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Landscape typology in the assessment of quality and level of pollution of the natural environment on the basis of example mouth sections of selected river valleys

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Abstract. Analysis of quality of the environment in the studied river valleys has shown that proper choice of study fields is of key importance for proper assessment of human impact (level of pollution) upon transformation of lowland ecosystems. Research has shown that the dynamics of toxic substances circulation within the evaluated units depended on water circulation (direction of precipitation, river, alluvial and flood waters flow determined the range of pollutants).

Physical and chemical properties of sediments, as well as synanthropic advancement of plant communities determined actual susceptibility of the environment to stress (pollution). Human impact on today's shape of natural units' structure was significant within the studied area.

On the basis of three structurally different fragments of river valleys, extra-environmental factors responsible for actual range of pollution have been determined. Attention was also paid in the course of research to the significant impact of alluvial, flood and river waters flow on the quality of river waters and, consequentially, on the quality of alluvial depositions. The relatively low mobility of heavy metals in alluvial soils depends on the acidity of soil solution.

Key words: landscape classification, valley ecosystems, dynamics of toxic substances circulation, heavy metals migration human impact

Introduction

Landscape classification constitutes the basis for proper space valuation and formation of natural environment resources, thus being an important environmental policy and contemporary environmental research tool (Bolliger, Mladenoff 2005). Analysis of the dynamics of separated spatial units, based on time variability of individual features, attributes and elements responsible for shaping their structure is the basis for assessment of landscape quality. Geostatistical models showing both cyclical, periodical and wave variability of individual elements of its structure are of high practical importance in the analysis of environmental variability and assessment of quality (Dammer et al. 1997, Radeloff et al. 2000). Spatial data being the basis for their structure should specify the character and range of any transformations, many of which are generated through increasing human pressure and reduced natural environment resistance to exogenous factors, such as pollution. Therefore, it has been assumed for purposes of this paper that assessment of landscape quality '... refers to present natural systems in a specific stage of development and transformed by human activity to a specific extent (landscapes that are completely exploited or exploited to a certain extent)'- Richling (1994), i.e. it shows the condition of the environment at the given time or time interval. Because contemporary natural systems are of mosaic or plane type and their variability determines both the character of processes that determine substance flow and the pace of ecosystems development (Bennett, Carpenter, Clayton 2004), it must be assumed that complexity of the environment depends not on one, but on a number of coincident processes and phenomena (Burrough 1983). The analysis of their progress, intensity and consequences should be based on monitoring selected bioindicators or geoindicators (Makholm, Mladenoff 2005).

For purposes of this paper, to show the dependency between the quality of the environment and the level of development of its spatial structure, we focused on the analysis of the natural environment of selected river valleys. Considering their location (component structure of river basin), type of riverbed (sedimentation conditions), regime (volume and type of sediment), or erosive base (sediment properties), river valleys constitute specific, highly dynamic and variable in time natural systems. Spatial units present within them, depending on land slope and river or flood water flow rate, represent varied environmental structures. Their complexity is a long historical record of processes and phenomena forming the basis of environment evolution and increasing human interference with natural spatial systems.

As a result of increasing anthropopressure (engineering of many riverbeds, intensive land cultivation, deforestation, etc.), circulation of mineral and organic matter in many river basins was artificially disturbed. A consequence of this process was a rapid growth of erosion and denudation processes of surface soil levels on uplands and in the mountains. A consequence of this was an increase of low-fraction sediment depositions within flood plains. This is confirmed by high thickness of alluvia covering the youngest flood plains of most rivers that drain the Sudeten. Their today's deposition is more and more frequently accompanied by strongly contaminated sediments (e.g. with heavy metals). However, a true danger for valley ecosystems is the high concentration of pollutants in river waters that improve the surface soil levels during freshets. During the recent 200 years, accumulation of alluvial sediments in most river valleys of southwest Poland was dramatically disturbed. Through artificial riverbeds engineering and construction of storage reservoirs on major Sudetian rivers, both the character and quality of transported sediments was altered. Restricting the flooding zone of flood waters because of increasing development of river valleys resulted in growth of the following processes: depth-erosion, in case of mountain rivers (e.g. when Bystrzyca Kłodzka flew over the Storage Reservoir during the 1997 flood, its riverbed lowered by ca. 1.5 m); lateral erosion of rivers with engineered riverbeds (e.g. Biała Lądecka on the section from sources to Bielice, where rapid flood water flow in 1997 nearly completely destroyed the concrete bands along the riverbed), and altered conditions of sedimentation in case of lowland rivers flood plains (Horska-Schwarz 2007).

According to the above, both the increasing accumulation of harmful substances in alluvial sediments and immediate human activity (riverbeds engineering, reclamation) contributed to the decrease of biological variety of lowland ecosystems. Despite that it is becoming more and more common to emphasize improvement of river waters quality (this is to be confirmed by lowering concentration of pollutants in flood area waters and soils), one must remember that during consecutive floods, contaminants from already polluted soil levels (which were supplied with harmful substances for many years) are again included in water transport and re-deposited (Horska-Schwarz 2006a). In the case of sour alluvial and hydrogenous soils, this is a serious threat for the quality of underground water. As a result, the area of farmlands on flood plains can be reduced in places where soils exhibited toxic contents exceeding the standards, including heavy metals (Horska-Schwarz 2006b).

For purposes of this paper, to assess variability and type of factors determining water environments' susceptibility to external conditions, three research areas have been distinguished. 37 metering posts were located in estuary sections of tributaries of the Odra river: Kaczawa (11), Widawa (12) and Nysa Kłodzka (14).

Characteristics of transport of harmful substances, including heavy metals, primarily depend on the volume of pollutants supply from anthropogenic sources in the case of the studied rivers. The extent of deposition is determined by the presence of water engineering, housing and similar infrastructures in the valley. Spatial units formed within them reflect the scale of processes occurring in individual partial basins. In addition, considering the change of direction and flow rates of river waters, estuary sections of rivers are the main zones of matter (pollutants) deposition, relatively easily included in recirculated river transport during floods. Analysis of quality of the studied sites was supposed to indicate the primarily change tendencies recorded within individual spatial units.

Materials and methods

Considering the increasing volume of pollutants supplied to the natural environment of river valleys (waters, soils, plants) from anthropogenic sources, including river waters, it is not sufficient to only determine their concentrations in soils, surface waters or plants. The main task seems to be the assessment of mechanisms responsible for their mobility and the impact of these substances upon individual components of the environment (determination of quantities of toxic substances present in active circulation of matter in the perspective of the geocomplex type).

The objective of research was to determine the impact of natural landscape components (unit type, character of site) upon the scale and rate of anthropogenic transformations responsible for quality of spatial units situated in the flood zone. In the author's opinion, the specific problem with environmental quality assessment is the choice of elementary fields of reference to be the basis for further classification and assessment of landscape. It has been assumed for purposes of this paper that field size shall depend on variability of diagnostic data (number of environmental features). It has been assumed that the physical and chemical qualities of spatial units vary according to component structure (erosion base of river and conditions of sedimentation). In accordance with the foregoing, the author concludes that the following factors primarily determine the quality of the environment and scale of pollution within the research fields: relief, sediment type, soil type, soil acidity and water conditions (Terelak et al. 2000). Then, assuming the geostatistical methods mentioned at the beginning as the basis of research, it has been concluded that the geocomplex model will be the best tool for complete analysis of natural environment quality (Horska-Schwarz, 2006c). The fields/spatial units distinguished via this method are structurally uniform, thus being a good basis for specialized environmental studies. During the consecutive stage, within individual fields / spatial units, a number of metering points were established: in the Kaczawa valley (from 1 to 10), in the Nysa Kłodzka valley (from 20 to 35) and in the Widawa valley (from 36 to 47). Selected environmental features were studied at these points. The basis for assessment of environmental quality was the analysis of river waters quality and soils quality factors. For this purpose, soil was sampled (at the depth of 0 to 15 cm) within the established metering points for laboratory tests. An experiment supplemented the laboratory tests, aimed at showing the relationship between concentration of pollutants in the tested soil and actual range (time and volume) of their permeation to the soil solution (for soils with given sediment acidity). In other words, toxic substances active in the circulation of elements were determined. Thus, information was obtained about actual impact of harmful substances on the condition of plant communities or water quality.

A number of methods were used in laboratory works, including: heavy metal contents (Cu, Pb, Cd, Zn and Ni) in surface soil layer were determined with the atomic absorption method within individual metering points (in <0.1 mm fraction, ppm). Then, sediment grain size was analyzed and acidity of soil solution (in water) was determined. The last phase of research covered the analysis of heavy metal contents in soil solution (obtained out of 10 g of dry soil and 50 ml of distilled water). As the studied sediment contained high proportions of <001 mm fractions (dust, dusty sand), 2.5 g of potassium chloride was added to neutralize the charges of silty particles and decantation of mineral substance (Raczyk - oral consultation). Measurements were taken after 24 hours (with atomic absorption spectrometer), as it was assumed that water composition (quality) altered by infiltration through argillaceous soils, i.e. water became enriched with individual elements during the first 24 hours, i.e. until reaching the so-called saturation balance (Raczyk 2005).

Record of human activity in the structure of natural environment of estuary sections **of Kaczawa, Widawa and Nysa Kłodzka**

The first research area was located in the Kaczawa valley, on the Kwiatkowice-Odra section (fig.1). This area belongs to the Silesian Lowland macroregion and the Odra Valley microregion. Moraine plains extend on both sides of the valley, interspersed with a number of smaller tributaries of the Kaczawa river. Today's shape of the natural environment results from accumulation activity of continental glacier and snowmelts. In consequence, a well-developed system of Pleistocene and Holocene inserted terraces can be found in the Kaczawa valley, made up of sands and river gravels. The highest terraces gradually transform into a Pleistocene high plain, and contemporary farming and industrial fen soil covers occur within the youngest flood plains. The Kaczawa valley, primarily dominated by oak and hornbeam forest sites, willow and poplar forest sites, and local swampy sites, also determines a prominent border between two fauna districts, which separates the Lower Silesian Coniferous Forests from the Silesian Lowlands (Szafer 1959). A major threat for proper functioning of the natural environment within the studied area is considered the copper industry, developing dynamically in the region of Legnica (the Legnica-Głogów Copper District) together with poor condition of municipal and welfare services.

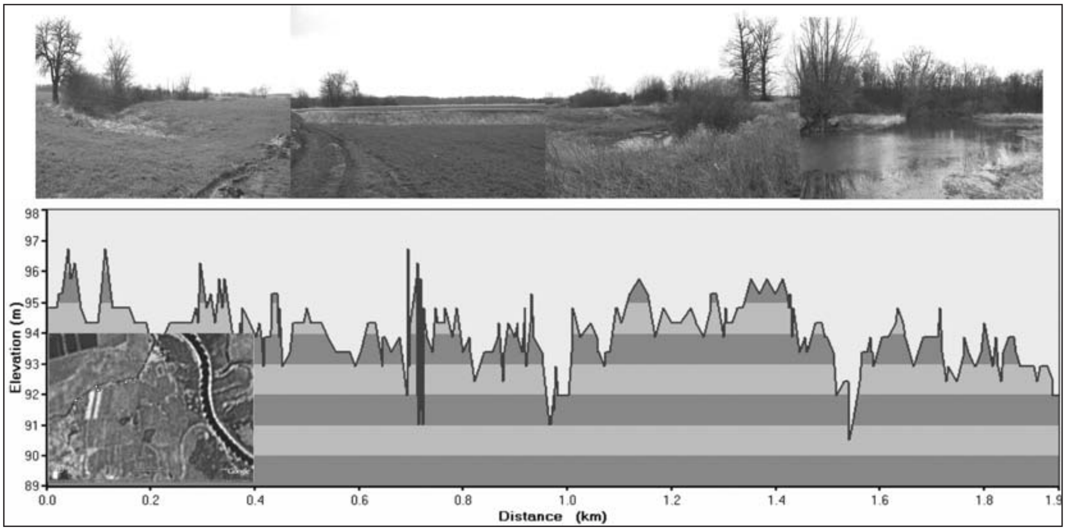

Fig. 1. Kaczawa Valley between Kwiatkowice and Odra

Analysis of river waters quality indicators (the Kwiatkowice point for 2006 - IMGW) has shown that the quality deteriorates with distance from the river sources and increasing number of contamination emitters. Physical parameters (TSS, reaction), oxygen parameters (BOD5, ChOD-Mn, ChOD-Cr) with salinity (sulfides, chlorides, fluorides) and industrial waste (pesticides) classify the waters of Kaczawa to purity classes I and II. According to the values of biogenic factors (i.e. nitrates, phosphates), these were classified as class II. The component that disqualifies the Kaczawa river waters from consumption is the value of microbiological components (volumes of fecal g. coli bacteria) and biological factors (saprobic index of phytoplankton), which significantly exceed the acceptable concentration values assumed for drinking waters. The volume of fecal bacteria of g. coli type is very high and is growing rapidly, particularly during snowmelt floods or streaming precipitation. As an example, one may quote the turn of March and April 2006, when the quantity of g. coli bacteria of fecal type rose as a result of flood from 46 000 (balance recorded in mid-March) to 240 000 (balance in mid-April). The probable cause of such situation was the rapid flow and long maintained high level of alluvial waters, resulting in consequence in draining all impurities from farms situated within the bottom of the valley. It must be added here that the development of flood plains zone, particularly including household waste storage locations, is a real threat for the purity and quality of waters. A positive factor pointed out by in his papers is the decrease of heavy metals percentage in river waters, being a regular tendency during the recent years, together with improvement of quality of the waters (Ciszewski 2001). This is due to legal restrictions and more severe regulations on waste emissions. The Kaczawa case is similar – heavy metals concentration in the river waters is within the acceptable standards. Analyses of the quality of waters and research of surface soil levels have confirmed this decreasing tendency. According to the example of 2006, one can notice relatively low concentration of heavy metals in river waters, the latter being thus classified as class I in terms of purity. However, these values increase in early spring and autumn freshets, which can be explained in the case in question by increasing erosion processes of previously contaminated soil levels and re-inclusion of contaminants in water transport through flood waters or snowmelt. Therefore, this paper puts a special emphasis on variations of individual substances' concentrations at times of high river water flows. Considering that the studied areas were flooded and permeated at the turn of March and April 2006 and the risk of contaminants re-inclusion in river waters increased, detailed analyses of river waters quality mainly refer to the period of early spring flood of 2006. Highest variability of concentration in river waters during 2006 was exhibited by copper (fig. 2). Laboratory tests of soil samples have confirmed that this substance (in soils of 5.02 to 6.82 acidity – in water) was most easily returned from soil to the soil solution. It migrated faster to the depth of soil profile, thus confirming higher migration capacity and faster washing out of soil.

The coefficient of correlation between the content of the given element (in $mgkg^{-1}$) in soil and the content of the same element in the soil solution (after 24 hours) at all metering points (for the heavy metals tested: Pb, Cd, Ni, Cu and Zn) was relatively high, and the highest values were obtained for copper: 0.93 (lowest - 0.36 were recorded for lead – tab. 1). It must be also pointed out that in the case of the assessed area, soil quality and rate of toxic substances migration to the soil solution was primarily determined by the development of individual hydrogenous units (fig. 3). When advancing towards the Odra River, these units represented erosion structures that were relatively well established in the morphology of flood plains, mostly in the final phase of development (Horska-Schwarz 2006d). With lowering the erosion base of the river, their character changed gradually. The changing qualities included soil subtype, water conditions, site acidity and type of plant communities (from marshy soils and movable grassland, to swampy soils and rushes communities) - (fig.1). In the case in question, the varying water typology of soils, their acidity and character of plant communities determined the change of harmful substances concentration in the soil, thus directly determining the values of their concentrations permeating to the soil solution.

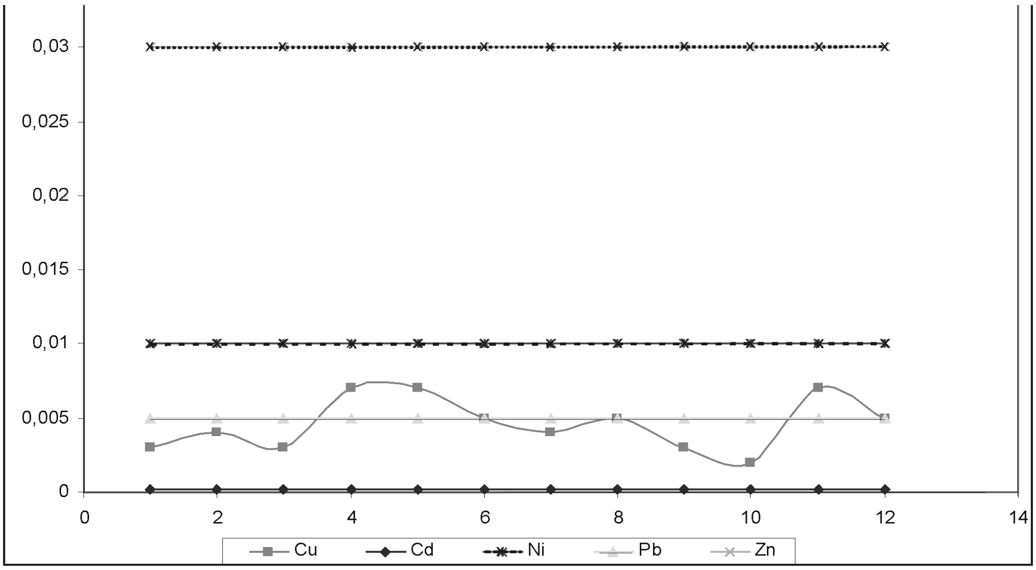

Fig. 2. Variability of the heavy metals concentration in the Kaczawa River, 2006.

Concentration of heavy metals within the studied points varied greatly, ranging from 100 to 362 ppm kg^{-1} for Zn, from 20 to over 522 ppm for Cu, from 23 to 225 ppm for Pb, and from 9 to 43 ppm for Ni. Highest values were recorded in the river bed outwash zone (industrial fen soil) and old river bed channels (filled with peat and peat earth soil). Therefore, according to the Environmental Protection Institute and the Environmental Monitoring Agency, most of the studied communities where soils were found strongly polluted should be excluded from agricultural production, with simultaneous restrictions on being used as grassland (tab. 2).

For the second research area, i.e. the estuary section of the Widawa valley where 12 metering points were installed, local research showed high variability of spatial units (fig. 4). At the Świniary-Odra section, the Widawa

Table 1. The coefficient of correlation between the content of the given element (in mg kg^{-1}) in soil and the content of the same element in the soil solution (after 24 hours)

X	correlation between the X (in mgkg^{-1}) in soil and the acidity	correlation between the X (in mgkg^{-1}) in the soil solution and the acidity	correlation between the X (in mgkg^{-1}) in soil and the content of the same element in the soil solution (after 24 hours)
Cu	-0,3667	-0,3037	0,93689
Zn	-0,4507	-0,7542	0,64215
Cd	-0,6198	-0,6759	0,79131
Pb	-0,1775	-0,838	0,36016

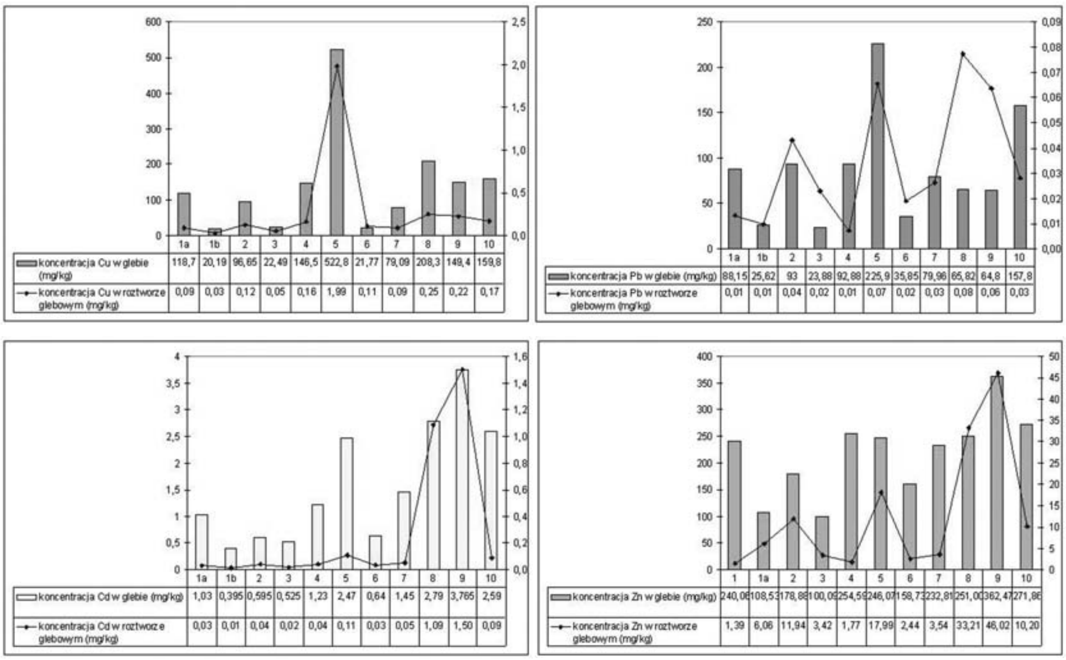

Fig. 3. Concentration of heavy metals in the soil and the rate of toxic substances migration to the soil solution (after 24 hours)

valley changes its character, thus determining establishment of different sites, depending on sediment lithology, area morphology and water conditions in soils (fig. 5). This is particularly evident in the flood plain zone, where the area is delimited in many places by flood banks. Here, both waterlogged alder-dominated Alno-Ulmion forests can be found and Alno-Ulmion forests turning into Carpinion betuli alliances within higher terrace levels made of medium and heavy fen soils. In case of those fragments of terraces that are cut off from flood, typical Carpinion betuli forests can be found, with poorly developed undergrowth.

Within the active valley, typical zones of matter (outwash) accumulation can be found, as well as erosion zones of high undercuts, locally reaching 2 m height, e.g. rivers formed at times of extreme flows. The system of old meanders that are well recorded in the morphology of the higher flood plain shows on one hand the change of sedimentation conditions throughout ages of history and on the other hand the intense in-depth erosion processes of active river bed (the meander system situated high above the contemporary active bed). Human impact on today's shape of natural units' structure was significant within the studied area. First of all, proximity of irrigation fields is a serious burden for proper functioning of hydrogenous ecosystems. Partially treated municipal sewage from Wroclaw and its surroundings are being distributed within them. That sewage is the main reason for enriching the tested alluvial soils with heavy metals (tab. 2). Concentration of these components indicates high percentage of mainly zinc and cadmium, particularly within poorly permeable heavy fen soils. According to limit values assumed according to the Environmental Protection Institute and the Environmental Monitoring Agency, concentrations of heavy metals in surface soil levels classify the soils in class I and II in terms of purity (within the scale from I to V). Obviously, concentrations of individual elements are determined by physical and chemical qualities of the soils themselves and vary with distance from active river bed and variability of spatial units' component structure. The relatively low mobility of heavy metals in alluvial soils depends on the acidity of soil solution. At the majority of tested metering points, reactions were recorded from weak acid to neutral. Detailed analysis of quality coefficients of the Widawa river waters (for 2006) enabled specification of toxic substances affecting degradation of hydrogenous ecosystems. Their concentrations are related to high flood and alluvial waters flow. Like in the case of Kaczawa, the quality of Widawa waters at the turn of March and April 2006, during the snowmelt flood, deteriorated significantly. Variability of oxygen parameters exhibited highest dynamics. The BOD5 ratio was primarily responsible for the significant deterioration of oxygen conditions. The concentration of this component equaled 2.86 in March (purity class I) and after the flood wave, it rose to 4.4 mg O_2 l^{-1} (purity class II). Another factor contributing to deterioration of river water quality was the ChOD-Mn. Its initial concentration ranges around 5.4 (balance of March 2006) rose to 9.6 mg O_2 l^{-1} (April 2006). In case of biological factors, variability of a-chlorophyl concentration in water rivers was focused on. As a result of an increase of its concentration from about 5 (as of March 2006) to 31.2 $\mu g l^{-1}$ (April), quality of the river waters deteriorated significantly and their classification changed from class I to class III in terms of purity. According to the remaining factors, i.e. biogenic factors and salinity, the Widawa waters were classified as purity class II and III, accordingly. The analyses show that extreme processes, i.e. floods, only slightly affect concentration of heavy metals in river waters in the studied area where alluvial soils do not exhibit excessive heavy metal contents. This is due to the small number of emitters supplying contaminants directly to the river, and relatively low concentration of pollutants in the flood area soils. However, it must be emphasized that the heavy metals concentration values in the soils can have a very negative impact on proper life processes of plants and animals, particularly within waterlogged old river beds filled with acid swampy soil.

Fig. 4. The alluvial soil of the Widawa Valley – flood plain.

The last research area is within the Silesian Lowlands. It covers the mouthpiece of the Nysa Kłodzka valley (at the section between Skorogoszcz and Odra - fig.6). The river disgorges itself into the Odra valley through a valley that is deeply cut into the upper floodland. Four terrace levels can be distinguished in its morphology. Each surface is the background for lower order units development. In case of upper floodland terraces, these are the dunes and tributaries of Nysa Kłodzka. The youngest lower floodlands, not more than 1.5 m above river level lower and 2.0 to 5 m above river level higher, constitute the main terrace level of the valley. These are made of sandy, sand/gravel and muddy sediments of river and flood accumulation (Winnicka, 1999). As a result of erosion undercuts, nearly vertical walls have formed within the former river beds and overfall beds, up to 2.5 m in height. These reveal the river sands and gravels forming the terrace levels 5 to 6.5 meters above river level. A number of erosion forms have been distinguished within the upper flood terrace, related to rapid flow of flood waters. Overfall ducts and flow beds are well distinguished in the morphology of flood plains on the studied section. Their deviated soil profile proves frequent refreshment of these forms during floods and re-deposition of alluvial deposits. Accumulation processes of matter transported by river waters are most intense in the contact zone with the Odra valley where they contribute to the development of swampy forest and Alno-Ulmion forest sites. These are transformed from typical forest establishment dominated by willow and alder into rushes and waterlogged flood meadow communities.

Laboratory tests have shown that enrichment of the studied sites with heavy metals is relatively low (tab. 2). Most frequently, these soils are not polluted, included in class zero of purity (for Cu, Cd, Pb and Ni). The quality of studied sites changes significantly only in the aforementioned contact zone, i.e. at the point where the Nysa Kłodzka valley meets the Odra valley. Pb and Cd contents increase dramatically within the metering points located there, which depend on the quality of the Odra waters.

Analysis of data as of the turn of March and April 2006 has shown that flood waters transported a major part of total suspended solids, which is an obvious phenomenon in the conditions of intensified erosion. Supply of mineral and organic matter from the river basin was the reason of deterioration of water physical parameters (from class I to class II in terms of purity). For the discussed early spring period of 2006, the remaining coefficients also deteriorated, including oxygen parameters (class II – III), biogenous (class II-IV) and biogenic ratios (class III). Significant changes of concentration were recorded for the volume of g. coli bacteria of fecal type in river water. After the flood wave has passed, the concentration of these bacteria grew from 9300 (as of March 13) to 15 000 (as of April 10). Like in the case of Kaczawa and Widawa, quality of waters of the Nysa Kłodzka river was primarily depending on microbiological parameters. These substances are a real threat for the proper functioning of muddy meadow sites and swampy forests. Increased surface waters eutrophication, followed by plant communities fluctuation is among the main reasons of transformation of spatial units situated in the Nysa Kłodzka valley.

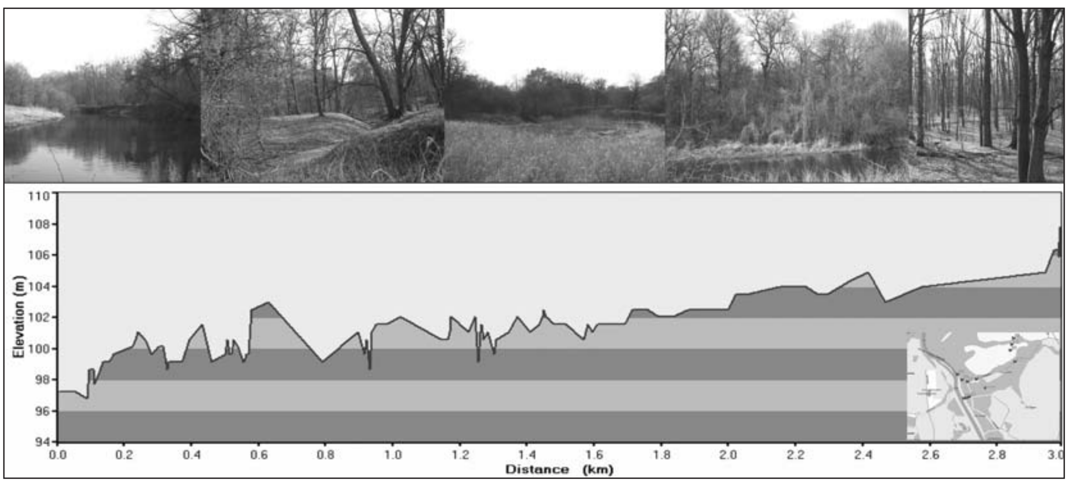

Fig. 5. Widawa Valley between Swiniary and Odra.

Table 2. Concentration of the heavy metals of the alluvial soil (ppm)

River	number of the research area	Zn	Cu	Cd	Pb	Ni
Kaczawa	1	240,06	118,68	1,03	88,15	33,60
	1a	108,53	20,19	0,40	25,62	9,40
	2	178,88	96,65	0,60	93,00	24,80
	3	100,09	22,49	0,53	23,88	9,40
	4	254,59	146,51	1,23	92,88	42,15
	5	246,07	522,82	2,47	225,95	40,35
	6	158,73	21,77	0,64	35,85	21,25
	7	232,81	79,09	1,45	79,96	27,05
	8	251,00	208,34	2,79	65,82	40,20
	9	362,47	149,40	3,77	64,80	37,15
	10	271,86	159,81	2,59	157,82	43,95
Nysa Kłodzka	20	111,08	8,61	0,31	20,78	14,40
	21	18,17	1,53	0,27	6,76	5,15
	22	51,10	8,07	0,39	20,70	20,05
	23	144,41	1,58	0,61	58,06	20,65
	24	169,39	16,78	0,98	31,12	22,65
	26	130,88	11,19	0,68	37,53	13,95
	27	99,69	8,16	0,47	28,89	10,00
	28	206,43	15,76	0,44	39,11	14,55
	29	154,65	7,53	0,86	22,79	35,35
	30	86,12	7,27	0,64	11,38	11,03
	31	265,28	28,28	1,87	74,62	31,35
	32	182,62	33,79	1,62	86,41	24,05
	34	226,42	9,16	1,05	19,54	13,50
	35	224,93	7,92	1,08	21,50	12,45
Widawa	36	98,78	9,77	0,45	25,25	14,90
	37	111,27	16,41	0,80	25,52	23,30
	38	15,29	7,18	0,37	17,04	14,9
	39	419,37	39,24	3,32	84,49	23,70
	40	178,15	10,46	1,17	29,32	17,65
	41	206,04	18,28	2,22	19,85	9,65
	42	178,25	13,65	1,06	38,78	24,75
	43	398,54	27,21	3,34	45,81	20,25
	44	251,18	36,18	1,48	51,75	20,25
	45	218,31	16,36	1,17	31,62	15,25
	46	386,76	15,88	3,56	41,07	23,05
	47	63,80	14,19	1,54	22,47	10,65
pollution standard	Pendias, Kabata-Pendias	250-300 ppm	do 100 ppm	0,2-1,05 ppm	100 ppm	100 ppm
	norm	300	150 ppm	4 ppm	100 ppm	100 ppm

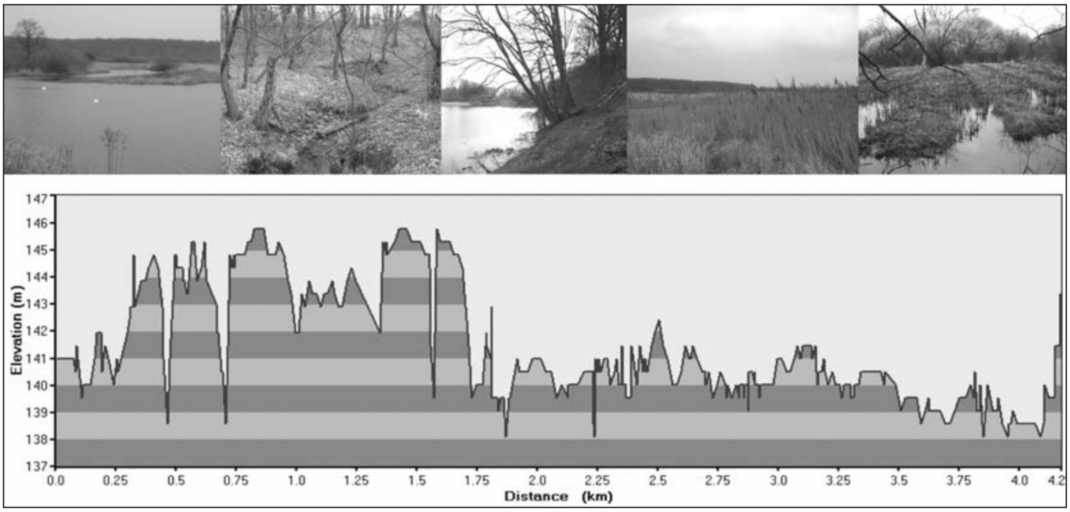

Fig. 6. Nysa Klodzka Valley between Skorogoszcz and Odra.

Summary

Analysis of quality of the environment in the studied river valleys has shown that proper choice of study fields is of key importance for proper assessment of human impact (level of pollution) upon transformation of lowland ecosystems. In case of rapidly changing natural systems, these fields should represent structurally uniform spatial units (distinguished on the basis of major components: sediment type, relief, moisture and plants to be the basis for further specialized research). Samples of deposits taken within such units perfectly reflect the conditions of mineral and organic matter circulation within the valley system. These account for variable deposit sedimentation conditions and the level of anthropogenic domination within the sites.

Research has shown that the dynamics of toxic substances circulation within the evaluated units depended on water circulation (direction of precipitation, river, alluvial and flood waters flow determined the range of pollutants). Physical and chemical properties of sediments, as well as synanthropic advancement of plant communities determined actual susceptibility of the environment to stress (pollution). The experiment covering units strongly contaminated with heavy metals, situated in the Kaczawa valley, was the basis for determining the rate of heavy metals migration from soils to waters. The tests rendered the information about purity class of studied sites and permeability of pollutants to the soil solution. Copper turned out to exhibit highest variability of concentrations in river waters among all the studied heavy metals (according to data of the Institute of Meteorology and Water Management for 2006). Experiments have proved that this substance (in soils of 5.02 to 6.82 acidity) was most easily returned from soil to the soil solution. Increased migration and washing out rates of copper were observed at times of freshets and streaming precipitation (April/May and November), where the flood plain areas were more easily eroded without the plant cover. The coefficient of correlation between the contents of heavy metals tested (in mg/kg) as contained in soil and in the soil solution (after 24 hours) at all metering points was highest for Cu (0.93) and lowest for Pb (0.36).

On the basis of three structurally different fragments of river valleys, extra-environmental factors responsible for actual range of pollution have been determined. Attention was also paid in the course of research to the significant impact of alluvial, flood and river waters flow on the quality of river waters and, consequentially, on the quality of alluvial depositions. It has been proved that regardless of the type of spatial units, the major threat for proper development of valley ecosystems is municipal sewage and chemical fertilizers. Deterioration of quality coefficients of river waters was related to increased volumes of pollutants supplied from local emitters. In the case of the areas in question, these facilities mainly included septic tanks situated in permeable alluvial sediments of flood terraces). It is possible that the rapid deterioration of microbiological quality of river waters (growth of coli bacteria) was caused by impurities being washed out from poorly sealed containers. Obviously, a

lot of impurities were transmitted to river waters through washing out from fields and melioration ditches. Summing up, it must be pointed out that there is a strong relationship between the quality of river waters and the quality of soils and vice versa within the studied fragments of river valleys. The range of pollution depends on: extreme processes (floods, intense precipitation), the volume of which is determined by the development level of flood plains.

Table 3. Norm of soil pollution (ppm)

metal	Norm of the soil pollution (IOŚ and BMŚ)					
	0	I	II	III	IV	V
Pb	70	200	500	2000	7000	>7000
Zn	100	300	1000	3000	8000	>8000
Cu	40	70	100	150	750	>750
Ni	50	75	100	300	1000	>1000
Cd	1	3	5	10	20	>20
	unpolluted	very low pollution	low pollution	medium pollution	high pollution	very high pollution

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