The Monitoring Comparative Results of Floodplain Ecosystems in Regulated and Natural Part of the Danube River (Geisling-Passau)

Kouzmina, Janna*, Sergey Treshkin[1] and Alfons Henrichfreise[2]

Water Problems Institute, Russian Academy of Sciences, Moscow 119991, Russia

[1] *Institute of Bioecology, Karakalpak Branch, Uzbek Academy of Sciences, Berdach pr. 41, Nukus 742000, Uzbekistan*

[2] *Federal Agency for Nature Conservation, Konstantinstrasse 110, 53179 Bonn, Germany*

ABSTRACT : The complex ecological researches were made in the broad-leaved forest zone of Central Europe in nature reserves and national parks located on the banks of the river (hydrology, vegetation, soils, unconfined ground waters). The natural conditions of terrestrial ecosystems and natural sites were compared along the course of the rivers. The significant negative influence of low-dammed (low-confined hydrotechnic) construction and small reservoirs on vegetation and soils of floodplain was revealed. On the basis of analysis of mean annual water level and flow trends on the multi-years series (60~100 years) of the hydrometric stations on the rivers under consideration the significant influence of natural long-term variability of watering on vegetation dynamics in the floodplains was revealed.

Key words : Ecosystem, Flood-plain, Nature conservation, Regulated river, Vegetation

INTRODUCTION

The hydrotechnical construction, significantly changing the natural hydrological regime of the rivers, considerably breaks the direction and development of natural geographical and ecological processes in valleys and deltas of the rivers (Avakyan *et al.* 1987, Glazovski 1991, Henrichfreise 1995, Weiger 1996, Kouzmina and Treshkin 2001). Unlike from large hydrotechnical construction the influence of average and low of the hydrotechnical construction is exhibited not at once, and after some decades. That's why their influence on the floodplain ecosystems is investigated insufficiently.

The Federal Agency for Nature Protection of Germany in cooperation with Russian Academy of Sciences has carried out scientific investigations the influence of low and average hydrotechnic constructions of river (low-dammed, navigable channels and sluice with afflux 4~10 m) on floodplain ecosystems in connection with changes of floodplain reservations in Germany part of the Danube river.

MATERIALS AND METHODS

The annual field researches were carried out since 1996 for 2001 on 6 permanent model profiles, length from 300 m to 1 km, which located in protected reserve areas: in middle reach of the Danube river with confluent Isar: NSG-Pfatterau/2348.8 Danube-km, NSG-Gmuenderau/2347.6~2347.0 Danube-km, NSG-Oberauer Schleife/2332.7 Danube-km, NSG-Staatshaufen/2278.0~2277.7 Danube-km, Muelhamer Schleife/2271~2270.7 Danube-km, Pielweichs/10.3 Isar-km (Fig. 1).

During scientific and expert work we used methods of historical, ecological, geographical analogues, methods of geobotanical indication, ecological profiling, statistical processing etc.

The impact of hydrotechnical construction and regulated flows upon the landscape status of floodplains was studied by means of such methods, as comparative geobotanical landscape profiles, detailed description of key areas (soils, GW, vegetation), repeated examination of model profiles: boring up to GW, description of vegetation, soil sampling for chemical analyses (Zaidelman 1998). To determine changes in alluvial soils, an original method was employed as based on estimating the moisture content soil level and intensity of its fluctuations in seasonal and long-term cycles taking into consideration morphological, physico-chemical and chemical properties of soils.

In studying the dynamics of vegetation cover in floodplains the typology of plant communities helped reflecting the features of vegetation cover with account of its environmental and geographical relationships (Kouzmina 1997, Kouzmina and Treshkin 2001). In this work were analyzed more than 400 own geobotanical description, published geobotanical contributions, which were made in

This article was presented at the INTECOL meeting (Seoul, August 2002).

* Corresponding author; e-mail: tugai@gol.ru; jannaKV@yandex.ru

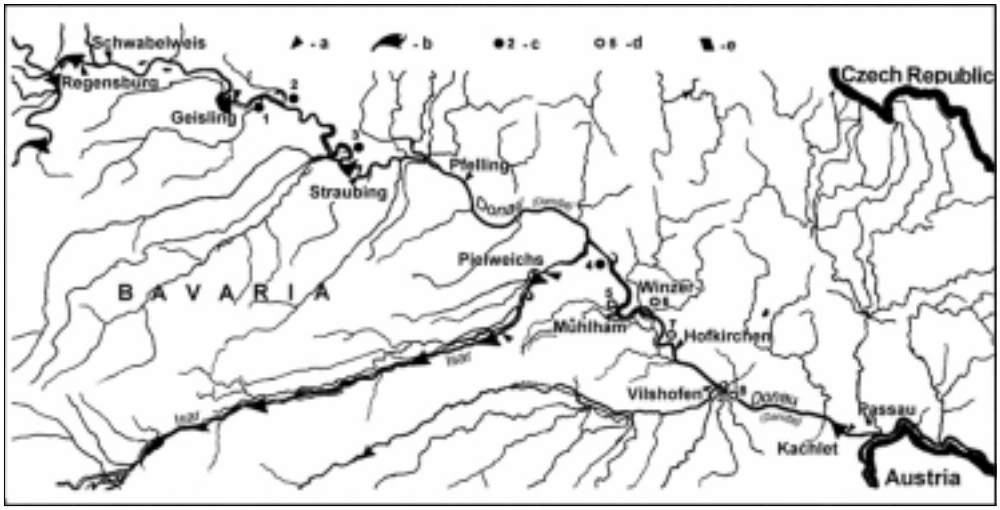

Fig. 1. The plan of region of researches: a - hydrometric station in the inhabited center, b - dams on the rivers, c - existing state reserved territories of flood-plain (1-Pfatterau, 2-Gmünderau, 3-Oberauer Schleife, 4-Staatshaufen), d - planned reserved territories of flood-plain (5-Mühlhamer Schleife, 6-Winzerer Lette, 7-Mühlau, 8-Inseln Vilshofen), e - the state border of Germany.

period before regulated of the Danube river on the studying site (Zahlheimer 1979), more than 60 own soil profiles and numerous boring till GW.

For revealing of multi-year dynamics of water content of the rivers we used data of stationary observation for level and charge of water of the rivers and channels officially published in hydrological year-books (Deutsches 1953~1996) and also hydrological data given to us by Bavarian Regional Agency for Water Management, Federal Administration for Water and Ship-management of Germany and German Federal Institute of Hydrology.

For evaluation of the state and dynamics of floodplain ecosystems we analyzed only annual average, monthly average and multi-years monthly average meanings of the discharges and levels of water, and also absolute annual and monthly maximal and minimal meanings.

The influence of low-dammed construction was estimated by comparison of landscapes state and ecosystems in sites, similar in physical-geographical conditions for regulated and natural river parts. The study were carried out in different periods of river water content: in drought period, in catastrophic summer flooding, under average multi-years of water level, high and low average multi-years of water level in river.

RESULTS

Hydrological situation in research region

The observed site of the Danube river from Regensburg to Passau (2376.49~2230.32 Danube km) was shared on 3 parts depending on period of functioning in regulated flow: 1) the long time ago regulated (since 1987) river (2376.49~2353.66 Danube km) site between dams Schwabelweis (1965) and Geisling (1987); 2) the short time ago regulated (since 1994) river site (2353.66~2321.25 Danube km) between dams Geisling (1987) and Straubing (1994); 3) the site of river with natural flow from Pfelling to Vilshofen (2305.53~2249.47 Danube km);

Comparison of the multi-year data on the water level and discharges on 4 hydrometric station of Bavarian Danube from 1900 till 1998 allowed us to reveal the existing on this site of the long smooth tendency of increase of water content in the river Danube from the beginning of century (Fig. 2), which is connected to increase of precipitation in region (Fig. 3). We used for the analysis

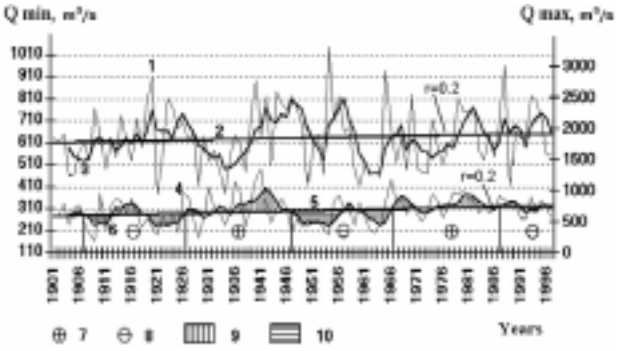

Fig. 2. Centenary dynamics of maximal and minimal water discharge (MaxQ, MinQ) in the Danube river (hydrometric station Hofkirchen/Danube - natural flow). 1, 2 and 3 - annual MaxQ, linear trend and 4-periode moving average MaxQ; 4, 5 and 6 - annual MinQ, linear trend and 4-periode moving average MinQ; 7 - the period of high water, 8 - the period of low water, 9 and 10 - damp and dry years.

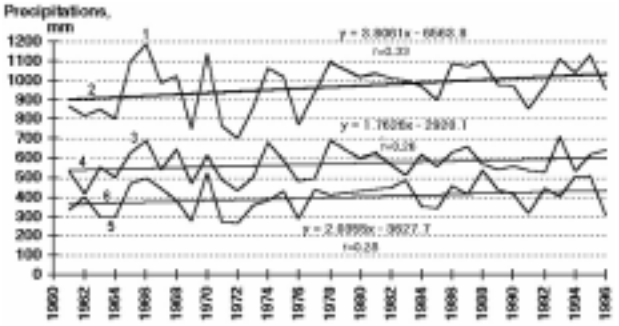

Fig. 3. Multi-years dynamics of distribution of atmospheric precipitations in the upper reach of the Danube river (Hofkirchen). 1 & 2 - Sum of annual precipitations and linear trend, 3 & 4 - precipitations of summer period and linear trend, 5 & 6 - precipitations of winter period and linear trend.

the data from hydrometric section both in regulated part of river (Regensburg-Straubing), and also on the site of natural part of the river flow (Pfelling-Vilshofen). For all analyzed hydrometric stations the trend of increase of the absolute minimal and maximal annual water discharges and water level is typical.

On the base of analysis of multi-years minimal and average discharges of water of the river Danube we established the 19~20 years periods of higher and lower water of the river Danube (Fig. 2). They on the whole correspond to multi-years fluctuations of atmosphere circulation of Northern hemisphere (Kononova and Harlamova 1982).

It is determined that during the period prior to regulation of the river Danube (1941~1960) the graphs of discharge and of water levels of seasonal distribution of monthly average means on all compared hydrolometric stations in the researches areas were identical (Fig. 4a). As the result of construction of dams Schwabelweis (1965), Gaisling (1987) and Shtraubing (1994) was increased of average water levels on regulated sites on 0.8 м since 1987 and the

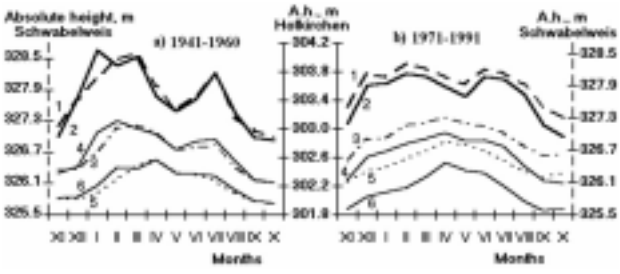

Fig. 4. Comparative change of amplitude fluctuation of water levels in the Danube river for two hydrometric stations Hofkirchen and Schwabelweis during (a/ 1941~1960) and after regulated river (b/ 1972~1991). Maximal, average and minimal water level/WL: 1, 3, 5 - Schwabelweis; 2, 4, 6 - Hofkirchen.

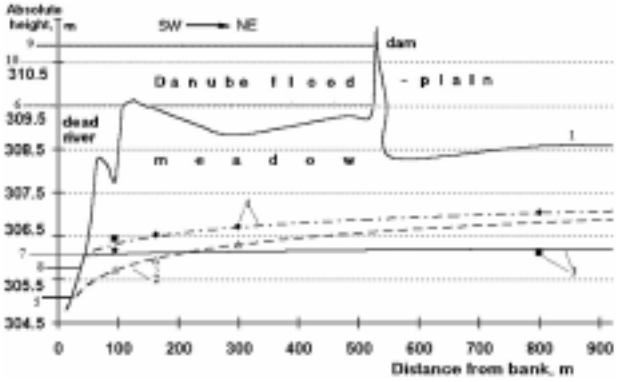

Fig. 5. Positive tendencies of GWL in floodplain transect Muehlhamer Schleife. 1 - relief (total leveling), 2 - ground water/GW on drought period 1998 (measured point and trend), 3 - GW on average period 2000 (measured point and trend), 4 - GW on average period 2001 (measured point and trend), 5 - WL on drought period 1998 (measured), 6 - WL on flood period 1999 (measured), 7 - WL on average period 2000, 8 - WL on average period 2001, 9- maximal high water 1944~1961, 10 - maximal high water 1981~1998.

fluctuation amplitude of a water level in the river was reduced (Fig. 4b).

Stabilization of stream-flow regime, reduction of flood in combination with increase of floodplain watering resulted in higher hydromorphism of alluvial soils, in processes of bogging, in everywhere watering of soil profiles by ground waters (of lower and middle parts of soils).

The results of researches has showed, that under regulated of river flow the equal situation GWT under forest and meadow communities is established, and the fluctuations of GWT on seasons are considerably reduced, and frequently amplitudes in 1 m do not exceed (Fig. 2).

On all relief elements of floodplain there is untypical process of new communities formation overwet habitat. This succession process differently mentions all complex of floodplain ecosystems, to occupying different floodplain elements, and as well as depends on intensity, duration of anthropogenic impact and degree of regulated river.

The periodic researches in the non-regulated part of the river Danube

As a model natural transects in the flood plain of the non regulated part of the river Danube we selected transect of Muehlhamer Schleife and NSG-Staatshaufen.

In the present time the massif NSG-Staatshaufen has the more high status of guarded territory, has some inaccessibility, and as by the presence of the satisfactory condition practically of the whole

complex of the flood plain ecosystems, applicable to the series of the relief forms of all floodplain levels: from the drowned depressions with *Nuphar lutea*, *Acorus calamus* and *Phragmites australis* up to the forests *Querco-Ulmetum* on the top levels of the flood plains (308.0~310.5 abs.h.m). The massif NSG-Staatshaufen, experiences slight local anthropogeneous effect and can be considered as the natural measurement of the standard flood plain with non regulated regime of the river. The high value of the model natural transect (NSG Staatshaufen) is established. The plant communities of the transect NSG Staatshaufen are the most miscellaneous among all inspected transect.

Transect Muehlhamer Schleife experiences anthropogeneous effect: recreation, transport loads, agricultural usage, influencing of the anti-freshet dam (1926). On this transect Muehlhamer Schleife is clone of peculiar "bumper zone" of the flood plain ecosystems in conditions of the non regulated fluvial outflow, i.e. the model natural transect, experiencing local anthropogeneous effect.

Is determined the Natural functioning of ecosystems and natural cycle of GW fluctuations in flood-plain model natural transects depending on the river water level. The GW has a trend in natural flow (with the exception of flooding period) - from the watershed to banks of the river course (Fig. 5).

It is determined that the flood plain ecosystems, the ecotope which is the least subjected to the changes of the environment at the hydraulic engineering effect (the regulation of the flow) differ by the considerable annual fluctuational changes and large species diversity (NSG-Staatshaufen). The ecosystems highly disturbed because of the hydraulic engineering effect differ with very weak fluctuational variability and smaller species diversity of plant communities.

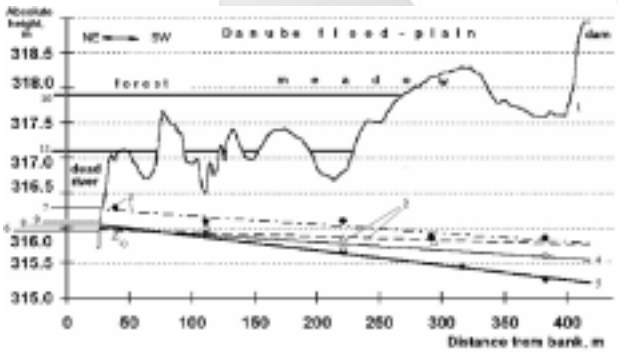

Fig. 6. Negative tendencies of ground water level (GWL) in floodplain reserved transect Oeberauer Schleife in zone influence of the brace Straubing dam. 1 - relief (total leveling), 2 - ground water/GW on drought period 1998 (measured point and trend), 3 - GW on flood period 1999 (measured point and trend), 4 - GW on average period 2000 (measured point and trend), 5 - GW on average period 2001 (measured point and trend), 6 - WL on drought period 1998, 7 - WL on flood period 1999, 8 - WL on average period 2000, 9 - WL on average period 2001, 10 - maximal high water 1999, 11 - maximal high water 2000.

It may be safely concluded that the planting of *Populus* spp. is practically inadmissible in the river floodplains with natural (non-regulated) hydrological regime. Poplars (*P. nigra*, *P. deltoides*, etc.) are usually perished in the age of 15~60 due to prolonged flooding taking place in rivers once for 15~50 years. At the same time native species of trees and shrubs (*Salix alba*, *S. triandra*, *S. viminalis*, *Quercus robur*, *Tilia cordata*, *Crataegus* spp., etc.) are capable to be adaptive to abrupt fluctuations of moistening in the floodplain and can bear prolonged flooding practically without adverse consequences.

Periodic investigations in the regulated part of the river Danube

In short time ago regulated (since 1994) river site the researches were continued on the constant model of the transects (Pfatterau, Gmuenderau, Oberauer Schleife), situated on the different remote from the locks of Geisling (2354 Danube-km; above the flow of the river) and Straubing (2330 - Danube-km; downstream rivers).

After 1986 the meander of Pfatterau has completely been uniting (from two parts) with the main channel of the river, and the transect has experienced the strong anthropogeneous influencing from the raising of the water level in the river Danube and also from the rise and stabilization of the GW in the flood plain. Plant communities of *Salix alba*, *S. triandra* on the site of the transect experience considerable depressing, and some of them have completely perished. In the depressions of the top level of the flood plain (the central flood plain) the transformation of the meadow communities into the more hydromorphic communities with the participation of the *Polygonum amphibium*, *Potentilla anserina*, *P. reptans*, *Carex* sp., *Cirsium arvense*, *Thalictrum flavum* etc. On the transect of Pfatterau the maximum speed of the irreversible change of the specific structure in the geobotanical descriptions from one year to another year is marked (1997~2001). About 50% of all the plant species have been changing for this time. Every year on different sites appeared from 30 up to 80 % of new plant species.

The transect Gmuenderau is situated in the mean part of the completely regulated part of the river Danube. Before and after the rising of the water level in the river (before and after the regulation of the fluvial flow) the meander had the half-flowing regime (i.e. the former river bed has the connection with the main channel of the river only on the one hand). After the regulation of the site of the river Danube all lower layers of the flood plain were completely drowned, and the communities of the *Salix* spp., *Phragmites aust-*

ralis, *Typha* spp., *Nuphar lutea* etc. were completely erased. At the present time there are the communities of the top flood plain - dried meadow, which experience sharp successions changes in connection with the increasing of the humidifying in the soil-ground (Kouzmina *et al*. 2000).

The transect Oberauer Schleife (Fig. 6) is situated in the upper pool of the lock of Straubing. Before the full regulation of the site of the river Geisling-Straubing this transect practically did not experience the influencing of the regional (*i.e*. indirect) antropogeneous effect, i.e. it was before the representative of the "typical model of the natural transect ". Now the transect Oberauer Schleife experiences very strong water logging from the lock and water storage basin, that was established by us at once after the decommission of the lock of Straubing and then completely demonstrated to the annual monitoring of soils, vegetation and GW. Here we didn" t mark significant fluctuations of GW (Fig. 6). We determined the static character in fluctuations of GW not only by seasons, but by years as well, notwithstanding the differences in water volume fluctuations of the Danube river. We determined extremely strong negative influence of Straubing dam on ecosystems of Oberauer Schleife reserve, which will increase in temporary. Connected with activation of filtration process the GW considerably increased because of flow from the floodplain part and direction of GW flow during the whole year was opposite (Fig. 6) - from river channel to watershed. While in the floodplain of natural part of the river flow the distribution of GW has natural slope - from watershed to river channel (Fig. 5).

In vegetation cover of riparian patch of the floodplain in the regulated part of the river Danube which has been occupied by communities of *Salicetum*, we revealed the tendency of formation of monodominant communities of *Urtica dioica* and *Phragmites australis* and dying of willow communities (*Salix wiminalis*, *S. triandra*, *S. alba*).

On higher elements (317.5~318.3 abs.h.m, Fig. 6) of the floodplain in the regulated part of the river Danube (on previous middle floodplain, on upper floodplain, on riparian levees) we noticed everywhere very intensive introduction of hydromorphous weed plant species: *Polygonum amphibium*, *Ranunculus repens*, *Girsium arvense*, *Thalictrum* spp., *Rumex* spp., *Alopecurus pratensis*, *Filipendula ulmaria*, *Glyceria maxima*, *Molinia caerulea*. The biodiversity on typical and dry meadows is reduced. The clay horizons are forming in the top parts of soil profiles (10~90 cm) and they move upwards along profile. It is feasible to observe an essential expansion of *Phragmites australis* from lower (and flooded now) relief elements into meadows of former middle and upper floodplains.

Hydromorphic and Weed plant species become indicators of anthropogeneous change under influence of low-dammed construction.

From three constant model transects, situated in the regulated part of the river Danube, the greatest negative influencing of water logging experiences the transect of Oberauer Schleife. Here is marked the formation of the more hydromorphic plant communities both on the lower flood plain, and on the increases high levels of the flood plain - in the dried meadows. In all the relief elements of profile Oberauer Schleife within the headwater zone of Straubing dam an accelerated boggy up of soils and vegetation as well as the ever increasing process of gleying in surface soil horizons take place.

CONCLUSION

Floodplain and deltas ecosystems even in protected natural reservations could not exist undisturbed at regulated river, because radical change of edaphic condition and regime of unconfined ground waters.

There is a deterioration of floodplain state populations of floodplain oak the top floodplain terraces and their complete destruction; the most valuable, typical and most diversity elm-oak forests systematically disappear on the European plain because of occurrence toxic gley in top (less than 1~1.5 m) of soil horizons and reduction of amplitude fluctuation GWT.

The multi-year trends of water content (centenary fluctuations) in different regions have various orientation and it should be taken into account for hydrotechnic construction and planning of nature protection measures, as in some regions they can deteriorate the conditions of protected ecosystems and in others - to support their preservation.

However, till now local anthropogenic transformations on the rivers that take part everywhere for economical reasons. By virtue of them numerous and cumulative influence on environment, it represent essentially large danger for natural communities, than natural regional hydroclimatic changes.

The study of microhearthes display (Kouzmina *et al*. 2000) has showed, that indicators of anthropogenic transformations of river flow become uniform soil processes and same plants species having extensive Eurasian areal. It can lead in the future to similarity of vegetation and soils of floodplains, reduction of biodiversity, disappearance of individuality floodplain landscapes of different regions.

ACKNOWLEDGEMENTS

The authors wish to express our appreciation to director the Federal Agency for Nature Protection of Germany to Prof., Dr. H.

Vogtman and to authorized person the Union of Nature Protection of Bavarian Land to Prof. Dr. H. Weiger and RFBR (grant № 03-05-64238) for financial support this study in Germany. The authors cordially are grateful for the help in field researches and for granting of the missing hydrological data to sirs K. Krauss, D. Scherf, Dr. F. Foeckler and to madam C. Lauschke and E. Kelling.

LITERATURE CITED

Avakyan, A.B., V.P. Saltankin and V.A. Sharapov. 1987. The Reservoires. Mysl, Moscow. 325 p.

Deutsches Gewaesserkundliches Jahrbuch. 19531996. Donaugebiet. Muenchen. Abflussjahr: 1951-1993.

Glazovski, N.F. 1990. The Aral Sea crisis. Nauka, Moscow. 136 p.

Henrichfreise, A. 1995. Staustufenbau an der Danube zwischen Straubing und Vilshofen: wirtschaftliche Notwendigkeit und oekologische Folgen des RMD Projekts. Tagungsband der Internationelen Danubekongresse. Ebner Druck, Deggendorf. pp. 4247.

Kononova, N.K. and I.V. Harlamova. 1982. Multi-year fluctuations of circulation atmosphere and climate in northern hemisphere in XX century. Materials of Meteorological Researches 6: 7-16.

Kouzmina, J.V. 1997. Classification of the vegetation of the Amudarya Delta. Botanical Journal 1: 86-101.

Kouzmina, J.V. and S.E. Treshkin. 2001. The modern status of flora and vegetation of the Baday-tugay reservation area in connection with changes of hydrological regime. Botanical Journal. 1: 73-84 .

Kouzmina, J.V., S.E. Treshkin and A. Henrichfreise. 2000. Microhearthes processes in connection with changes of hydrological regime of local territories. *In* Microhearthes processe-sindicators of destabilization environment, N.M. Novikova (ed.), Moscow. pp. 87-95.

Weiger, H. 1996. Staustufenbau an der Donau zwischen Straubing und Vilshofen: wirtschaftliche Notwendigkeit und oekologische Folgen des RMD Projekts . Tagungsband Vierter Internationeler Donaukongress. Deggendorf: Ebner Druck. pp. 53-57.

Zahlheimer, W.A. 1979. Vegetationsstudien in den Danubeauen zwischen Regensburg und Straubing als Grundlage fuer den Naturschutz. Hoppea. Denkschriften der Regensburgischen Botanischen Gesellschaft 38: 1-393.

Zaidelman, F.R. 1998. Gleyzation process and its role in soil formation. Moscow University Press. 300 p.

(*Received May 27, 2004; Accepted July 25, 2004*)