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LOSS OF RIVER NATURALNESS – CAUSES AND CASES

Marta Kiraga[1]✉, Anna Maria Remer[2]

[1]Institute of Civil Engineering, Warsaw University of Life Sciences – SGGW, Warsaw, Poland
[2]Environmental Protection student (MSc programme), Faculty of Civil and Environmental Engineering, Warsaw University of Life Sciences – SGGW, Warsaw, Poland

ABSTRACT

The economic growth of lowland areas is closely related to water management, with the development of valley areas limited by local hydrological conditions. The water retention shaped by hydro-technical structures enables the subsequent use of water for flood protection, agricultural, industrial, fire-fighting, energy, or recreational purposes, conditioning the potential development opportunities of the region. Over the years, there have been different approaches to the exploitation of water resources – from total subordination of nature by man to the development of sustainable solutions. However, to utilise the potential of rivers, channels and valleys were subjected to regulation, which in some cases provided immediate economic benefits, but in the long-term, deprived the river of its natural qualities, inhibiting its ability to self-purification morphodynamic processes. The water runoff acceleration as a result of channel straightening and concreting, combined with the narrowing of river valleys, led to a progressive increase in flood risk. As observed, over the years, such rivers increased the flood problem, oppositely to intentions. In response to deteriorating hydromorphological conditions, a variety of mitigation measures have been undertaken, which can be broadly termed as river restoration. The article presents the most common causes leading to the loss of naturalness, one of the most significant environmental effects. As demonstrated, most often, the loss of naturalness of water occurs through the influence of several factors, although in individual cases, it is possible to recognise one of them as the main threat source.

Keywords: river restoration, natural river, river habitat, water contamination, pollution, river water quality

INTRODUCTION

The river's natural status loss is particularly the result of various activities and treatments carried out in channels and valleys or is related to the water quality. The recognised causes for the impoverishment of river reach naturalness usually play a major role in the decision of a restoration project, its main direction, and the advancement of included activities (Żelazo, 2006).

Natural rivers in a properly managed landscape are a stable and self-sustaining part of the environmental water cycle. A regulated river whose channel is straight and uniform in depth, and whose banks are devoid of shady trees and shrubs, loses its status as a naturally formed ecological habitat, as well as increases the dynamics of flood discharges and impairs retention capacity during drought periods. The achievement of the intended objectives of river regulation, such as land drainage and flood protection, the provision of significant water quantities, and the improvement of waterway transport conditions required specialised hydraulic work and the introduction of drainage works. The undertaking of extensive hydraulic engineering measures to regulate rivers has taken place almost all over the world and has generally formed the basis of economic prosperity. The article presents the most

Marta Kiraga https://orcid.org/0000-0001-9729-4209
✉marta_kiraga@sggw.edu.pl

common causes leading to the partial impoverishing or total loss of river naturalness. It demonstrates that it derives from the influence of several factors, although in individual cases, it is possible to recognise one of them as the main threat source.

RIVER ECOLOGICAL STATUS SPECIFICATION

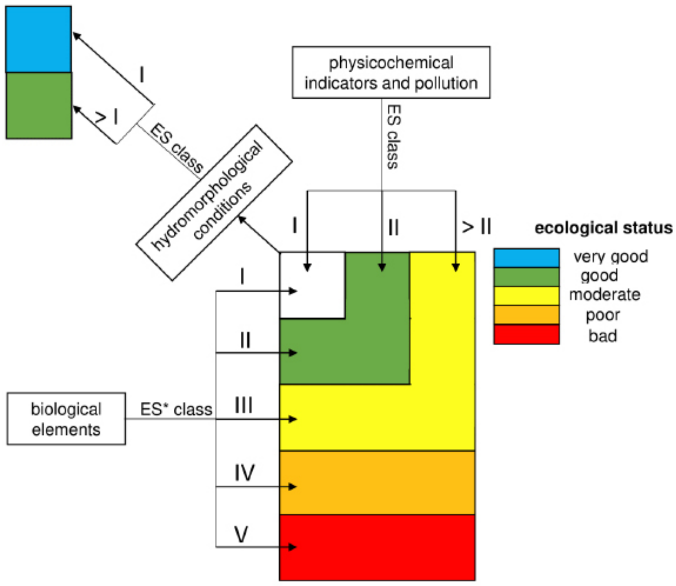
Surface water body status evaluation (of rivers, lakes, transitional, and coastal water bodies) is determined by environmental monitoring and presented as an ecological and chemical status assessment. Within EU countries, the ecological status of surface water bodies can be classified by assigning one of five quality classes. Good water body status could be recognised if the habitat is relatively close to the natural condition. The obligation to study and assess the quality of surface waters arises from Article 349 of the Polish Water Law (Ustawa z dnia 20 lipca 2017 r. – Prawo wodne). The rules for the classification and assessment of the status of surface water bodies in Poland are contained in the Regulation of the Minister of Environment of 21 July 2016 on the classification of surface water bodies and environmental quality standards for priority substances (Rozporządzenie Ministra Środowiska z dnia 21 lipca 2016 r. w sprawie sposobu klasyfikacji stanu jednolitych części wód powierzchniowych oraz środowiskowych norm jakości dla substancji priorytetowych) and the Regulation of the Ministry of Environment of 9 November 2011 regarding ecological state classification, ecological potential and chemical state of the surface water bodies (Rozporządzenie Ministra Środowiska z dnia 9 listopada 2011 r. w sprawie klasyfikacji stanu ekologicznego, potencjału ekologicznego i stanu chemicznego jednolitych części wód powierzchniowych). According to the Polish Water Law, the implementation of surface water monitoring is aimed at obtaining information on surface water status for management and achieving environmental objectives. The ecological status characterises the quality of structure and functioning of the aquatic ecosystem and is determined by the following groups of elements: biological, physicochemical, and hydromorphological indicators. Both hydromorphological and physicochemical elements are supporting groups for the set of biological elements (Żelazo, 2006).

THE NATURAL STATUS OF A RIVER AND ITS VALLEY

The river's naturalness is gradable value – a river or any other land use object may be more or less natural. The assessment of anthropological influences on the hydromorphological regime serves to recognise the proximity to the natural state of the habitat. An undisturbed or insignificantly disturbed state will indicate a high degree of channel naturalness.

From an engineering perspective, a river is natural when it has not been modified by channel regulation works or any other river engineering activities (Żelazo, 2006). The natural characteristics of rivers, adjacent valleys, and catchments, can be divided as follows:

1. Adequate purity and quality of flowing and standing waters. It should be emphasised that the biological quality of water has an overriding value in the process of ecological status assessment. A river cannot achieve a very good ecological status when biological elements have reached a status lower than very good (Fig. 1).
2. The function of waters as a habitat, providing conditions suitable for life and development of aquatic organisms: water bodies without abiotic features are transformed into almost unsettled or completely degraded watercourses, which cannot carry out self-purification processes. Such rivers are also deprived of any space that could create the possibility to form feeding grounds for biodiversity inhabiting the aquatic space, refuges, enclaves, spawning places, and others. Natural riverbeds are characterised by elements such as variation in river depth, cross-section shapes, longitudinal profile shapes, or alluvial bed formations resulting from sediment and debris transport (Fig. 2).
3. A significant role in landscape shaping, as well as natural and recreational-touristic values: this aspect is strongly correlated with the naturalness of the horizontal distribution of the river network and its bed structure, as well as with the river valley development and shape properties, with the specificity of slopes and vegetation presence.



ES – ecological status

Fig. 1. Ecological status classification scheme

Source: own work based on the Common Implementation Strategy for the Water Framework Directive (Directive 2000/60/EC).

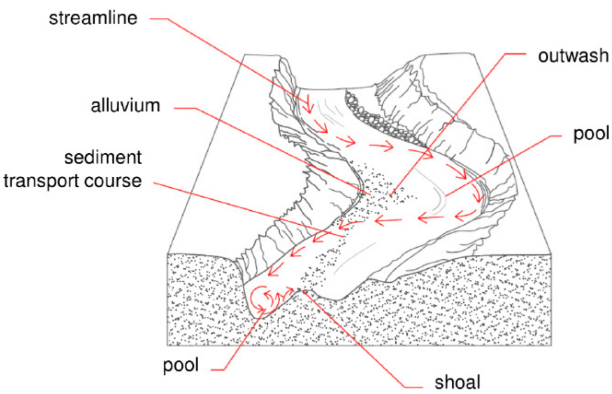


Fig. 2. Unregulated river and its hydromorphological elements

Source: own work.

CAUSES OF NATURAL STATUS LOSS

For a variety of reasons, the naturalness of rivers and their valleys has been lost. The majority of them were caused by total watercourse modifications connected with river regulation, involving such actions as:

- straightening of river channels (Fig. 3);
- standardisation of cross-section dimensions and shapes;
- elimination of irregularities of the river bed and banks;
- the devastation of ecotone vegetation (Fig. 4);
- elimination of connections between the old river bed and the main channel;
- an increase of slopes;
- duration and range of floods diminishing.

The main source of river pollution is sewage, both domestically discharged from cities and settlements, and all types of industrial and agricultural sewage. However, the most toxic wastewater from industry carries a lot of heavy metals, nitrates and phosphates, petroleum substances, phenols, cyanides, benzene, and formaldehyde (Kulikauskaitë & Paliulis, 2015; Grabiec & Kurpisz, 2020). The consequences of their presence and further reactions are huge losses in river ecosystems and the accumulation of toxins in animal bodies.

Another group of river pollution is debris, which is formed by the sedimentation of mineral and organic suspensions resulting from previous erosion and constituents precipitated from the flowing water. In many

Fig. 3. Straightened river bed – the Zagożdżonka river in central-eastern Poland

Source: photo by Marta Kiraga, summer 2013.

Fig. 4. Scorched shoreline vegetation – the Zagożdżonka river in central-eastern Poland

Source: photo by Marta Kiraga, winter 2012.

cases, debris formation also involves material delivered with municipal and industrial wastewater and carried by surface runoff from urbanised, industrial, and agricultural areas (Madeyski, 2007; Wichowski, Nowak & Rutkowska, 2017). Aquatic debris stores most of the potentially harmful metals (including copper, zinc, nickel, chromium, lead, cadmium, and mercury) and organic compounds that enter surface waters. River sediments also accumulate persistent organic pollutants (POPs), including polycyclic aromatic hydrocarbons (PAHs) and organochlorine compounds such as organochlorine pesticides and polychlorinated biphenyls (PCBs), (Bach, Röpke & Frede, 2005).

River waters lost their naturalness not only as a result of improperly planned regulation but also through any unfavourable works within the channel and the valley. The most important causes leading to naturalness deterioration include (Table 1):

- works in the catchment area leading to an increase in flood discharges, e.g. deforestation, drainage works, degradation of landscape retention, development of urbanisation and transport infrastructure as well as watercourses regulation (Khalegi, 2017);
- activities leading to a decrease in flood discharges due to the construction of too many artificial retention reservoirs (Mei, Van Gelder, Dai & Tang, 2017);
- too frequent equalisation of water surface levels and discharge variability, which reduces their dynamics; accumulation of river sediment upstream of weirs or barrages has unfavourable consequences for the dammed river sections (Galay, 1983);
- introduction of alien fish species to the waters, which are unsuitable for a given river, which causes a threat to native species (Meixler, Bain & Walter, 2009);
- preventing mass migrations of fish and other aquatic organisms along the river by installing sills or weirs (Meixler et al., 2009);
- undertaking maintenance works that are too frequent or too extensive, or that are completely unnecessary and consist in the elimination of the riverbed morphological diversification (elimination of islands, stone sills, and sediment bedforms), unification of banks, and devastation of vegetation (Buckley & Crone, 2008; Normile, 2010);
- carrying out maintenance works on a small scale, which is insufficient for a given river, which results in an intensive process of erosion and degradation of the riverbed;

Table 1. Causes for a loss of naturalness in river ecosystems

Construction processes and site organisation causes	Hydraulic engineering development causes
deforestation	development of urbanisation and transport infrastructure
drainage works	embankments
degradation of landscape retention	watercourse regulation
elimination of ponds and oxbow lakes in floodplains by filling them with soil from the foundation trench	construction of too many artificial retention reservoirs, weirs, barrages, sills, etc.
destroying and draining wetlands	introduction of alien fish species
excessive ground compaction	preventing mass migrations of fish and other aquatic organisms along the river by installing sills, weirs, and dams
machinery and vehicle movement on the site	too frequent or too extensive maintenance works
erosion processes occurring downstream of the construction site	insufficient scale of maintenance works
drainage of the subsoil	elimination of ponds and oxbow lakes
conducting tree and shrub clearing to provide space for construction facilities	–

Source: own work base on: Galay (1983), Gibbs (2000), Kaufman (2000), Buckley and Crone (2008), Meixler et al. (2009), Alonso and Cardoso (2010), Normile (2010), Winemiller (2010), Verachtert, Maetens, Eeckhaut, Poesen and Deckers (2011), Bai et al. (2013), Khalegi (2017), Mei et al. (2017), Wiekenkamp, Huisman, Bogena and Vereecken (2020).

- elimination of ponds and oxbow lakes by filling them with soil (Żelazo, 2006);
- destroying and draining wetlands (Gibbs, 2000; Bai, Cui, Cao, Li & Zhang, 2013);
- planting trees unsuitable for valley conditions (Żelazo, 2006).

The loss of water body naturalness also occurs as a result of works related to the implementation of various hydraulic and wastewater facilities, accompanied by the construction site organisation process. The thread for natural habitat value can be divided into two components – direct causes invoked by the structure introduction itself and causes related to the entire construction cycle. The main causes related to the construction cycle include:

- excessive compaction of the ground resulting from machinery movement and any vehicles on the site, soil storage, and the storage of construction materials and equipment (Wiekenkamp et al., 2020);
- erosion processes occurring downstream of the construction site (Kaufman, 2000);
- works related to the drainage of the subsoil, leading to a lack of water in wells in the adjacent area, excessive area drying, as well as to the collapse of that area (Alonso & Cardoso, 2010; Verachtert et al., 2011).

MITIGATING EFFORTS

The first step to protect the river that has been regulated is to subject it to restoration works. These are activities aimed at restoring or approximating the natural character of the watercourse with the appearance of greater species diversity and increased effectiveness in the fight against excessive anthropopressure. One of the important activities responsible for water quality is minimising the need for soil fertilisation. Water restoration projects should include activities improving water purity itself. These are properly initiated, stimulated, and intensified biological and chemical processes that take place in the significant presence of organisms. Technical undertakings may include:

- habitat modifications that increase the share of naturally occurring processes, for instance, conversion of erosion-inhibiting steps to ramps that allow aquatic organisms to communicate, and the removal of impermeable barriers;
- works that, when completed, do not create a finished element of a restored habitat, but initiate a natural process that is supposed to return the river to its natural state, such as vegetation introduction;
- maintenance works, which consist of minor corrections to the natural transformation of the river, not aimed at natural habitat creation, such as fallen trees and replenishment of bushes;
- maintenance of water quality in the course of restoration (care and maintenance procedures, protection and improvement of its quality);
- abandoning some maintenance activities and leaving them to the influence of nature; therefore, rivers may undergo transformations that bring them closer to nature due to morphodynamic channel processes, beaver activities, the imapct of vegetation, etc. (Żelazo, 2006).

Therefore, the process of river restoration could be generally divided into three basic stages: initiation activities, which aim to provide the right conditions for the restoration process to begin; spontaneous activities carried out by nature; conservation works, monitoring, and supervision.

Restoration activities serve to create a living space for aquatic organisms as well as because they lead to improving the natural purity of water. Surface water restoration is an example of increasing natural retention possibility, which is realised by measures aimed at protecting water resources by restoring or maintaining natural ecosystems. Such measures contribute significantly to reducing the losses incurred by society, the environment, and the country's economy as a result of climate change, constituting one of the possibilities for adaptation to climate change.

Surface water restoration includes, therefore: improvement of channel and valley retention, normalisation of water relations in the catchment, wetlands, and peat bog restoration, as well as restoration of continuity and hydromorphological diversity of watercourses and lakes. Such activities improve habitat resilience, that is, the adaptation of ecosystems and the continuity of services provided by them. Water restoration reduces flood risk, mitigates the drought effects, reduces the necessary costs of maintenance works, and creates socially attractive places.

The studies on surface water quality result from the legislation (Directive 2000/60/EC, as well as regional legal frameworks, such as the Polish Water Law or French Legislative Framework) in the scope of physicochemical, chemical, and biological elements. The idea of conducting such studies is to increase and disseminate knowledge on the ecological and chemical status of water bodies. To obtain a habitat with a high ecological status, it is necessary to undertake activities aiming to improve its hydromorphological condition, as well as to protect waters against industrial pollution, including salinity and substances especially harmful to the aquatic environment, leading to eutrophication. Implementation of water quality monitoring and other planned activities is carried out according to the water management cycle described in regional legislation.

To protect the hydromorphological status of water as well as its quality, the following measures could be undertaken:

- reducing the use of artificial fertilisers and plant protection products on farms and in households in favour of fast biodegradable products, as well as the use of cleaning products containing lower amounts of phosphorus;
- abandonment of discharging wastewater into waters or land, which contributes to the construction of sewage networks and new wastewater treatment plants;
- reconstruction and improvement of existing wastewater treatment plants and investment in new cleaner technologies;
- discharging only treated wastewater into waters or land;
- treating and desalinating mine and road water, leading to a reduction of salt used for gritting roads and pavements during winter;
- applying geotextiles to separate landfills and waste dumps from groundwater and surface water;
- basing on new, safe industrial technologies and modernising environmentally unfriendly technologies: using closed water circuits, building treatment plants, and using more efficient filters.

Spontaneous river regulation, which is the natural river activity in the process of restoration, contributes

a b

Fig. 5. Examples of river regulation based on natural materials: a – the Barranco Mogán river (Puerto de Mogán, Gran Canaria) fortified with stone rubble with a fraction more than 25 cm; b – the Szum river (Aleksandrów, Lubelskie Voivodship, Poland) fortified with stone rubble with a fraction less than 25 cm

Source: photo by Anna Maria Remer, summer 2019.

to the achievement of greater variation in both spatial and species diversity. The spatial abiotic features that have diversified as a result of spontaneous restoration are water velocity and depth, the grain size of the riverbed material, and access to light and oxygenation. In turn, the increase in species diversity is due to the diversification of habitat conditions so that the development of different biocoenoses occurs, leading to an ecological status improvement. However, spontaneous river restoration is a very long-term process and usually does not guarantee the complete restoration of morphological and biocenosis characteristics of the natural river habitat.

Regulation activities do not always have to result in river environment degradation. Sustainably conducting regulation and maintenance works consists of applying environmentally friendly measures that allow achieving the assumed technical objectives while limiting the negative effects. Examples of environmentally friendly materials are wood, natural stone (Fig. 5), and fascine – including regrowth naturally present in habitats elements such as large boulders or tree trunks and stumps.

CAUSES FOR THE LOSS OF NATURAL FEATURES USING THE EXAMPLE OF SELECTED LOWLAND RIVERS

In the past, a large number of small lowland rivers in Europe were regulated. Such changes generally led to improved water management. Unfortunately, regulation activities also caused adverse changes in the natural environment of rivers and their valleys. A loss of naturalness often occurred in situations leading to significant modification of a watercourse, such as new river channel creation.

Examples of works carried out on rivers, assuming mainly regulation activities, as a result of which the waters lost their naturalness are:

- The Prosna river in Kalisz (Poland, Wielkopolskie Voivodship) – the regulation of the river consists of straightening, narrowing, and unifying the longitudinal inclination of the bottom of the river as well as strengthening banks by covering them with concrete slabs. The result of these actions is a complete deprivation of the river flora and aquatic fauna (Małecki & Wira, 2011).
- The Wierchomlanka river near its confluence with the Poprad river (Poland, Małopolskie Voivodship) – the stream was regulated by completely unifying its channel by levelling the bed and by introducing concrete elements. Straightening of the naturally meandering riverbed contributed to the flow of large water increment, and its concreting resulted in the disappearance of aquatic organisms. Regulatory works also included covering the banks with perforated panels, which was associated with the devastation of shoreline vegetation (Froehlich, 1980).
- The Isenach channel in Carlsberg (Germany, Rhineland-Palatinate) – the channel regulation was performed by creating an artificial channel embanked by stones, narrowing its cross-sections at a certain reach, as well as standardising the cross-section. These actions resulted in a faster stream, which also led to higher peak flows. The scope of regulation works includes completely removing one of the banks and replacing it with a vertical wall made of gabions. The newly created river is completely devoid of vegetation and aquatic organisms, which additionally affects the loss of its naturalness.
- The Emscher river in Oberhausen (Germany, North Rhine-Westphalia, Westphalia) – the river regulation consisted of levelling the river bed and straightening it, which leads to faster runoff and higher flood risk. The regulation works on the Emscher also included the unification of the banks' inclination, which made the river symmetrical in cross-section (Hemmings & Kagel, 2010).

CONCLUSIONS

Rivers staying in a natural state constitute habitats that occur naturally in the environment. From a morphodynamic point of view, they result from fluvial processes occurring in nature. These rivers are also characterised particularly by the absence of pollution by foreign waters and other toxic substances and by the fact that suitable animals and plants can live and grow in these habitats. A river in its natural state has not been modified by regulation or other river engineering projects but has been shaped by the forces of nature. The naturalness of a river and its valley is characterised by three basic features: the purity of water (quality), its ability to function as a living space and its important role in shaping the landscape, and its aesthetic and recreational values.

The most significant problem is that in the past, regulation was mainly carried out from a technical point of view. According to the development directions at that time, environmental aspects were not adequately considered or, at worst, were completely neglected. Technical river regulation was popular due to an overriding role of water management towards economic growth and development of non-urbanised areas with the prevailing fashion of straightening rivers – unjustified, as we know it today. Therefore, technical regulation was carried out on a large scale, as were the consequences of these activities causing adverse effects on the aquatic environment. In addition to the impact of hydraulic works and the introduction of water structures, the loss of river habitat naturalness is very strongly and negatively affected by various external factors. One of the most dangerous of them is the introduction of water polluted in a mechanical, chemical, or biological way into rivers, lakes, or other water bodies.

The basic aims of water ecosystem management are to protect it from the inflow of pollutants (sewage) and to improve the quality of already polluted waters (re-naturalisation). Another activity carried out in the field of protection of waters and their naturalness is restoration works – recovering the naturalness or approximation to the natural status of regulated river habitats. Water body management also includes carrying out environmentally friendly maintenance works, which ensure safe and natural methods of watercourse regulation.

The beginning of natural feature disappearance usually takes place at the construction project realisation stage, and it occurs immediately after the building process begins. Over the following years, the loss of naturalness is strongly influenced by factors that harm the environment for longer and slower. The main reason for the loss of naturalness of flowing and standing waters is the undertaking of reasonable and previously planned activities leading to economic benefits without considering the environmental aspect of the operation.

Authors' contributions

Conceptualisation: M.K. and A.R.; methodology: M.K. and A.R.; validation: M.K.; formal analysis: M.K.; investigation: M.K. and A.R.; resources: M.K. and A.R.; writing – original draft preparation: M.K. and A.R.; writing – review and editing: M.K. and A.R.; visualisation: M.K. and A.R.; supervision: M.K.; project administration: M.K.; funding acquisition: M.K.

All authors have read and agreed to the published version of the manuscript.

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UTRATA NATURALNOŚCI RZEK – PRZYCZYNY I PRZYKŁADY

STRESZCZENIE

Wzrost gospodarczy na obszarach nizinnych jest ściśle związany z gospodarowaniem wodą. Ograniczeniem rozwoju obszarów dolinowych są m.in. lokalne warunki hydrologiczne. Retencja kształtowana przez budowle hydrotechniczne umożliwia późniejsze wykorzystanie wody do celów przeciwpowodziowych, rolniczych, przemysłowych, przeciwpożarowych, energetycznych czy rekreacyjnych, warunkując potencjalne możliwości rozwoju regionu. Na przestrzeni lat stosowano różne podejścia do eksploatacji zasobów wodnych – od całkowitego podporządkowania przyrody człowiekowi po opracowanie zrównoważonych rozwiązań. W celu wykorzystania potencjału rzek kanały i doliny poddawano regulacji, która w niektórych przypadkach przynosiła doraźne korzyści ekonomiczne, ale w dłuższej perspektywie pozbawiała cieki wodne naturalnych walorów, hamując zdolność do samooczyszczania lub procesy morfodynamiczne zachodzące w korycie. Jak zaobserwowano, problem powodzi jest wciąż często spotykany i uciążliwy, pomimo prowadzonych działań z zakresu inżynierii wodnej i w opozycji do jej zamierzeń. W odpowiedzi na pogarszające się warunki hydromorfologiczne podejmowane są różnorodne działania łagodzące, które można ogólnie określić mianem renaturyzacji rzek. W artykule przedstawiono najczęstsze przyczyny prowadzące do utraty naturalności, mające najistotniejsze skutki środowiskowe. Jak wykazano, najczęściej utrata naturalności wód następuje w wyniku oddziaływania kilku czynników, choć w pojedynczych przypadkach możliwe jest uznanie jednego z nich za główne źródło zagrożenia.

Słowa kluczowe: renaturyzacja rzek, rzeka naturalna, siedlisko dolinowe, zanieczyszczenie wód, odpady, stan rzeki