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THE WATER EROSION PROCESS AGAINST THE BACKGROUND OF OUTFLOW CONDITION CHANGES IN UPLAND CATCHMENT

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The investigations of denudation processes were carried out in the Mielnica Stream catchment area in the hydrological years 1977/78-1993/94. The object is situated in the Trzebnica Hills area, considered as one of the most eroded regions of Poland. Daily bathometrical measurements of suspended load and observations of hydrometeorological conditions were made. Investigations were extended by analysis of washed out chemical compounds in the years 1987/88-1989/90. The character of agricultural production has changed as a result of the economic transformation in Poland since 1990. The need for new ways of agriculture production in the catchment, led to fishponds being built in 1997. The outflow denudation investigations were restarted in 1998. In this article the amounts of carried out material are presented against the background of changes in the catchment area.

Keywords: water erosion, chemical denudation, agricultural catchment, sediment yield

INTRODUCTION

The Trzebnica Hills area is subjected to intensive agricultural use because of the very fertile soil cover. The influence of the anthropogenic factor on environmental elements has caused increases in many negative processes such as accelerated water erosion. Problems of soils degradation, relief changes, water reservoirs silting-up and difficulties in irrigation systems management arise there. Because of this the estimation of the quantity and dynamic changes of the ero-

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sion processes and location of eroded areas is a very important task. Water erosion processes can be assessed by bathometrical analysis. Changes of sediment transport in streams are strictly connected with erosion events on the slopes. The amount of carried material reflects the dynamics of the water erosion process in the catchment area. Another problem is the chemical denudation.

Until recently it was known that pollution of rivers, lakes and wells in the countryside was an effect of wastewater dumps. Nowadays also the surface run-off is believed to have an impact on water quality.

The chemical compounds washed out from the catchment area, dissolved in flowing waters are delivered to streams as a consequence of the surface run-off and the process of soil profile wash-out. The quantity of chemical erosion depends on the chemical composition of the soil type, intensity of agriculture production and environmental degradation. The vegetation also has a serious influence on the size of chemical compound denudation.

Chemical soil erosion is a potential threat to the soil environment. It is necessary to investigate this relatively little known process in detail. This kind of research is not common in Poland because of the huge capital expenditure connected with the costs of chemical analysis (Froehlich 1975, Kostrzewski et al. 1994).

OBJECT CHARACTERISTICS AND RESEARCH METHODS

The Trzebnica Hills are situated in the Lower Silesia province in the Trzebnica administrative district. The potential erosion threat is determined by hilliness, loess soils cover very susceptible to erosion and the intensive agricultural use. Monitored Mielnica Stream catchment is situated in the region mentioned above.

The investigations of the erosion rate were conducted both in the field and laboratory. The following were collected:

- daily measurements of water levels at the catchment closing cross-section,
- periodical flow rate measurements by hydrometric current meter,
- daily bathometrical measurements and laboratory analysis,
- periodical analyses of the water is chemical composition.

The aim of the investigation was to estimate the rate of the erosion process and its changes for the last 22 years, on the basis of analysis of the amount of sediment and chemical compounds carried. The methodology of investigations in 1998/99 was the same as in the years 1974/75-1993/94 to make the data comparable (Józefaciuk 1996).

The investigated Mielnica Stream catchment is situated in the Lower Silesia province, in the Trzebnica administrative district. The catchment area contains the territories of the villages of Boleścin, Głuchów Dolny and Głuchów Górny, Radłów, Skotniki, Piersno and Krakowiany. The stream supplies the Dobra River, which is a tributary of the Widawa River. The Widawa is a part of the Odra River system. The catchment area of 6.67 km² was estimated in the years 1977-1994. Nowadays the cross-section has been moved down the stream and the catchment area is 7.11 km². The reason was a fish pond situated near the old

cross-section. The elevation ranges from 171.25 m a.s.l. to 246.1 m a.s.l. Its length is about 3.7 km and the mean width is 1.8 km. There is an area of 0.364 km² mostly stabilised gullies in the catchment. The average slope for the catchment is 2.9 % and calculated on the basis of the slope map, the average slope gradient is 8 %.

97 % of the catchment area is covered by loess soil. Nearly 80 % of the total area is in agricultural use (among this: croplands 70 %, meadows 2 %, pastures 8 %, see Fig. 1). Forest cover in the studied catchment area is only 6 % of the total area (Licznar et al. 1999, Rojek 1992, Szewrański et al. 1999, Żmuda 1998).

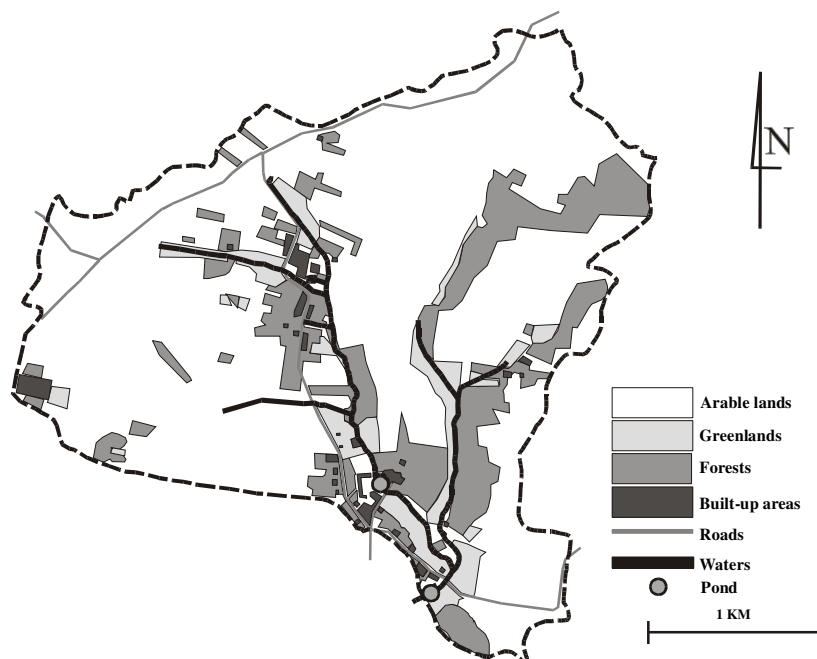


Fig. 1. The map of Mielnica catchment

In 1997 two fish ponds with a total area of 0.7 ha were built in the catchment area, which had a serious influence on out-flow conditions as well as the quantity and quality of the material carried out.

Knowledge of the local meteorological conditions is of special importance in erosion studies. The mentioned above conditions were characterized on the basis of the data from Trzebnica and Chwałkowiec IMGW meteorological stations. The Trzebnica station is located 9 km from the research site and Chwałkowiec – 40 km.

RESEARCH RESULTS

Water erosion phenomena are strongly determined by hydrological and meteorological conditions. Time series analyses of the amounts of material carried

show its dependence on periodical changes of climate factors (Žmuda 1998). Knowledge of precipitation and temperature is necessary to describe erosion. Data collected during the investigation in the years 1977/78-1993/94 are presented below.

The maximum noticed annual precipitation was 777.6 mm, the minimum was 529.8 mm, and the mean 649.2 mm. The monthly precipitation ranged from 4.8 mm to 215.5 mm, and the mean monthly value was 54.2 mm.

The annual mean temperatures in the area fluctuated from 7.1 °C to 9.7 °C, and the mean was 8.3 °C. The coldest month was recorded with temperature of 9.4 °C, and the warmest with 22.3 °C.

The data from the current investigation are shown against the background of the values mention above.

Annual precipitation was 513.6 mm, the monthly amount ranged from 11.7 mm to 76.6 mm. The mean monthly precipitation was 42.8 mm. Statistical analyses led us to classify the year 1998/99 as a dry one.

The mean annual temperature was 8.7 °C. The mean temperature of the coldest month was -0.7 °C, and of the warmest about 19.2 °C.

The daily suspended sediment concentration and discharge rate measurements let us estimate daily and periodical quantities of the soil material washed out through the bathometrical cross-section. Total amounts of sediment were referred to the surface unit and calculated values were presented as sediment yield [Mg km^{-2}]. Such data presentation is necessary for comparing two catchments with different areas.

In the period 1977/78-1993/94 the monthly sediment yield ranged from 0.005 to 16.50 Mg km^{-2} and the mean annual yield was 8.78 Mg km^{-2} .

The greatest soil loss, in the research period, was on 22 May 1987, when the biggest amount of washed material was measured. About 16.15 Mg of the soil material was washed out from 1 km^2 . This event was caused by torrential rain with precipitation of 33 mm (Pływaczyk et al. 1999, Szewrański et al. 2000, Žmuda 1998). In current investigations the minimum monthly sediment yield was 0.02 Mg km^{-2} and the maximum 0.07 Mg km^{-2} . The annual sediment yield was 0.52 Mg km^{-2} .

Land use is one of the most important factors, which determines the quantity of sediment carried out. It refers especially to the buffer role of fish ponds in the catchment area. The ponds change the discharge conditions and cause accelerated sedimentation and deposition processes. The objects built in 1997 reorganised the hydrographical network in the catchment area and they had a serious influence on the total amounts of carried out soil material.

Water erosion is often determined by single events like torrential rains of the annual total sediment can be "produced" in just one day. It is very difficult to assess the land use impact on such an accidental process as denudation.

The year 1998/99 was described as a dry one with precipitation of 513.6 mm. From data collected in 1977/78-1993/94 similar dry hydrological years were selected. These were: 1982/83 with precipitation of 575.9 mm; 1989/90 – 536.8 mm; 1988/89 – 535.8 mm and 1990/91 with the annual sum of 529.8 mm.

The cumulative curves of precipitation were plotted to find the best fitting year to 1998/99 (Fig. 2). The year 1990/91 turned out to be the most similar regarding precipitation.

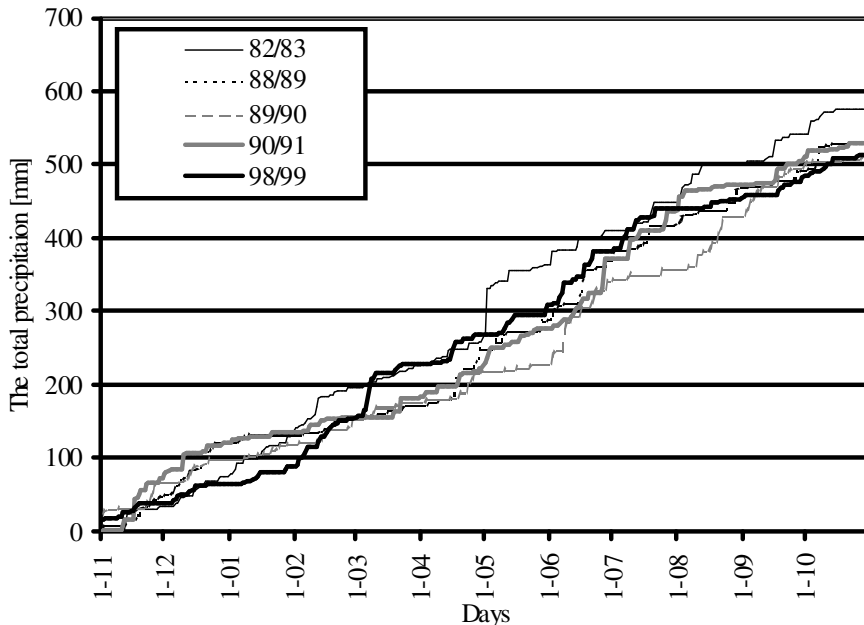


Fig. 2. The cumulative curves of precipitation

The same analyses were made for cumulative curves of temperature. The aim was to find the analogous year in response to such events as snow melts. In this case, the year 1990/91 fitted the year 1998/99 much better than others (Fig. 3).

Finally, the year 1990/91, regarding meteorological conditions, was selected as the representative for further analysis.

To present the changes of outflow denudation the cumulative curves of daily sediment yield were plotted (Fig. 4). The cumulative curve of the median values of daily (1977/78-1993/94) sediment yield was also attached. The medians were calculated to describe the average course of denudation during a year, excluding accidental events. The total amount of soil material carried out from the catchment in the year 1990/91 as 1.17 Mg km^{-2} , on the basis of the median it was about 1.01 Mg km^{-2} annually. In 1998/99 the serious reduction of sediment transport was noticed, with annual denudation yield on the level of 0.52 Mg km^{-2} . The monthly values of sediment yield are presented in Fig. 5. The calculated percentage reduction of denudation yield in each month is shown below in Tab. 1.

In similar meteorological conditions the total amount of carried soil material was reduced by almost half. The buffer role of fishponds proves distinct here.

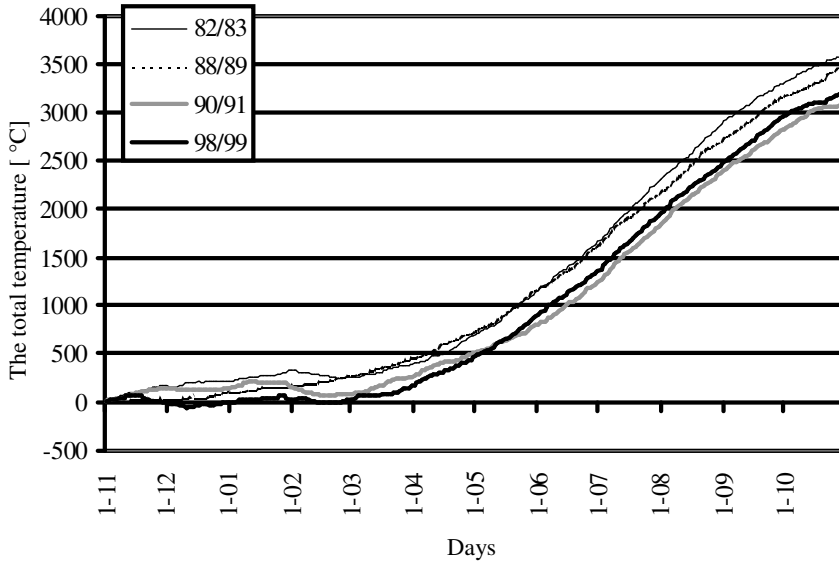


Fig. 3. The cumulative curves of air temperature

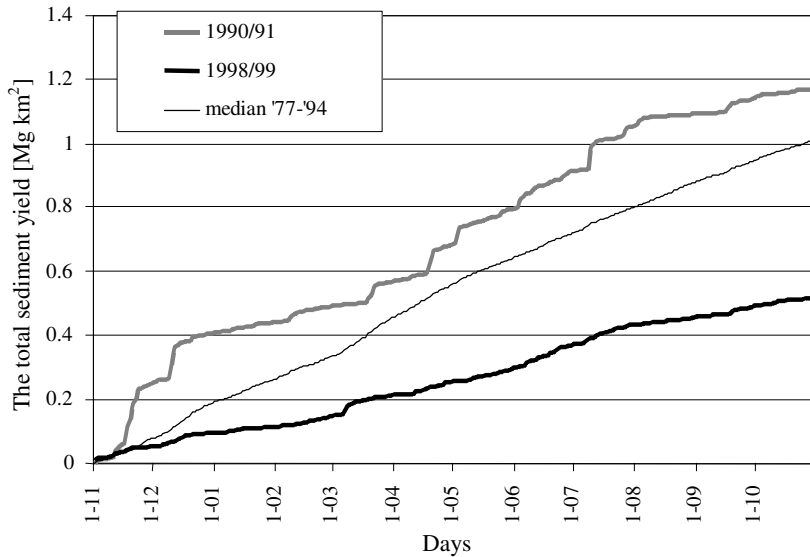


Fig. 4. The cumulative curves of the daily sediment yield

Sedimentation and deposition processes taking place in reservoirs can explain the changes. The serious fact is that the year 1998/99 was the driest of the selected years. But the total annual precipitation is not so important as single tor-

rential rains. Respecting USLE instructions daily rains higher than 12.7 mm were analysed. In 1990/91 only 10 such rains took place and during the current investigation – 8. Regarding the above there are also no significant differences.

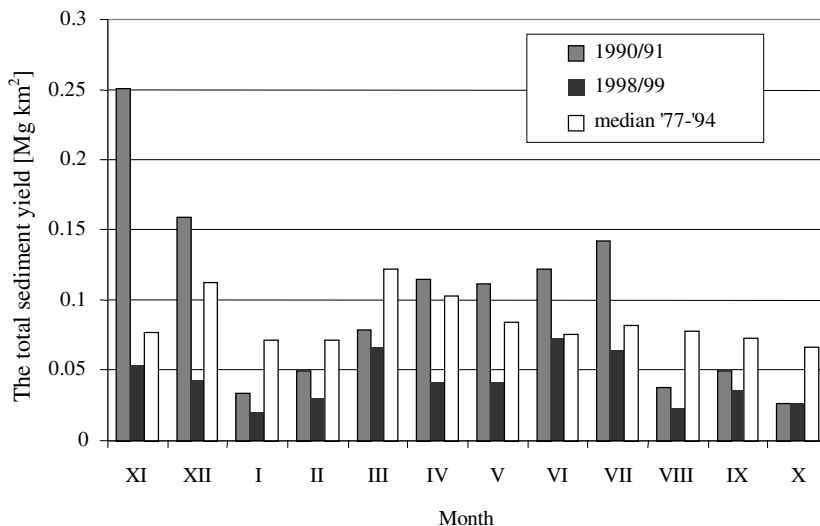


Fig. 5. The monthly values of sediment yield

Tab. 1. Reduction of denudation yield

Month	In relation to	
	1990/91 by:	median by:
XI	78.48 %	30.00 %
XII	73.17 %	61.99 %
I	39.49 %	71.61 %
II	39.13 %	58.16 %
III	15.19 %	45.57 %
IV	63.24 %	59.18 %
V	61.75 %	49.15 %
VI	40.50 %	4.41 %
VII	54.87 %	22.44 %
VIII	40.54 %	70.86 %
IX	28.31 %	51.03 %
X	2.33 %	61.02 %

Erosion investigations were extended for chemical denudation analyses in the years 1988-1990. Currently the chemical aspect of erosion is also analysed.

Chemicals compounds, carried out from the catchment area with the stream flowing water, are delivered to the watercourses as a result of surface and underground flows. This phenomenon is closely related to hydrometeorological conditions. Apart from the water factor, the chemical denudation amount is determined by the chemical composition of the soil and parent rock fertilization and environmental pollution (Rojek 1992, Szwerański et al. 1999).

The composition of the soil chemical was analysed. Concentrations of some analysed chemical compounds were (in 1977/78-1993/94): P about $0.72 \text{ mg}\cdot\text{g}^{-1}$; $\text{N-NO}_3 - 0.013 \text{ mg}\cdot\text{g}^{-1}$. Soil pH was measured on the level of 5.8. In the current investigation, the following concentrations were observed: $\text{N-NO}_3 - 0.007 \text{ mg}\cdot\text{g}^{-1}$; $\text{N-NH}_3 - 0.033 \text{ mg}\cdot\text{g}^{-1}$; P – $0.56 \text{ mg}\cdot\text{g}^{-1}$; K – $3.3 \text{ mg}\cdot\text{g}^{-1}$ and pH of soil was 4.7.

The mean use of mineral fertilizers was described on the basis of questionnaires and archival data. Since 1985 their quantity has generally come down and it reflects the economical condition of agricultural production in the Trzebnica Hills. The collected data are shown below in Tab. 2.

Tab. 2. Mean use of mineral fertilizers in years 1985-1996 [Mg ha^{-1}]

Year	N	P_2O_5	K_2O
1985	0.090	0.090	0.070
1986	0.070	0.050	0.060
1987	0.070	0.050	0.070
1988	0.070	0.045	0.060
1990	0.100	0.060	0.090
1991	0.060	0.030	0.050
1995	0.060	0.030	0.030
1996	0.055	0.020	0.025

The amounts of chemical compounds, washed out from the catchment area, were calculated on the basis of water outflow rates and measured concentrations. The chemical denudation yield [Mg km^{-2}] was received by referring the obtained results to the surface unit.

In the years 1987/88-1989/90 the mean annual chemical denudation yields were as follows: $\text{N-NH}_4 - 0.031$; $\text{N-NO}_x - 0.044$; P – 0.0145 and K – 0.570 Mg km^{-2} . In 1998/99 they were $\text{N-NH}_4 - 0.009$; $\text{N-NO}_x - 0.050$; P – 0.015 and K – 0.775 Mg km^{-2} . The monthly distribution of chemical denudation is presented in Fig. 6.

The problem has not been looked into thoroughly. Regarding phosphorus and nitrates, the washing out processes seem to be similar and amounts of carried out compounds do not differ much. Lower denudation is noticed in the case of ammonium nitrogen. There is still no explanation for such changes. It might be connected with livestock production and manure utilization. The analyses are continued. The same problem concerns the potassium denudation and lower pH of soils. There are still no satisfying answers. Investigations have just been finished, further data analysis should bring the solution.

CONCLUSIONS

The results of the erosion rate investigation in the Mielnica Stream catchment area allow us to assess the erosion risk in this region. The mean annual sediment yield depends on extreme values of water discharge, especially the maximum daily ones, generally determined by torrential rains.

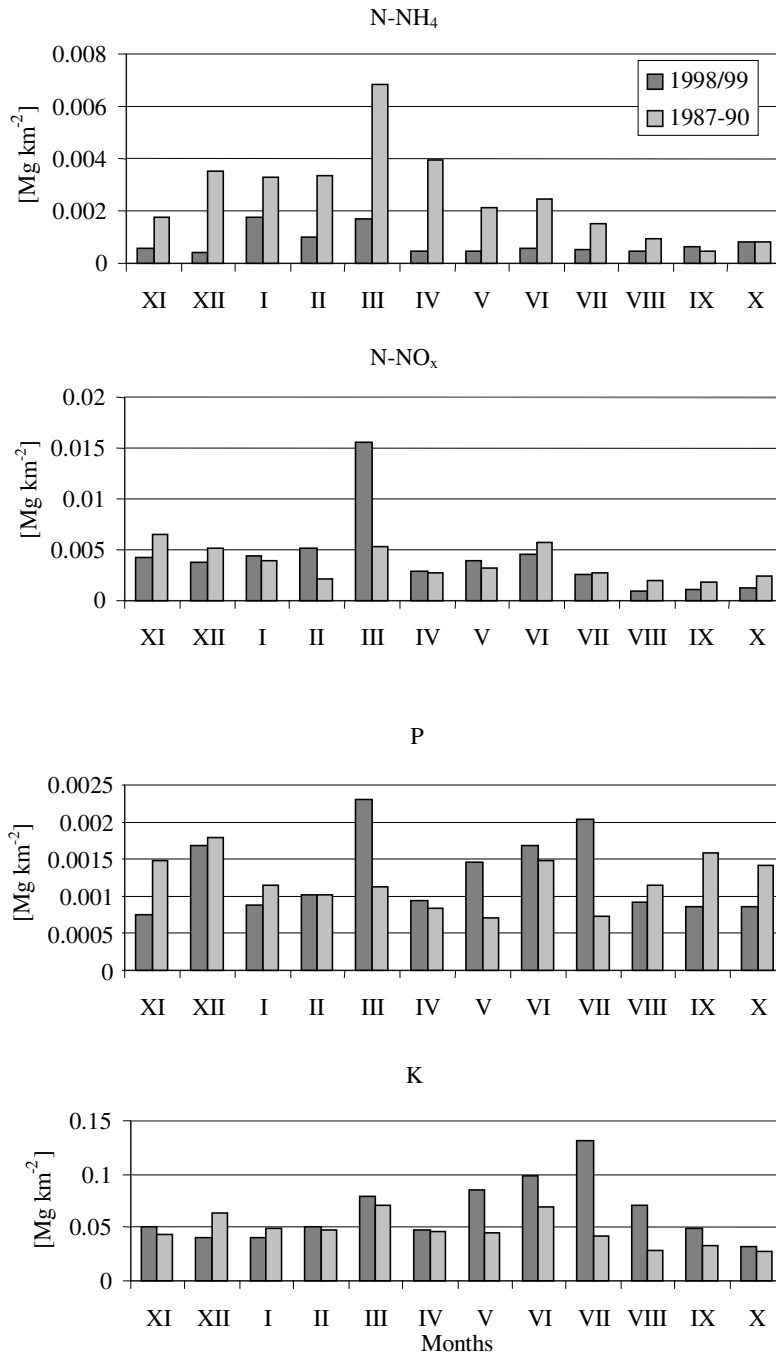


Fig. 6. The monthly distribution of chemical denudation yield

Land use is one of the most important of the factors, which determine the quantity of carried out sediment. It especially refers to the buffer role of fish ponds in the catchment. The ponds change the discharge conditions and cause accelerated sedimentation and deposition processes.

The analyses of the cumulative curves of daily sediment yield showed the serious buffer role of the fish ponds. In similar meteorological conditions the total annual amount of carried soil material was reduced by almost 50 %.

Chemical denudation investigations showed some differences among washed out chemical compounds. The problem has not been well recognized yet. The solutions should appear when the investigations are finished.

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PROCES VODNEJ ERÓZIE NA POZADÍ ZMIEN ODNOSOVÝCH PODMIENOK VO VRCHOVINNOM POVODÍ

Denudačné procesy sa skúmali v povodí Mielnice počas hydrologických rokov 1977-78 až 1993-94 v oblasti Trzebnických vrchov na juhozápade Poľska. Výskum sa

uskutočnil v teréne a v laboratóriu a pozostával z denných meraní vodnej hladiny v priereze povodia, pravidelných meraní intenzity toku hydrometrickým krídlom, denných batometrických meraní a ich laboratórnej analýzy a napokon z pravidelných rozborov chemického zloženia vody.

V rokoch 1987-88 a 1989-90 sa výskum rozšíril o analýzu vyplavených chemických zlúčenín. Výskum odnosového procesu sa obnovil v roku 1998 a dal do súvisu so zmenami v poľnohospodárskej výrobe po roku 1990.

Predbežné analýzy údajov ukázali rozdiely medzi vyššie uvedenými dvoma výskumnými obdobiami. V rokoch 1977-78 až 1993-94 sa mesačné množstvo sedimentov pohybovalo od 0,005 do 16,50 mg km⁻² a priemerne to bolo 8,78 mg km⁻². Pri výskume prúdu bolo minimálne množstvo sedimentov 0,02 mg/km⁻² a maximálne 0,07 mg/km⁻². Ročné množstvo sedimentov bolo 0,52 mg/km⁻². V roku 1998-99 bol z jedného štvorcového kilometra vyplavené asi 0,85 mg/km⁻². Maximálna mesačná hodnota chemickej denudácie dosiahla 0,14 mg NPK na km⁻² a minimálna 0,035 mg/km⁻². V rokoch 1977/78 až 1993/94 sa mesačné množstvo chemickej denudácie pohybovalo medzi 0,002 a 0,14 mg/km⁻² a jeho priemerné ročné množstvo sa rovnalo 0,66 mg/km⁻².

Preložila H. Contrerasová