the experiment. Similar initial rapid decomposition observed H o w a r d - W i l l i a m s and H o w a r d - W i l l i a m s (1978) for *Typha*

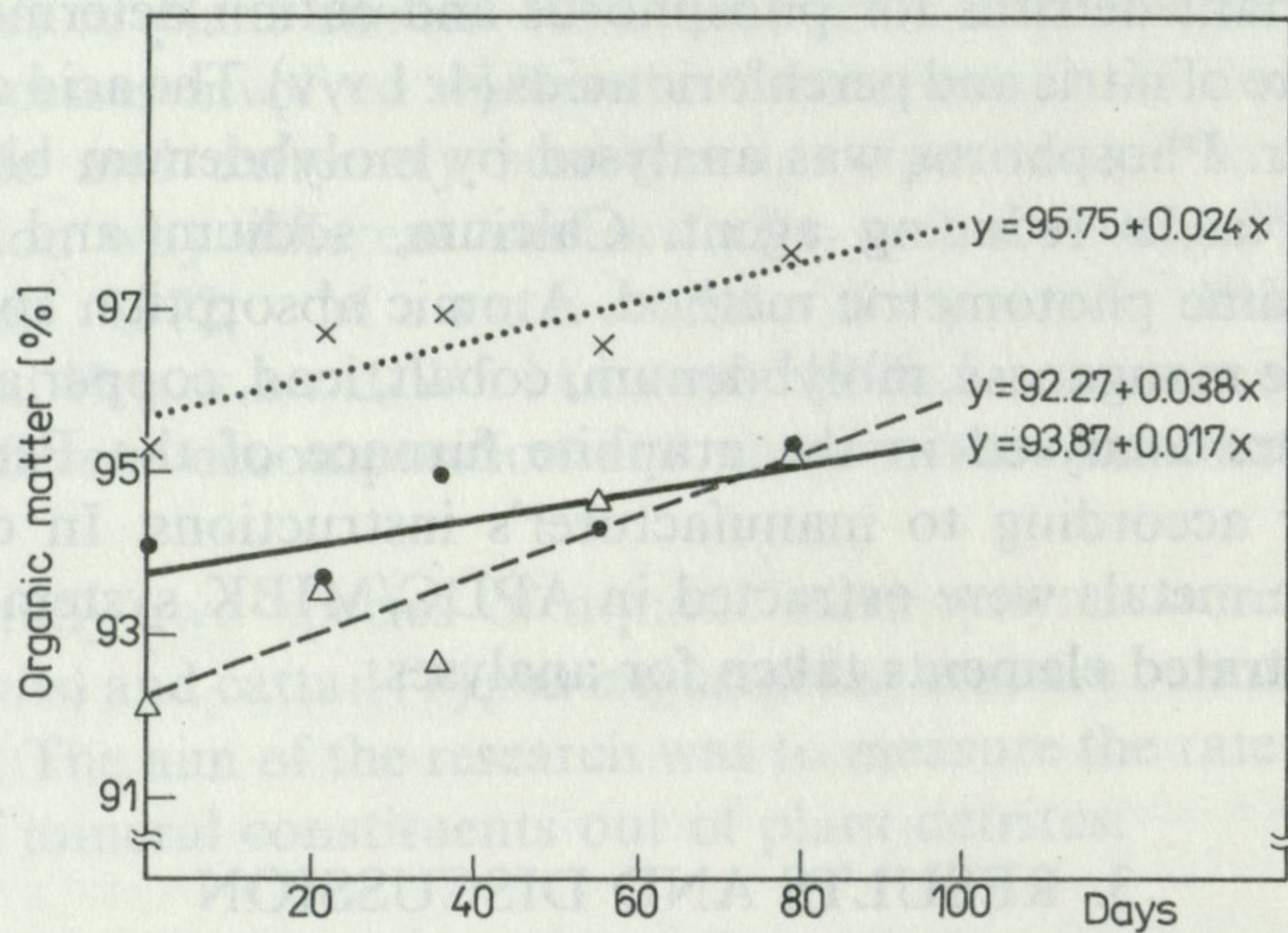


Fig. 2. Changes of organic matter content in plant material during the decomposition (description of lines as in Figure 1)

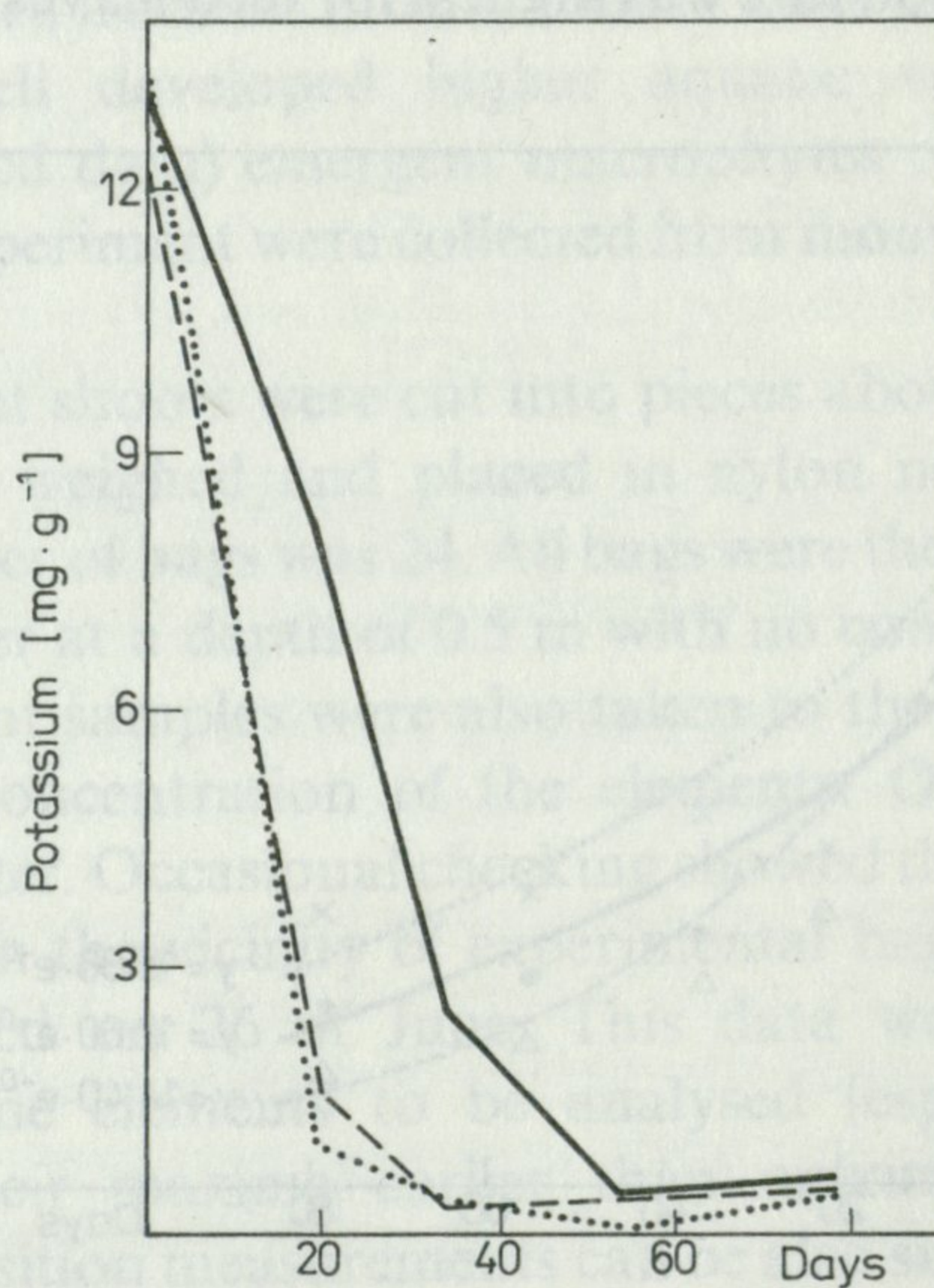


Fig. 3. Changes of potassium concentration in plant detritus during the decomposition (description of lines as in Figure 1)

domingensis Pers. from African Lake Chilwa. P i e c z y ń s k a (1972) reported the much slower decomposition of reed stems — she did not observe the decrease of stem weight during two months of exposition. In our experiment reed stems decomposed only 3 times slower than leaves (Fig. 1).

Other authors found much slower decomposition of emergent macrophytes. M a s o n and B r y a n t (1975) basing on linear (and not exponential) regression equations calculated the times of 100% decomposition of *Typha angustifolia* between

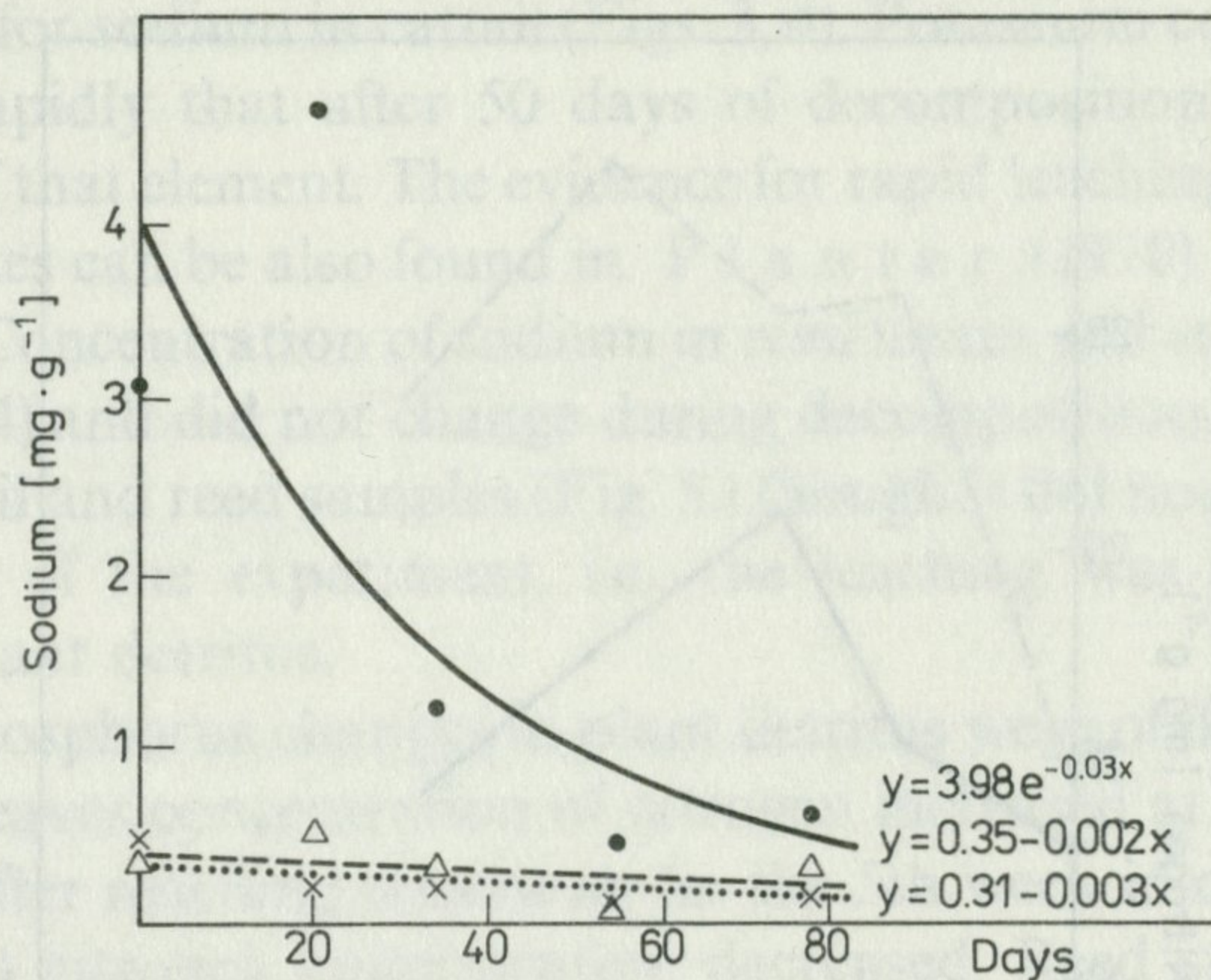


Fig. 4. Changes of sodium concentration in plant detritus during the decomposition (description of lines as in Figure 1)

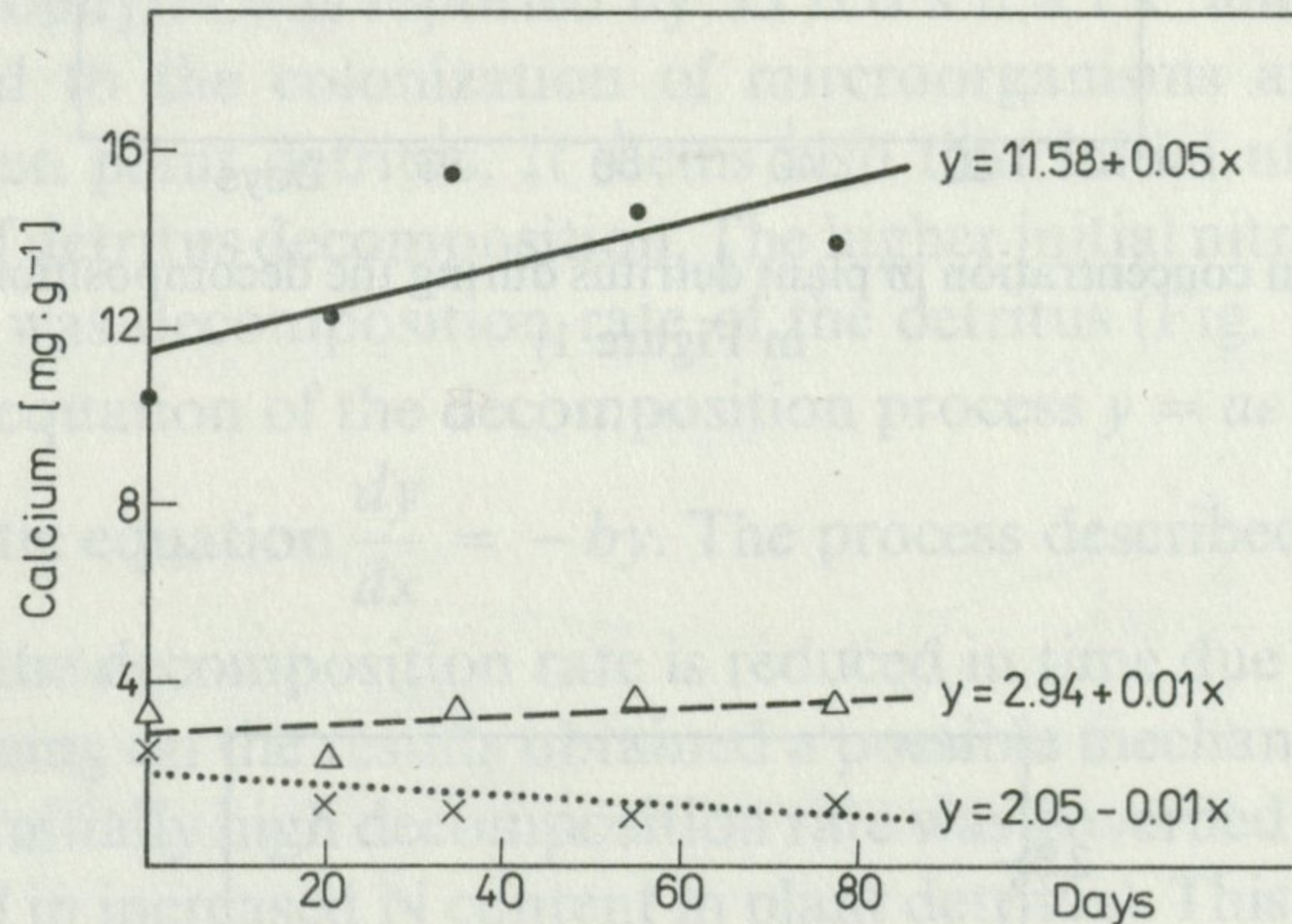


Fig. 5. Changes of calcium concentration in plant detritus during the decomposition (description of lines as in Figure 1)

778 and 881 days and those of *Phragmites australis* between 494 and 566 days depending on the lake and mesh size of experimental litter bags. Larsen and Schierup (1981) analysing reed decomposition in two lakes of different trophic state found that 50% of reed leaves decomposed from 242 to 293 days and 50% of stems — between 976 and 1665 days. Whichever are the reasons, these data point clearly to the unfavourable conditions for plant decay. As a result considerable accumulation of plant litter in littoral zone should occur. Values given in Larsen and Schierup (1981) mean that about 80% of stems and 40% of leaves from annual reed production remains undecomposed in plant stand for the next year.

As seen from Figure 2 content of organic matter steadily increased in decomposing material, the process being statistically significant for reed leaves and stems. The increase of organic matter content means that mineral components of plant tissue were released faster than organic ones. This was particularly true for potassium in both

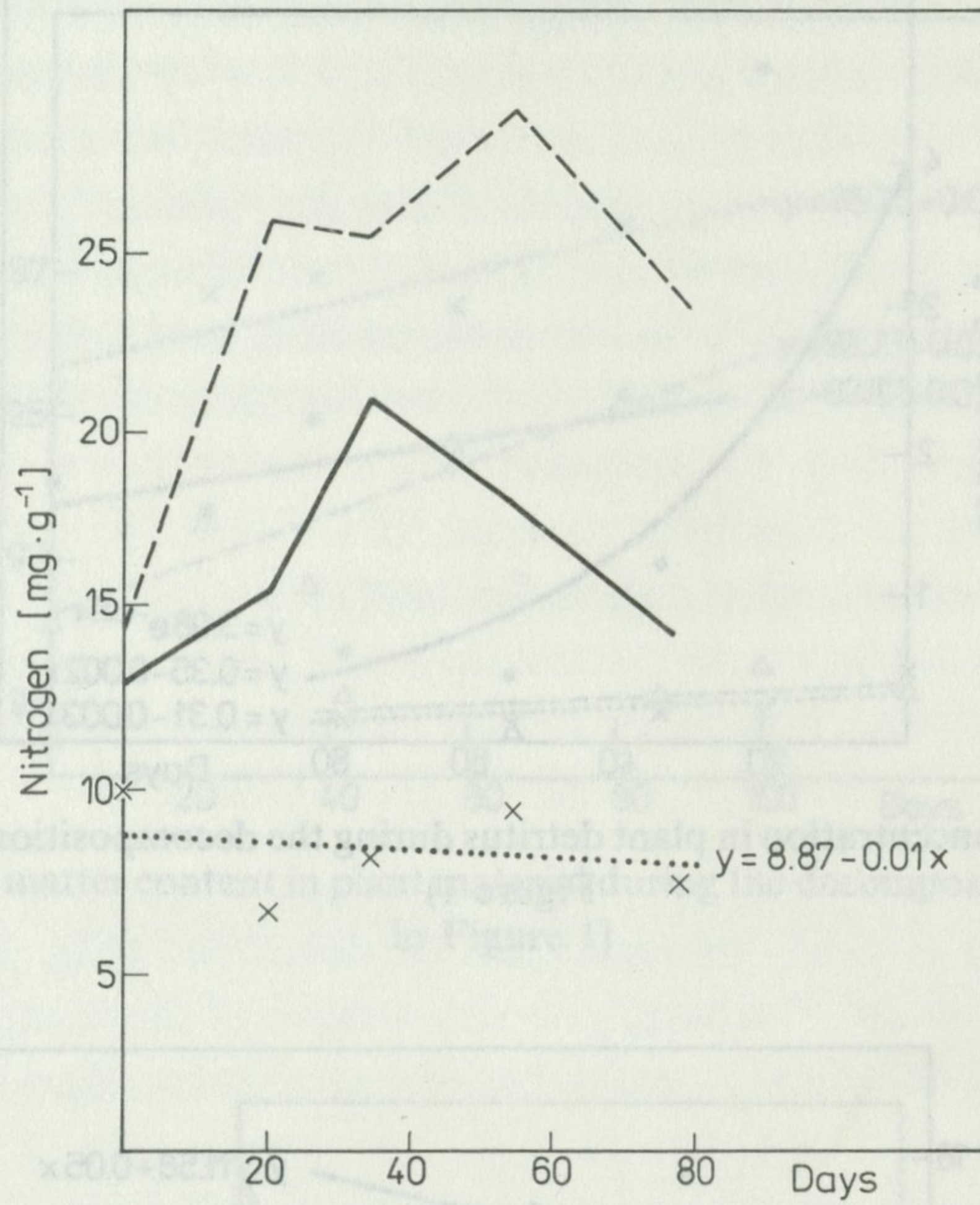


Fig. 6. Changes of nitrogen concentration in plant detritus during the decomposition (description of lines as in Figure 1)

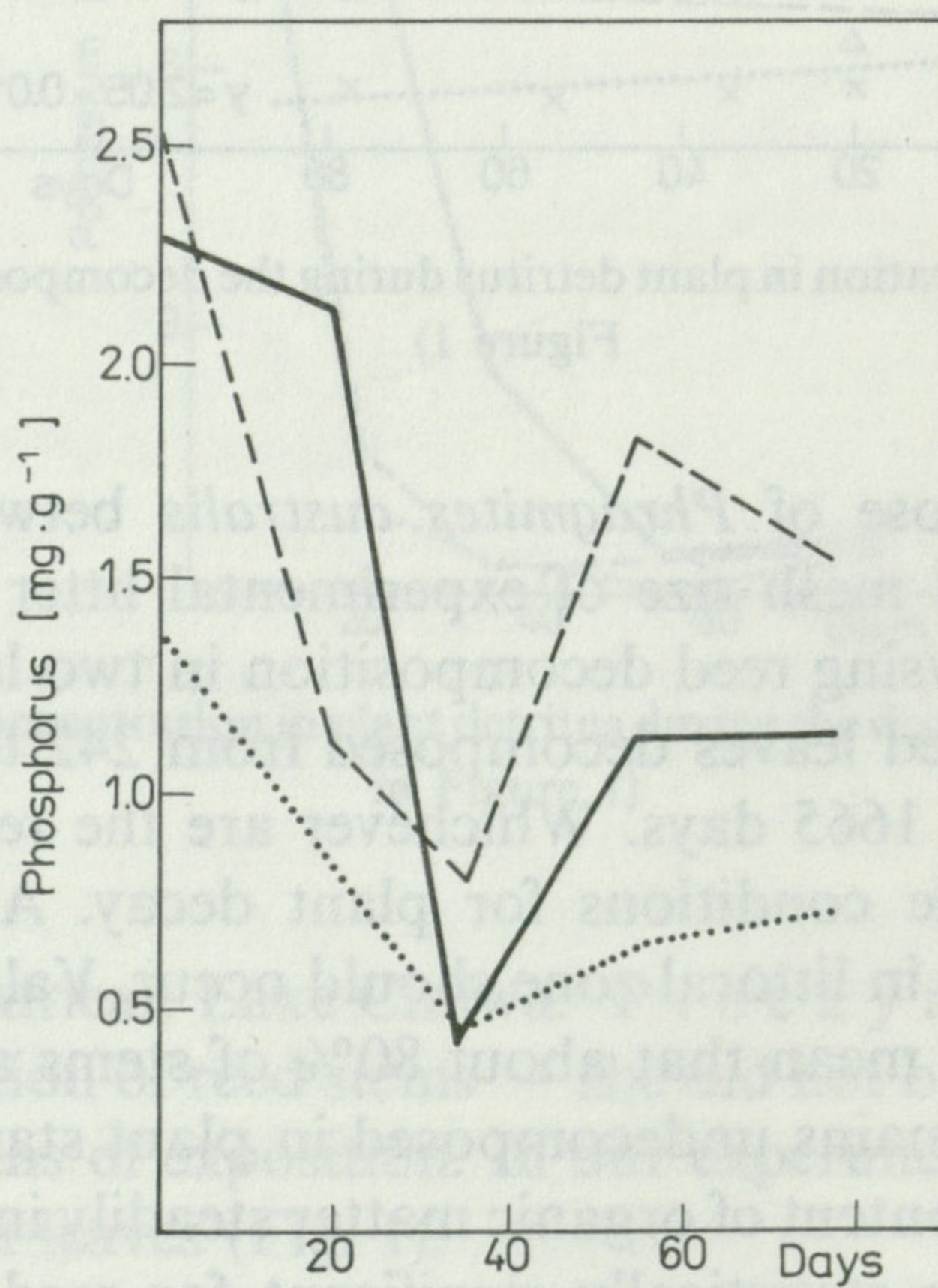


Fig. 7. Changes of phosphorus concentration in plant detritus during the decomposition (description of lines as in Figure 1)

plants analysed and for sodium in cattail (Figs. 3, 4). Potassium concentration in plant litter dropped so rapidly that after 50 days of decomposition plant material was practically devoid of that element. The evidence for rapid leaching of potassium out of decaying macrophytes can be also found in P l a n t e r (1970) and M a s o n and B r y a n t (1975). Concentration of sodium in reed leaves and stems was much lower than in cattail (Fig. 4) and did not change during decomposition. Calcium concentration differed in cattail and reed samples (Fig. 5.) though it did not change significantly through the course of the experiment, i.e., the leaching was proportional to the decomposition of plant detritus.

Nitrogen and phosphorus changes in plant detritus were of different character. In cattail and in reed leaves concentration of nitrogen increased at the beginning of the experiment. Then, after reaching maximum (in the 5th week in cattail and in the 8th week in reed leaves) nitrogen concentration decreased. Reed stems showed almost constant concentration of nitrogen during the whole experimental period (Fig. 6). On the contrary, in case of phosphorus, rapid initial decrease in all analysed plants was followed by the later rise of concentration (Fig. 7). Similar nitrogen maximum in decomposing macrophytes was reported by G o d s h a l k and W e t z e l (1978) and was attributed to the colonization of microorganisms and accumulation of microbial protein on plant detritus. It seems also that initial nitrogen content may influence the rate of detritus decomposition. The higher initial nitrogen in plant sample (Fig. 6) the higher was decomposition rate of the detritus (Fig. 1).

The regression equation of the decomposition process $y = ae^{-bx}$ is the solution of the first order kinetic equation $\frac{dy}{dx} = -by$. The process described by that equation is self inhibiting, i.e., the decomposition rate is reduced in time due to the exhaustion of the substratum. Basing on the results obtained a possible mechanism of the inhibition may be suggested. Initially high decomposition rate was governed mainly by microbial activity (manifested in increased N content in plant detritus). This led to solubilization and leaching out of mineral compounds, among others phosphorus (or at least its labile fraction). In consequence, the depletion of P was observed in detritus (see Fig. 7) and the N:P ratio reached values 51 in cattail and 31 in reed leaves. Phosphorus deficit in substratum inhibited probably further growth of microorganisms what appeared as a decrease in N concentration at the end of the experiment. Simultaneous increase of phosphorus concentration may represent its more refractory pool resistant to further decomposition. Another possible explanation lies in resorption of phosphorus from water into finely fragmented detritus, the phenomenon observed also by P l a n t e r (1970). Thus N : P ratio seems to be decisive for the decomposition of the macrophytes analysed.

Heavy metals selected for analyses were chosen from two groups. First are those known to be of significance in plant or animal metabolism. Manganese, molybdenum and cobalt represented that group of cations. In the second group three elements of possible toxic properties were included — lead, copper and cadmium.

Manganese concentration increased during decomposition in cattail and in reed stems (Fig. 8). In reed leaves minimum concentration was observed in the middle of the

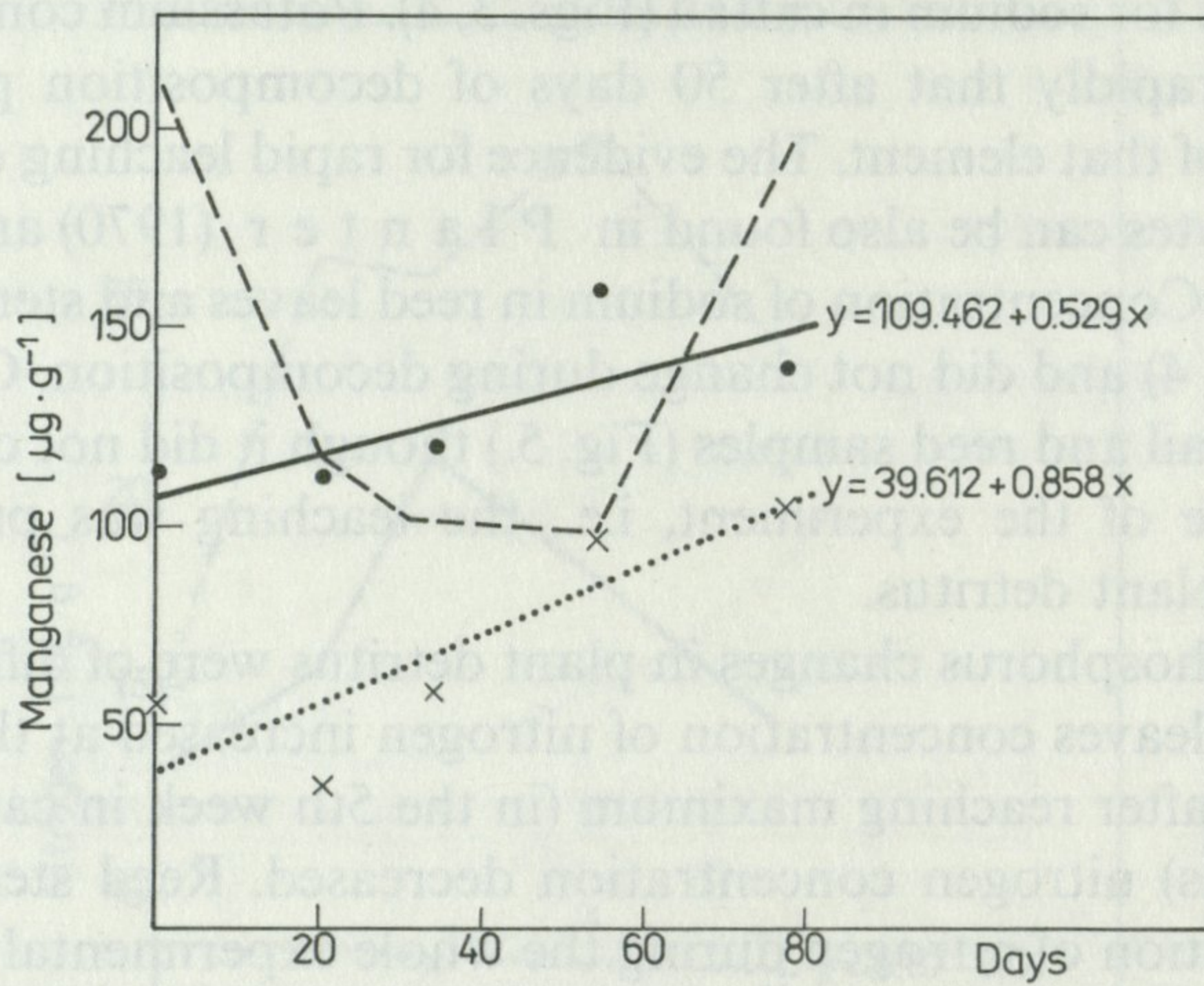


Fig. 8. Changes of manganese concentration in plant detritus during the decomposition (description of lines as in Figure 1)

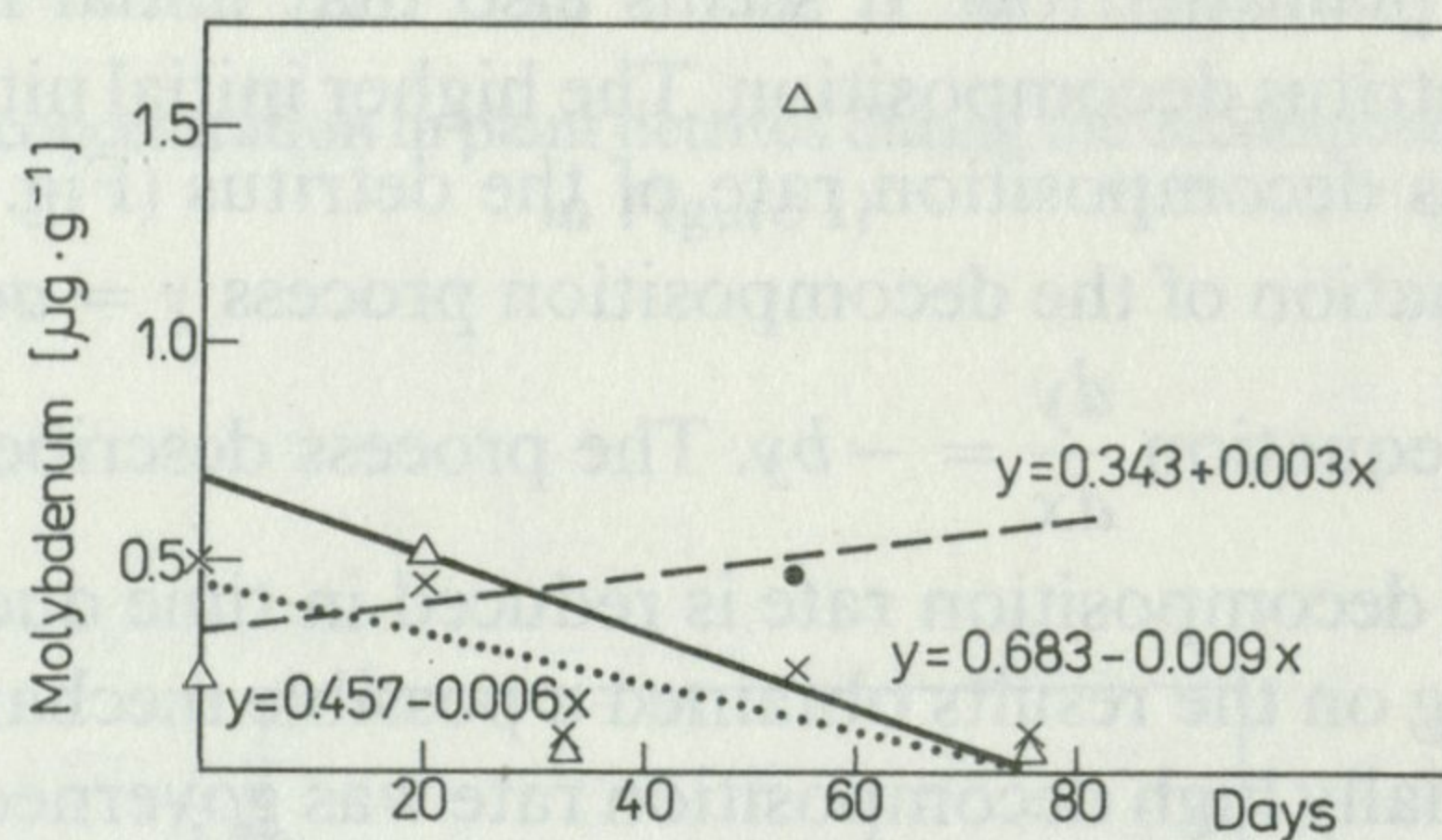


Fig. 9. Changes of molybdenum concentration in plant detritus during the decomposition (description of lines as in Figure 1)

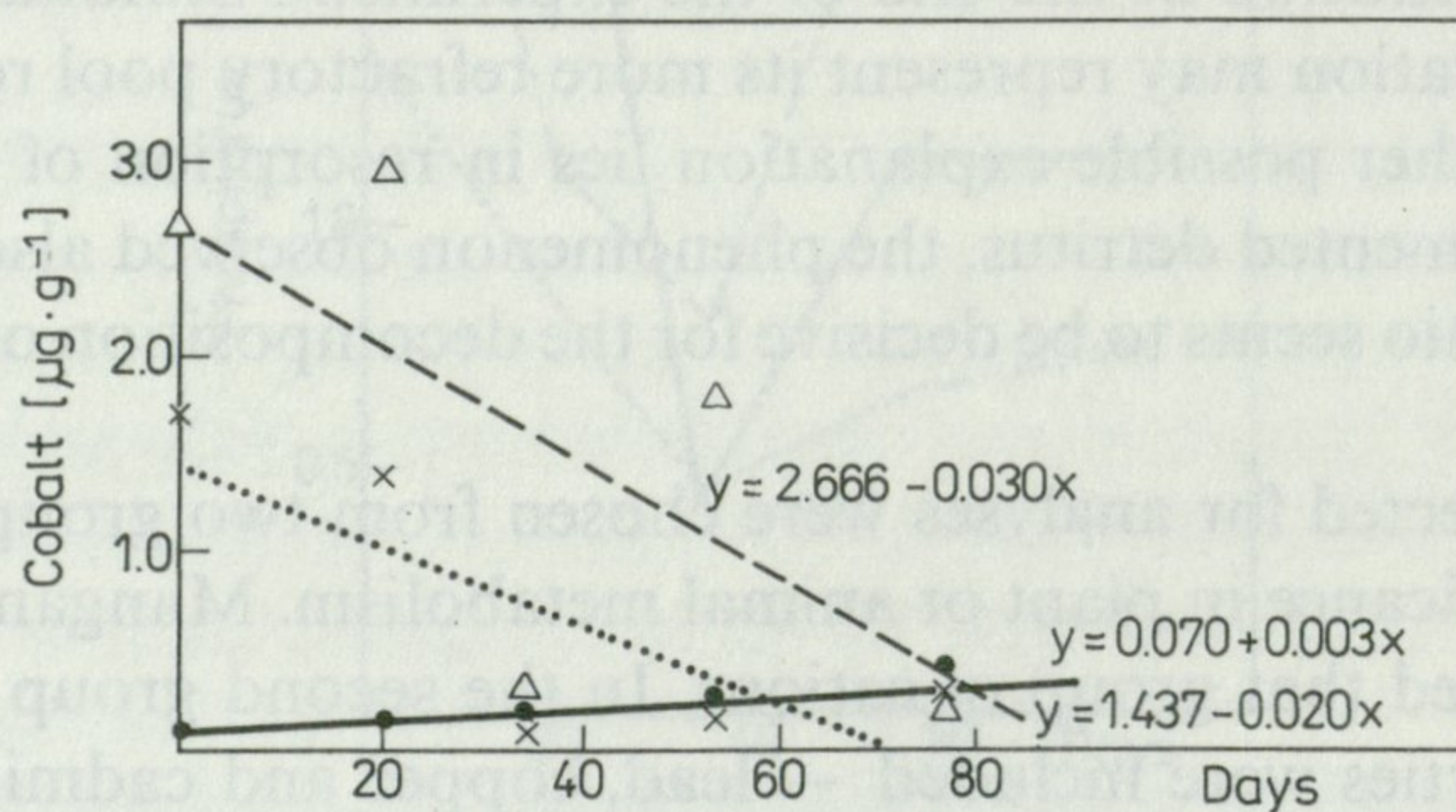


Fig. 10. Changes of cobalt concentration in plant detritus during the decomposition (description of lines as in Figure 1)

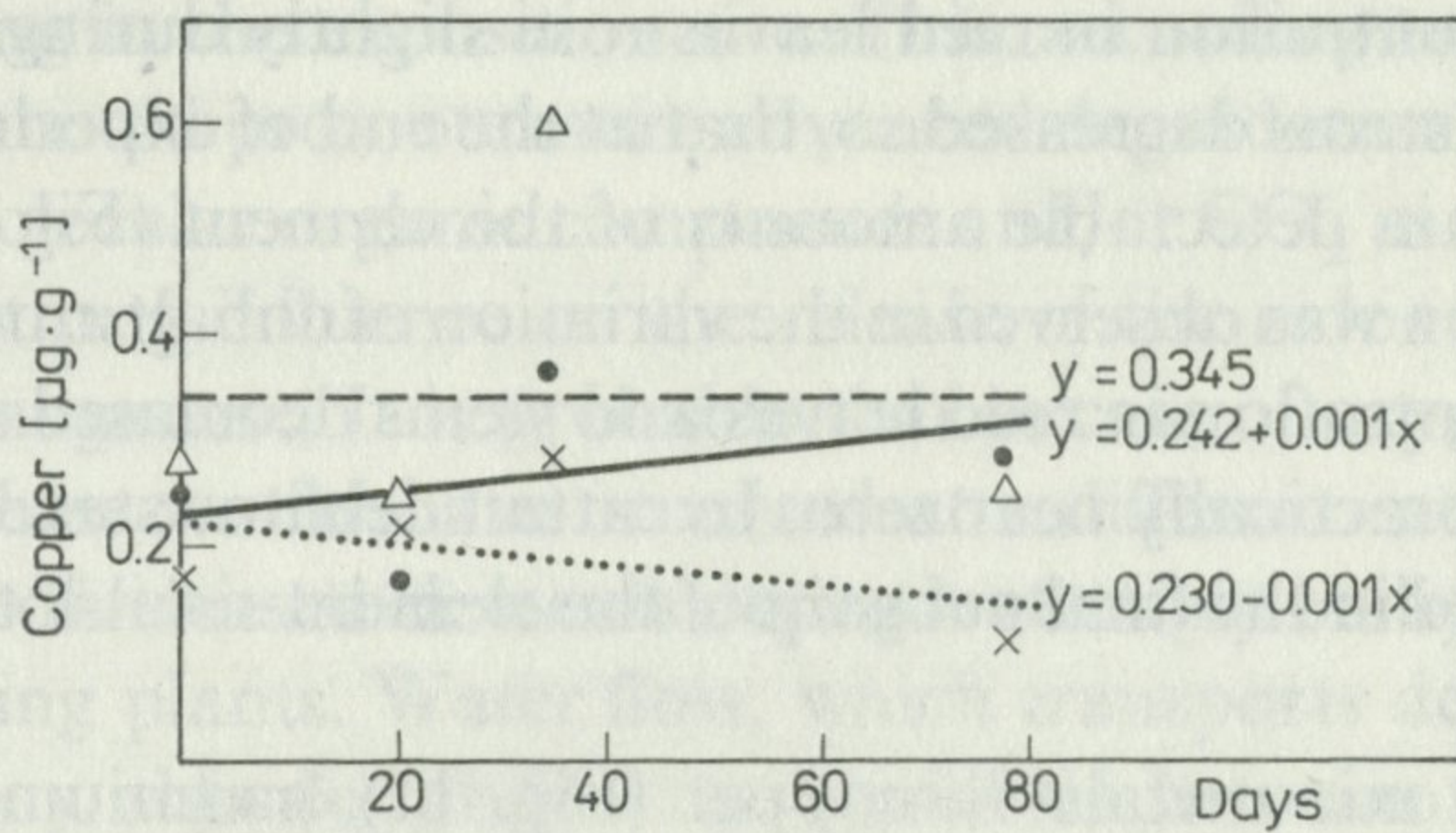


Fig. 11. Changes of copper concentration in plant detritus during the decomposition (description of lines as in Figure 1)

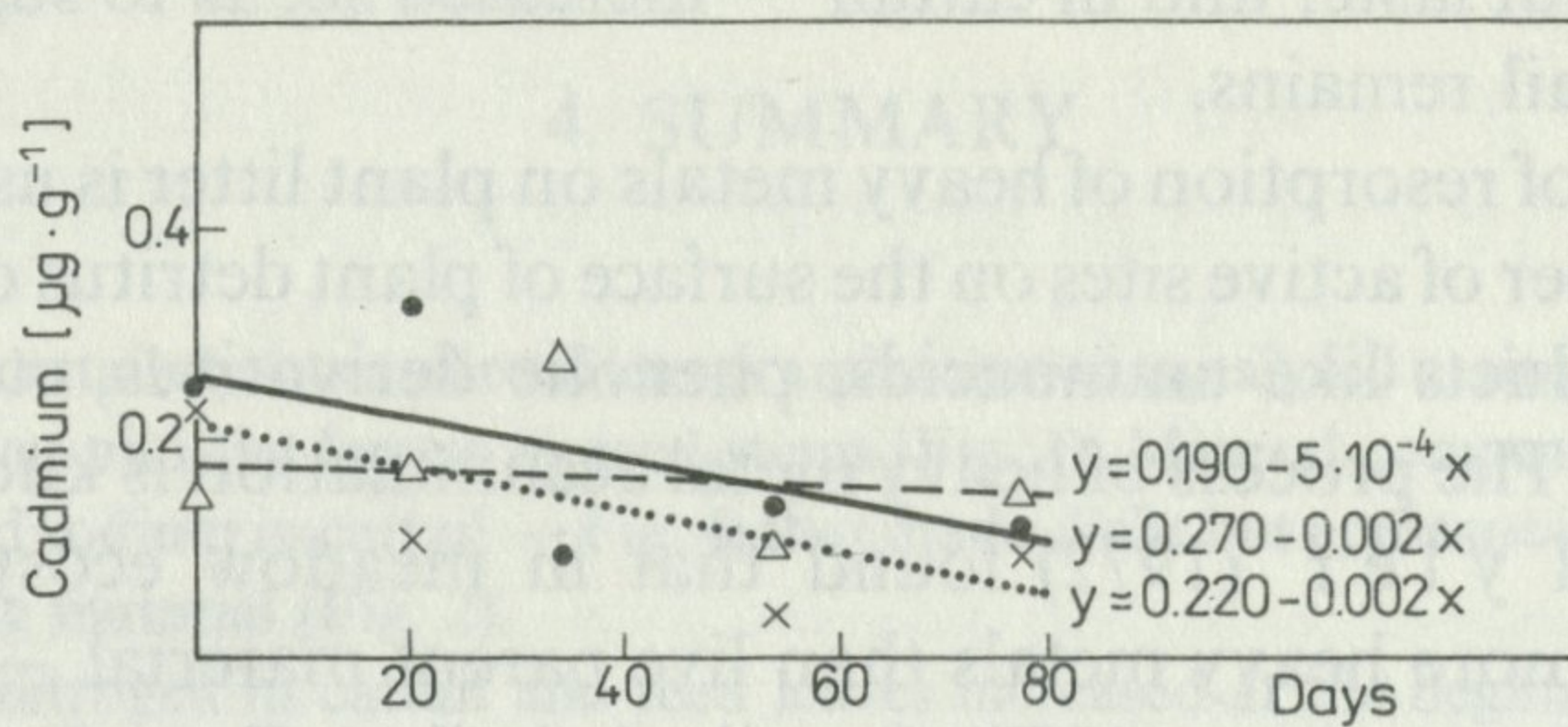


Fig. 12. Changes of cadmium concentration in plant detritus during the decomposition (description of lines as in Figure 1)

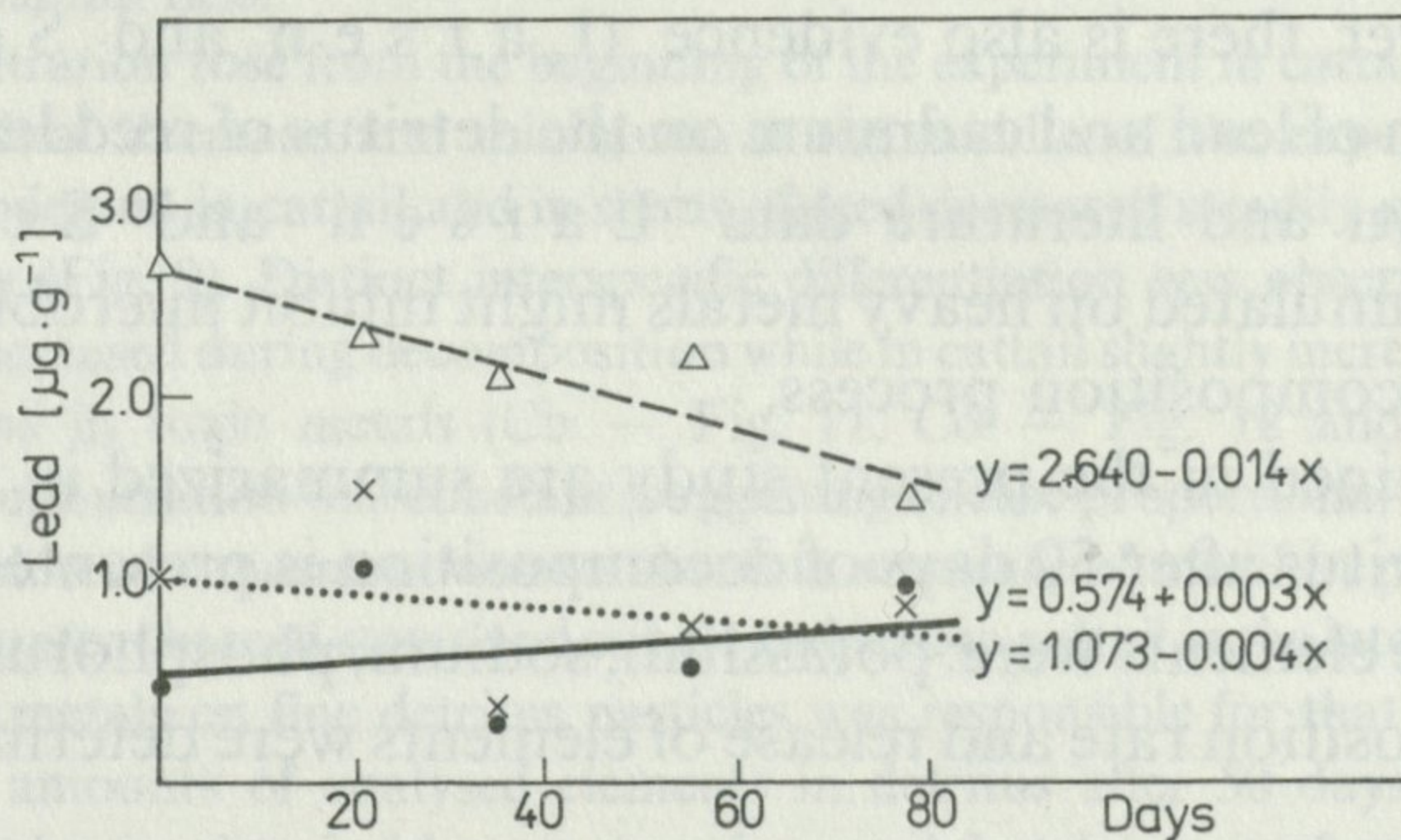


Fig. 13. Changes of lead concentration in plant detritus during the decomposition (description of lines as in Figure 1)

experiment followed by the increase later on. These results when calculated on the total amounts of Mn in plant sample in bags showed that detritus of reed stems gained manganese after first 20 days of initial loss. The amount of Mn in the cattail and reed leaf samples remained constant after similar initial loss. The mechanism of Mn accumulation on plant detritus is not known, however, it is possible that resorption is responsible for the observed effect.

Molybdenum concentration in reed leaves rose slightly during the decomposition and in cattail and reed stems decreased so, that at the end of experimental period plant material did not contain detectable amounts of the element (Fig. 9).

Apparent distinction was observed in the variation of cobalt among plants analysed (Fig. 10). Cobalt concentration in reed leaves and stems decreased so that at the end of the experiment it was practically near zero. In cattail detritus steady increase of cobalt was noted. This resulted in the final net gain of the element similar to that described for manganese.

Concentration of toxic metals – copper (Fig. 11), cadmium (Fig. 12) and lead (Fig. 13) were constant or varied insignificantly as illustrated by low appropriate constants in regression equations. That means that loss of these heavy metals from plant detritus was proportional to the general decomposition rate. Only lead from reed leaves was leached out faster and in cattail – increased so, as to suggest resorption of the element on cattail remains.

The mechanism of resorption of heavy metals on plant litter is usually explained by the increase in number of active sites on the surface of plant detritus or by the formation of degradation products like aminoacids, phenolic derivatives, etc. that are able to complex metal ions. The process of heavy metal accumulation is known for the litter of terrestrial plants. Tyler (1972) found that in meadow ecosystems dead plant material contained more heavy metals than live parent material – shoots of grasses, herbs and sedges. Somers (1978) described similar effects for the forest litter in various decomposition stages acting as a sink for cadmium. Aquatic environment creates specific conditions that may influence sorption of metals on plant detritus (e.g. by changing the equilibria between solid and liquid phase, different pH and oxygen regime, etc.). However, there is also evidence (Larsen and Schierup 1981) for the accumulation of lead and cadmium on the detritus of reed leaves in lake littoral. Basing on their own and literature data Larsen and Schierup (1981) underlined that accumulated on heavy metals might inhibit microbial activity and thus influence overall decomposition process.

The results obtained in the present study are summarized in Table 1, where the content of plant detritus after 50 days of decomposition is presented. The table reveals that the most mobile elements were: potassium, sodium, phosphorus, molybdenum and cobalt. The decomposition rate and release of elements were determined by the aerobic

Table 1. The quantities of elements analysed remaining in plant detritus after 50 days of in situ decomposition (in per cent of initial value)

Plant material	Dry weight	Organic matter	Ca	Na	K	N	P	Mn	Mo	Co	Cu	Cd	Pb
Cattail	36.8	37.1	44.7	8.9	2.3	52.5	16.1	45.7	12.6	115.7	44.4	23.2	46.4
Reed leaves	22.3	22.8	26.1	15.9	0.7	43.4	13.9	10.6	32.1	9.7	22.3	19.4	16.4
Reed stems	60.7	61.5	45.9	31.3	0.4	50.4	26.4	126.5	20.9	18.5	47.5	33.1	49.4

conditions prevailing in the exposition site. This, according to Godshalk and Wetzel (1978) should promote more advanced degradation of organic matter with formation of low molecular organic compounds and/or CO_2 as final products. Oxygen in water had also strong influence on the release of the redox sensitive elements like phosphorus and manganese. It is probable that in case of oxygen deficit phosphorus and manganese release would have occurred at a different rate.

The further fate of released elements depends strongly on hydrologic regime in the stand of decomposing plants. Water flow, which transports decomposition products out of the stand may also destabilize the equilibria between detritus and dissolved forms of elements and may renew the oxygen pool in the zone adjacent to decomposing plants. Transport processes were not measured in the present study and need further explanation.

4. SUMMARY

Decomposition of cattail shoots and reed leaves and stems was analysed in situ. Decomposition rate was the highest in reed leaves and the lowest in reed stems (Fig. 1). Mineral components were released faster (potassium — Fig. 3 and sodium in cattail — Fig. 4) that made slight but constant increase of organic matter content in decomposing material (Fig. 2).

Concentration of nitrogen in cattail and reed leaves increased at the beginning, then, after reaching maximum diminished (Fig. 6). Phosphorus showed minimum concentration around 5th week of decomposition in both plants analysed (Fig. 7). Initial nitrogen increase was probably due to microbial development on the surface of detritus. This caused the rise of N:P ratio up to values of 51 in cattail and 31 in reed leaves. High N:P ratio was probably responsible for the later inhibition of microorganisms activity and in effect restrained the decomposition rate.

Manganese concentration rose from the beginning of the experiment in cattail and reed stems while in reed leaves — after initial decrease and minimum in the middle of the experimental period (Fig. 8). Concentration of molybdenum in cattail and in stems of reed decreased steadily practically to zero, in reed leaves increased slightly (Fig. 9). Distinct interspecific differentiation was observed in case of cobalt, its concentration in reed decreased during decomposition while in cattail slightly increased (Fig. 10). There were no significant variations in toxic metals (Cu — Fig. 11, Cd — Fig. 12 and Pb — Fig. 13) during decomposition. Their concentration was constant (suggesting release proportional to decomposition rate) or varied slightly. Conversion of concentrations to absolute amounts of metal in plant sample revealed net increase of manganese content in reed stems and cobalt and lead in cattail in the later stage of decomposition. Probably resorption of metals on fine detritus particles was responsible for that effect.

In conclusion the amounts of analysed elements in detritus after 50 days of decomposition were compared (Table 1) and physicochemical factors were discussed that determine further fate of decomposition products.

5. POLISH SUMMARY

Analizowano rozkład pędów pałki i trzciny (osobno liście i łodygi) w warunkach naturalnych. Procesowi rozkładu najszybciej ulegały liście trzciny, najwolniej — łodygi (rys. 1). Mineralne składniki uwalniane były szybciej z detrytusu roślinnego (potas — rys. 3, sód w pałce — rys. 4), co spowodowało stały, niewielki wzrost zawartości materii organicznej w rozkładającym się materiale roślinnym (rys. 2).

Stężenie azotu w pałce i liściach trzciny w pierwszej fazie rozkładu rosło, następnie — po osiągnięciu maksimum — malało (rys. 6). Fosfor wykazywał minimum stężenia ok. 5 tygodnia rozkładu w obu analizowanych roślinach (rys. 7). Początkowy wzrost stężenia azotu był prawdopodobnie wynikiem rozwoju

mikroorganizmów na powierzchni detrytus. To spowodowało wzrost stosunku N:P do wartości 51 w pałce i 31 w liściach trzciny. Tak wysoki stosunek N:P zahamował prawdopodobnie później aktywność mikroorganizmów i zwolnił tempo rozkładu.

Stężenie manganu rosło od początku eksperymentu w pałce i łodygach trzciny, a w liściach trzciny — po wstępnym spadku i minimum w połowie okresu badawczego (rys. 8). Stężenie molibdenu w pałce i łodygach malało równomiernie praktycznie do zera, w liściach trzciny nieznacznie rosło (rys. 9). Wyraźne różnicowanie między gatunkami obserwowano w przypadku kobaltu, którego stężenie w trzcinie malało w trakcie rozkładu, podczas gdy w pałce nieznacznie rosło (rys. 10). W przypadku metali toksycznych (miedź — rys. 11, kadm — rys. 12 i ołów — rys. 13) nie notowano wyraźnych zmian w trakcie rozkładu. Stężenie metali było stałe (co sugeruje uwalnianie metalu proporcjonalne do szybkości dekompozycji) lub zmieniało się w niewielkim stopniu. Przeliczenie stężeń na bezwzględną zawartość metalu w próbce roślin wykazało wzrost ilości manganu w łodygach trzciny oraz kobaltu i ołowiu w pałce w późniejszej fazie eksperymentu. Przepuszczalnie wtórna sorpcja tych metali na rozdrobnionym detrytusie spowodowała obserwowany efekt.

W konkluzji porównano ilości analizowanych pierwiastków w detrytusie po 50 dniach rozkładu (tab. 1) oraz przedstawiono uwarunkowania fizykochemiczne, jakim podlegają produkty rozkładu.

6. REFERENCES

1. D a v i s C. B., v a n d e r W a l k A. G. 1978 — Litter decomposition in prairie glacial wetlands (In: Freshwater wetlands. Ecological processes and management potential, Eds. R. E. Good, D. F. Whigham, R. L. Simpson) — Academic Press, New York-San Francisco—London, 99—113.
2. G ł o w a c k a I., S o s z k a G. J., S o s z k a H. 1976 — Invertebrates associated with macrophytes (In: Selected problems of lake littoral ecology, Ed. E. Pieczyńska) — Wydawnictwa Uniwersytetu Warszawskiego, Warszawa, 97—122.
3. G o d s h a l k G. L., W e t z e l R. G. 1978 — Decomposition in the littoral zone of lakes (In: Freshwater wetlands. Ecological processes and management potential, Eds. R. E. Good, D. F. Whigham, R. L. Simpson) — Academic Press, New York—San Francisco—London, 131—143.
4. H o w a r d - W i l l i a m s C., H o w a r d - W i l l i a m s W. 1978 — Nutrient leaching from the swamp vegetation of Lake Chilwa, a shallow African lake — Aquat. Bot. 4: 257—267.
5. K u f e l L. 1978 — Seasonal changes of Pb, Cu, Mo and Co in above-ground parts of *Phragmites australis* Trin. ex Steudel and *Typha angustifolia* L. — Bull. Acad. pol. Sci. Cl. II, Sér. Sci. biol. 26: 765—770.
6. L a r s e n V. J., S c h i e r u p H.-H. 1981 — Macrophyte cycling of zinc, copper, lead and cadmium in the littoral zone of a polluted and a non-polluted lake. II. Seasonal changes in heavy metal content of above-ground biomass and decomposing leaves of *Phragmites australis* (Cav.) Trin. — Aquat. Bot. 11: 211—230.
7. M a s o n C. F., B r y a n t R. J. 1975 — Production, nutrient content and decomposition of *Phragmites communis* Trin. and *Typha angustifolia* L. — J. Ecol. 63: 71—95.
8. P i e c z y ń s k a E. 1972 — Ecology of the eulittoral zone of lakes — Ekol. pol. 20: 637—732.
9. P i e c z y ń s k a E. 1976 — Destruction (In: Selected problems of lake littoral ecology, Ed. E. Pieczyńska) — Wydawnictwa Uniwersytetu Warszawskiego, Warszawa, 195—209.
10. P l a n t e r M. 1970 — Elution of mineral components out of dead reed *Phragmites communis* Trin. — Pol. Arch. Hydrobiol. 17: 357—362.
11. S o l s k i A. 1962 — Mineralizacja roślin wodnych. I. Uwalnianie fosforu i potasu przez wymywanie [Mineralization of aquatic vegetation. I — Release of phosphorus and potassium salts by leaching] — Pol. Arch. Hydrobiol. 10: 167—196.
12. S o m e r s G. F. 1978 — The role of plant residues in the retention of cadmium in ecosystems — Environ. Pollut. 17: 287—295.
13. T y l e r G. 1972 — Heavy metals pollute nature, may reduce productivity — Ambio, 1: 52—59.

(Received 27 March 1987)