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Effect of treated wastes on cyanobacteria, algae, and macroinvertebrate communities in an alpine stream

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Abstract – The Warme Mandling stream (the Dachstein Alps, Austria) was studied at 8 stations (forest zone, alt. 1240–950 m) above and below the discharge of wastes from the Filzmoos treatment plant with a high concentration of phosphates (6.3 mg L^{-1}), total phosphorus (10.7 mg L^{-1}), nitrates (15.8 mg L^{-1}), and total nitrogen (28.2 mg L^{-1}). Below the treatment plant the abundance of tolerant taxa (*Cymbella silesiaca* Bleisch, *Gomphonema olivaceum* (Hornemann) Bréb., *Nitzschia capitellata* Hust., *N. fonticola* Grun., *Leuctra* spp., *Orthocladius (E.) rivicola* (Kieffer), *Cricotopus* and *Orthocladius* species) increased, while the share of taxa typical of unpolluted streams (*Homoeothrix janthina* (Bory et Flah.) Starmach, *Fragilaria arcus* Cl., *Baetis alpinus* Picted, *Rhithrogena* spp.) decreased.

Key words: stream, pollution, community, cyanobacteria, algae, macroinvertebrate.

1. Introduction

The problem of ecology of running waters and their protection is widely discussed in the literature (Hynes 1960, 1972, Whitton 1975, 1984, Ward 1992, Boon *et al.* 1992). However, those works chiefly concern lowland and submontane rivers. In high mountain streams, the problem has rarely been investigated. It was generally assumed that high mountain streams retained their natural characteristics. Nevertheless, human activity more and more frequently enters these areas. Here the Alps are an example, since in the last 30 years large recreation resorts have been developed in most of the valleys at an altitude above 1000 m, and in the winter and summer seasons thousands of tourists from all over the world arrive there. Among other factors, the intensive tourism brings about an increase in the amount of wastes. At first, they were released directly or through septic tanks to the streams. Under the pressure of public opinion, especially Greenpeace activities, most recreation resorts now have water treatment plants.

However, the question arises of how the discharge of treated sewage affects the ecosystems of high mountain streams, and especially their communities. It is also

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necessary to estimate the degree of pollution of the streams on the basis of their communities. In high mountain streams, owing to the turbulent water current, oxygen decline does not occur. The classic model of the effect of sewage on the communities of aquatic organisms (Bartch and Ingram 1959) breaks down or is subject to perturbation. Such perturbation was observed, among others, by Sadovskij (1940) in Caucasian streams and by Kownacki (1977, 1980, 1989) in those of the Tatra Mountains. Also in Zimmerman's experiments (1961) in streams polluted with organic matter, the rapid current beneficially brought about the development of algal species characteristic for purer waters.

In order to find an answer to the above questions an investigation was carried out in the Warme Mandling stream (Dachstein massif, the Alps, Austria) concerning the effects of treated wastes discharged from the Filzmoos water treatment plant on the cyanobacteria, algae and macrofauna communities in the stream.

2. Study area

The Warme Mandling stream rises from springs lying in the forest zone at an altitude of 1650 m and flows down the slopes of the Dachstein massif in the Alps, Austria, (13°35'N, 47°25'E). At alt. 930 m it joins the Kalte Mandling stream from this point taking the name Mandling. After 11.5 km at an altitude of 809 m, the stream flows into the River Enns. The catchment area is 33.2 km^2. The gradient of the stream is 73 ‰. In 1990/1991 the following average discharge values were recorded at an altitude of 1000 m: May–June – 1200 L s^{-1}, July–August – 700 L s^{-1}, September–14 Ocober – 500 L s^{-1}, 15 October–14 December – 200 L s^{-1}, 15 December–February – 100–200 L s^{-1}, and March–April – 500 L s^{-1}.

In the valley of the Warme Mandling stream, at an altitude of 1055 m, the Filzmoos recreation resort is located. In 1980, 1 km below Filzmoos, a sewage treatment plant was built for treating the wastes from hotels and boarding houses. In 1990, 214 226 m^3 of treated wastes were fed to the stream, this constituting about 1.2 % of the total amount of water flowing into the Warme Mandling. The amount of easily biodegraded organic matter in the treated sewage was small, as shown by BOD_5 values of 5 mg L^{-1}. On the other hand, the total organic matter content expressed by COD (37 mg L^{-1}) and TOC (11.2 mg L^{-1}) increased. In waters discharged from the treatment plant the content of ammonia was low, amounting to 0.25 mg L^{-1}, while the concentrations of nitrates and phosphates were high (15.8 and 6.3 mg L^{-1}, respectively). The content of total phosphorus was 10.7 mg L^{-1} and of total nitrogen 28.2 mg L^{-1}. The content of chlorides and sulphates (29.5 and 34.4 mg L^{-1}, respectively) was higher in the discharged waters than in the water of the mountain streams.

Apart from the treatment plant, a number of hydrotechnical constructions connected with the power station were installed on the Warme Mandling stream, affecting the amount of flowing waters. A small water intake for meeting the demand of the Steinbacher power station lies at an altitude of about 1000 m. At the place where the Warme Mandling and Kalte Mandling streams merge, a Mandling dam reservoir was built, retaining a great part of the water, hence the so-called "Restwasser" only flows below the reservoir.

The studies concerning the communities of cyanobacteria, algae, and macroinvertebrates were carried out at the following eight sites (Fig. 1): Station 1 (alt. 1240 m) situated about 1 km below the sources, the stream being about 3 m in width and the effects of human activity were there insignificant (the samples of

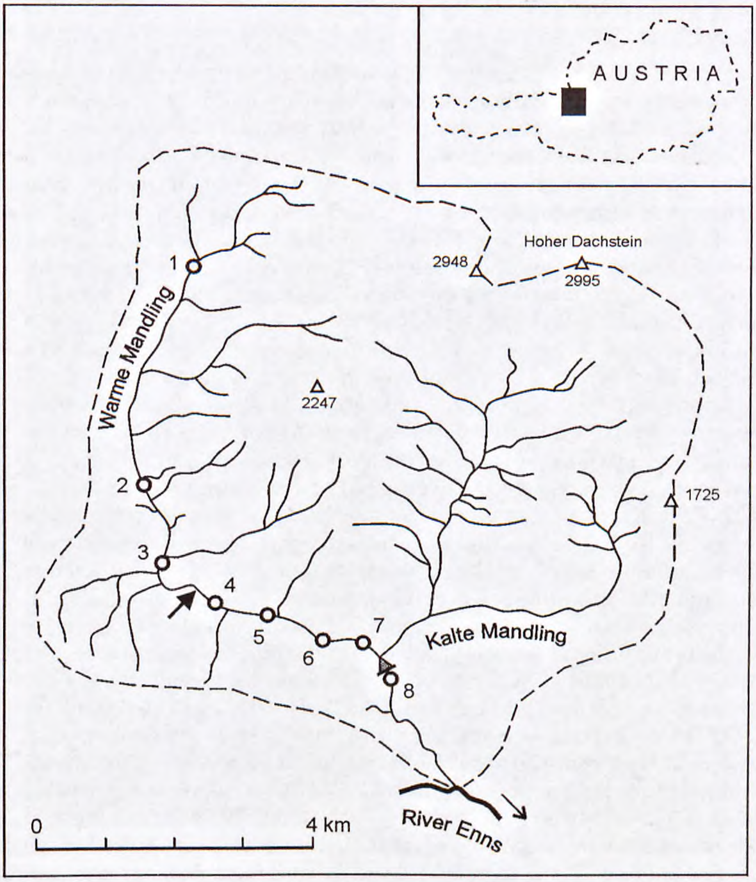


Fig. 1. Location of the investigated Stations (1–8) in the Warme Mandling catchment. Arrow indicates inflow of sewage from Filzmoos.

cyanobacteria and algae collected only in September); Station 2 (alt. 1090 m) about 4 km below the sources in the forest zone above the Filzmoos recreation resort with minimum effects of human activity (samples collected in March only); Station 3 (alt. 1050 m) within the Filzmoos area above the treatment plant (samples collected only in September); Station 4 (alt. 1030 m) in a steep reach of the stream in a ravine about 300 m below the point of waste discharge from the Filzmoos treatment plant; Station 5 (alt. about 1020 m) ca. 1 km below the treatment plant, above the water intake for the Steinbacher power station; Station 6 (alt. 1000 m) below the intake for the Steinbacher power station (samples collected only in March); Station 7 (alt. 990 m) above the dam reservoir of the Mandling power station; Station 8 (alt. 950 m) below the dam reservoir of the Mandling power station where the water flow was very poor. Everywhere the bottom was covered with stones.

3. Material and methods

Samples were collected twice in 1991, in March at the peak of the winter skiing season, and early in September, towards the end of the summer tourist season. Cyanobacteria and algae were studied using the method proposed by Starmach (1969) and applied by Kawecka (1980) and Kwandrans (1989). They were sampled from stones and the material was preserved in a 4% formalin solution. Plant communities were characterized by the number of taxa and their abundance and the index of diatom biomass. The coverage of cyanobacteria and algae which formed macroscopic aggregations on about 1 m^2 of the stream bottom was estimated using the following scale: 1 – organisms form small aggregations, 2 – cover less than 25% of the bottom area, 3 – 25–50%, 4 – 50–75%, and 5 – 75–100%.

The abundance of diatoms was determined by counting the individuals of each species in ten microscope fields delimited by the contours of the micrometric net (Zeiss) installed in the eyepiece at 400x magnification. The percentage share of each species in the community was calculated. As numerous were assumed species whose share in the community was at least 10%, and those which attained the value of at least 3 in the scale of coverage. The remaining species were determined as sporadic. The average size of cells of each diatom species was determined, presenting it in multiples or fractions of the square of the micrometric net mesh. By multiplying the abundance by the average size of a cell the coefficient of coverage was calculated. By summing the coefficient of coverage of all species in a sample and multiplying those values by 2 (accepted assimilation area), the conventional index of diatom biomass was obtained, this being a comparable value for the communities of diatoms at separate sites. In taxonomic analysis, the nomenclature according to Krammer and Lange-Bertalot (1986, 1988, 1991*a*, 1991*b*) was applied.

In order to determine the communities of macroinvertebrates, each time two samples were taken from the stony substratum in places of rapid current (this type of condition dominated in the stream). The samples were taken with a hand net (mesh size 0.3 mm) from the bottom surface of 20x20 cm and transferred to a water container where animals and plants were carefully scraped from the stones. The obtained material was preserved with 4% formalin. In the laboratory all animals were selected under a stereomicroscope at magnification x 20, then identified and counted. The obtained data were computed per 1 m^2. The dominant structure was determined on the basis of the percentage share of taxa in the communities. The taxa whose share exceeded 10% were classified as dominants, those between 1–9.9% as subdominants, and below 1% as adominants.

4. Results and discussion

4.1. Cyanobacteria and algal communities

In the stream investigated 45 taxa of organisms were identified. Most of them were diatoms. The structure of communities varied along the stream course (Table I, Fig. 2). In the natural upper course (Stations 1 and 2) the number of species and their abundance were low. *Hydrurus foetidus* and *Homeothrix janthina* together with diatoms dominated there. Diatoms occurred in small numbers and showed the lowest index of biomass, both in winter and summer. The species *Achnanthes* (mainly *A. minutissima* var. *minutissima*), *Fragilaria arcus*, and *Gomphonema* (*G. angustum, G. angustatum, G. olivaceum*) were the most numerous.

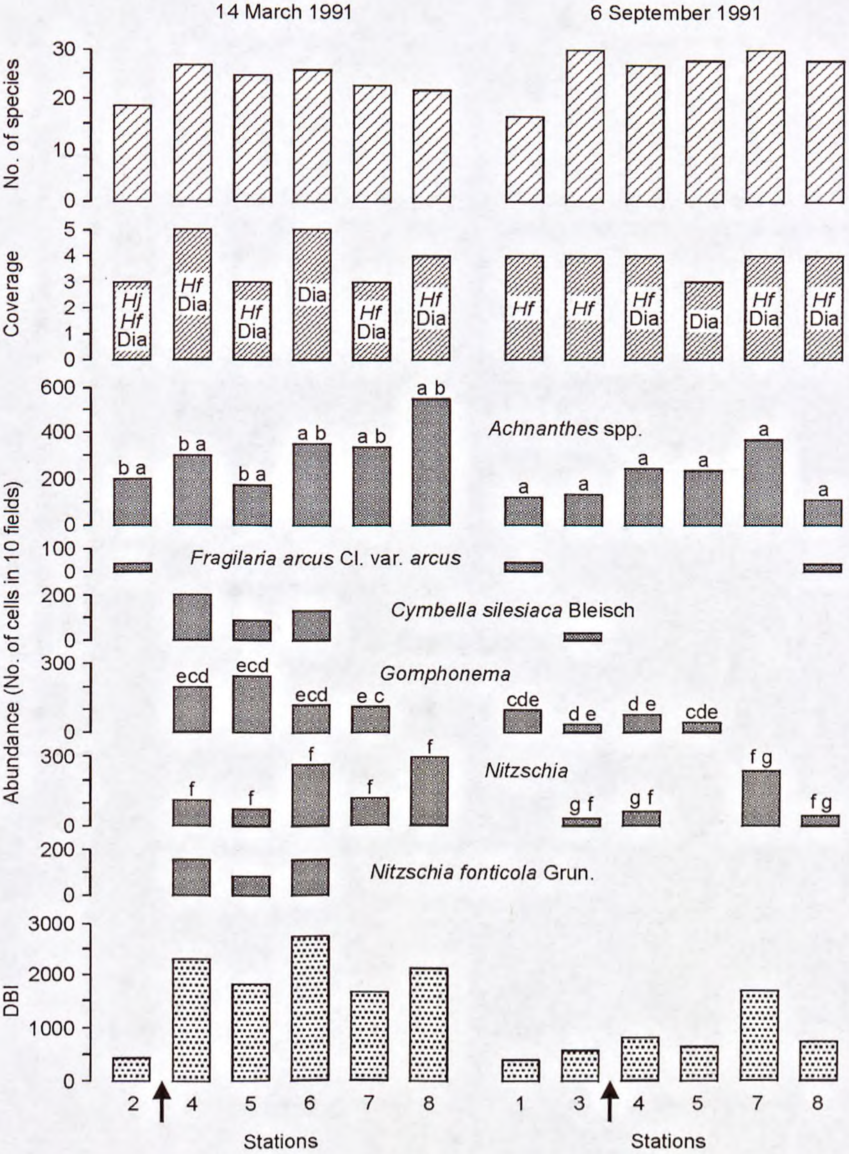


Fig. 2. Cyanobacteria and algae forming macroscopic aggregations and the dominating species of diatoms in the Warme Mandling stream (arrow indicates the point of sewage discharge): *Hj* – *Homoeothrix janthina* (Borne et Flah.) Starmach, *Hf* – *Hydrurus foetidus* (Villars) Trev., Dia – diatom aggregations, a – *Achnanthes minutissima* var. *minutissima* Kütz., b – *A. biasoletiana* var. *biasoletiana* Grun. in Cl. et Grun., c – *Gomphonema angustum* Agardh., d – *G. angustatum* (Kütz.) Rab., e – *G. olivaceum* (Hornemann) Bréb., f – *Nitzschia capitellata* Hust, g – not identified *Nitzschia* species. Scale of coverage: 3 – 25–50% of the bottom area, 4 – 50–75%, 5 – 75–100%. The Diatom Biomass Index (DBI), i.e. a conventional assimilation area of the diatom assemblage was calculated as 2 Σ N_i A_i where N_i and A_i – abundance and average cell size (area) of ith species (Starmach 1969).

Table I. List of cyanobacteria and algae found at investigated Stations (1–8) in the Warme Mandling stream: ● – numerous, + – sporadic.

Taxa	Sampling dates and stations											
	14 March 1991						6 September 1991					
	2	4	5	6	7	8	1	3	4	5	7	8
CYANOBACTERIA												
Homoeothrix janthina (Borne et Flah.) Starmach	●			+			+					
Phormidium favosum (Bory) Gomont		+	+	+	+	+				+	+	
CHRYSOPHYCEAE												
Hydrurus foetidus (Villars) Trev.	●	●	●	+	●	●	●	●	●	+	●	●
BACILLARIOPHYCEAE												
Achnanthes biasoletiana var. *biasoletiana* Grun. in Cl. et Grun.	●	●	●	●	●	●	+	+	+	+	+	+
- *minutissima* var. *gracillima* (Meister) Lange-Bertalot	+											
- *minutissima* var. *minutissima* Kütz.	●	●	●	●	●	●	●	●	●	●	●	●
- *lanceolata* Bréb.		+			+		+	+	+	+	+	+
Amphora pediculus (Kütz.) Grun.		+	+	+		+		+		+	+	
Cocconeis sp.				+								
- *placentula* var. *euglypta* Ehr.	+	+	+	+	+	+	+	+	+	+	+	+
Cyclotella sp.				+	+					+	+	+
Cymbella affinis Kütz.		+	+			+		+		+	+	+
- *silesiaca* Bleisch	+	●	●	●	+	+	+	●	+	+	+	+
- *sinuata* Gregorg	+	+	+	+	+	+	+	+	+	+	+	+
Denticula tenuis Kütz.	+					+		+	+	+	+	+
Diatoma ehrenbergii Kütz.							+				+	
- *hyemalis* (Roth.) Heib.		+			+							
- *mesodon* (Ehr.) Grun.	+	+	+	+	+	+	+	+	+	+	+	+
Diploneis sp.								+				
Fragilaria arcus (Ehr.) Cl.	●	+	+	+	+	+	●	+	+	+	+	●
- *capucina* Desm. var. *capucina*		+	+		+			+	+	+		+
- *capucina* var. *vaucheriae* (Kütz.) Lange-Bertalot	+	+	+	+	+	+	+	+	+	+	+	+

- *pinnata* Ehr.				+								
- *ulna* (Nitzsch) Lange-Bertalot							+	+	+	+	+	+
Frustulia vulgaris (Thwaites) De Toni							+					
Gomphonema angustatum (Kütz.) Rab.	+	●	●	●			●	●	●	●	+	+
- *angustum* Agardh.	+	●	●	●	●	+	●	+		●		+
- *olivaceum* (Hornemann) Bréb.	+	●	●	●	●	+	●	●	●	●	+	+
Meridion circulare (Greville) Ag.	+	+			+			+	+	+	+	+
Navicula cryptocephala Kütz.		+	+			+	+	+	+	+	+	+
- *gregaria* Dankin								+				
- *tripunctata* (O.F. Müller) Bory		+	+	+	+	+					+	+
- *veneta* Kütz.					+	+		+	+	+	+	+
- *viridula* (Kütz.) Ehr.									+			
Nitzschia sp.							+	●	●	+	●	●
- *capitellata* Hust.	+	●	●	●	●	●		●	●	+	●	●
- *dissipata* (Kütz.) Grun.	+	+	+	+	+	+	+	+	+	+	+	+
- *fonticola* Grun.		●	●	●	+	+	+	+	+			+
- *linearis* (Agardh) W. Smith								+	+		+	+
Surirella angusta Kütz.								+	+	+	+	+
- *brebissonii* Krammer et Lange-Bertalot											+	+
CHLOROPHYTA												
Klebsormidium sp.				+								
Ulothrix sp.		+	+	+								
RHODOPHYTA												
Chantransia sp.			+									

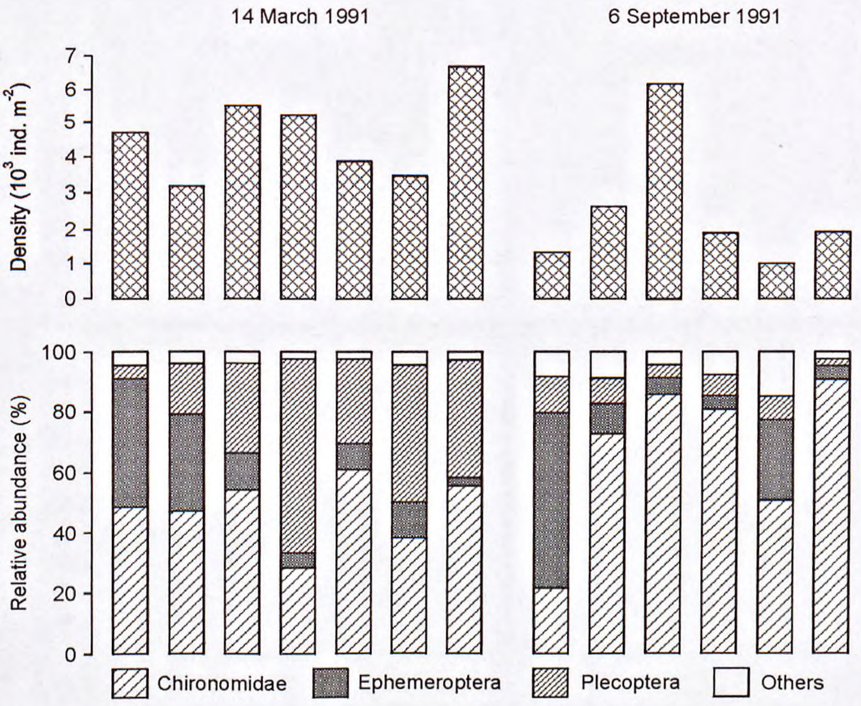
In further reaches of the stream (Stations 3–8), the number of species rose and remained at a more or less uniform level. The abundance of algae increased particularly in March. Diatoms and *Hydrurus foetidus* developed abundantly, especially at Station 4 directly below the treatment plant. However, *Homoeothrix janthina* disappeared. Among diatoms the most numerous were *Achnanthes* genus (mainly *A. minutissima* var. *minutissima*), as well as *Cymbella silesiaca, Gomphonema* (*G. angustum, G. angustatum, G. olivaceum*) and *Nitzschia* species (*N. capitellata* and *N. fonticola*). The index of diatom biomass increased several times in relation to the natural Stations 1–2. Particularly higher values were noted below the water treatment plant (Station 4), the water intake (Station 6), and the dam reservoir (Station 8). The diatom biomass index attained much higher values in March than in the September sampling date.

4.2. Macroinvertebrate communities

In the Warme Mandling stream 53 invertebrate taxa of Oligochaeta, Turbellaria, Collembola, Ephemeroptera, Plecoptera, Trichoptera, Diptera, and Coleoptera occurred (Table II). This number does not include juvenile stages whose precise identification was impossible. The most numerous group, both with respect to the number of taxa and to the number of individuals, was composed of Chironomidae (Diptera). The representatives of Ephemeroptera and Plecoptera were also abundant (Fig. 3). The other groups of fauna were scarce and were not always encountered at all sites.

In winter, the numbers of fauna were fairly high (always >3000 ind. m^{-2}) and the differences between the studied sites rather small (Fig. 3). The fauna abundance at Stations 4 and 5 below the treatment plant were greater than at Stations 1 and 2 above it and at Stations 6 and 7, where the self-purification process occurred, but the differences, however, were small. On the other hand, the species composition of the benthic fauna above and below the treatment plant differed distinctly. In the stream above the treatment plant, mayflies *Baetis alpinus* (Stations 1 and 2) and *Rhithrogena* spp. (Station 2) were dominant. At the sites below stoneflies of the genus *Leuctra* and juvenile stages of Orthocladiinae (Chironomidae) were the major components. A similar composition of the fauna was recorded below the reservoir at Station 8, although *Stilocladius montanus* (Chironomidae) larvae were the first dominant.

In summer, the numbers of fauna were much smaller, usually not exceeding 3000 ind. m^{-2}. Only at Station 4, below the treatment plant, did the numbers increase to 6199 ind. m^{-2} and again decrease at further sites, approximating the numbers above the plant. A small increase in the numbers of fauna were noted at Station 8 below the reservoir. Similarly as in winter, mayflies *Baetis alpinus*, and *Rhithrogena* spp. and also stoneflies *Protonemura* sp., dominated at Station 1. At the remaining sites *Orthocladius* (*E.*) *rivicola* and hard to differentiate larvae of the genera *Orthocladius* and *Cricotopus* (*Chironomidae*), appeared as dominants. The processes of self-purification of sewage followed very rapidly at that time. In consequence, at Station 7 mayflies *Baetis alpinus* were abundant, although *Orthocladius* (*E.*) *rivicola* larvae continued to occur as the first dominant. At Station 8 below the reservoir, the composition of the fauna was similar to that at sites below the treatment plant.



Dominance (%)	1	2	↑ 4	5	6	7	8	1	3	↑ 4	5	7	8
Ba	**42***	**16***	2.2	1.4	4.4	4.9	3.0	**19***	2.7	4.1	1.9	**16**	3.1
Orth	**27**	**13**	**31***	**13**	**32***	**17**	9.7	**10**	2.7	6.9	**18**	**11**	**12**
Rhi	1.0	**12**	8.0	3.3	4.4	6.3	1.5	**19**	5.9	1.6	2.6	6.1	+
Leu	2.6	9.8	**19**	**56***	15	**32***	**31***	+	+	+	+		+
Sm							**17**						
Pro	2.1	3.0		+	4.4	3.5	2.2	**10**	5.5	2.8	6.4	7.4	
Or	5.7	2.3	2.2	2.3	3.1	1.4	1.5	+	**27***	**32***	7.7	**17**	**11**
C+O		3.0			5.0	2.1	4.1		**19**	**27**	**28***	6.1	**33***
Dia	2.6	**16**	4.0	+	4.4	1.4	2.6		2.7	5.7	5.1	1.2	**26**

Stations Stations

Fig. 3. Communities of benthic invertebrates in the Warme Mandling stream (arrow indicates the point of sewage discharge): *Ba* – *Baetis alpinus* Pictet, *C+O* – *Cricotopus* and *Orthocladius* spp., *Dia* – *Diamesa* spp., *Leu* – *Leuctra* spp., *Or* – *Orthocladius* (*E.*) *rivicola* (Kieff.), Orth – Orthocladiinae (juv.), *Pro* – *Protonemura* sp., *Rhi* – *Rhithrogena* spp., *Sm* – *Stilocladius montanus* Rossaro (bold type – >10% of total number, + – <1%, * – most numerous taxon).

Table II. Composition and abundance (ind. m^{-2}) of benthic invertebrate communities at investigated Stations (1–8) in the Warme Mandling stream.

Taxa	Sampling dates and stations												
	14 March 1991							6 September 1991					
	1	2	4	5	6	7	8	1	3	4	5	7	8
OLIGOCHAETA non det.						50	50		12				
TURBELLARIA non det.	25												
COLLEMBOLA non det.								25	12		12		
EPHEMEROPTERA													
Baetis spp. (juv.)		100				50		62	12				12
Baetis spp. (gr. *alpinus*) (juv.)								125	12	25		25	
- *alpinus* Pictet	2000	525	125	75	175	200		262	75	250	37	162	62
- *melanonyx* Pictet								50	12				
- *rhodani* Pictet		50				50	75	12	12				
Rhithrogena spp. (juv.)	50	300	225	75	50	100		162	62	50	25	37	12
- gr. *alpestris*			50	25	50	100	25	25					
- gr. *hybrida*	50	75	100	75	75	25	75	75	37	50	25	25	
- gr. *semicolorata*		25	75						62				
Epeorus alpicola Eaton			25										
Ecdyonurus spp.								12		25		25	12
PLECOPTERA													
Taeniopterygidae (juv.)			100		50	50	75						
Protonemura sp.	100	100		50	175	125	150	137	150	175	125	75	
Nemoura sp.							25						
Capnia sp.			75										
Leuctra spp.	125	325	1050	2975	600	1150	2125	12	12	25	12		12
- gr. *fusca*	25	100	225	200	175	125	125						
- gr. *inermis*	25		275	175	100	75	100						
Dictyogenus fontium Ris					25					25			

Perla sp.		25	25	25	25	25	25	12	25			12	
Isoperla sp.						75	25						
Chloroperla sp.		25		50									
Plecoptera (juv.)													12
TRICHOPTERA													
Rhyacophila spp. (juv.)			50	25	25	25	75				12	25	
- *torrentium* Pictet			25	25				12	12	12	37	75	25
- *tristis* Pictet		25	75	75	25			25	12		37	37	
Drusus biguttatus Pictet	25					75			25	12	37		
- *discolor* Ramb.	50							25	12	25			
DIPTERA													
Chironomidae													
Pseudodiamesa sp.							250					12	
Diamesa spp. (juv.)	125	475			125	25	25		12	100	25		100
- *starmachi* Kown. et Kown.							75						
- gr. *cinerella*		50	150	50	50	25	50		37	125	50	12	212
- gr. *latitarsis*			75				25				12		
- gr. *zernyi*									25	125	12		212
Tvetenia sp.	25	50			75	50	225			25	62	25	
- *bavarica* (Goetgh.)	50		550	159									
Eukiefferiella spp. (juv.)	225	150		175	25		100	25	12		12		12
- *brevicalcar* (Kieff.)								12	62	25	37		37
- *minor* (Verr.)					50	100	75	25	87	125	12		
- gr. *claripennis*												12	
Orthocladius (E.) rivicola (Kieff.)	275	75	125	125	125	50	100	12	725	2000	150	175	212
- *(E.) rivulorum* (Kieff.)	75	25			50		25		12	150	12	25	12
- *(O.) frigidus* (Zett.)	150	100	275	50	225	150	100		162	25	112		75
Orthocladius spp. + *Cricotopus* spp.		100			200	74	150		512	1675	550	62	650
Parorthocladius nudipennis (Kieff.)	50				100		375	75	162	50	25	37	12
Stilocladius montanus Rossaro							1125						
Parametriocnemus sp.												12	
Hydrobaenus sp.									12		12		

Table II. *continued*

Taxa	Sampling dates and stations												
	14 March 1991							6 September 1991					
	1	2	4	5	6	7	8	1	3	4	5	7	8
Corynoneura sp.							175		12	25	100	25	
Thienemanniella sp.													12
Orthocladiinae (juv.)	1300	450	1725	725	1275	600	650	137	75	425	362	112	237
Micropsectra sp.									37	50	12		
Tanytarsini (juv.)		75	125	200	125	275	150			300			
Simuliidae non det.							25	12	175	25		12	25
Limoniidae													
Dicranota sp.									37	250	12		
Limoniidae non det.		25			25	25					12		25
Psychodidae non det.		50						12					
Empididae non det.							25			25			
COLEOPTERA non det.	25												
Total	4775	3300	5525	5334	4000	3675	6675	1343	2714	6199	1940	1019	1980

4.3. Conclusions and discussion

In the Warme Mandling stream (alt. 1240–950 m), within the same ecological zone (streams of the forest zone), two separate types of community were distinguished:

1. Above the Filzmoos treatment plant, in a stream reach not affected by human activity, the communities present were characteristic of cold, oligotrophic streams of the forest zone. In plant communities the prevailing species were: *Hydrurus foetidus* and *Homeothrix janthina*, with accompanying diatoms. Mayflies *Baetis alpinus* and species of the genus *Rhithrogena* dominated in macroinvertebrate communities. Communities of this type were previously reported from other high mountain streams of this zone (Jäger *et al.* 1985, Kawecka 1971, 1980, Kawecka *et. al.* 1971, Kownacka and Margraiter 1978, Kownacki 1991).

2. Below the Filzmoos treatment plant, changes occurred in the abundance and structure of the cyanobacteria, algal, and benthic invertebrate communities. Among diatoms, apart from the still numerous *Achnanthes minutissima* var. *minutissima*, the share of *Cymbella silesiaca*, species of the genera *Gomphonema* (*G. angustum, G. angustatum, G. olivaceum*) and *Nitzschia* (*N. capitellata.* and *N. fonticola*) increased considerably. *Homoeothrix janthina* disappeared, while *Hydrurus foetidus* developed abundantly, especially in winter. The index of diatom biomass was particularly high in the winter, exceeding considerably the values so far recorded in high mountain streams of the forest zone (Kawecka 1974, 1980). Such groups as *Chironomidae* and in the winter also stoneflies (*Leuctra* sp.) dominated in invertebrate communities, while the percentage of mayflies in the total number of fauna was considerably reduced. Similar changes were observed in the Tatra stream below the discharge of sewage from a tourist shelter (Kownacki 1977).

Sewage loads discharged into the stream are not toxic but cause an increase in water fertility. Among the dominants of invertebrate communities, no taxa occurred which might have been eliminated by the inflow of sewage. Even such organisms as mayflies *Baetis alpinus* and *Rhithrogena* spp., which are highly sensitive to pollution, are encountered, though in much smaller numbers below the inflow of sewage. Similarly in the cyanobacteria and algae communities, *Achnanthes minutissima* var. *minutissima* developed abundantly along the entire course of the investigated stream. *A. minutissima* var. *minutissima* is an organism sensitive to pollution (Krammer and Lange-Bertalot 1991*b*, Kawecka 1974, 1977, 1980, 1981), avoiding conditions worse than beta-mesosaprobic (Steinberg and Schiefele 1988) and determined as an indicator of waters of high oxygen concentration (Cholnoky 1968). However, below the inflow of sewage the numbers of *Homoeothrix janthina* faded, similarly as in eutrophicated streams of the Zakopane Basin and polluted Rybi Potok stream in the Tatra Mts (Kawecka 1977, 1993), this probably being connected with the increasing fertility of the stream water. The organism is determined as characteristic for oligotrophic waters (Backhaus 1968).

In the stream below the treatment plant, the abundance of a species of a wide ecological spectrum increased. There was *Nitzschia fonticola*, which develops in oligotrophic or slightly enriched waters, avoiding highly polluted ones. *Nitzschia capitellata* is among organisms with a wide range of occurrence in fresh and saline waters and also tolerates strongly polluted habitats (Krammer and Lange-Bertalot 1988). *Gomphonema olivaceum* and *Cymbella silesiaca* occur in great numbers, both in oligotrophic and eutrophic waters (Krammer and Lange-Bertalot 1986). However, Kawecka (1974, 1977, 1980) observed increases in the number of *Cymbella silesiaca* (*C. ventricosa*) in high mountain streams below the inflow of domestic sewage. Chironomidae: *Orthocladius* (*E.*) *rivicola* and larvae of *Cricotopus* and *Orthocladius* species which dominated below the inflow of sewage, are characteristic of clean submontane rivers (Kownacki 1971, Kawecka et al. 1971) or those polluted with municipal sewage (Dratnal et al. 1979). *Orthocladius* (*E.*) *rivicola* also sometimes dominates in the middle and lower course of high mountain streams (Kownacki 1991). No taxa, which in the Saprobien system were given as characteristic of highly polluted waters (the polysaprobic zone) (Sládeček 1973), were found in the investigated stream.

An increase in water fertility was already observed in the stream flowing across Filzmoos (Station 3). As compared with the sector undisturbed by human activity (Stations 1 and 2) the number of algal taxa increased (Fig. 2). However, it was especially confirmed by the macroinvertebrate communities. The fauna abundance increased and a change in the structure of invertebrate communities was observed (Fig. 3). These changes may suggest the occurrence of uncontrolled inflow of domestic sewage to the stream. Below the Mandling reservoir (Station 8) the effect of an increase in water fertility, particularly evident in the winter, was observed, especially in the case of invertebrate communities. The changes were similar to those below the discharge of sewage (Fig. 3).

The investigation supported the opinion expressed by Illies and Schmitz (1980) that, in evaluating the purity of waters of mountain streams, the starting point should be the determination of the degree of changes in relation to undisturbed communities. Such studies should be based on the precise analysis of abundance and structure of plant and animal of benthic communities. Starmach (1959), Cairns (1982), and Whitton et al. (1991) already stressed the value of such a methodical approach. The use of the system of saprobic organisms of bottom fauna (Sládeček 1973) appears to be inconvenient in mountain streams.

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