Oecologia Montana 1998,
7, 13 - 20

Effect of treated wastes on algal and macroinvertebrate communities in an alpine stream

M. MARGREITER[1], A. KOWNACKI[2], B. KAWECKA[2] and J. KWANDRANS[2]
[1]*Institut für Ökonometrie, 1120 Wien, Vienotgasse 46, Austria,* [2]*Karol Starmach Institute of Freshwater Biology, Polish Academy of Sciences,31-106 Krakow, 17 Slawkowska Str., Poland*

Abstract. The investigation was carried out in the Warm Mandling stream(the Dachstein Alps, Austria) at eight stations (1,240-950 m a.s.l.) lying above and below the discharge of wastes from the treatment plant high concentrations of phosphates (6,3 mg PO_4 dm^{-3}), total phosphorus (10,7 mg P_{tot} dm^{-3}), nitrates (15,8 mg N-NO_3 dm^{-3}), and total nitrogen (28,2 mg N_{tot} dm^{-3}) were assessed. The discharge of wastes brought about changes in the algal and macroinvertebrate communities. Below the treatment plant the abundance of tax of a wide ecological spectrum rose (algae - *Cymbella silesiaca, Gomphonema olivaceum, Nitzschia capitellata, N. fonticola* macroinvertebrates - *Leuctra spp., Orhtocaladius (E) rivicola*, and larvae of the genera *Cricotopus* and *Orthocladius),* while the share of tax typical for pure streams (algae - *Homoeothrox janthina, Fragilaria arcus; macroinvertrabrate - Baetis alpinus, Rhithrogena* spp.) decreased.

Key words: hydrobiology, stream algae, macroinvertebrate, community, pollution

Introduction

The problem of ecology of running waters and their protection is widely discussed in literature (Hynes 1960, 1972, Whitton 1975, 1984, Ward 1992, Boon *et al.* 1992). However, these works chiefly concern lowland and submountain rivers. In high mountain streams, this problem has been rarely 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 great recreation resorts have been developed in most valleys at an altitude above 1000m, and in 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 have water treatment plants now.

The question arises however, how the discharge of treated sewage effects the ecosystems of high mountain streams and especially their communities. It is also necessary to estimate the degree of pollution of the streams on the basis of their communities. In high mountain streams, due 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, Ingram 1959) breaks down or is subject to perturbation. The model was observed among others by Sadovskij (1940) in Caucasian streams and by Kownacki (1977, 1980, 1989) in the streams of the Tatra Mountains. Also in Zimmerman´s experiments (1961) in streams polluted with organic matter, the rapid current beneficially effected the development of algae species characteristic for purer waters.

In order to find a response to the above questions an investigation was carried out in the Warm Mantding stream (Dachstein massif, the Alps, Austria) concerning the effects of treated wastes discharged from the Filzmoos water treatment plant in the communities by the stream.

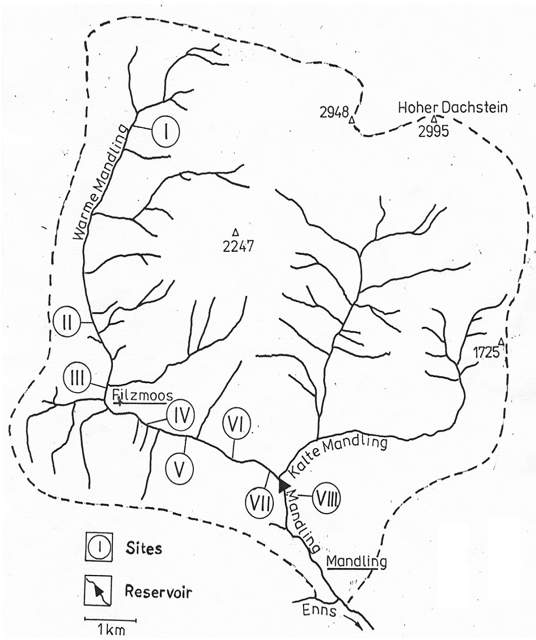
Description of the study area and sites

The Warme Mandling stream begins from springs lying in the forest zone at an altitude of 1650 m and flows down the slopes of the Dachstein massif (the Alps, Austria). At 930 m it flows into the Kalte Mantling stream and from this point its name is 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 °/oo.. In 1990/1991 the following quantities of average flow in the stream were recorded at an altitude of 1000m: May-June 1,200 dm^3 s^{-1}, July-August 700 dm^3 s^{-1}, September-October 500 dm^3 s^{-1}, October15-December 14,200 dm^3 s^{-1}, December 15-February 100-200 dm^3 s^{-1}, March-April 500 dm^3 s^{-1}.

In the valley of the Warme Mandling stream at the altitude of 1,055 m there lies the Filzmoos recreation resort. In 1980, 1 km below Filzmoos, a sewage treatment plant was built for treating wastes from hotels and pensions. 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 Warm Mandling. The amount of easily biodegradable organic matter in the treated sewage was small, as shown by BOD_5 values of 5 mg O_2 dm^{-3}. On the other hand, the total organic matter connect expressed by COD = 37 mg O_2 dm^{-3} and TOC = 11.2 mg C dm^{-3} increased. In waters discharged from the treatment plant the content of ammonia was small, amounting to 0.25mg N-NH_4 dm^{-3} while the concentrations of nitrates and phosphates were high: 15.8 mg N-NO_3 dm^{-3} and 6.3 mg PO_4 dm^{-3}. The content of total phosphorus was 10.7 mg $P_{tot}dm^{-3}$ and of total nitrogen 28.2mg $N_{tot}dm^{-3}$. The content of chlorides and sulphates was greater in the discharged waters (29.5 mg Cl dm^{-3} and 34.4 SO_4 dm^{-3}) than the water of mountain streams.

Apart from the treatment plant, a number of hydrotechnical construction connected with the power station were installed on the Warm 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 1,000m. At the place where the streams Warm Mandling and Kalte Mandling merge, a Mandling dam reservoir Was built, retaining a great part of the water and hence the so-called "Restwasser" only flows below the reservoir.

The samples were collected along the stream at eight sites everywhere the bottom was covered with stones. (Fig. 1):



site I –(altitude 1,240 m), situated about 1 km below the sources(the stream is about 3 m in width and the effects of human activity were insignificant here (sampling in September only(
site II –(altitude 1,090 m), about 4 km below the sources in the forest zone above the Filzmoos recreation resort, minimum effects of human activity (sampling in March only),
site III –(altitude 1,050 m), within the Filzmoos area above the treatment plant (samples were only collected in September),
site IV –(altitude 1,030 m), in a steep sector of the stream in a ravine about 300 m below the point of discharge of wastes from the Filzmoos treatment plant,
site V –(altitude at about 1,020 m), ca. 1 km below the treatment plant above the water intake for the Steinbacher power station,
site VI –(altitude 1,000 m), below the intake for the Steinbacher power station (here the samples were only collected in March),
site VII –(altitude 990 m), above the dam reservoir of the Mandling power station,
site VIII –(altitude 950 m), below the dam reservoir of the Mandling power station(here the water flow was very poor.

Materials and methods

Hydrobiological studies concerning the communities of algae andmacroinvertebrates were carried out twice in 1991: in March at the peak of the winter skiing season and early in September, towards the end of the summer tourism season.

Algae were collected and studied using the method proposed by Starmach (1969) and applied by Kawecka (1980) and Kwandrans (1989). Algae were sampled from stones and the material was preserved in a 4% formalin solution. Algal communities were characterised by the number of tax, their abundance, and the index of diatom biomaas. The coverage of algae which formed macroscopic aggregations on 1 m^2 in the stream was estimated using a following scale of coverage: 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 were determined by computing individuals of each species in ten microscope fields delimited by the contours of the micrometric net (Zeiss produce) installed in the eyepiece.

The percentage share of species in the communities was calculated. The most numerous diatoms were those organism whose share in the community was at least 10% and this 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 multiplies those values by 2 (accepted assimilation area) the conventionally index of diatom biomass was obtained, this being a comparable value for the communities of diatoms at separate sites. In taxonomical analysis, the nomenclature according to Krammer, Lange-Bertalot (1986-1991) was applied.

In order to determine the communities of macroinvertebrates at each site and each sampling date, two samples were taken from the stony substrate 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 20 x 20 cm and transferred to a water container where animals and algae were carefully scrubbed from the stones. The obtained material was preserved with 4% formalin. In the laboratory all animals were selected under a binocular microscope at magnification x20, then identified and counted. The obtained data were computed per 1 m2. The dominant structure was determined on the basis of the percentage share of tax in the communities. The tax whose share exceeded 10% were classified as dominants, these in the interval of 1-9,9% as subdominants, and bellow 1% as adominants.

Results

Algal communities

45 tax of algae were identified in the investigated streams. Most of them were diatoms. The structure of communities of sessile algae varied along the stream course (Table 1, Fig. 2,). In the algal communities of the natural upper stream course (sites I and II) the number of species (and their abundance) was law. A yellow-brown alga *Hydrus foetides* and blue-green alga *Homeothrix janthina* together with diatom dominated. Diatoms occurred in small population and showed the lowest index of biomass, both in the winter and the summer seasons. The species of *Achnanthes genus* (mainly *Achnanthes minutissima* var. *minutissima*), *Fragilaria arcus* and *Gomphonema* genus (*G. angustum, G. angustatum, G. olivaceum*) were the most numerous.

In further sectors of the stream of (sites III-VIII), the number of species rose and remained at a more or less uniform level. The abundance of algae increased particularly in March. Diatoms and *Hydrusus foetidus* developed abundantly especially at site IV directly below the treatment plant. However *Homoeothrix janthina* disappeared. Among diatom the most numerous were species of the genus *Achnanthes* (mainly *Achnanthes minutissima* var. *minutissima,* as well as *Cymbella silesiaca* and species of the genus *Gomphonema (G. angustum, G. angustatum, G. olivaceum)* and *Nitzschia (N. capitellata* and *N. fonticola).* The index of diatom boimass increased several times in relation to natural sites I-II. Particularly higher values were noted below the water treatment plant (site IV), the water intake (siteVI), and the dam reservoir (site VIII). The diatom biomass index attained much higher values in March compared with the September sampling date.

Macroinvertebrate communities

In the investigated sector of the Warm Mandling stream there occurred 53 invertebrate tax of the genera *Oligichaeta, Tubellaria, Collembola, Ephemeroptera, Plecoptera, Trichoptera, Diptera* and *Coleoptera* (Table 2). This number does not include juvenile stages whose more precise identification was impossible. The most numerous group both in respect to the number of tax and to the number of individuals was composed of *Diptera* of the family *Chironomidae*. The representative of *Ephemeroptera* and *Plecoptera* also were fairly numerous (Fig. 3). The other groups of fauna were scarce and were not always encountered at all sites.

In the winter season, the numbers of fauna were fairly high (always above 3,000 indiv.m^2) and the differences between the different sites were rather small (Fig. 3). Really, the numbers of the fauna at sites IV and V below the treatment plant were greater than at sites I and II above it and also at sites VI and VII where

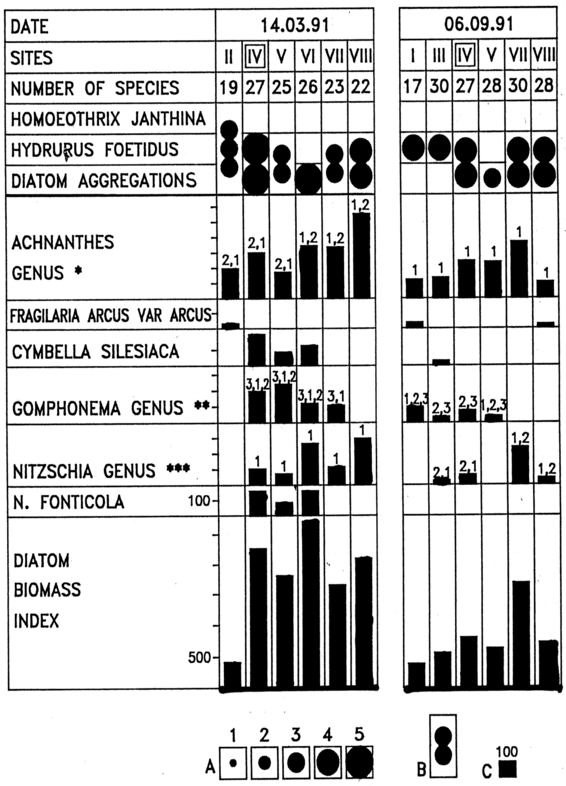


Fig. 2. Communities of algae in the Warme Mandling stream, algae forming macroscopic aggregations and the dominanting species of tiadoms. A - scale of coverage, B - coverage includes a group of organisms, C - number of cells in the 10 microscopic fielsd. **Achnantes* genus: 1 - *A. minutissima var. minutissima*, 2 - *A. biasolettiana var. biasolettiana;* ** *Gomphonema* genus: 1 - *G. angustum*, 2 - *G. angustatum*, 3 - *G. olivaceum;* ****Nitzchia* genus: 1 - *N. capitallata*, 2 - *Nitzchia* sp. Site marked in square means place inglow of sewage treatment plant.

Taxon	Date 14.03.1991						06.09.1991					
Sites	II	IV	V	VI	VII	VIII	I	III	IV	V	VII	VIII
CYANOPHYTA:												
Homeothrix janthina (Bor.et Flah) Starmach	+			+			+					
Phormidium Favosum (Bory) Gomont		+	+	+	+	+				+	+	
CHRYSOPHARE:												
Hydrusus foetidus (Villars) Trev.	+	+	+	+	+	+	+	+	+	+	+	+
BACILLARIOPHYCEAE:												
Achalanthes lanceolata (Bréb.) Grun.		+			+		+	+	+	+	+	+
A. biasolettiana Grun. var.*biasolettiana*	+	+	+	+	+	+	+	+	+	+	+	+
A. minutissima Kutz. var. *minutissima*	+	+	+	+	+	+	+	+	+	+	+	+
A. minutiss. var. gracillima (Meister)L.-Bertalot	+											
Amphora pediculus (Kutz.) Grun.		+	+	+		+		+		+	+	
Cocconeis placentula var. *euglypta* (Ehr.) Cl.	+	+	+	+	+	+	+	+	+	+	+	+
Cocconeis sp,				+								
Cyclotella sp.				+	+					+	+	+
Cymbella affinis Kutz.	+	+			+		+		+	+	+	
C. silesiaca Bleisch	+	+	+	+	+	+	+	+	+	+	+	+
C. sinuata Greg.	+	+	+	+	+	+	+	+	+	+	+	+
Denticula tenuis Kutz.	+					+		+	+	+	+	+
Diatoma hyemalis (Roth) Heib.		+			+							
D. mesodon (Ehr.) Grun.	+	+	+	+	+	+	+	+	+	+	+	+
D. vulgaris Bory	+	+	+	+	+	+		+	+	+	+	
D. ehrenbergii Kutz.							+				+	
Diploneis sp.								+				
Fragilaria arcus (Ehr.) Cl.	+	+	+	+	+	+	+	+	+	+	+	+
F. capucina Desm. var. *capucina*		+	+		+			+	+	+		+
F. cap. var. *voucheriae* (Kutz.) L.-Bertalot	+	+	+	+	+	+	+	+	+	+	+	+
F. pinnata Ehr.				+								
F. ulna (Nitzsch) L.-Bertalot							+	+	+	+	+	+
Frustrulia vulgaris (Th.) De Toni							+					
Gomphonema angustatum (Kutz.) Rabh.	+	+	+	+			+	+	+	+	+	+
G. angustum Ag.	+	+	+	+	+	+	+	+		+		+
G. olivaceum (Lyngb.) Kutz.	+	+	+	+	+	+	+	+	+	+	+	+
Meridion circulare Ag.	+	+			+			+	+	+	+	+
Navicula cryptocephala Kutz.		+	+			+	+	+	+	+	+	+
N. gregaria Dankin								+				
N. veneta Kutz.					+	+		+	+	+	+	+
N. viridula (Kutz.) Ehr.									+			
N. tripunctata (O.F. Mull.) Bory		+	+	+	+	+					+	+
Nitzschia capitellata Hust.	+	+	+	+	+	+		+	+	+	+	+
N. dissipata (Kutz.) Grun.	+	+	+	+	+	+	+	+	+	+	+	+
N. fonticola Grun.		+	+	+	+	+	+	+	+			+
N. linearis (Ag.) W. S.								+	+		+	+
Nitzschia sp.							+	+	+	+	+	+
Surirella angusta Kutz.								+	+	+	+	+
S. brebissonii Kramer & L.-Bertalot var. *brebissonii*											+	+
CHLOROPHYTA:												
Klebsormidium sp.				+								
Ulothrix sp.		+	+	+								
RHODOPHYTA:												
Chantransia sp.			+									

Table 1. List of algae found in the Warme Mandling stream.

the self-puritifaction process occurred, nevertheless the differences were small. On the other hand, the composition of the fauna above and below the treatment plant distinctly differed. In the stream above the plant, mayflies *Beatis alpinus* (sites I and II) and *Rhithrogena* (site II) dominated. At the sites below the treatment plant, stoneflies of the genus *Leuctra* and juvenile stages of *Orthocladiinae (Chironomidae)* occurred in masses. A similar composition of the fauna was recorded below the reservoir at station VIII. *Stilocladius montanus (Chironomidae)* was an additional dominant at this site.

In the summer, the numbers of fauna were much smaller, usually not exceeding 3,000 indiv.m^2. At site IV only, below the treatment plant, the numbers rose to 6,199 indiv.m^2 and again decreased at further sites, approximating the numbers above the plant. A small increase in the numbers of fauna were noted at site VIII below the reservoir. Similarly like in winter, mayflies *Baetis alpinus,* and *Rhithrogena* spp. and also stoneflies *Protonemura* sp. dominated larvae of the genera *Orthocladius (E) rivicola* and hardly differentiated larvae of the genera. *Orthocladius* and *Cricotopus (Chrionomidae),* appeared as dominants. The processes of the purification of sewage followed very rapidly at that time. At site VII mayflies *Beatis alpinus* dominanted again, however, *Orthocladius (E) rivicola* larvae continued to occur as the first dominant. At site VIII below the reservoir, the composition of the fauna was similar to that at sites below the treatment plant.

Date	14.03.1991							06.09.1991					
Sites	I	II	IV	V	VI	VII	VIII	I	III	IV	V	VII	VIII
Taxon													
OLIGOCHAETA	-	-	-	-	-	50	50	-	12	-	-	-	-
TURBELLARIA	25	-	-	-	-	-	-	-	-	-	-	-	-
COLLEMBOLA	-	-	-	-	-	-	-	25	12	-	12	-	-
EPHEMEROPTERA													
Beatis alpinus Pict.	2000	525	125	75	175	200	-	262	75	250	37	162	62
Beatis melanonyx Pict.	-	-	-	-	-	-	-	50	12	-	-	-	-
Beatis spp. (gr. *alpinus*)(juv.)	-	-	-	-	-	-	-	125	12	25	-	25	-
Beatis rhodani Pict.	-	50	-	-	-	50	75	12	12	-	-	-	-
Beatis spp. (juv.)	-	100	-	-	-	50	-	62	12	-	-	-	12
Rhithrogena gr. *alpestris*	-	-	50	25	50	100	25	25	-	-	-	-	-
Rhithrogena gr. *hybrida*	50	75	100	75	75	25	75	75	37	50	25	25	-
Rhithrogena gr. *semicolorata*	-	25	75	-	-	-	-	-	62	-	-	-	-
Rhithrogena spp. (juv.)	50	300	225	75	50	100	-	162	62	50	25	37	12
Epeorus alpicola Etn.	-	-	25	-	-	-	-	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	-	-	-	-	-	-
Capina sp.	-	-	75	-	-	-	-	-	-	-	-	-	-
Leuctra gr. *fusca*	25	100	225	200	175	125	125	-	-	-	-	-	-
Leuctra gr. *inermis*	25	-	275	175	100	75	100	-	-	-	-	-	-
Leuctra spp.	125	325	1050	2975	600	1150	2125	12	12	25	12	-	12
Oictyogenus fontium Ris	-	-	-	-	25	-	-	-	-	25	-	-	-
Perla sp.	-	25	25	25	25	25	25	12	25	-	-	12	-
Isoperla sp.	-	-	-	-	-	75	25	-	-	-	-	-	-
Chloroperla sp.	-	25	-	50	-	-	-	-	-	-	-	-	12
TRICHOPTERA													
Rhyacophila tristis Pictet	-	25	75	75	25	-	-	25	12	-	37	37	-
Rhyacophila torrentium Pictet	-	-	25	25	-	-	-	12	12	12	37	37	-
Rhyacophila spp. (juv.)	-	-	50	25	25	25	75	-	-	-	12	25	-
Orusus discolor Ramb.	50	-	-	-	-	-	-	25	12	25	-	-	-
Orusus biguttatus Pictet	25	-	-	-	-	75	-	-	25	12	37	-	-
DIPTERA													
CHIRONOMIDAE													
Pseudodiamesa sp.	-	-	-	-	-	-	250	-	-	-	-	12	-
Diamesa starmachi Kown., Kown,	-	-	-	-	-	-	75	-	-	-	-	-	-
Diamesa gr. *latitarsis*	-	-	75	-	-	-	25	-	-	-	12	-	-
Diamesa gr. *cinerella*	-	50	150	50	50	25	50	-	37	125	50	12	212
Diamesa gr. *zernyi*	-	-	-	-	-	-	-	-	25	125	12	-	212
Diamesa spp. (juv.)	125	475	-	-	125	25	25	-	12	100	25	-	100
Tvetenia bavarica (G.)	50	-	550	159	-	-	-	-	-	-	-	-	-
Tvetenia sp.	25	50	-	-	75	50	225	-	-	25	62	25	-
Eukifferiella minor (Verr.)	-	-	-	-	50	100	75	25	87	125	12	-	-
Eukiefferiella brevicalcar (K.)	-	-	-	-	-	-	-	12	62	25	37	-	37
Eukiefferiella gr. *claripennis*	-	-	-	-	-	-	-	-	-	-	-	12	-
Eukiefferiella spp. (juv.)	225	150	-	175	25	-	100	25	12	-	12	-	12
Orthocladius (E.) rivicola (K.)	275	75	125	125	125	50	100	12	725	2000	150	175	212
Orthocladius (E.) rivulorum (K.)	75	25	-	-	50	-	25	-	12	150	12	25	12
Orthocladius (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
Parorthorladius nudipennis (K.)	50	-	-	-	100	-	375	75	162	50	25	37	12
Stilocladius montanus Rossaro	-	-	-	-	-	-	1125	-	-	-	-	-	-
Parametriocnemus sp.	-	-	-	-	-	-	-	-	-	-	-	12	-
Hydrobaenus sp.	-	-	-	-	-	-	-	-	12	-	12	-	-
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	-	-	-
SIMVLIIDAE	-	-	-	-	-	-	25	12	175	25	-	12	25
LIMONIIDAE													
Dicranota sp.	-	-	-	-	-	-	-	-	37	250	12	-	-
Limoniidae non det.	-	25	-	-	25	25	-	-	-	-	12	-	25
PSYCHODIAE	-	50	-	-	-	-	-	12	-	-	-	-	-
EMPIDIDAE	-	-	-	-	-	-	25	-	-	25	-	-	-
COLEOPTERA	25	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	4775	3300	5525	5334	4000	3675	6675	1343	2714	6199	1940	1019	1980

Table 2. Changes in the composition and abundance (ind, m^{-2}) of benthic invertebrates communities in Warme Mandling stream.

Conclusions and Discussion

1. In the investigated sector of the Warme Mandling stream (1,240-950 m) within the same ecological zone (streams of the forest zone). two separate types of communities were distinguished.

Above Filzmoos, in the stream sector not affected by human activity, the developing communities were characteristic for cold oligotrophic streams of the forest zone. In algal communities the prevailing species were: *hydrurus foetidus* and *Homeothrix janthina* with accompanying diatoms. Mayflies *Beatis alpinus and species of the genus* Rhithrogena dominated in macroivertebrates communities. The communities of this type were 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).

Below the Filzmoos treatment plant, changes occurred in the struscutre of the communities of algae and abundance and structure of the communities of bottom fauna. Among diatoms apart from the still numerous *Achanthes minutissima*var. *minutissima* the share of *Cymbella silasiaca,* species of genera *Gomphonema (G. angustum, G. angustatum, G. olivaceum)* and *Nitzschia (N. capitessata* and*N. fonticola)* considerably increased. *Homoeothrix janthina* disappeared while *Hydrurus fotidus* developed abundantly, especially in winter season. The index of diatom biomass was particularly high in the winter season, considerably exceeding the values so far recorded in high mountain streams of the forest zone (Kawecka 1974, 1980). Such groups as *Chironomidae* and also in the winter stoneflies,(*(Leuctra* sp.) dominated in zoocenosis while the percentage of may flies in the total number of the fauna was considerably reduced. Similar changes were observed in a Tatra stream below the discharge of sewage from a shelter-house (Kownacki 1977).

2. Sewage loads discharged into the stream are not toxic but cause an increase in water fertility.

Among the dominants there does not occur tax which might have been eliminated by the inflow of sewage. Even such organisms as mayflies *Beatis alpinus* and *Rhithrogena* spp., which are highly sensitive to pollution, are encountered though in much smaller numbers below the inflow of sewage. Similarly, in algal communities *Achnanthes minutissima* var. *minutissima* develops abundantly in the entire course of the investigated stream. *Achanthes minutissima* var. *minutissima* is a organism sensitive to pollution (Krammer, Lenge-Bertalot 1986, Kawecka 1974, 1977, 1980, 1981), avoiding conditions worse than b-mesosaprobis ones (Steinberg, Schiefele 1988) and determined as an indicator of waters of high oxygen concentration (Cholnoky 1968). Below the inflow of sewage the numbers of *Homoeothrix janthina* disappeared but probably not because of the disappeared but probably not because of the increasing fertility of the stream. This organism is determined as characteristic for oligotrophic waters (Bachkaus 1968), nevertheless it occurs in Tatra streams, and also in environments of an enriched nutrient content (Kawecka 1977, 1980).

In the stream below the treatment plant, the abundance of species fo a wide ecological spectrum increased. It was *Nitzchia fonticola* which develops in the environment of oligotrophic or slightly enriched waters, avoiding highly polluted ones. *Nitzchia capitellata* belongs to organisms of a wide range of occurrence in fresh and saline waters and tolerates also strongly polluted aquatic environments (Krammer, Lange-Bertalot 1986). *Gomphonema olivaceum* and *Cymbella silesiaca* occur in great numbers, both in oligotrophic and eutrophic waters (Krammer,, Lange-Bertalot 1988). However Kawecka (1974, 1977, 1980) always observed increased 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 the genera *Cricotopus* and *Orthocladius* which dominate below the inflow of sewage, are characteristic for pure submountain rivers (Kownacki 1971, Kawecka et al. 1971) or those polluted with municipal sewage (Dratnal *et al.* 1979). *Orthocladius* (O.) *rivicola* also sometimes dominates in the middle and lower course of high mountain streams (Kownacki 1991).

No tax, which in the system of saprobes were given as characteristic for highly polluted waters (the polysaprobic zone) (Sladecek 1973) were found in the investigated stream.

3. An increase in water fertility is already observed in the stream flowing across Filzmoos (site III). As compared with the sector unaffected by human activity (sites I, II) the number of tax of algae increased (fig. 2). However, it was showed better in the macroinvertebrate communities. The abundance increased and change of the structure of invertebrate communities was observed (fig.3). These changes may suggest the occurrence of uncontrolled inflows of domestic sewage to the stream.

4. Below the Mantling reservoir (site VIII) the effect of an increase in water fertility, particularly evident in the winter season was observed, especially in the case of invertebrate communities. The changers were similar to those below the discharge of sewage (fig. 3).

5. 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 deviation from the natural state. Such studies should be based on 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

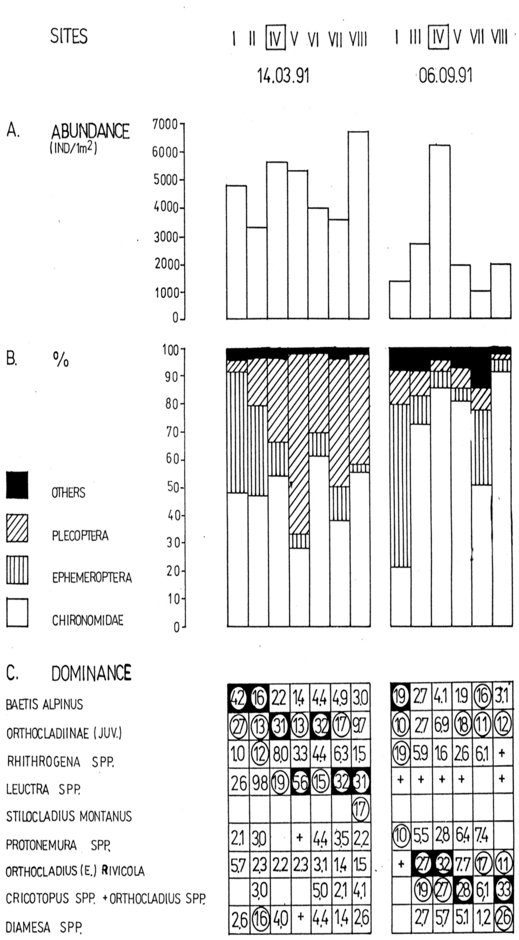


Fig. 3. Communities of algae in the Warme Mandling stream (Site marked in square means place inflow of sewage treatment plant).

fauna (Sládeček 1973) appears to be inconvenient in mountain streams.

Acknowledgements

The study was sponsored by Landes Regierung Salzburg and Gemeinde Filzmoos. We express our thanks to Dr. Paul Jäger from Landes regierung for charging us with the project. We are also grateful (also thank) to Associate professor Bronislaw Szczeny for the identification of Trichoptera and to Dr. Malgorzata Olejnik-Klonowska for the revision of the identification of mayflies of the genus Rhithrogena/ for help to identify mayflies of the genus Rhithrogena.

References

Backaus D., 1968: Okologische Untersuchungen an den Aufwuchsalgen der obersten Donau and ihrer Quellflusse. Die Agenverteilung und ihre Beziehungen zur Milieuofferte. *Archiv fur Hydrobiol.* Suppl., **34**: 130-149.

Bartch, A.F. and Ingram, W. M. 1959: Stream life and the pollution environment. *Publik Works,* **90**: 104-110.

Boon, P.J., Calow, P. and Petts, E.E.1992 (eds): River conservation and management. John Wiley & Sons, Chichester, New York, Brisbane, Toronto, Singapore.

Carins,Jr. J. 1982: Biological monitoring in water pollution. Pergamon Press. Oxford, New York, Toronto, Sydney, Paris, Frankfurt.

Cholnoky, B.J. 1968: Die Okologie der Diatomen inBinnengew]ssern. Weinheim J. Cramer Verlag.

Drantal, E., Sowa, R. and Szczesny, B. 1979: Benthic invertebrate communities in the Dunajec River BetweenHraklowa and Sromowce Nizne. *Ochrona. Przyrody,* **42**: 183-215.

Hynes, H.B.N. 1960: The biology of polluted waters. Liverpool University Press, Liverpool.

Hynes, H.B.N. 1972: The ecology of running waters. (Second impression). Liverpool Univer sity Press, Liverpool.

Illies, J. and Schmitz, W. 1980: Die Verfahren der biologischen Beurteilung des Guteyustandes der Fliessgewässer (systematisch-kritische Ubersicht. *Studien zum Gewässerschutz,* **5**: *1-125.*

Jäger, P., Kawecka, B. and Margreiter-Kownacka, M. 1985: Zur methodic der Untersuchungen der Auswirkungen des Wasserentzuges in Restwasserstrecken auf die Benthosbiozonosen (Fallbeispiegel: Radurschlbach). *Oesterreichische Wasserwirtschaft,* **37**: 190-202.

Kawecka, B. 1971: Zonal distribution of alga communities in stream of the Polish High Tatra Mts. *Acta Hydrobiologica,* **13**: 393-414.

Kawecka, B. 1974: Effect of organic pollution and the development of diatom communities in the alpine streams Finsterttaler bach and Gurgler Ache (Northern Tyrol, Austria). *Ber. Nat. - med. Ver. Insbruck,* **61**: 71-82.

Kawecka, B. 1977: Biocenosis of high mountain stream under the influence of tourism. 3. Attached algae communities in the Rybi Potok (the High Tatra Mts, Poland) polluted With domestic sewage. *Acta Hydrobiologica,* 22: 271-292.

Kawecka, B. 1980 : Sessile algae in European mountain streams. 1. The ecological charac teristics of communities. *Acta Hydrobiologica,* **22**: 361-420.

Kawecka, B., 1981: Sessile algae in European mountain streams. 2. Taxonomy and autoecology. *Acta Hydrobiologica,* 23: 17-46.

Kawecka, B., Kownacka, M. and Kownacki, A. 1971: General characteristics of the biocenosis in the streams of the Polish High Tatras. *Acta Hydrobiologica,*13: 465-476.

Kownacka, M. and Margraiter, G. 1978: Die Zoobenthos gesellschaften des Piburger Baches Otzal, Tirol). *Inter. Revue Ges. Hydrobiologica.,* **63**: 212-232.

Kownacki, A. 1971: Taxocens of Chironomidae in streams of the Polish High Tatra Mts. *Acta Hydrobiologica,* **13:** 439-464.

Kownacki, A. 1977: Biocenosis of high mountain stream under the influence of tourism. 4. The bottom Fauna of the stream Rybi Potok (the High Tatra Mts.) *Acta Hydrobiologica,***19**: 293-312.

Kownacki, A 1980: Taxocens of Ephemeroptera luted streams of Tatra Mountains. In *Advances in Ephemeroptera biology* (eds. J. F. Flannagan and K. E. Marshall), pp. 405-428. Plenum Press, New York, London.

Kownacki, A. 1989: Taxocenes of Chironomidae as an indicator for assessing the pollution of rivers and streams. *Acta Biologica Debrecina,* *Oecologica Hungarica*, **3**: 231-240.

Kownacki, A. 1991: Zonal distribution and classification of the invertebrate communities in high mountain streams in South Tirol (Italy). *Verhandlungen. Internationale. Vereinigung fur Theoretische und angewandte Limnology*, **24**: 2010-2014.

Krammer, K and Lange-Bertalot, H. 1986-1991: Bacillariophycae. In *Susswasserflora von Mitteleuropa* (eds. Ettl, H., Gärtner, G.. Gerloff, J., Heynig, H and Mollenhauer, D.), 2(1-4), VEB G. Fischer Verlag, Jena, 4 Vols.

Kwandrans, J. 1989: Ecological characteristics of communities of sessile algae in Biala and Czrana Wiselka streams, Headwaters of the River Vistula (Silesian Beskid, southern Po land). *Acta Hydrobiologica*, **31**: 43-74.

Sadovskij, A.A. 1940.: (Used of saprobic system in mountain rivers). *Soobšcenija Gruzinskogo Filiala AN SSSR*, **1**: 369-376 (in Russian).

Sládeček, V. 1973: System of water quality from the biological point of view. *Archiv fur Hydrobiologie Beiheft, Ergebnisse der Limnologie*, **7**: 1-218.

Starmach, K. 1959: Biocenoses of rivers and their protection. *Ochrona Przyrody*, **26**: 33-49 (in Polish).

Starmach, K. 1969: Hildenbrandtia rivularis i glony towarzsace w potoku Cedronka kolo Wejherowa (wojwództwo Gdansk) - *Hildebrandtia rivularis* and associating algae in the strem Cedronka near Weherowo (Gdansk voivode). *Fragmenta floristica et Geobotanica*, **15**: 378-398.

Steinberg, C and Schiefele, S. 1988: Biological indication of trophy and pollution of running waters. *Z. Wasser-Abwasser-Forsch.* **21**: 227-234.

Ward, J.W. 1992: Aquatic insect ecology.1. Biology and habitat. John Wiley & Sons, Inc., New York, Chichister, Brisbane, Toronto, Singapore.

Whitton, B.A. (eds) 1975: River Ecology. Studies in Ecology. 2. Blackwell Scientific Publications. Oxford, London, Edinburgh, Melbourne, pp.725.

Whitton, B.A., 1984: Ecology of European Rivers. Blackwell Scientific Publications. Oxford, Edinburgh

Whitton, B.A., Rott, E. and Friedrich, G. (eds) 1991: Use of algae for monitoring rivers. STUDIA Studentenforderungs - Ges. M. b. H., Insbruck.

Zimmermann, P. 1961: Experimentelle Untersuchungen uber den okologische Wirkung der Stromungsgeschwindigkeit auf die Lebengemeinschaften des fliessender Wasser. *Schweizerische Zeitschrift fur Hydribiologie*, **23**: 1-81.

Received 27 March 1997; revised 19 November 1997; accepted 3 March 1998.