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Changes of the basic physico-chemical characteristics of small rivers influenced by anthropogenic elements in the area of Łódź, Poland

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Abstract Two small rivers draining the western part of the Łódź Hills (central Poland) were studied. The rivers differ in both land use and bed characteristics (one urban and one suburban). The analyses were based on six-year-long time series. The spatial and temporal variability of basic physical and chemical parameters of surface water, such as temperature, pH, SEC and dissolved oxygen, were investigated. The level of urbanization defines the rate and direction of pollutant migration in the environment; it also influences the environment's ability to reduce the contamination. Understanding the seasonal variability of the basic physico-chemical water properties enables the prediction of transformations in the basin and the design sanitary sewer management adequate for the areas of different urbanization levels.

Key words water quality; anthropopressure; urban hydrology; Poland

INTRODUCTION

Surface water is the environmental element that is most endangered by human impacts. Relatively fast migration of ions in the epigeosphere results in rapid interaction between its anthropogenic components and river and reservoir waters. Precipitation is an enduring connection, and its quantitative and qualitative transformations directly depend on spatial developments. Hence, investigating alterations in a basin area is vital to identification of the local hydrological cycle mechanisms.

The strength of the human impact indirectly depends on the population inhabiting a particular area. Tight clusters of people, such as cities or estates, influence the areal hydrographic conditions more than the zones of dispersed village settlement. Different features characterize urban basins and those situated within agricultural areas. Among the factors influencing qualitative and quantitative water characteristics, changes of land use and the related soil permeability, groundwater level and groundwater table architecture, the moisture content of valley zones plus the magnitude and the migration directions of contaminants developing in the area, are very important.

In the last case, the most important factor is the susceptibility of the surface geology to pollutant dispersion and wastewater/sewage disposal, and is characteristic for the particular part of the basin. The major parts are also the riverbed features and the way a river valley has developed. These can influence river water quality. Hard-paved road drainage systems are also of great importance because they are linked to the natural drainage system and discharge contaminant loads directly to the surface water (Marszalek *et al*., 2008).

Areas with a high degree of urbanization affect the conditions of the water cycle in the catchments. Urbanization, in the contemporary meaning of this word, is a specific sign of the transformations that have taken place since the beginning of the 19th century and are related to industrialisation (Liszewski & Maik, 2000). The main feature of the urban areas is replacement of green areas (forests and meadows) with housing, industrial and transport development, which contributes to increased impervious surface, so significantly limiting absorption of rainwater and accelerating surface discharge. Due to the lowering of the groundwater level caused by sealing of the surface, rivers usually lose their hydrological connection with waters in their valley. Therefore, to ensure that they will function as rainwater collectors, their beds are sealed, which changes their morphology and significantly affects the speed of flow.

The rivers in Łódź, similar to those in many other Polish cities (Kowalczak & Kundzewicz, 2011), have been significantly modified and affected by pressures on the environment in the river valleys; modified streams collect the water coming from the storm-water sewerage system. Most of the Łódź rivers represent such water courses, and this includes the Sokołówka. On the one hand, the rainwater has to drain quickly (a straight concrete bed is best), while, on the other hand, habitat diversity means the diversification of flow, the accumulation of deposits on the bed and the formation of fluvial deposits, bars, islands, etc.

Urbanization also contributes to changes in water circulation. Streets, parking places and rooftops may represent up to 98% of the catchment area. Consequently, during intensive precipitation or snow melting, a great majority of water very quickly and directly goes into rivers through the sewage system, which results in a shorter time of run-off concentration and increased peak flows. The following dependence is clearly noticeable: the more in-built areas there are in a city and the denser they are, the higher and the more frequent the flood waves are. The runoff from the city is very muddy and carries a huge load of various types of contamination.

The hydrochemical consequences of urbanization constitute a separate category. They include an increased mobility of heavy metals, a significant share of chlorides, eutrophic processes caused by compounds of nitrogen and phosphorus, increased deficiency of dissolved oxygen accompanied by biomass accumulation, increased concentration of ammonia, chlorine, cyanides, sulphides, phenols and surfactants that impact the general toxicity of sewage drained to urban rivers. The main pollutants in urban areas are: road transport (fuel, fluids, exhaust gas, oil, de-icing agents, rubber residues) and uncontrolled wastewater discharge (blackwater and greywater). The average long-term characteristics of the basic physico-chemical water properties of the rivers of the Lodz area were shown in Table 1.

METHODS AND STUDY AREA

The water quality assessment was conducted in central Poland in the area of two river basins discharging from the west part of the Lodz Hills (Figs 1 and 2). Their relief is a result of the accumulation of alluvium deposits from the Warta glaciations, and was ultimately formed due to riverine activity in the Holocene. The elevation is 130–230 m a.s.l., and mean annual precipitation is 600–650 mm. The total specific runoff amounts to approx. 5.3 $dm^3 s^{-1} km^{-2}$. The average long-term flow of the Sokolowka River is 0.075 $m^3 s^{-1}$, while for the Dzierzazna River it is 0.23 $m^3 s^{-1}$. The basins, located in the northern part of the Łódź agglomeration are distinguished by their different land use and river bed characteristics. The Sokolowka River and its right tributary the Brzoza River, both belong to the Bzura basin, and drain the northern part of Łódź. The basin area above the gauge in Sokolow is 19.2 km^2. Among the deposits forming the basin, shallow tills and fluvioglacial sands dominate. The Sokolowka River valley is characterized by steep side slopes (denivelation of the basin is about 85 m), while the average riverbed slope is 70‰.

The Sokolowka river basin is a typical urbanized basin, almost entirely placed within the administrative boundaries of the city. The forest and parkland area is relatively small, only 19% of

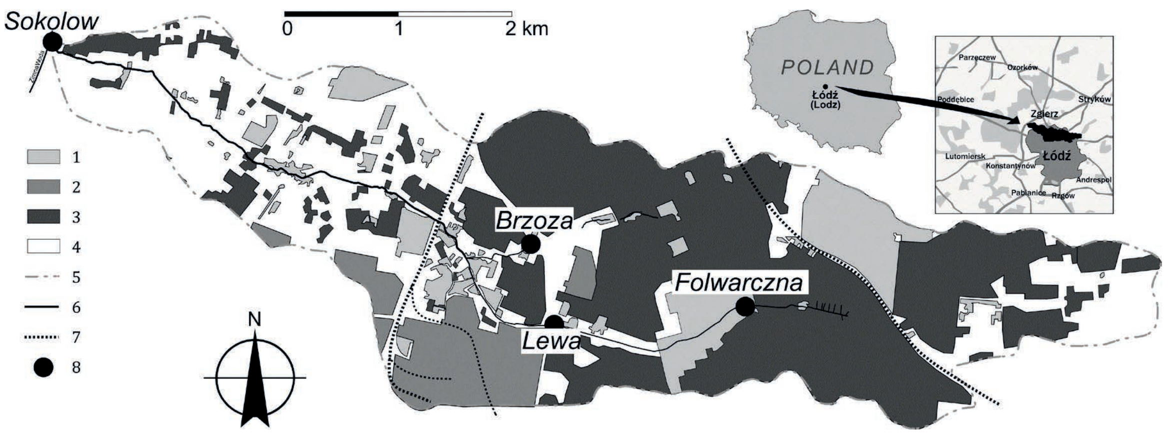

Fig. 1 Location, land use and cross-sections of the Sokolowka basin. 1: forests and parks; 2: industrial areas; 3: built-up area; 4: barrens, meadows and arable lands; 5: watershed; 6: rivers; 7: railway; 8: measurement points.

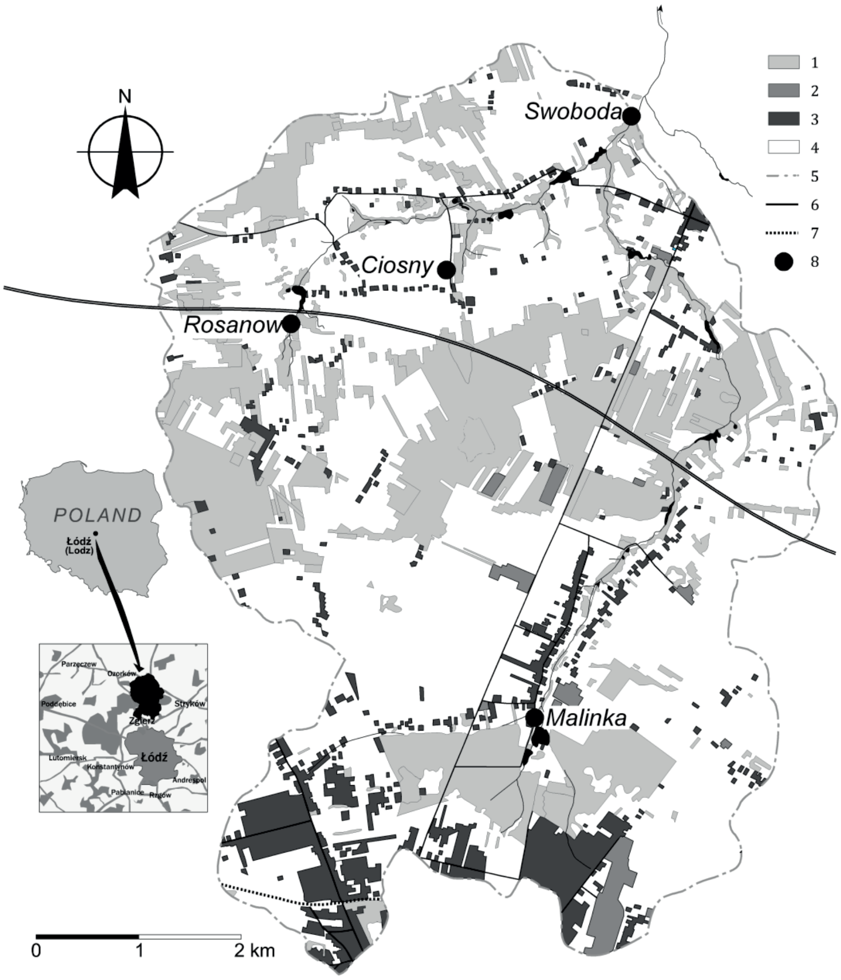

Fig. 2 Location, land use and cross-sections of the Dzierzazna basin. 1: forests and parks; 2: industrial areas; 3: built-up area; 4: barrens, meadows and arable lands; 5: watershed; 6: rivers; 7: railway; 8: measurement points.

the total (Fig. 1). The greatest portion is built-up (47 %) and almost entirely within the range of the sanitation system (Bartnik & Moniewski, 2011). High density housing combines with a high proportion of impermeable surfaces – streets, pavements, rooftops, hard-paved squares and car parks. Rainfall precipitation and melt water are discharged directly to the riverbed with numerous trunk sewers outlets. This influences not only the dynamics of river flow in the artificial, concrete-strengthened riverbed, but also the high variability of physico-chemical water properties of the Sokolowka River (Bartnik & Moniewski, 2012a).

A few kilometres to the north is the Dzierzazna, a small stream flowing off the northern Łódź Hills to the Warsaw-Berlin ice marginal valley. Its basin is characterized by significant denivelation, reaching 85 m, which is rare for central Poland. The Dzierzazna basin is 42.9 km^2, and slopes down a few degrees towards the north. Tills dominate the geology of the south and southeastern part of the basin. The central part is covered by several thick sands and fluvioglacial gravels with sandur characteristics. In its northern part, the basin is definitely flatter, and lacustrine loams dominate the surface formations. The drainage system consists of the main watercourse of 9.2 km length and its left tributary, the Ciosenka, which flows from the highly-efficient seepage spring area (>40 $dm^3 s^{-1}$) in Rosanow, which is fed with water from sandur formations. The second, smaller spring (almost 20 $dm^3 s^{-1}$) is located in Ciosny village and also feeds the Ciosenka River (Bartnik & Moniewski, 2012b).

The Dzierzazna is a representative basin of the suburban areas, where the agricultural land use is slowly superceded by residential housing and communication infrastructure. The most densely built-up area is the southern part of the basin, located above the river's source sections and reaching the suburbs of Zgierz city (Rudunki and Proboszczewice districts). Its boundaries delineate the northern range of the Łódź agglomeration (Fig. 2). The second densely built-up area is Rosanow. In the last decades this town has become an attractive summer resort for Łódź inhabitants due to its location in the forests dominating the sandy-gravel deposits of the Grotnicki–Lucmierski sandur. A significant part of the building is of year-long nature, and the allotment management does not differ from the city conditions. Rosanów, as well as the rest of the villages within the basin boundaries, has its own water supply networks, although they are not supplied with storm and sanitary sewer systems, unlike urban areas.

The road network in the basin is mainly local. The voivodeship road number 702 (Zgierz–Kutno) and A2 highway (one of the largest road investments in Poland) are of more importance. The 7-km Emilia–Strykow section crossing the Dzierzazna basin east–west was opened in July 2006. The highway drainage system is made up of ditches sealed with insulating foil, which conveys stormwater into oil separators. Then the water is directly discharged to the Dzierzazna River or into shallow infiltration ponds located in the proximity of the Ciosenka River.

There are several flow-through reservoirs along both river courses. In the Sokolowka basin they have mainly landscape (in urban parks) and ecological functions, and their presence triggers deposition and reduction of river transported contaminants. The reservoir cascades also have an anti-flooding role, moderating high water levels from the urban basin. Many breeding ponds are located alongside the Dzierzazna and the Ciosenka rivers.

To identify the spatial diversification and seasonal changeability of the basic physico-chemical surface water properties, a network of a few dozen points, where field measurements were taken, was built up in the area of both basins (Figs 1 and 2). The water conductivity, pH, temperature, concentration of dissolved oxygen (eletrochemical methods) and turbidity (nephelometry) were measured every two weeks. The data used here were measured between 2007 and 2012. Since 2011, water samples were also taken at four control points in each basin for laboratory analysis of selected water quality indicators (e.g. chloride anion and nitrate nitrogen concentrations).

RESULTS

Analysing the spatial differentiation of the surface water conductivity in both basins, demonstrates that this parameter is strongly dependent on the urbanization level of their areas. The average conductivity of the Sokolowka water is twice or even thrice that of the conductivity of the Dzierzazna water (Table 1). The greatest values were registered in the upper, the most changed part of the Sokolowka basin (Folwarczna, 1409 $\mu S\ cm^{-1}$) and its tributary, the Brzoza (1074 $\mu S\ cm^{-1}$). Along the river course, the conductivity decreases (Sokolow, 765 $\mu S\ cm^{-1}$). Similar relationships can be observed in the Dzierzazna River basin, where the higher average conductivity values, >400 $\mu S\ cm^{-1}$, were recorded at the measuring points at the highest altitudes (Malinka, Rosanow). Conductivity gradually decreases to the outlet of the basin (Swoboda). In both cases it is clear that the reduction is the effect of the biological processes occurring in the shallow, flow-through reservoirs. During the growing season, water plants take up some of the chemical compounds, mainly nutrients. This process can also be seen in the reduction of nitrate nitrogen and the turbidity (NTU) between the upper parts of both basins and the closing cross-sections. The lowest average conductivity was recorded in the seepage spring area in Ciosny, where the basin is partly wooded, and elsewhere where there are very few farms. Both seepage spring areas are also characterized by the lowest average temperature, the lowest and constant (because of the stable discharge) water turbidity, and the lowest oxygen concentration (due to the underground water discharge).

The average, long-term water pH for all eight control points is almost neutral. In the Dzierzazna basin it is slightly more alkaline due to the intensive fish farming conducted in the water ponds, and the recreational character of the Malinka Reservoir (resort). Smaller inputs of the acidic rainfall water and ice-melt water directly discharged to the river are also important. The direct inflow and significantly higher discharge dynamics during high water periods result in better water oxygenation in the Sokolowka basin. Its temperature is modified mainly because of the

Table 1 The average long-term characteristics of the basic physico-chemical water properties in the Sokolowka and Dzierzazna rivers at the selected measuring points, 2006–2012, relative to other rivers in the Lodz area (2001–2011). SEC: water conductivity, pH: acidity or alkalinity, T: temperature, DO: concentration of dissolved oxygen, NTU: turbidity (in nephelometric turbidity units), Cl^-: concentration of chloride anion, N-NO_3-: concentration of nitrate nitrogen.

Rivers	Cross-section	SEC (µS cm^{-1})	pH	T (°C)	DO (mg dm^{-3})	NTU	$Cl^{-(2)}$ (mg dm^{-3})	N-$NO_3^{-(2)}$ (mg dm^{-3})
Sokolowka	Folwarczna	1409	7.03	10.9	8.20	59.1	66	3.13
	Lewa	889	6.98	11.5	8.91	13.3	63	0.63
	Brzoza	1074	6.93	10.5	7.53	15.4	83	1.49
	Sokolow	765	7.07	9.8	8.70	7.1	63	1.27
Dzierzazna	Malinka(1)	467	7.73	11.3	7.81	13.3(3)	21(3)	2.31(3)
	Rosanow	418	7.39	9.8	6.94	1.8	16	1.51
	Ciosny	363	7.19	9.9	7.44	2.5	-	-
	Swoboda	394	7.39	10.5	7.79	5.2	15	0.87
Bzura	Aniolow(4)	1077	7.34	11.3	8.05	-	123	6.26
Jasien	Odrzanska(5)	881	7.47	10.7	8.96	-	107	1.43
Ner	Smulsko(6)	631	7.62	10.1	9.45	-	49	2.29
Lodka	Krancowa(7)	1093	7.51	9.9	8.24	-	108	3.16

(1) data from 2004–2005; (2) data from 2011–2012; (3) data for the Dabrowka cross-section; (4) data from 2001–2009; (5) data from 2001–2011; (6) data from 2004–2009; (7) data from 2001–2006.

flow-through reservoirs thermodynamics, and the greater heating of the urban basin surface, especially in summer. There is no stabilizing impact of groundwater, because of its small contact with water flowing through the concrete bed and the lowered water table of the valley bottom.

All measured parameters are characterized by seasonal variability, which is particularly visible in temperature. It is worth pointing out that among the observed objects, only seepage spring areas show a small annual amplitude and this is only modified by the natural factors.

The highest temperature in Ciosny seepage spring area, being a spring niche discharge measurement, is usually recorded in August (12.1°C), while the lowest in February (5.6°C). The water in Rosanow spring is heated much as at Ciosny (11.9°C), although the maximum is reached as early as April, because the angle at which the sunlight strikes the surface of the seepage spring area is big, while the tree foliage is small. The lowest temperatures were recorded in December (6.6°C).

In the case of the remaining cross-sections, the water temperature is mainly changed by artificial water ponds through which the watercourses flow. It depends on the water's exposure to direct sunlight radiation, which is influenced by the water pond magnitude, and shading of its banks and the river bed by tall plants. The water reservoirs are effective heat absorbers, which contribute to the increase in river water thermal inertia. Their maximum temperatures are therefore recorded in the summer months (May–August), and equal about 20°C. The highest value was recorded in May 2005 in Malinka (24.4°C), just below a vast waterpond fed with Dzierzazna waters. However, the runoff of this river was then very low (a few dm^3 s^{-1}, with no runoff on hot days), and this enabled fast heating of the water. The highest temperature variability occurs during spring and autumn and depends on the ponds icing. The lowest temperatures, 1.4–2.2°C, at most measuring points are recorded in January. Only in the Brzoza River, which flows in a partially covered channel, is the temperature change smaller: from 5.2°C in February to 16.2°C in August. In March 2008, 20.6°C was recorded; however, this incident was caused by the uncaulking of the nearby heat pipeline, and leakage of water into the river bed. A greater change was seen in the Sokolowka water temperature in the Lewa cross-section (3.7°C) because of inflow of ice-melt water from the underground storm sewer system.

Water conductivity is also characterized by significant seasonal variability. In urban basins, its annual variability results from the temporal inflow of contaminants resulting from winter road maintenance (Fig. 3). The highest average conductivity is recorded in February in water of upper courses of the rivers: the Sokolowka in Folwarczna cross-section (3689 µS cm^{-1}) and the Brzoza (2123 µS·cm^{-1}), which show high variability in winter. The maximum registered values reached

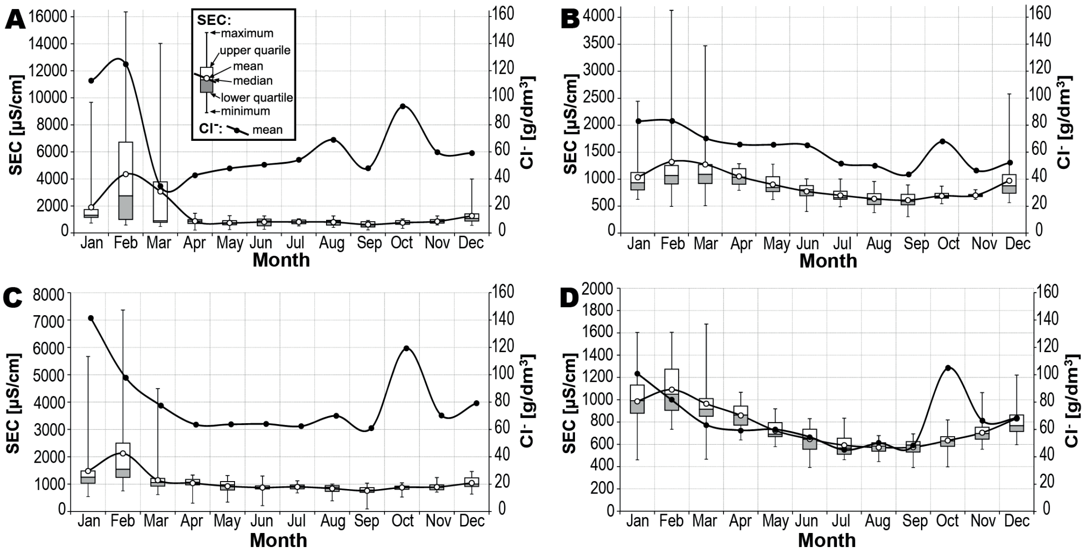

Fig. 3 The seasonal variability of the Sokolowka River conductivity (SEC) during the period 2006–2012 and the concentration of chloride anion (Cl^{-}) during the period 2011–2012, at the following cross-sections: A – Folwarczna, B – Lewa, C – Brzoza, D – Sokolow.

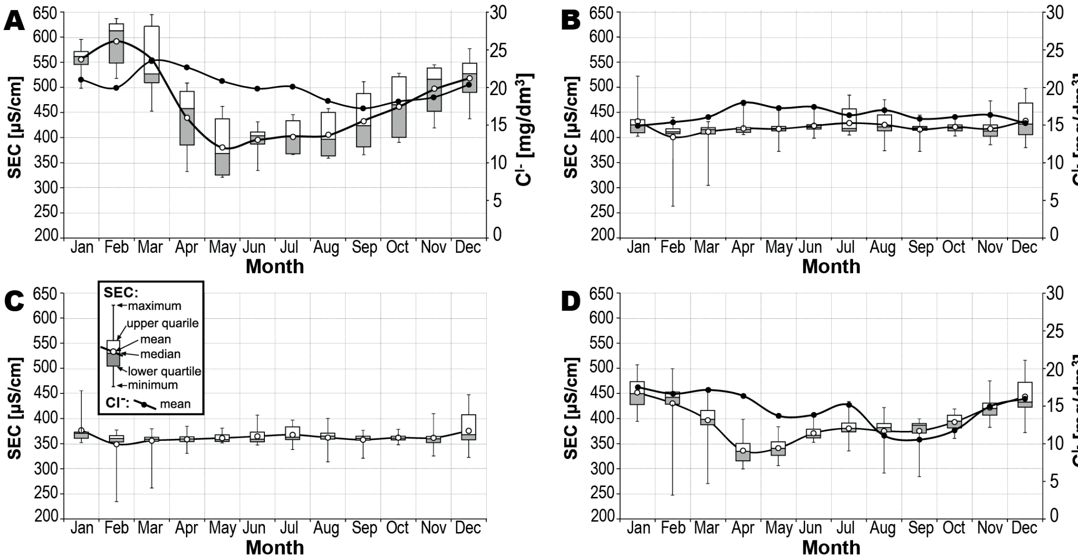

Fig. 4 The seasonal variability of the Dzierzazna River waters conductivity (SEC) during the period 2006–2012 and the concentration of chloride anion (Cl^{-}) during the period 2011–2012, at the following cross-sections: A – Malinka and Dabrowka (chloride), B – Rosanow, C – Ciosny, D – Swoboda.

16 360 and 7370 μS cm^{-1}, respectively, in February 2009. Much lower conductivity in winter (1100–1300 μS cm^{-1}) is recorded in the cross-sections down the river course, where river water mixes with flow-through reservoir water. Lower conductivity 572–626 μS cm^{-1} characterizes river water in September. This is the time of low discharge and, simultaneously, a period of water plant development, which is responsible for absorbing a large portion of nutrients.

In the Dzierzazna basin only the spring section of the river has a similar pattern of changing conductivity, with the maximum value observed in February (592 μS cm^{-1}) (Fig. 4A). The lowest conductivity occurs from May until August (380–406 μS cm^{-1}). The similarity of this basin to the urban catchment is not accidental, as the upper section of the main course is influenced by the sewer system of Zgierz. The raised water conductivity in winter (January) is also recorded at Swoboda cross-section (453 μS cm^{-1}) and in Ciosny (377 μS cm^{-1}). Because both measuring points are situated below the A2 highway drainage system discharge, it can be assumed that the conductivity increase is due to road transport. Measurements made in the trunk sewer outlets, showed that the conductivity of water draining from the highway can reach 18 800 $\mu S\ cm^{-1}$ in late autumn–winter (November 2010), or even 21 300 $\mu S\ cm^{-1}$ (February 2009). The lowest conductivity of river water in Dzierzazna basin is recorded in spring, during the inflow of poorly mineralized ice-melt and rainfall water.

The conductivity regime of the seepage spring area in Rosanow is slightly different. The highest conductivity was also recorded in January (429 $\mu S\ cm^{-1}$), but almost equally high is the maximum observed from June until August (421–426 $\mu S\ cm^{-1}$). It is a period of a high sewage discharge from this popular summer resort. We should emphasise that in this area due to a lack of a sewerage system, the wastewaters from leaky cesspits drain to groundwater feeding the seepage spring area. The lowest conductivity was observed in February (398 $\mu S\ cm^{-1}$), although, as in the remaining cross-sections, greater variability characterizes the winter half-year.

It is not difficult to notice that the magnitude of water conductivity, especially its increase in winter, is influenced by chlorides coming from winter road maintenance activities (Table 1). Their concentration is highest in January (84–145 mg dm^{-3}), and in the urban river water it exceeded by several times the maximum values in the suburban basin (21.5–28.4 mg dm^{-3}). In the Sokolowka basin, the concentration of chlorides doubles during the summer months (Figs 3 and 4), and reduces in winter. In the Dzierzazna, this drop is also proportional, although in the case of Rosanow spring, the increase of chlorides coming from households is recorded in summer.

The concentration of nitrate-nitrogen in river water has a different seasonal pattern. In most cross-sections higher concentrations and variability are recorded in winter, while in summer and autumn nitrate-nitrogen concentrations reduce (Figs 5 and 6). This happens only in the segments of the river course which flow through reservoirs. Consequently, nitrogen concentrations rarely exceeds 2.0 mg dm^{-3}. In the urban basin in the upper parts of the watercourses (Folwarczna, Brzoza), due to a lack of water ponds, there is no reduction of nutrients. In summer, the nitrogen concentration values amount to even more than 4.0 mg dm^{-3}. In winter, because of decomposition of dead plants in reservoirs, water is again contaminated with nitrate-nitrogen and its concentration may reach 4.0 mg dm^{-3}. In the strongly polluted underground water (upper part of the Dzierzazna basin) the concentration of nitrate-nitrogen can even exceed 20.0 mg dm^{-3}.

At almost all measuring points, highest pH values are observed in April, before the water flora becomes fully developed (Figs 5 and 6). In the upper part of the basins (Folwarczna, Malinka) water is usually more alkaline (pH > 8) than in the lower parts. It results from the higher sewage loading. Intensive fish farming causes a situation in which water in the Swoboda cross-section (Dzierzazna basin) in April (pH 8.26) is almost one unit more alkaline than in the closing cross section of the urban basin (pH 7.40). It should be emphasized that the discharges from the highway and others roads drainage systems may be very alkaline in winter; their pH values often exceed 10.

During a year, it is frequently observed that pH has a second, autumnal, peak, which is related to the discharge decrease. The most neutral reaction characterizes water in early summer and winter. During the summer it is caused by the luxuriant growth of aquatic vegetation, and in winter by inflow of snow-melt water, whose pH is similar to that of the rainfall water. This can be primarily seen in the urban basin, where the winter pH is in the range 6.70–7.30. In the Dzierzazna basin the role of the surface runoff in the formation of the total river runoff is usually insignificant; therefore water pH is different 7.16–7.38. The exceptions are melt-water supplied to the upper part of the Dzierzazna basin during the spring of 2005 (pH 6.50 in March).

Water dissolved oxygen (DO) comes from the air, and is also produced by water flora. A certain amount dissolves in water with highly oxygenated rainwater. In shallow littoral zone of ponds oxygen is also produced by plants. However, the ability of gases to dissolve decreases with increasing water temperature. Hence, the highest concentrations of dissolved oxygen (80–90 %) are recorded not in summer, but most frequently in April. Both basins are similar in this respect because the water reservoirs impact the biological life and the thermal properties of the rivers. Greater dynamics of water favours better oxygenation of the Sokolowka River water.

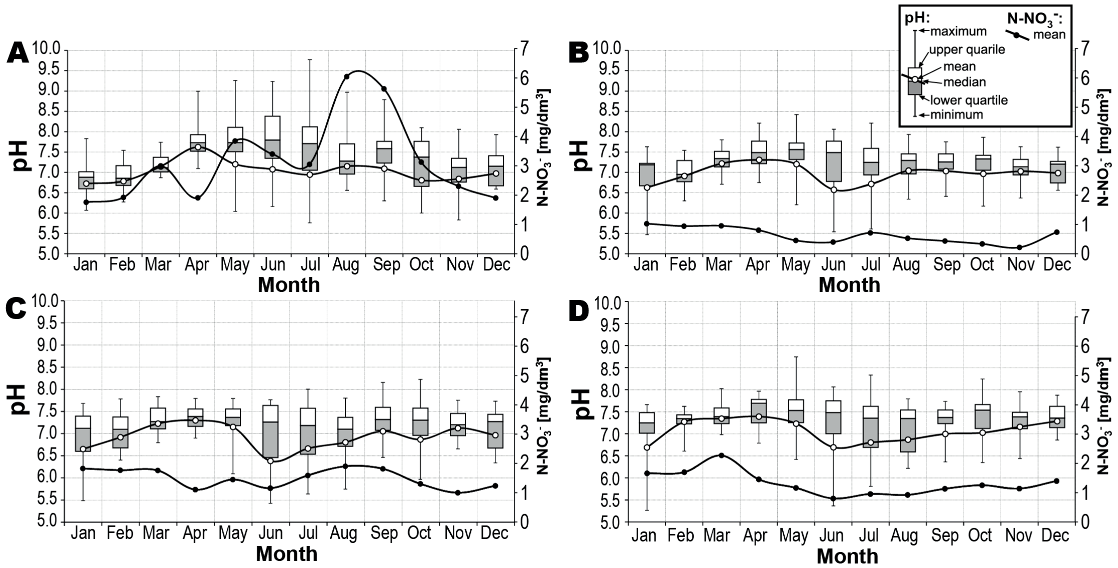

Fig. 5 The seasonal variability of the Sokolowka river waters pH during the period 2006–2012 and the concentration of nitrate nitrogen (N-NO$_3$) during the period 2011–2012, in the following cross-sections: A – Folwarczna, B – Lewa, C – Brzoza, D – Sokolow.

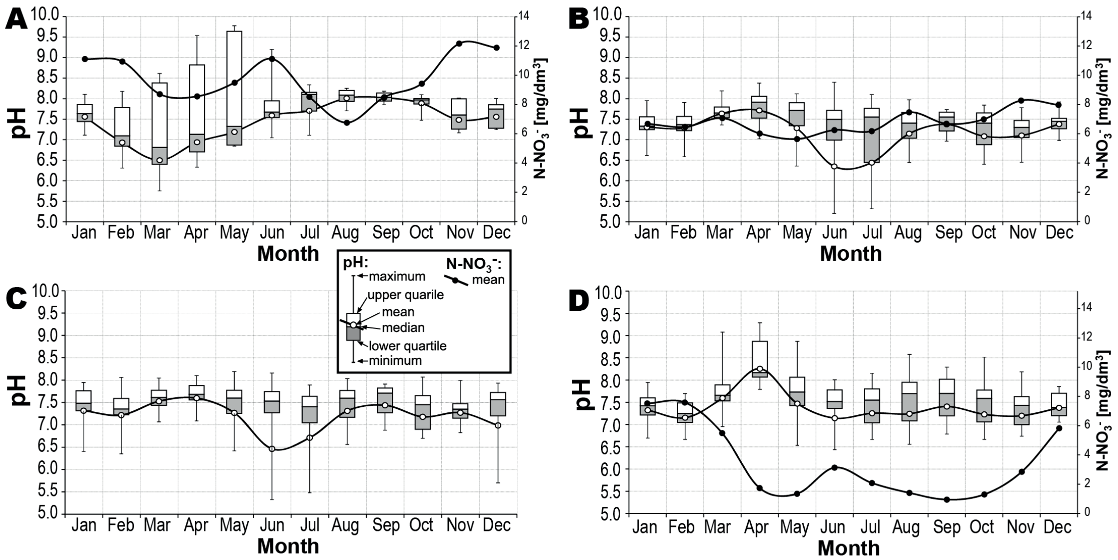

Fig. 6 The seasonal variability of the Dzierzazna river waters pH during the period 2006–2012 and the concentration of nitrate nitrogen (N-NO$_3$) during the period 2011–2012, in the following cross-sections: A – Malinka, B – Rosanow, C – Ciosny, D – Swoboda.

In an urban basin the concentration of dissolved oxygen significantly decreases in autumn, because it is used to decompose organic matter accumulated at the bottom of ponds and transported with river water. In the upper cross-sections the concentration of dissolved oxygen is about 55%, in the lower courses 70%. In the Dzierzazna basin the minimum concentration of dissolved oxygen is recorded in June (42–51%), probably due to inflow of oxygen-lacking underground water, which drains along the river course. Underground water feeding is responsible for more than 80% of the Dzierzazna total runoff. Only in summer months (July, August) is the impact of underground water on oxygen concentration compensated by the increased production of this gas by water pond plants.

Distinctive differences between basins can be also observed if we analyse the seasonal variation of water turbidity. The lowest turbidity, 0.9–2.8 NTU, characterizes the water discharged from spring areas. Its highest variability, due to the spring thaw and snowmelt runoff periods, is observed in winter and also in May, when water microorganisms and water flora develop. Slightly higher values, with a maximum in April (8.1) and a minimum in November (2.3), were recorded in Dzierzazna River water in the Swoboda cross-section. This is due to river valley flora development in the growing period, which interrupts the surface runoff. The highest turbidity is characteristic of the urban basin, and the registered values diminish along the river course. The reason is not only the flow velocity, which decreases with the decrease of the water-table, but also the material deposition in the flow-through reservoirs. The highest turbidity is observed in winter in the upper river courses (Folwarczna 136.8, Brzoza 59.9); although values exceeding 100 NTU can also be recorded in almost every month (they appear due to collapse of earthworks created within rivers beds). Winter, spring and summer months are characterized by higher variability in turbidity, which is influenced by snow-melt periods and rainfall-storm floods. Minimum values are recorded in autumn, when low discharges dominate.

CONCLUSION

Human impact on the qualitative parameters of the water cycle can be revealed in different basin transformation levels. The level of urbanization determines the rate and the direction of pollutant migration in the environment, and also influences environmental ability to reduce contamination. Impervious surfaces increase runoff dynamics and result in the decrease in underground water feeding and water level dropping. It is reflected by a high variability of almost all physical-chemical water characteristics, which is caused by a temporary lack or a serious shortage of water in the riverbed, mainly during winter time. At the same time the contamination discharge to river water is the highest due to the systematic transportation infrastructure development, and the use of road maintenance chemicals.

Flow-through reservoirs play a very important role in small river basins. Water plants help in mechanical deposition of the sediments, being simultaneously oxygen producers and biological filters reducing the amount of nutrients in water. It is known that oxygen is necessary for the decomposition of these substances. River valley plant cover plays a similar role in relation to water running off valley slopes. An increase in infiltration results in elongation of the path of contaminants migration and the possibility of their neutralization in the environment.

It is very important in responsible spatial planning to take into account as many relationships between human activities and the water environment as possible. Gaining knowledge about seasonal variability of the basic physico-chemical water properties enables projection of transformations of the basin and design of sanitary sewer management adequate to the areas of different urbanization levels.

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