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Particulate organic matter in the high mountain stream Sucha Woda (the High Tatra Mts, Poland)*

Joanna Galas

Polish Academy of Sciences, Institute of Freshwater Biology,
ul. Sławkowska 17, 31-016 Kraków, Poland

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Abstract - Spatial and temporal changes in coarse and fine particulate organic matter (POM) were monitored at nine stations on a mountain stream in the Polish Tatra Mts. Standing stock of benthic POM measured as ash-free dry mass (AFDM) increased with increasing stream size. The coarse and fine POM mass tends to settle in a pool habitat rather than in a riffle. The concentration of transported POM remained at the some level at all sampling stations.

Key words: particulate organic matter, pool, riffle, mountain stream.

1. Introduction

The importance of particulate organic matter (POM) as the major energy source in rivers has been well documented (Cummins et al. 1983). The allochthonous litter from the surrounding watershed falls into the stream and decomposes into particulate organic matter. It becomes settled on the stream-bed or suspended in the water and then carried downstream. Some studies show the dynamics of POM in forested headwater streams (Richardson 1992), processing rates, and downstream transport (Naiman, Sedell 1979). In Poland, investigations on POM in lowland rivers were carried out by Grzybkowska et al. (1990).

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Some work on the quantity of benthic or transported allochthonous organic matter has been done in high mountain streams which have a low primary production (Newbern et al. 1981, Short, Ward 1981, O'Hop, Wallace 1983, Angradi 1991). There have been no such studies, however, in Polish montane streams.

The aim of the present study was to characterize the longitudinal changes of benthic and transported POM in the high mountain stream Sucha Woda. The spatial distribution and annual changes of benthic POM were also investigated.

2. Study area

Samples were collected from the Sucha Woda, draining a relatively undisturbed catchment in the High Tatras. This stream is 15.5 km long, with a catchment area of 68 km^2, and mean gradient of up to 68‰. The altitude ranges from 1787 to 775 m. The Pańszczycki and Filipka streams are major tributaries of the Sucha Woda (fig. 1). The physical and geological characteristics of this stream were described in detail by Pasternak (1971).

The studied stream flows through several vegetation zones, where the following species dominate: mountain pine *Pinus mugo* in the dwarf pine zone, Norway spruce *Picea abies* in the montane forest zone and grey alder *Alnus incana* in the submontane zone. Its bed consists almost entirely of bedrock, boulders, and stones. The substratum of the catchment basin is composed of crystalline rocks in the upper parts and sedimentary rocks in lower parts (Pasternak 1971). Therefore, alkalinity (0.1-2.5 meq dm^{-3}) and pH (6.0-8.0) vary longitudinally. The concentrations of the main dissolved nutrients and ions are low (< 1mg dm^{-3}); conductivity averages from 215 to 18 µS at 18°C. Dissolved oxygen saturation ranges from 78 to 94%. During the study maximum and minimum air and water temperatures were: 23°C, -8°C and 11°C, 1°C subsequently (Wojtan, unpubl.).

Characteristic features of this stream are great fluctuation of the water level taking place over a short period of time (Gieysztor 1961). Water depth is variable, ranging from a few centimeters in winter to about 90 cm in spring and summer. A peculiarity of this stream is its complete loss of water in the zones of karst rocks and drying up in the bed over a large section.

Nine sampling stations were studied (fig. 1, Table I).

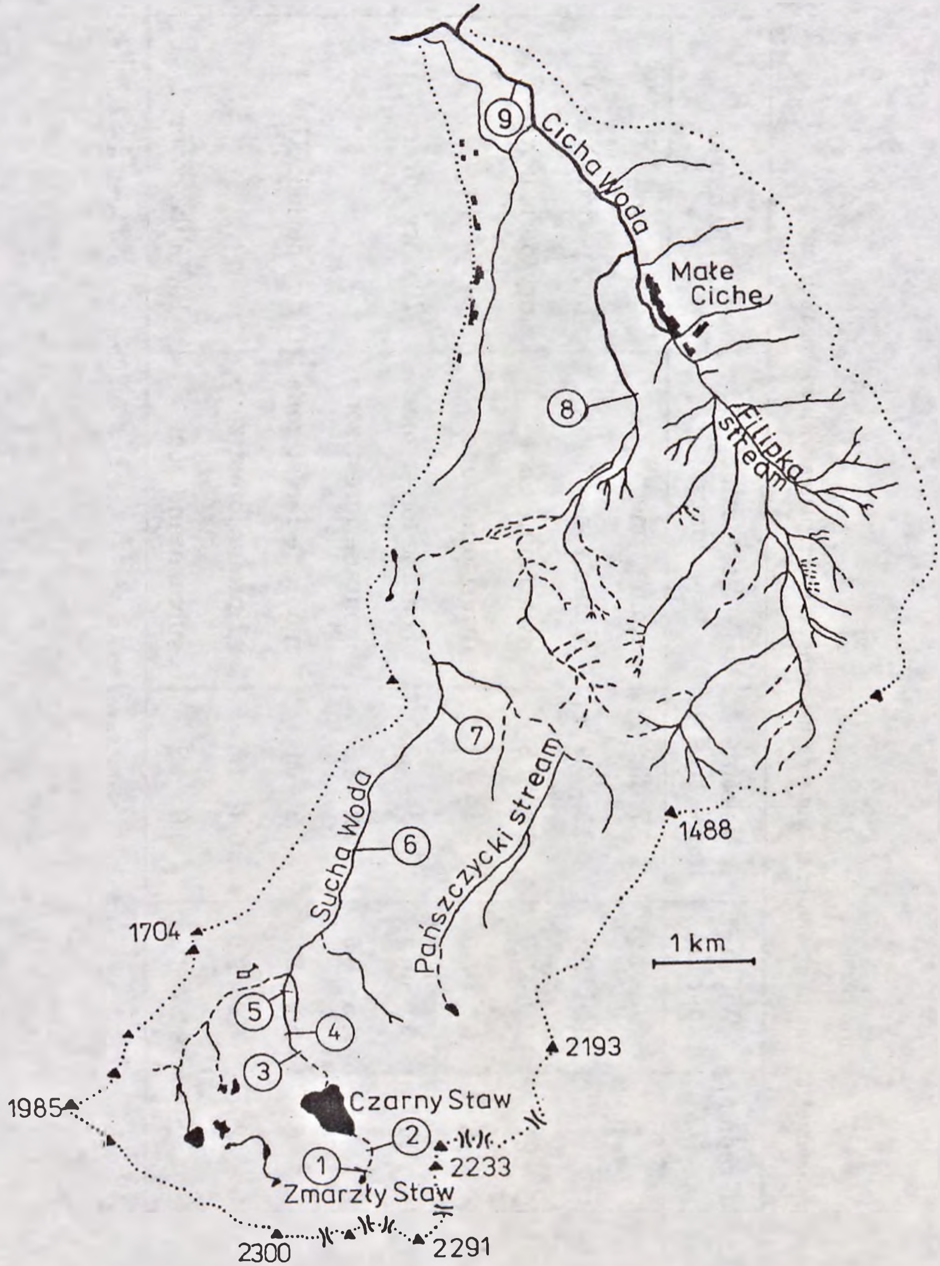

Fig. 1. Catchment area of the Sucha Woda stream showing the location of the nine sampling stations. Dotted lines indicate periodically dried up sections

Table I. Selected abiotic variables for sampling stations - the measurements concern places with average current

Station number	Altitude (m)	Gradient (‰)	Width range (m)	Velocity range (m s^{-1})	Vegetation zones	Remarks
1	1780	344	1.0 - 1.5	0.7 - 0.9	alpine zone	dry period: XI - VI
2	1700		1.5 - 2.5	0.5 - 0.9	alpine zone	dry period: XI - VI
3	1560	210	2.0 - 5.0	0.8 - 1.3	dwarf pine zone	dry period: XI - V
4	1540	80	3.5 - 4.0	0.4 - 1.1	dwarf pine zone	
5	1460	100	5.0 - 6.5	0.3 - 1.2	montane forest zone	70% ice cover: I, II
6	1330	66	4.5 - 6.5	0.2 - 1.5	montane forest zone	
7	1180	66	5.0 - 8.0	0.6 - 0.9	montane forest zone	dry period: XII - IV
8	860	20	6.0 - 9.0	0.4 - 1.5	montane forest zone	
9	775	20	8.0 - 10.0	0.6 - 1.2	submontane zone	100% ice cover: I, II

3. Materials and methods

In the study two types of particulate organic matter (POM) were investigated: the benthic organic matter (BOM), and transported organic matter (TOM). Each month, from October 1990 to September 1991 samples of BOM were collected at all of the nine sampling stations. The samples of BOM were obtained from plastic traps (area 0.006 m^2) placed at ground level, one in a riffle and one in a pool, the samplers being left there for one week. During a heavy flood some of the traps were washed out. At Stations 1 and 2 the data were too small, hence they were excluded from the analyses. 125 benthic samples were collected. The BOM samples were fractioned into CPOM (coarse POM), which represents particles > 1 mm, and FPOM (fine POM) - particles between 1 mm and 0.45 μm in diameter.

The monthly samples of TOM were collected at all stations from January to September 1991. The coarse TOM was collected in two 0.3 mm mesh nets (Water type), left in the main stream channel for 0.5 h. Fine TOM particles were determined by filtering 25 dm^3 of water through a 10 μm net.

All material was oven-dried at 105°C, weighed and incinerated for 3 h at 550°C to determine the organic matter. BOM samples are reported as grams of ash-free dry mass (AFDM) m^{-2} day^{-1}, and CTOM samples as grams AFDM m^{-3} and FTOM samples as mg m^{-3}. Analysis of variance (ANOVA) was used to test for significant differences.

4. Results

The annual means of the benthic organic matter from seven sampling stations along the stream are shown in fig. 2. The spatial distribution of coarse and fine BOM showed a higher concentration of both fractions in the pool habitat (mean value: 6.25 g m^{-2} and 5.98 g m^{-2}) (fig. 2C, D). The pattern of the CPOM along the stream pool was similar to that of FPOM, with a minimum at Station 4 and maximum at Station 9. Station 4 had significantly less CPOM than Stations 3 ($p < 0.01$) and 7 ($p < 0.001$). The Station 9 value for FPOM in the pool was statistically ($p < 0.01$) higher than in all the other stations. Benthic POM biomass in the riffle was smaller than in pool habitat, higher for CPOM (mean 4.07 g m^{-2}) than for FPOM (mean 0.94 g m^{-2}) (fig. 2A, B). The values of the two fractions of benthic POM at the riffle were at the same level along the stream, with the exception of Station 7 which had 12 g m^{-2} of CPOM. This value differed statistically ($p < 0.05$) from those at Station 4.

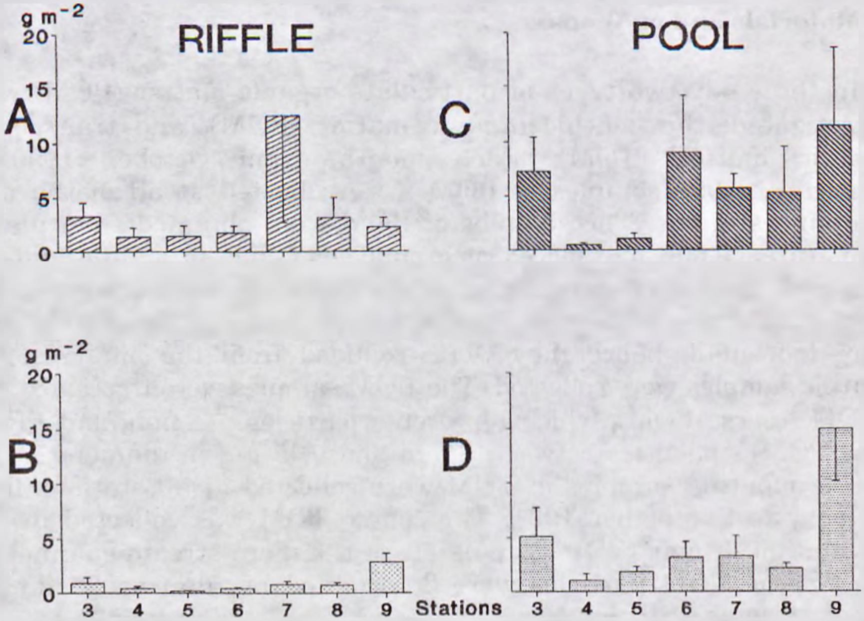

Fig. 2. Mean CPOM (A, C) and FROM (B, D) in riffle and pool habitats in the Sucha Woda stream. Vertical bars indicate standard errors

During the year a high concentration of BPOM was found in July, August, and September at all the investigated stations. In the remaining months of the year the amounts of BPOM were low. This is shown in two examples: the periodically drying Stations 3 and 8 (fig. 3).

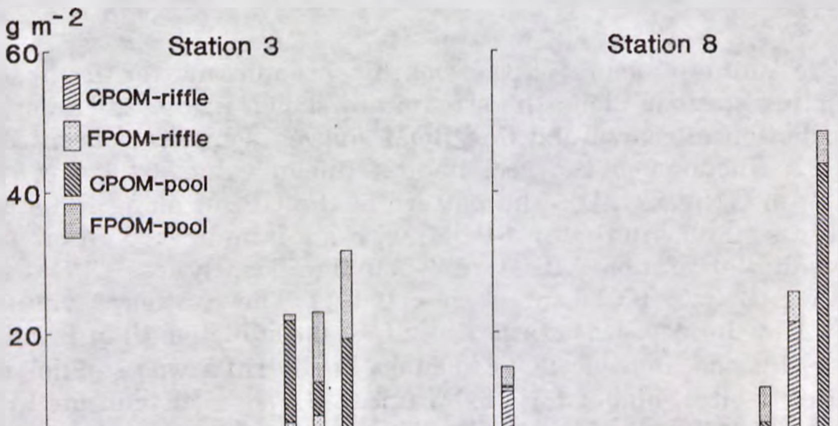

Fig. 3. Monthly changes of the benthic POM biomass at Stations 3 and 8 of the Sucha Woda stream

The annual mean values of coarse TOM along the stream were at a uniform level of 10 g m^{-3}. (fig. 4). Only at Stations 1, 3 and 7 was the concentration of coarse TOM 3 times higher. The mean annual values of fine TOM at all stations of the Sucha Woda were low, at a level of 300 mg m^{-3}. At Station 7 the FTOM value was 700 mg m^{-3} (fig. 4). There were no significant differences in CTOM and FTOM between any of the sampling stations.

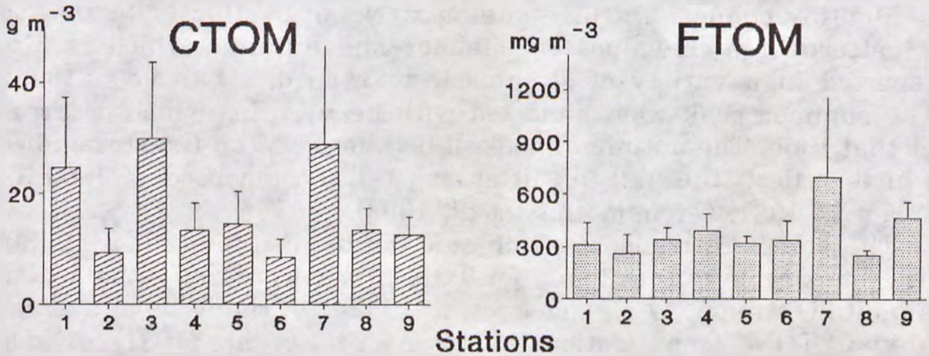

Fig. 4. Annual means of the transported POM biomass in the Sucha Woda stream. Vertical bars indicate standard errors

5. Discussion

The amount of benthic organic matter in the Sucha Woda stream was very small, much smaller than that reported for streams in deciduous forest (N a i m a n, S e d e l l 1979) but similar to many other brooks (S h o r d, W a r d 1981, R i c h a r d s o n 1992). Detritus may originate from drainage basin vegetation, bank erosion, and input from algal production (C o r k u m 1992). BOM standing stocks along the studied stream were variable and originated mainly from allochthonous sources. At the upper stations coniferous vegetation dominated and consequently the level of organic matter in the stream-bed was small. The coarse and fine fractions generally showed a increase downstream, suggesting that local input and tributaries play a major role in introducing additional large particles downstream with the flow of the Sucha Woda (M i n s h a l l et al. 1982, S t e w a r t, D a v i e s 1990). A considerable accumulation of detritus on the dried up sections occurred so that when the water level rose this material entered the stream. The high value of POM at Stations 3 and 7 might therefore reflect the incorporation of this material.

The effect of stream-bed morphology on the distribution of BOM within the stream channel seems to be the most important factor. Marked deposition of both coarse and fine POM in the stream pools occurred at all sampling stations. This stream belongs to the group with a bed divided into erosional and depositional areas (M i n s h a l l et al. 1982). The trend towards a greater accumulation of organic matter in areas of low flow rather than in the stream margin is characteristic for many small streams (M a c k a y 1977).

Monthly changes in the standing stocks of benthic POM showed a pattern of high values in summer and autumn, which is also reported in a variety of streams (S t e w a r d, D a v i e s 1990). The summer peak was connected with heavy rains which occurred at that time. The autumnal peak of benthic POM on the stream-bed which reflect the fall of litter is well documented (S h o r d, W a r d 1981, C u m m i n s et al. 1983).

The values of transported organic matter in the studied stream are comparable to that found for TOM in a 1st ordered Appalachian Mountain stream (W a l l a c e et al. 1982). On the basis of average annual TOM concentrations, N e w b e r n et al. (1981) divided rivers into two categories: high > 40 g m^{-3}, located in deciduous regions, and low, < 20 g m^{-3} in coniferous forest areas. The Sucha Woda belongs in the low category (mean 17.2 g m^{-3}). TOM values did not differ significantly at any of the sites, though TOM concentration increased markedly at the dried up one. This was probably due to the high variability of the data. In July, increased discharge flushed organic material from the stream-bed, resulting in raised CPOM values. Such results are comparable with these shown by N e w b e r n et al. (1981), O ' H o p, W a l l a c e (1983).

As is the case of most small streams largely depending on allochthonous input, the Sucha Woda is rather poor in organic matter as food resources for the benthic community. Further investigations are required to show the relationship between the amount of detritus and the density of invertebrates.

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6. Polish summary

Materia cząstkowa w wysokogórskim potoku Sucha Woda (Wysokie Tatry, Polska)

Zmiany zawartości cząstkowej materii organicznej (POM) dennej (BOM) i transportowanej (TOM) badano na dziewięciu stanowiskach potoku Sucha Woda (ryc. 1, tabela I). Próby BOM pobierano co miesiąc do pojemników ustawionych w nurcie i zastoiskach potoku. Materiał dzielono na frakcję gruboziarnistą - cząsteczki > 1 mm (CPOM) i frakcję drobnoziarnistą - cząsteczki < 1 mm (FPOM). Do badań TOM używano siatki o oczkach 0.3 mm, ustawionej w nurcie potoku przez 0.5 h i drugiej o oczkach 10 m, przez którą przelano 25 dm^3 wody. Zawartość materii organicznej dennej obu frakcji była wyższa w zastoiskach niż w nurcie (ryc. 2); wzdłuż potoku zmieniała się podobnie dla CPOM jak i FPOM: najmniej jej było na stanowisku 4 a najwięcej na stanowisku 9.

W ciągu roku maksymalne wartości POM stwierdzono od lipca do września, w pozostałych miesiącach wartości te były niskie (ryc. 3). Ilość TOM w potoku utrzymywała się na podobnym poziomie zarówno w ciągu roku jak i na wszystkich badanych stanowiskach (ryc. 4).

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