Environment and Ecology Research 10(3): 355-369, 2022 http://www.hrpub.org
DOI: 10.13189/eer.2022.100304

Synthetic Analysis of Thematic Studies towards Determining the Recreational Potential of Anthropogenic Reservoirs

Sebastian Kuś, Edyta Sierka, Iwona Jelonek, Zbigniew Jelonek*

Faculty of Natural Sciences, University of Silesia in Katowice, Poland

Received February 27, 2022; Revised April 22, 2022; Accepted May 23, 2022

Cite This Paper in the following Citation Styles

(a): *[1] Sebastian Kuś, Edyta Sierka, Iwona Jelonek, Zbigniew Jelonek , "Synthetic Analysis of Thematic Studies towards Determining the Recreational Potential of Anthropogenic Reservoirs," Environment and Ecology Research, Vol. 10, No. 3, pp. 355 - 369, 2022. DOI: 10.13189/eer.2022.100304.*

(b): *Sebastian Kuś, Edyta Sierka, Iwona Jelonek, Zbigniew Jelonek (2022). Synthetic Analysis of Thematic Studies towards Determining the Recreational Potential of Anthropogenic Reservoirs. Environment and Ecology Research, 10(3), 355 - 369. DOI: 10.13189/eer.2022.100304.*

Abstract Processes associated with surface mining promote the creation of artificial water reservoirs. In most cases, these post mining reservoirs can be adapted for recreational purposes after slight modifications. The authors analyzed the characteristics of inland reservoirs created as a result of opencast mining of diverse types of deposits in terms of the possibility of their best use for recreation and the identification of good management practices. The solutions and methods of monitoring the current status of anthropogenic waters and aquatic ecosystems serving the local community and tourists are briefly presented. The typical conditions for the formation of artificial water reservoirs and the risks associated with the genesis of such reservoirs for users and administrators of these facilities are discussed. The possibilities of managing anthropogenic reservoirs for economic purposes, considering their origin, shape, depth, and water quality, are also presented. The development of recreation infrastructure was discussed, not only the one directly in contact with the water reservoir, but also the one located at a distance, which corresponds to the definition of water-based tourism, which also takes place in the areas surrounding the lakes. Considering the innovative and constructive view on the risks of the use of post-anthropogenic ecosystems, both from the user's and administrator's perspective, we believe that the manuscript will be a useful compilation of knowledge on the subject and could be of value to wide readership.

Keywords Anthropogenic Reservoir, Artificial Lake, Management, Recreation, Biohazard

1. Introduction

According to estimates presented by Cassardo [1], there is a total of 1400 million cubic kilometers of water on the entire planet, but only a small part - only 3% - is freshwater, mostly stored in glaciers and ice caps. Less than 0.01% of all water on Earth is made up of freshwater rivers and lakes, estimated to be around 100 000 km^3 [2]. In recent years, it has been shown that lakes, including those of small size, cover a total of approx. 3.7% of the Earth's land area is not covered by ice, which has turned out to be a larger area than originally thought [3, 4]. It is obvious that water is essential for living organisms and technological progress would not be possible without it, as it is widely used in almost all sectors of the economy [5, 6]. Water - both salt and fresh - is also commonly used for recreational purposes [7, 8]. Almost on all continents - with the exception of Antarctica - in the area of water reservoirs there are places where you can use water in various forms. According to the Outdoor Industry Association, more than 50% of the adult population of the developed countries frequently uses water for recreational purposes. It has been shown that an extremely important element for recreation is water quality, because the cleaner the water, the greater the experience.

This rule applies to both direct water activities and indirect activities, e.g., nature observation [9, 10]. With urban sprawl and a growing population there are more and more needs for recreational water activities in urban waters this also applies to highly urbanized areas transformed by industrial activities and is related to human health benefits associated with urban aquatic environments [11, 12].

Maintaining the good quality of water intended for recreation is a priority task for managers of such places, as it determines not only the attractiveness and popularity of a given place, but above all has a great impact on the safety and health of users. In order to standardize the principles and criteria for assessing the quality of both water and places located in the immediate vicinity, e.g., beaches, guidelines were established to regulate these issues within the European Union [13] and outside its territory. This has become necessary because globally, each year, more than 120 million cases of gastrointestinal diseases and 50 million cases of acute respiratory diseases are caused by bathing in wastewater-polluted coastal waters. With more than half of the world's population living on the coasts, the polluted seas and oceans have a far-reaching impact on public health and ecosystem, including recreation [14]. For this reason, this water, more often than inland water, is of interest to scientists and researchers. The studies involved the identification of water pollutants [15, 16], the types of risks to beachgoers, and the risk of specific medical conditions [17, 18]. Relationships between water quality and sand quality on surrounding beaches [19], and tools and methods for monitoring the quality of bathing waters at seacoasts [20, 21] were also indicated.

Inland reservoirs, especially those resulting from opencast or underground exploitation of natural resources, are much less explored areas in terms of assessing the quality of recreational waters, the quality of beaches, or identified threats. Lakes created after the exploitation of sand or gravel are usually located in an area where the excavated material was used as a building material and therefore, they are new aquatic ecosystems in an urbanized landscape [22]. They are often located near or in residential areas [23]. Reservoirs of anthropogenic origin, apart from their recreational functions, are of economic importance, e.g., they secure the supply of usable water and are essential for agriculture or industry, as well as for flood protection. They also perform other important functions related to biodiversity creation and preservation, pollution disposal, microclimate formation, carbon bonding or recreation [24], which are referred to as ecosystem services provided for people.

It should be mentioned that after the end of exploitation, the mines are left not only with extensive excavations (of various depths), but also with spoil tips, including post-flotation spoil heaps. Various types of industrial water tanks are also very common [25]. Many of the lakes formed after the flooding of abandoned open-cast mines are toxic, threatening the safety of both humans and the ecosystem [26]. The Berkeley Pit in Montana (USA), 244 meters deep, is one of the largest bodies of contaminated water in the world. It is assumed that the Rum Jungle Lake in Australia, formed after the flooding of the uranium mine, and the world's largest - over 176 km^2 - Oil Sands lakes in Alberta province in Canada are an equally serious threat. All of the above should be taken into account when planning adaptation works aimed at adapting post-exploitation reservoirs for recreational purposes. The close proximity of hazardous wastes, despite the maintenance of far-reaching measures to prevent their penetration into the environment, will always pose a risk of contamination of surface water and groundwater.

2. Materials and Methods

In order to analyze the usefulness of anthropogenic reservoirs for recreation, an analysis of articles, focused on the conditions for the formation of anthropogenic reservoirs, covered by the Web of Science, Scopus, Google Scholar, ResearchGate, and similar databases was carried out. The literature review allowed for an analysis of the circumstances of the formation of the abiotic and biotic properties of the water environment and of the land surrounding such artificial structures, including the immediate coastal areas. The known tools used in the assessment of the water purity class were compiled in order to describe the process underlying the administration and use of artificial water bodies. During the database review, the most characteristic keywords, including the following phrases: anthropogenic water reservoir, recreation water quality, post mining lake, cyanobacterial toxins, and bathing beach, were used, artificial lake, management, recreation, biohazard. The key words were additionally verified on the basis of a long-term experience gained during the management of a recreational facility created after the extraction of oil sands (OWR Sosina) [27]. A generalized meta-analysis of the data was also applied to identify the most effective management practices and the optimal use of water reservoirs (recreational and economic) while maintaining the highest standards of safe use of bathing facilities. Specific descriptions of the features and qualitative elements of the specific structures of the construction of individual artificial basins, their size and characteristic of their functionality and development were extracted. An analysis of the literature on the subject was then carried out by adapting the problem in question to the existing knowledge and similarities and differences and their essential features discussed in the analyses of scientific literature were shown. Applying the principle of the consideration of components, the final process synthesizes the key issues covered in many publications separately.

2.1. Procedures for the Assessment of Reservoir Water Quality

The most common water quality testing methods use techniques that determine physicochemical properties using advanced spectroscopy, integrated water quality sensors, micro-flowmeters, and biosensors [28, 29]. Bioindication methods with the use of living organisms sensitive to specific substances or habitat conditions are used independently or in conjunction with the identification of physical and chemical parameters [30, 31]. One of the recent research trends is the assessment of the microbiological state of water using advanced molecular biology techniques, such as gene probes, which have undergone significant development in the last decade [32]. The most modern and promising water quality monitoring techniques related to the use of nanotechnology, i.e., the study of nanoparticles acting as sensors that react to given elements identified as pollutants, are also currently being introduced [33].

2.2. The Genesis of Anthropogenic Reservoirs

Anthropogenic reservoirs storing rainwater, surface water, or groundwater are most often created as a result of exploitation of energy resources, including subbituminous coal and lignite, rock resources - i.e., gravel, sand, granite, limestone, or metal ores - copper, iron, etc. In some parts of the globe, the density of anthropogenic reservoirs is very high (Fig.1). In the Netherlands, one of the smallest EU member states in terms of area (www.europa.eu), more than 500 lakes formed in quarries and gravel pits can be found at the meeting point of the Rhine and Meuse rivers. In Central Europe, within southern Poland, there is an area referred to as the Upper Silesian Anthropogenic Lake District comprising 4773 reservoirs with a total area of 6766 km^2 [34]. A similar concentration of anthropogenic reservoirs, mostly strongly acidified, is found in Germany - where more than 500 post-mining lakes have been identified - and Poland, in the area of former lignite mining [35, 36] According to Strzodka [37], East German post-mining lakes constitute the largest artificial lake district in Europe. In France, within the Massif Central, there are reservoirs resulting from coal mining [38]. In Spain, the residues of sulfide ore opencast mining in the Iberian Pyrite Belt include numerous lakes which, due to high acidification and metal pollution, cannot be used for recreational, agricultural, or industrial purposes [39]. In the south of the Czech Republic there are reservoirs after lignite mining and clusters of reservoirs used for fish farming [40], in the south of England numerous reservoirs (lakes, ponds, ditches, floodplains) were created in connection with agricultural activities, in Northern Austria mining lakes formed after the end of opencast lignite mining [41], and in southern Sweden several thousand pit lakes, resulting from opencast mines and quarries, where sulfides, limestone and clay, among others, were mined [42]. Anthropogenic (post-mining) reservoirs can also be found in Australia [43], the United States [44], Canada [45], northern Morocco [46], Kazakhstan [47], Tajikistan [48], or in Brazil [49]. In South Africa we can find one of the world's most famous post-mining reservoirs, the Big Hole, which was created by flooding the pit after the end of diamond mining in this area [50].

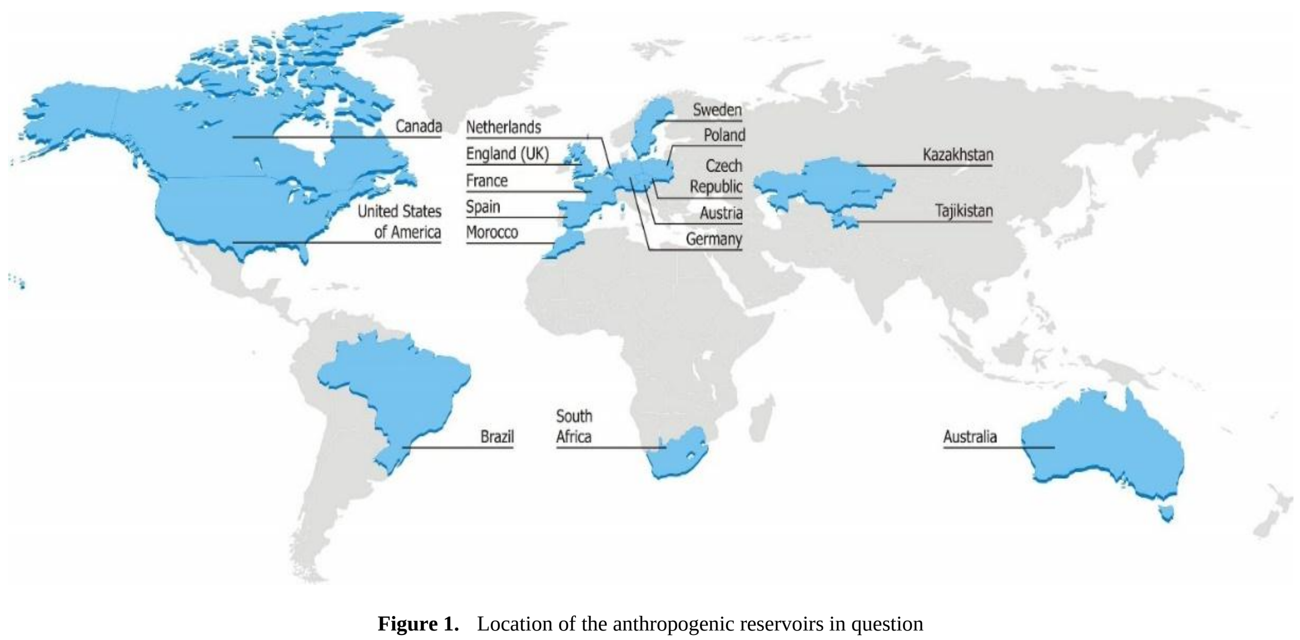

Figure 1. Location of the anthropogenic reservoirs in question

2.3. Adaptation of Anthropogenic Water Reservoirs

The end of exploitation is associated with the need to manage anthropogenic reservoirs so that the space obtained can serve the public as a place for tourism, recreation, or leisure, among other things. These activities are referred to as "revitalization" or bringing them back to life. The aim of revitalization is to create a renewed landscape, which should not only be in harmony with the environment, but also increase its diversity, enriching it ecologically. At the same time, the renewed landscape should not interfere with today's local and regional needs and should meet the needs of tomorrow. Revitalization activities should be well thought-out and carefully planned - also in financial terms - long before the decision to end the exploitation of a given raw material. This is important because a well-planned and carried out revitalization process can bring tangible benefits to both the local ecosystem and the inhabitants [51]. It often turns out that water reservoirs created after mining or industrial exploitation are organic-rich, offer a spectacular variety of flora and fauna, and are abundant in rare and protected species. Even small water reservoirs can be used economically and increase the aesthetic value of the landscape. They affect the species diversity of both plants and invertebrates [52, 53]. These reservoirs, as a result of the normalization of water relations, usually fill up spontaneously, and the natural succession of vegetation restores the dynamic ecological balance. Much larger reservoirs are created after opencast mining of natural resources, for example limestone, dolomite, lignite, sand, or sulfur. The possibilities of using these reservoirs are also changing. They can have many functions, such as water intakes for drinking or industrial purposes, fish breeding ponds, retention reservoirs, etc. Increasingly, they are used as recreational sites or are part of landscape compositions [54]. The common feature of water reservoirs of different origins is that they can be used for recreational and tourist purposes. In the literature, you can find many definitions of recreation and physical activity, depending on the age group, economic sector, or finally depending on a specific location [55]. Although there is no single, universal definition, one could say that recreation is a fully conscious, voluntary outdoor activity in nature, making use of its values, bringing satisfaction, relaxing, and unwinding, which we devote to pursuing our own needs, passions, and interests. Recreation may take many forms, but all of them strive to eliminate anxiety, tension, or frustration. Depending on the raw material extracted, the resulting workings vary in depth, bank structure, physical and chemical properties of the water. On the other hand, the nature of the excavated deposit has a direct impact on both the shape of the reservoir (bottom and bank system, depth) and the physical and chemical properties of the water. The information gathered in Table 1 shows these relationships and indicates that the greatest number of recreational activities is possible in anthropogenic reservoirs resulting from opencast mining of natural resources [56, 57, 58, 59].

Table 1. Types of anthropogenic reservoirs based on [56, 57, 58, 59].

Type of tailing pond	Characteristic features	Possible uses
Mines (porphyry, limestone, sandstone, ores) etc. (quarries)	- limited inflow and outflow of feedwater - steep, irregular shores - denudation of rock layers - possible high acidification of water - heavy metal content in water - possible salinity - susceptibility to landslides - no shallow coastal zone - possible high-water turbidity - limited light penetration to the lower parts of the water - deep workings	- sailing - snorkeling - bathing - wildlife conservation
Loose rock mining (sand pits, gravel pits, etc.)	- shallow depth (usually up to 5 m) - natural sandy or gravel bottom - risk of cyanobacterial occurrence - usually, a small area <50 ha - usually, no heavy metals in the water - shallower coastal zone - limited inflow and outflow of feedwater - "bowl" shaped reservoir	- bathing area - sailing - fishing - powerboating - other water sports - wildlife conservation - drinking water supply - fire protection water supply source - aquaculture
Opencast bituminous coal and lignite mines	- unstable walls - high heavy metal content - high pH acidity = - deep workings	- bathing - powerboating - other water sports - fire protection water supply source - fishing grounds - aquaculture

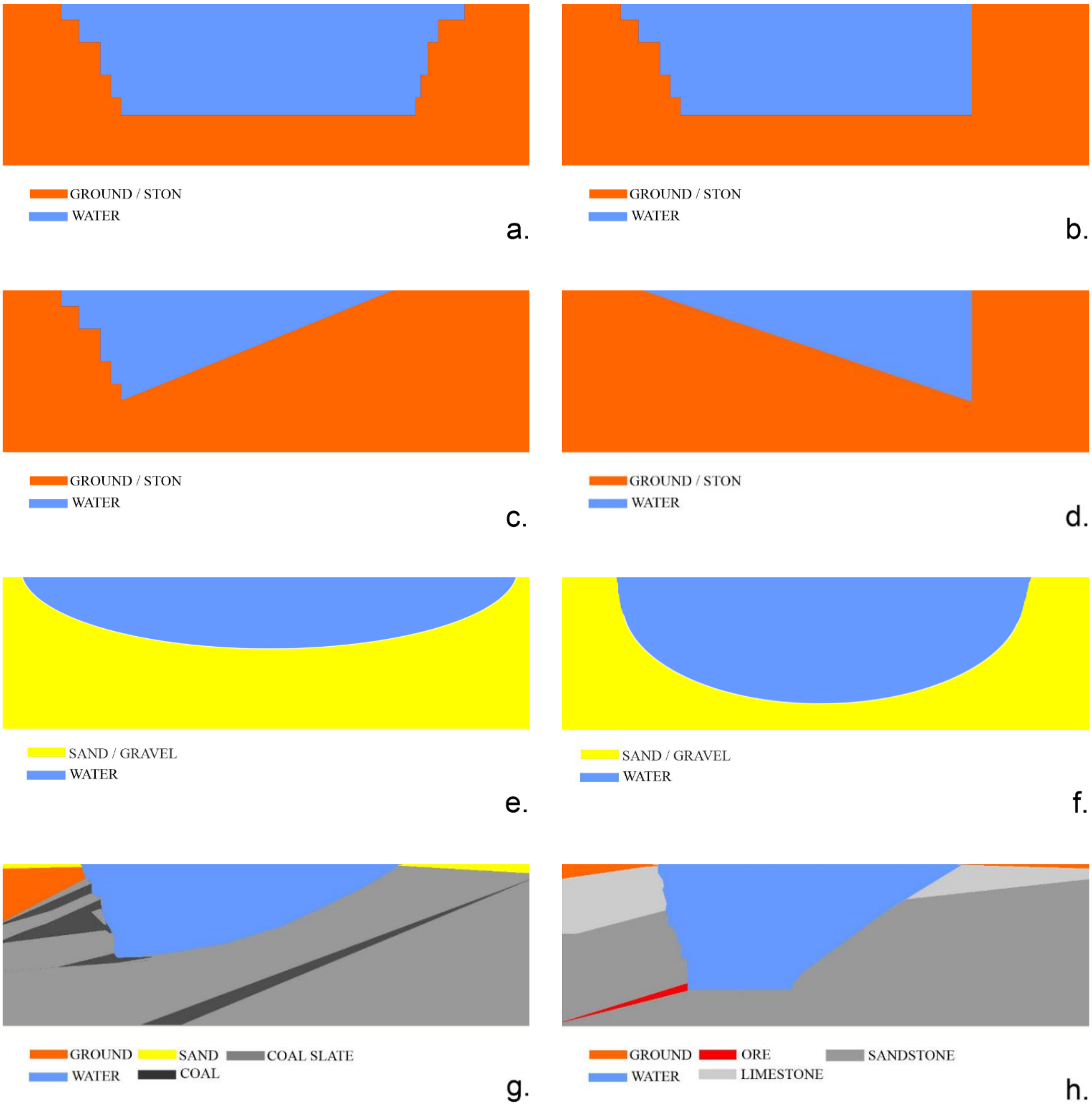

Figure 2. The cross sections illustrate the different slopes and slope lines of the banks to the water body depending on the type of post-mining pit (a,b,c,d - pits left over from the extraction of porphyry, limestone, etc., e,f - pits left over from the extraction of sand, gravel, etc., g - pits left over from the extraction of coal, h - pits left over from the extraction of ore)

2.4. Characteristics of Reservoirs Formed in Quarries

Post-mining reservoirs (of porphyry, limestone, and sandstone mines, etc.) are created as a result of flooding the excavation with groundwater, surface water or rainwater. Anthropogenic reservoirs created in such pits are characterized by a relatively large relative depth (Fig. 2 a,b,c,d), which usually causes a clear stratification of water. Thus, the chemical properties of water can vary significantly depending on the depth [60]. Metal ore mines can take many shapes - from oval, rectangular, to irregular. The common feature of all of them is that, regardless of their shape, they are much wider at the top and narrower at the bottom. Opencast diamond mines have more regular, cylindrical shapes. They are usually deep and shaped like a cone in a cross section. Their structure generally excludes a shallow coastal zone of the lake. [61].

The physicochemical properties of water between individual reservoirs in such a pit may differ significantly. This is both because of the different geological structures of these particular sites and the type and size of the catchment area. There are examples of artificial lakes where the water is heavily loaded with heavy metals and even naturally radioactive, which is directly related to the exploited raw material. Another factor that can occur in water bodies whose surroundings are made up of poorly permeable rock is salinity. This phenomenon occurs when evaporation exceeds groundwater inflow and precipitation. Sulphide ore deposits contain pyrite, which reacts with oxygen and water to form sulfuric acid, causing high acidification of water. A common solution to neutralize acid lakes is liming, which has been implemented on a large scale in Sweden since the 1970s. The main purpose of liming is to keep the pH of the water above 6 in order to protect existing flora and fauna and to allow new species to colonize. Similar treatments were carried out in 2006-2019 in the area of Lusatia (Germany), where over 266 kilotons of neutralizing agents, mainly quicklime and powdered limestone, were deposited in acidified lakes. Liming, however, has serious disadvantages. First of all, it cannot be a one-off action, but a continuous process, systematically spread over time. The second element, which can be an insurmountable obstacle, is the high cost of the process. According to estimates, EUR 20 million is spent each year on liming surface waters in Sweden [36, 62, 63]. Increased turbidity is a common feature of mine lakes, which is related to the rapid erosion of steep shorelines. Another reason for turbidity may be the oxidation of iron dissolved in water to hydrated iron oxide. It is in the form of a fine-grained substance which settles very slowly to the bottom due to gravity. High water turbidity can have negative consequences for photosynthesis due to the blocking of sunlight, essential for this process. And for many forms of aquatic life - especially fish - photosynthesis is essential for life.

The use of water reservoirs created in post-mining excavations of porphyry, limestone, sandstone, etc. largely depends on their physical and chemical properties while any technologies using artificial or natural biocenosis are difficult to implement. However, such artificial lakes can successfully fulfil new roles, such as recreational, which, if properly planned, can be a potential source of income. There are many examples of this type in the literature. A lake district in the Lusatia region (Germany) is currently being converted for public recreation and is expected to generate an income of 10-16 million euros per year for the local economy [64]. Examples of the conversion of a post-mining excavation site for recreational purposes include the year-round water park at the Shartashsky quarry in the Yekaterinburg region, the Tangua Park in Brazil, or the Zakrzówek and Kryspinów quarries in the Kraków area in southern Poland. An important element of the quarry revitalization process is to plan it in advance, and to diagnose the needs and possibilities of the local environment (both society and the natural environment) in seeking the best possible harmonization with the surroundings. When adapting the pit for recreational purposes, different forms of recreation - active and passive - should be taken into account, and thus different zones should be organized: beach, active recreation (playing fields, marinas) and quiet recreation (walking, fishing) [65]. The post-mining excavations lack infrastructure, which is necessary if the site is to be used for recreational purposes. This includes not only infrastructure directly related to water and water-based activities (bathing area, beach) but also communication routes, car parks, access to electricity, drinking water, sewage systems, catering facilities, or greenery arranged around the reservoir. The discussed reservoirs can also be used for industrial processes (irrigation, industrial water source) or as a water source for livestock (aquaculture). In some cases, when the physico-chemical quality of the water does not meet the basic criteria for water for a specific purpose, water treatment tools are necessary [55]. However, this involves additional financial resources and the need for more frequent water quality monitoring and biotope intervention.

2.5. Characteristics of Reservoirs Formed after the Exploitation of Rock Resources such as Sand, Gravel, etc.

The depth of water reservoirs created in sand and gravel excavations can vary greatly and is usually related to the thickness of the geological layer of the raw material in question. There are shallow floodplains with depths of less than 3 meters, medium floodplains oscillating between 7-12 meters, and deep floodplains with depths up to 60 meters [66, 67]. The depth of the excavation is also related to the construction of the banks of the floodplain and consequently to the accessibility for people. Shallow reservoirs are characterized by a gradual, gentle descent to the bottom of the excavation, which later, when such a reservoir is used for recreation, definitely facilitates the creation of accompanying infrastructure (bathing sites, beach, piers) Fig. 2 e. In contrast, deep reservoirs characterized by steep edges, irregular bottoms and cold-water inflow can be dangerous for users Fig. 2 f. The sand pits usually had a geometric profile with a fairly flat bottom and slopes, which were often characterized by a stepped descent due to the fact that the extraction of the raw material was carried out on several (2-4) levels. The development of the open pits has resulted in a strong disturbance of groundwater levels, which have fallen by several tens of meters, as well as changes to riverbeds, which have moved up to several kilometers. During the reclamation period, work focused on creating the slopes and bottoms of the future reservoirs as well as introducing vegetation around the banks. The banks of bathing areas gently descend into the water [68]. Sand and gravel deposits are characterized by high permeability and therefore lakes created in such excavations generally allow a significant exchange of surface water with groundwater. The geological substrate and direct connections to surface water and groundwater have a decisive influence on the physico-chemical properties of water in pits resulting from sand and gravel exploitation. The quality of water in different, even nearby reservoirs, can be significantly different. A comparative study of 51 lakes in the Netherlands and 35 lakes in Denmark showed that water from gravel lakes has better properties than water from shallow natural reservoirs in close proximity. They were of good chemical and biological quality, contained low nutrient concentrations and abundant macrophytes that differed in species from those found in natural lakes [69]. Taking into account that sand and gravel are generally chemically inert raw materials, the immediate surroundings of the reservoir and its catchment area will have the greatest impact on the physico-chemical properties of the water stored there. Due to the fact that the excavation walls are free from contamination typical of metal workings, the water in sandy or gravel lakes may have relatively good quality water, although it is not a rule when looking at the lakes formed after sand extraction in the Sepetiba basin (Brazil), which are characterized by acidic water [70]. However, it is worth noting that often such water bodies are located on fairly flat flood plains, so the water inflow to them is limited compared to natural lakes with steeper catchments. The exceptions are workings located in the vicinity of lakes or rivers, which will usually have an inflow and outflow. In most cases, however, the artificial lakes created in such pits are hydrologically isolated from surface waters [67]. The depth of mining activities has a direct impact on the pattern of adjacent aquifers, resulting in a strong groundwater influence on the resulting reservoir. In contrast to natural lakes, groundwater quality is crucial for the water quality in such post-mining reservoirs [71]. Some of the reservoirs are deep enough to clearly divide them into water layers that differ in temperature [72]. Their structure - steep banks, a very small coastal zone and the frequent absence of a swamp zone - have a large impact on the ecosystem of the entire lake, as the water exchange between the coastal and pelagic zones is very limited [73]. It was observed that reservoirs with large hypolimnion are much less prone to eutrophication than shallow reservoirs where the water is completely mixed [74].

After finishing the exploitation of sand or gravel, the lakes created in the former excavations can be used for recreational purposes such as water sports, fishing, but can also be potential reservoirs of drinking water. Some reservoirs have a large surface area, which makes them ideal for sailing, windsurfing or, in areas where motorboats are allowed, water skiing [66, 75]. The designation of these facilities for recreational purposes must not only be part of the approved reclamation project for the pit in question, but must result in a series of preparatory works necessary to provide adequate infrastructure for the inhabitants One of the priorities when planning new functions of such places should be to ensure safety for future users by designating bathing areas, providing beaches, a safe coastline, fishing stands, and finally accompanying infrastructure - catering outlets, parking lots, and communication routes [53]. Another way to use post-mining lakes is to organize fish farming that would have good living conditions in relatively clean sand and gravel waters.

2.6. Characteristics of Flooded Areas Resulting from the Abandonment of Opencast Mining of Bituminous Coal and Lignite

Opencast coal mines (Fig. 2 g) are not as deep as metal ore mines (Fig. 2 h). The raw material is extracted linearly in a certain direction. The excavation deepens as the work progresses. The access roads to the bottom of the pit do not run spirally along the walls of the excavation but descend linearly. After mining, the excavation is usually characterized by a clear linear pattern and, at least on one side, a gradual descent of the excavation towards the bottom of the pit can be observed [61]. Coal workings (Fig. 2 g) are characterized by quite steep banks with a very high angle of inclination, which significantly affects the shaping of the coastal zone (littoral). In many cases, the coastal zone is virtually absent, which directly affects the quantity and quality of coastal vegetation. The size of the water reservoirs created in opencast coal mines varies greatly; their surface area is often above 500 hectares. In terms of surface area, the post-mining lakes in the North Bohemian Brown Coal Basin compete with the largest natural and anthropogenic reservoirs in the Czech Republic (they are over 1 000 ha, the largest one is 1 300 ha). Such a large area creates the need to protect the shoreline against erosion caused by waves. Due to the large area, the pits will fill up with water relatively slowly, forcing the shores to be protected as the water table rises [76].

Bituminous coal and lignite, as well as the geological environment of the deposition, are not chemically inert and have a significant impact on the water that fills the excavation pit after the end of the exploitation. Coal mining often results in acidic mine drainage. Typically, pyrite (FeS2) is deposited in the walls of coal workings, which, when in contact with atmospheric oxygen and water, produces sulfuric acid, directly affecting water quality [50]. Chemical analysis of water from lakes formed in residual pits after coal mining shows that they are usually contaminated with heavy metals such as iron, cadmium, aluminum, lead, or nickel, or with metalloids - arsenic, selenium, or antimony. pH is a very important parameter, as the activity of metals and metalloids is very strongly dependent on its value [77, 78]. Strongly acidified reservoirs (pH <4) usually have high concentrations of cationic trace metals (Al3+, Cu2+, Fe2+). In waters with low pH, the predominant anion is sulphate (SO42- or $HSO4^-$). Reservoirs with near neutral pH tend to have low concentrations of cationic trace metals and may contain significant amounts of bicarbonate ($HCO3^-$) in addition to dissolved sulphate. Alkaline reservoirs may have significantly elevated metalloids (As/Se) present in the form of dissolved anions such as HAsO42- or SeO42- [79]. Water reservoirs in former coal workings are formed under rather difficult conditions (geochemical environment and physical structure of the workings) which means that they are usually characterized by lower biological activity during their initial period of existence. The development of a biotope is mainly influenced by the chemical factors in the reservoir, such as metal concentration, water pH, water clarity and nutrient levels [80, 81].

Opencast mining drastically affects almost every area of the environment. Flora and fauna, soil, air, and water - all these elements are negatively affected by mining activities, and hundreds of degraded hectares of land pose a serious challenge to the reclamation process. With the use of appropriate solutions for the neutralization of heavy metal-contaminated soils and water in the pit, it is possible to restore the degraded areas to life and for use by the local community [82]. Flooded excavations after coal mining can fulfill three basic functions: serve as a refuge for wildlife, for active and passive recreation, or constitute a fish breeding area. The specific structure of the reservoirs - including steep cliffs and a very limited coastal zone - means that not all species of flora and fauna will find suitable conditions there. The growth rate and range of aquatic macrophytes will also be limited [83]. A common way to use flooded post-mining pits is to transform them into fishing grounds. This requires a number of preparatory works, not only because of the need to ensure the quality of the water itself, but also because of the need for adequate stocking of the reservoir in question [84]. By recreational use of the reservoir, we mean both active recreation (e.g., using water equipment, swimming) and passive recreation (e.g., sunbathing). If the reclamation process succeeds in bringing the water up to current standards for recreational purposes (bathing), it will be completely safe to use the lake. If the physicochemical quality of the water is poor, then recreation can only take place in the area adjacent to the water surface [85]. It is important to remember that while water quality is the biggest concern and challenge in this type of reservoir, other factors affecting user safety such as steep and high banks, and possible great water depth should not be overlooked [86]. Therefore, the use of post-mining water reservoirs as fire protection or retention reservoirs should be considered. The high acidity and metal content prevent the water from being used as drinking water [87].

2.7. Management of Anthropogenic Reservoirs Used for Recreational Purposes

The management of a water reservoir for recreation involves a number of processes related to ensuring both good water quality that meets the standards set by law and a number of activities related to providing infrastructure in the vicinity of the reservoir, which are not strictly defined by law but belong to a broad catalogue of so-called good management practices. It should be borne in mind that many human activities aimed at improving accompanying infrastructure or facilitating leisure and recreation, such as roads, hotels, marinas, catering facilities, can have a negative impact on the environment. Good management of recreational water bodies is primarily intended to reduce the risk of negative impacts of recreation on the environment, which will occur when the level of human use of the environment is greater than the capacity of the environment to cope with that usen [88]. It should not be forgotten that the best management of the water body itself may not be sufficient, as it is also influenced by external factors such as water levels in the catchment area, over which basin managers have little or no control [8].

The efficiency and effectiveness of the management of water reservoirs also depend on the knowledge and understanding of biological interactions taking place in the water. For many years, one of the biggest problems faced by managers of recreational water bodies has been their eutrophication, i.e., excessive enrichment with nutrients, mainly nitrogen and phosphorus [89, 90, 91]. There is a view in the literature that eutrophication is one of the main problems related to water quality [92, 93]. This can lead to a number of harmful biological processes, including excessive algal blooms, which not only affect the appearance and smell of the water but can also result in toxic cyanobacteria blooms [94, 95]. These processes can cause not only serious environmental and social impacts (fish deaths or human poisoning) but also economic ones. Economic losses related to water eutrophication may result, among others, from the lack of recreational use of water, loss of value of the areas adjacent to the lake, and the costs of combating toxic blooms. In the United States, economic costs associated with eutrophic waters are estimated to be $2.2 billion per year and in Australia $150-250 million per year [89]. The prevailing view is that shallow waters are more vulnerable (to eutrophic conditions) than deep reservoirs due to the lack of thermal stratification of the water during the summer months. Both artificial and natural deep lakes, which become thermally stratified in summer, act as nutrient reservoirs and do not form dangerous suspended solids [96]. For managers of recreational water reservoirs, the key element is therefore to control and effectively manage the inflow of external nutrients, which boils down to monitoring potentially dangerous sources, such as: runoff from agricultural areas or discharge of sewage [97, 98]. It has been calculated that, on average, each swimmer or bather contributes 0.094 g P per day to the water body [88]. The excessive enrichment of these waters in nitrogen, both from the users themselves and from watercourses and groundwater, especially in the vicinity of agricultural land, is also becoming a problem.

Scientists analyzing the human impact on the aquatic environment remind us that the bathers themselves pose serious risks to themselves. It should be borne in mind that bacteria carried by humans, including Escherichia coli, faecal streptococci, Pseudomonas aeruginosa, as well as yeasts and fungi, may pose a potential risk to others. One of the primary responsibilities of recreational water body managers is the continuous microbiological monitoring [99] of water. This is the way to avoid many gastrointestinal and respiratory diseases and skin infections [100]. The shoreline is also often thoughtlessly trampled and degraded by beachgoers, the coastal vegetation is destroyed, as are the breeding grounds of birds. Reservoir managers tend to modify the shoreline too much, so that it no longer resembles its original form [88]. However, it is important to take care of good quality sand on the beach, as numerous studies have shown that it can contain high concentrations of faecal pathogens, pathogenic bacteria, viruses, parasitic nematodes [101], and solid elements that cause minor injuries. Although this is a major concern for water reservoir managers, there are currently no standards for monitoring, sampling, analyzing, or managing beach sand quality [102].

One of the most popular forms of activity at reservoirs is recreational fishing. It is estimated that 10 to 12 percent of the world's population engages in this form of recreation worldwide [103, 104]. For managers of water reservoirs, especially those actively used for recreational fishing, it is very important to determine how many anglers will be fishing at once. This is crucial for determining the stocking level of a given water body, and thus for controlling the fishing economy and the environmental impact of fishing [105, 106]. It is important whether fishing takes place from vessels, piers or directly from the shore, because anglers' preferences and expectations force the managers of water reservoirs to build appropriate infrastructure and, of course, each of these forms of angling may have a negative impact on the environment. Boating or wandering around the shore can disturb coastal habitats, boats with engines can generate too much noise and too high waves, and baits thrown into the water or rubbish left behind can adversely affect the physical and chemical quality of the water itself [107].

3. Results and Discussion

Anthropogenic reservoirs differ in their genesis and potential for later use. Examples of anthropogenic reservoirs and their use can be found in the literature. The selected examples of the use of anthropogenic reservoirs are presented in Table 1. Due to the exploitation method, the relative chemical neutrality of the sand and the physical and chemical properties of the water filling the pit, which to a large extent reflects the properties of water from the surroundings and the catchment area, post-sand excavations are widely used as recreational sites. Of course, the exploitation of sand (as well as any other raw material) has a negative impact on the environment, but researchers also point out the benefits that can arise from this activity. One such benefit is the creation of new water reservoirs that can function as drinking water reservoirs or recreational reservoirs [108]. It is perfectly understandable that not all opencast sand mines are converted into water bodies after the mining process is completed. The reclamation depends on several factors, including, inter alia, lithological, and genetic parameters of the underlying formations, their physical and chemical properties, relief and, finally, water conditions. It is important for the managers of such water reservoirs to meet all the legal and organizational requirements for reservoirs intended for recreation (including bathing), above all with regard to the physical and chemical safety of the water. However, the literature points out that people who use water actively (bathing or participating in water sports) pay a lot of attention to the aesthetic effects of water - its color, turbidity, or transparency - which for them are the main determinants of water quality. They are not able to verify its physico-chemical properties, but recognize that if the water is clean, clear, and odorless, it is fit for recreation [109]. In the case of regular, gently sloping coastlines, it does not require much preparation to establish safe bathing places. The lakes created on the area of former sand exploitation, with relatively uncomplicated preparatory works, may become naturally valuable and attractive recreation places from the point of view of inhabitants. Anthropogenic reservoirs intended for recreation require not only care for good water quality, but also proper preparation of the adjacent terrain. It is necessary to systematically clean the sand of physical impurities - garbage, cigarette butts, leaves, etc. These activities, in turn, require the owners or managers of water reservoirs to secure adequate financial resources, which means that these activities should be designed and planned in advance [110]. It seems that an important aspect of water protection is that when planning the use of a reservoir for recreational purposes, the arrangement and layout of the various functional zones should be properly planned: recreational (beach and bathing area), sports (sports fields), services (catering, accommodation), parking, landscape, etc. It is also necessary to develop a network of sanitary facilities for the lake users so that they do not contribute to the deterioration of water quality by urinating into water. When creating these facilities, the needs and expectations of different users should be taken into account, taking into account their age or degree of disability [66]. The development of recreation infrastructure, not only the one directly in contact with the water reservoir, but also the one located at a distance, corresponds to the definition of water-based tourism, which also takes place in the areas surrounding the lakes [111]. It is also necessary to set the daily visitor limits, in other words to determine how many people can simultaneously use various forms of recreation without causing damage to the aquatic environment and terrestrial ecosystems, and what form of activity may cause threats to the water body (e.g., using boats with internal combustion engines). The periods of maximum environmental load, when the risk of water contamination is the highest, and the periods of occasional use, when human activity is unlikely to have a negative impact on the environment, should be taken into account [112]. The maximum number of boats with internal combustion engines, motorboats and jet-skis that can travel on the water body at the same time should be determined. Exceeding the maximum number of boats not only causes a direct danger to other users, such as those who bathe or engage in other water sports but can also adversely affect the parameters of water (fuel and oil spills), near-shore and shore area [113]. Waves generated by motorboats, which depending on speed range from a few to several dozen centimeters, can significantly accelerate shoreline erosion and also affect submerged and surface macrophytes by physically damaging them (propellers and hulls) or affecting them by generating increased water turbidity. Based on the above considerations, Table 2 presents criteria for water bodies formed after surface mining operations for their suitability for recreational purposes. The basic information shown in the table should be collected and considered by future administrators before they begin to adapt and operate the facility.

4. Conclusions

Based on the database review, typical anthropogenic water reservoirs were analyzed. Information was collected on their structure, general properties, and the possibility of using them for recreational purposes. This paper provides a compendium of knowledge, useful for both administrators and users of the discussed facilities. The individual elements of the considered problem related to the economic potential of recreational use of anthropogenic reservoirs were analyzed and synthesized. Artificial floodplains or lakes created in urban and industrial areas as a result of open-cast mining activities were discussed. The scope of the knowledge and topics covered is large, there is a lot of information in one place, and the paper provides a compressed compendium of essential facts.

Table 2. Basic criteria for a post-mining reservoir and its surroundings for recreational purposes

Suggested review of the facility's qualifying values for recreational use prior to adaptation:		**Notes:**
Surrounding	- current land use	- access to road infrastructure, public transport.
Surrounding	- planned land development	- analyze the possibility of development of communication infrastructure - evaluate the accessibility of the site taking into account the topography of the terrain
Surrounding	- capacity of the facility	- determine the amount of floatation equipment and the number of users who can safely stay at the facility
Surrounding	- identification of biological life	- occurrence of plants and animals, including protected and endangered species
Water	- determination of chemical composition - pH determination - visual color assessment - limpidness - degree of opacity - scent	- Necessary physical and chemical tests must be conducted before a decision is made to use the reservoir for recreational purposes
Water	- identification of aquatic biological life	- occurrence of aquatic plants and animals and phytoplankton, including protected and endangered species
Geological structure and location of the reservoir	- shoreline falling gently	- in places of planned beaches, the slope of the ground going down to the bottom of the reservoir from the shoreline should not be stepped
Geological structure and location of the reservoir	- sandy areas	- can be planned under the organization of natural beaches
Geological structure and location of the reservoir	- geology	- assess the impact of surrounding rocks and remnants of human activity on the potential for contamination of the environment and the waters of both the catchment and the reservoir
Geological structure and location of the reservoir	- catchment area	- evaluate the influence of tributaries and underground supply of water to the reservoir on its quality
Economical	- evaluate the cost of maintaining the facility and good water quality in the reservoir	- take into account the costs of maintenance of sanitary infrastructure, service, waste disposal, energy costs

The origin of a water reservoir is of great importance in terms of its operation, maintenance costs, and methods of combating or preventing threats resulting from natural and anthropogenic conditions. The influence of such factors as the geological structure of the catchment area, the type of tributaries, and the possibility of water outflow is of crucial importance, yet often overlooked, for the caretakers of recreational facilities. Water reservoirs in former sand or gravel pits, although they are relatively young ecosystems, can be important for biodiversity protection and recreation. They can also pose a serious threat to biological and human life through the accumulation and re-emission of harmful pollutants.

REFERENCES

[1] Cassardo C, Antony J, Jones A. 2011. Managing Water in a Changing World. Water. vol. 3, pages 618-628.https://doi.org/10.3390/w3020618

[2] Jackson R, Carpenter S, Dahm C, McKnight D, Naiman R, Postel S, Running S. 2001. Water in Changing World. Ecological Applications, vol. 11, pages 1027-1045. https://doi.org/10.1890/1051-0761(2001)011[1027:WIACW]2.0.CO;2

[3] McDonalds C, Rover J, Stets E, Striegl R. 2012. The regional abundance and size distribution of lakes and reservoirs in the United States and implications for estimates of global lake extent. Limnology and Oceanography, vol. 57, pages 597-606. https://doi.org/10.4319/lo.2012.57.2.0597

[4] Seekell D, Pace M, Tranvik L, Verpoorter Ch. 2013. A fractal‐based approach to lake size‐distributions. Geophysical Research Letters, vol. 40, pages 517-521. https://doi.org/10.1002/grl.50139

[5] Ringler C, Karelina Z, Pandya-Lorch R. 2011. Emerging Country Strategies for Improving Food Security: Linkages and Trade-Offs for Water and Energy Security. Bonn 2011 Conference: The Water, Energy, and Food Security, Nexus, Bonn, Germany, 17 Nov. http://www.fewlbnexus.uct.ac.za/sites/default/files/image_tool/images/91/Ringler%20et%20al.%202011_emerging_country_strategies_for_improving_food_security.pdf

[6] Wang X, Zhang J, Shahid S, Guan E, Wu Y, Gao J & He R. 2016 Adaptation to climate change impacts on water demand. Mitig Adapt Strateg Glob Change, vol. 21, pages 81-99. DOI: 10.1007/s11027-014-9571-6.

[7] Williams J, Ryan B. 2003. A National Survey of Water-Based Leisure Activities in Ireland. www.esri.ie/pubs/BKMNEXT62.pdf (dostęp 28.12.2020, godz. 23.20).

[8] Breen B, Curtis J, Hynes S. 2018. Water quality and recreational use of public waterways. Journal of Environmental Economics and Policy, vol. 7, page 1-15.

[9] Dorevitch S, DeFlorio-Barker A, Jones R, Liu L. 2015. Water Quality as a Predictor of Gastrointestinal Illness Following Incidental Contact Water Recreation. Water Research, 2015, vol. 83, pages 94-103. https://doi.org/10.1016/j.watres.2015.06.028

[10] Lee L, Lee Y. 2015. The Impact of Water Quality on the Visual and Olfactory Satisfaction of Tourists. Ocean and Coastal Management, vol. 105, pages 92-99. https://doi.org/10.1016/j.ocecoaman.2014.12.020

[11] Völker S, Kistemann T. 2011. The Impact of Blue Space on Human Health and Well-Being-Salutogenetic Health Effects of Inland Surface Waters. International Journal of Hygiene and Environmental Health, vol. 214, pages 449-460. https://doi.org/10.1016/j.ijheh.2011.05.001

[12] Zhong S, Geng Y, Qian Y, Chen W, Pan H. 2019. Analyzing ecosystem services of freshwater lakes and their driving forces: the case of Erhai Lake, China. Environmental Science and Pollution Research, vol. 26, pages 10219-10229. DOI: 10.1007/s11356-019-04476-9

[13] Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC Official Journal of the European Union, L 64/37, 4.3.2006.

[14] Fujioka R, Solo-Gabriele H, Byappanahalli M, Kirs M. 2015. U.S. Recreational Water Quality Criteria: A Vision for the Future. International Journal of Environmental Research and Public Health, vol. 12, pages 7752-7776. doi:10.3390/ijerph120707752

[15] Briciu-Burghina C, Heery B, Duffy G, Brabazon D, Regan F. 2019. et al.: Demonstration of an optical biosensor for the detection of faecal indicator bacteria in freshwater and coastal bathing areas. Analytical and Bioanalytical Chemistry, vol. 411, pages 7637-7643. Doi.org/10.1007/s00216-019-02182-6.

[16] Barnett M, Jackson-Smith D, Heaffner M. 2018. Influence of recreational activity on water quality perceptions and concerns in Utah: A replicated analysis. Journal of Outdoor Recreation and Tourism, vol. 22, pages 26-36. DOI: https://doi.org/10.1016/j.jort.2017.12.003

[17] Heaney D, Sams E, Wing S, Marshall S, Brenner K, Dufour A, Wade T. 2009. Contact With Beach Sand Among Beachgoers and Risk of Illnes. American Journal of Epidemiology, vol. 170, pages 164-172. https://doi.org/10.1093/aje/kwp152

[18] Vogel C, Rogerson A, Schatz S, Laubach H, Tallman A, Fell J. 2007. Prevalence of yeasts in beach sand at three bathing beaches in south Florida. Water Research, 2007, vol. 41, pages 1915-1920. DOI: 10.1016/j.watres.2007.02.010

[19] Kelly E, Feng Z, Gidley M, Sinigalliano Ch, Kumar N, Donahue A, Reniers A, Solo-Gabriele H. 2018. Effect of beach management policies on recreational water quality. Journal of Environmental Management, vol. 212, pages 266-277. https://doi.org/10.1016/j.jenvman.2018.02.012

[20] Schiff K, Weisberg S, Dorsey H. 2001. Microbiological Monitoring of Marine Recreational Waters in Southern California. Environmental Auditing, vol. 27, pages 149-157. DOI: 10.1007/s002670010140

[21] McPhail C, Stidson R. 2009. Bathing water signage and predictive water quality models in Scotland. Aquatic Ecosystem Health and Management, 2009, vol. 12, pages

183-186. https://doi.org/10.1080/14634980902907540

[22] Higgs E. 2017. Novel and designed ecosystems. Restoration Ecology, vol. 25, pages 8-13.

[23] Seelen L, Teurlincx S, Bruinsma J, Huijsmans T, Donk E, Lurling M, de Senerpont Domis L. 2021. The value of novel ecosystems: Disclosing the ecological quality of quarry lakes. Science of Total Environment, vol. 769. https://doi.org/10.1016/j.scitotenv.2020.144294

[24] Absalon D, Matysik M, Woźnica A, Łozowski B, Jarosz W, Urbańczyk R, Babczyńska A, Pasierbiński A. 2020. Multi-Faceted Environmental Analysis to Improve the Quality of Anthropogenic Water Reservoirs. Sensors MDPI, vol. 20, 2626. https://doi.org/10.3390/s20092626

[25] Gaidin A. 2011. Transformation of Quarries to Lakes. Russian Meteorology and Hydrology, vol. 37, pages 485-494. DOI: 10.3103/S1068373912070084

[26] Blanchette M, Lund M. 2016. Pit lakes are a global legacy of mining: an integrated approach to achieving sustainable ecosystems and value for communities. Current Opinion in Environmental Sustainability, vol. 23, pages 28-34. https://doi.org/10.1016/j.cosust.2016.11.012

[27] Zielonka-Hałczyńska A. 2021. Miejskie Centrum Kultury i Sportu w Jaworznie, Od ponad pół wieku… https://mckis.jaworzno.pl/od-ponad-pol-wieku/ (Accessed 14 February 2022).

[28] Kessler A, Ostfeld A, Sinai G. 1998. Detecting accidental contaminations in municipal water networks. Journal of Water Resources and Planning Management, vol. 124, pages 192–198. https://doi.org/10.1061/(ASCE)0733-9496(1998)124:4(192)

[29] Lagarde F, Jaffrezic-Renault N. 2010.Cell-based electrochemical biosensors for water quality assessment. Analytical and Bioanalytical Chemistry, vol. 400, pages 947-964. DOI: 10.1007/s00216-011-4816-7

[30] Gnyubkin V. 2009. An early warning system for aquatic environment state monitoring based on an analysis of mussel valve movements. Russian Journal of Marine Biology, vol. 35, pages 431-436.

[31] Bernd A. Markert, Anton M. Breure, Harald G. 2003. Zechmeister, Chapter 1 Definitions, strategies and principles for bioindication/biomonitoring of the environment, Trace Metals and other Contaminants in the Environment, Elsevier, Volume 6, Pages 3-39, https://doi.org/10.1016/S0927-5215(03)80131-5.

[32] Boehm A, Soller J. 2020. Refined ambient water quality thresholds for human-associated fecal indicator HF183 for recreational waters with and without co-occurring gull fecal contamination. Microbial Risk Analysis, vol. 16. https://doi.org/10.1016/j.mran.2020.100139

[33] Prosposito P, Burratti L, Venditti I. 2020. Silver Nanoparticles as Colorimetric Sensors for Water Pollutants. Chemosensors MDPI, 8,26. https://doi.org/10.3390/chemosensors8020026

[34] Rzętała M, Jaguś A. 2012. New lake district in Europe: origin and hydrochemical characteristics. Water and Environmental Jaournal, vol. 26, pages 108-117. https://doi.org/10.1111/j.1747-6593.2011.00269.x

[35] Duis K, Oberemm A. 2001. Aluminium and calcium — Key factors determining the survival of vendace embryos and larvae in post-mining lakes? Limnologica, vol. 31, issue 1, April 2001, Pages 3-10 https://doi.org/10.1016/S0075-9511(01)80040-2

[36] Nixdorf B, Krumbeck H, Jander J, Beulker C. 2003. Comparison of bacterial and phytoplankton productivity in extremely acidic mining lakes and eutrophic hard water lakes. Acta Oecologica, vol. 24, pages 281-288. https://doi.org/10.1016/S1146-609X(03)00031-6

[37] Strzodka M, Claus R, Preuss V, Thurmer K, Viertel K. 2016. Advanced treatment of pit lakes using limestone and carbon dioxide. Proceedings International Mine Water Association (IMWA). https://www.imwa.info/docs/imwa_2016/IMWA2016_Strzodka_155.pdf

[38] Denimal S, Bertrand C, Mudry J. 2005. Evolution of the aqueous geochemistry of mine pit lakes – Blanzy–Montceau-les-Mines coal basin (Massif Central, France): origin of sulfate contents; effects of stratification on water quality. Applied Geochemistry, vol. 20, pages 825-839. https://doi.org/10.1016/j.apgeochem.2004.11.015

[39] Espana J, Pamo E, Pastor E, Ercilla M. 2008. The acidic mine pit lakes of the Iberian Pyrite Belt: An approach to their physical limnology and hydrogeochemistry. Applied Geochemistry, vol. 23, pages 1260-1287. https://doi.org/10.1016/j.apgeochem.2007.12.036

[40] Pokorny J, Hauser V. 2002. The restoration of fish ponds in agricultural landscapes. Ecological Engineering, vol. 18, pages 555-574. https://doi.org/10.1016/S0925-8574(02)00020-4

[41] Moser M, Weisse T. 2011. The most acidified Austrian lake in comparison to a neutralized mining lake. Limnologica, vol. 41, pages 303-315. doi:10.1016/j.limno.2011.01.002

[42] Mantero J, Thomas R, Holm E, Raaf C, Vioque I, Ruiz-Canovas C, Garcia-Tenorio R, Forssell-Aronsson E, Isaksson M. 2020. Pit lakes from Southern Sweden: natural radioactivity and elementary characterization. Scientific Reports, vol. 10. https://doi.org/10.1038/s41598-020-70521-0

[43] Mudd G, Petterson J. 2010. Continuing pollution from the Rum Jungle U–Cu project: A critical evaluation of environmental monitoring and rehabilitation. Environmental Pollution, vol. 158, pages 1252-1260. https://doi.org/10.1016/j.envpol.2010.01.017

[44] Tucci N, Gammons Ch. 2015. Influence of Copper Recovery on the Water Quality of the AcidicBerkeley Pit Lake, Montana, USA Environmental Science & Technology, vol. 49, pages 4081-4088. https://doi.org/10.1021/es504916n

[45] Giesy J, Anderson J, Wiseman S. 2010. Alberta oil sands development. Proceedings of the National Academy of Sciences of the United States of America (PNAS), 2010, vol. 107, pages 951-952. https://doi.org/10.1073/pnas.0912880107

[46] Hakkou R, Benzaazoua M, Bussiere B. 2016. Valorization of phosphate waste rocks and sludge from the Moroccan phosphate mines: Challenges and perspectives. Procedia Engineering, vol. 138, pages 110-118. https://doi: 10.1016/j.proeng.2016.02.068

[47] Salbu B, Burkitbaev M, Stromman G, Shishkov I, Kayukov P, Uralbekov B, Rosseland B. 2013. Environmental impact assessment of radionuclides and trace elements at the Kurday U mining site, Kazakhstan. Journal of Environmental Radioactivity, vol. 123, pages 14-27.

[48] Skipperud L, Stromman G, Yunusov M, Stegnar P, Uralbekov B, Tilloboev H, Zjaajev G, Heire L, Rosseland B, Salbu B. 2013. Environmental impact assessment of radionuclide and metal contamination at the former U sites Taboshar and Digmai, Tajikistan. Journal of Environmental Radioactivity, vol. 123, pages 50-62. https://doi.org/10.1016/j.jenvrad.2012.05.007

[49] Ferrari C, de Azevedo H, Wisniewski M, Rodgher S, Roque S, Nascimento M. 2015. An Overview of an Acidic Uranium Mine Pit Lake (Caldas, Brazil): Composition of the Zooplankton Community and Limnochemical Aspects. Mine Water Environmental, vol. 34, pages 343-351. DOI 10.1007/s10230-015-0333-9

[50] Molenda T, Ciupa T, Suligowski R. 2020. The properties of reservoir water in post mining excavations of Cambrian and Devonian quartzite sandstones (Holy Cross Mountains). Environmental Earth Sciences, vol. 79. https://doi.org/10.1007/s12665-020-09054-8.

[51] Soni A, Mishra B, Singh S. 2014. Pit lakes as an end use of mining: A review. Journal of Mining and Environment, vol. 5, pages 99-111. https://doi.org/10.22044/jme.2014.326

[52] Kadoya T, Akasaka M, Aoki T, Takamura N. 2011. A proposal of framework to obtain an integrated biodiversity indicator for agricultural ponds incorporating the simultaneous effects of multiple pressures. Ecological Indicators, vol. 11, pages 1396-1402. https://doi.org/10.1016/j.ecolind.2011.03.001

[53] Oertli B, Joye D, Castella E, Juge R, Does, Cambin D, Lachavanne J. 2002. Does size matter? The relationship between pond area and biodiversity. Biological Conservation, vol. 104, pages 59-70. https://doi.org/10.1016/S0006-3207(01)00154-9

[54] Kwiatkowska-Malina J, Wyszomierska M. 2014. Zagospodarowanie obszarów po eksploatacji kruszyw naturalnych na przykładzie złoża SITNO w gminie Rzewnie (Redevelopment of natural aggregates post-mining areas: the Sitno deposit case study) (in Polish). Infrastructure and Ecology of rural areas, vol. 2, pages 705-717. DOI: http://dx.medra.org/10.14597/infraeco.2014.2.3.052

[55] Koj J. 2011. Obiekty poprzemysłowe jako czynniki rozwoju regionu w turystyce i rekreacji (POST-Industrial objests as the factors of regionaldevelopment in tourism and recreation) (in Polish). Zeszyty Naukowe Uniwersytetu Szczecińskiego, vol. 690, pages 95-108. http://www.wzieu.pl/zn/690/ZN_690.pdf#page=9786.

[56] Doupé R, Lymbery A. 2005. Environmental Risks Associated with Beneficial End Uses of Mine Lakes in Southwestern Australia. Mine Water and the Environment, vol. 24, pages 134-138. https://doi.org/10.1007/s10230-005-0084-0

[57] Zhou T, Nijssen B, Gao H, Lettenmaier. 2016. The Contribution of Reservoirs to Global Land Surface Water Storage Variations. Journal of Hydrometeorology, vol. 17, pages 309-325. https://doi.org/10.1175/JHM-D-15-0002.1

[58] Nestler P, Stoll D. 2001. Stabilisation of bank slopes that are prone to liquefaction in ecologically sensitive areas. Waste Menagement, vol. 21, issue 2, pages 153-159.

[59] Schultze M, Pokrandt K, Hille W. 2010. Pit lakes of the Central German lignite mining district: Creation, morphometry and water quality aspects. Limnologica, vol. 40, issue 2, pages 148-155. https://doi.org/10.1016/j.limno.2009.11.006

[60] Sahu P, Lokhande R. 2015. An Investigation of Sinkhole Subsidence and its Preventive Measures in Underground Coal Mining. Procedia Earth and Planetary Science, 2015, vol. 11, pages 63-75. https://doi.org/10.1016/j.proeps.2015.06.009

[61] Castro J, Moore J. 2000. Pit lakes: their characteristics and the potential for their remediation. Environmental Geology, vol. 39, pages 1254-1260. https://doi.org/10.1007/s002549900100

[62] Gammons Ch, Harris L, Castro J, Cott P, Hanna B. 2009. Creating Lakes from Open Pit Mines: Processes and Considerations, Emphasis on Northern Environments. Canadian Technical Report of Fisheries and Aquatic Sciences. https://digitalcommons.mtech.edu/geol_engr/2/

[63] Weber A. 2020. Surrounded by Pit Lakes: New Landscapes After Lignite Mining in the Former German Democratic Republic. Mine Water and the Environment, 2020, vol. 39, pages 658-665. https://doi.org/10.1007/s10230-020-00696-5

[64] Wällstedt T, Borg H, Meili M, Morth C. 2008. Influence of liming on metal sequestration in lake sediments over recent decades. Science of The Total Environment, vol. 407, pages 405-417. https://doi.org/10.1016/j.scitotenv.2008.07.062

[65] Lienhoop N, Messner F. 2009. The economic value of allocating water to post-mining lakes in East Germany. Water Resour Manage, vol. 23, pages 965-980. DOI 10.1007/s11269-008-9309-x50.

[66] Kalybekov T, Sandibekov M, Rysbekov K, Zhakypbek Y. 2019. Substantion of ways to reclaim the space of the previously mined-out quarries for the recreational purposes. E3S Web of Conferences, 2019, vol 123, Ukrainian School of Mining Engineering. https://doi.org/10.1051/e3sconf/201912301004

[67] Mollema P, Antonelli M, Dinelli E, Greggio N, Stuyfzand. 2015. The influence of flow-through saline gravel pit lakes on the hydrologic budget and hydrochemistry of a Mediterranean drainage basin. Limnology and Oceanography, vol. 60, pages 2009-2025. doi: 10.1002/lno.10147

[68] Mollema P, Antonellini M. 2016. Water and (bio)chemical cycling in gravel pit lakes: A review and outlook. Earth-Science Reviews, vol. 159, pages 247-270. https://doi.org/10.1016/j.earscirev.2016.05.006

[69] Dulias R. 2010. Landscape planning in areas of sand extraction in the Silesian Upland, Poland. Landscape and Urban Planning, vol. 95, pages 91-104. https://doi.org/10.1016/j.landurbplan.2009.12.006

[70] Sondergaard M, Lauridsen T, Johansson L, Jeppesen E. 2018. Gravel pit lakes in Denmark: Chemical and biological state. Science of The Total Environment, vol. 612, pages 9-17. https://doi.org/10.1016/j.scitotenv.2017.08.163

[71] Marques E, Sella S, de Mello W, Lacerda L, Silva-Filho E. 2008. Hydrogeochemistry of Sand Pit Lakes at Sepetiba Basin, Rio de Janeiro, Southeastern Brazil. Water, Air, and Soil Pollution, vol. 189, pages 21-36. DOI 10.1007 / s11270-007-9550-6E.

[72] Muellegger Ch, Weilhartner A, Battin T, Hofmann T. 2013. Positive and negative impacts of five Austrian gravel pit lakes on groundwater quality. Science of The Total Environment, 2013, vol. 443, pages 14-23. https://doi.org/10.1016/j.scitotenv.2012.10.097

[73] Younger P, Wolkersdorfer Ch. 2004. Mining Impacts on the Fresh Water Environment: Technical and Managerial Guidelines for Catchment Scale Management. Mine Water and the Environment, vol. 2004, pages 2-80. https://doi.org/10.1007/s10230-004-0028-0.

[74] Sollie S, Janse J, Mooij W, Coops H, Verhoeven J. 2008. The Contribution of Marsh Zones to Water Quality in DutchShallow Lakes: A Modeling Study. Environmental Management, vol. 42, pages 1002-1016. https://doi.org/10.1007/s00267-008-9121-7

[75] Welch E, Cooke D. 2005. Internal Phosphorus Loading in Shallow Lakes: Importance and Control. Lake and Reservoir Management, vol. 21, pages 209-217. https://doi.org/10.1080/07438140509354430.

[76] Zhao T, Grenouillet G, Pool T, Tudesque L, Cucherousset J. 2016. Environmental determinants of fish community structure in gravel pit lakes. Ecology of Freshwater Fish, vol. 25, pages 412-421. https://doi.org/10.1111/eff.12222

[77] Svoboda I, Pecharova E, Prikryl I, Kasparova I. 2008. The Development of Future Lakes in Opencast Mine Residual Pits in the Krušné Mountain Region of the Czech Republic. Project of the Czech Science Foundation. https://www.imwa.info/docs/imwa_2008/IMWA2008_104_Svoboda.pdf

[78] Wollmann K, Deneke R, Nixdorf B, Packroff G. 2000. Dynamics of planktonic food webs in three mining lakes across a pH gradient (pH 2-4). Hydrobiologia, vol. 433, pages 3-14. https://link.springer.com/article/10.1023/A:1004060732467

[79] Nordstrom D. 2011. Mine Waters: Acidic to Circmneutral. Elements, vol. 7, pages 393-398. https://doi.org/10.2113/gselements.7.6.393

[80] Eary L. 1999. Geochemical and equilibrium trends in mine pit lakes. Applied Geochemistry, vol. 14, pages 963-987. https://doi.org/10.1016/S0883-2927(99)00049-9

[81] Castendyk D, Webster-Brown J. 2006. Geo-chemical prediction and remediation options for the proposed Martha Mine Pit Lake, New Zealand. 7th International Conference on Acid Rock Drainage (ICARD) Proc., American Society of Mining Reclamation. (ASMR), Lexington, Kentucky, pages 306–324. http://mwen.info/docs/imwa_2006/0306-Castendyk-NY.pdf

[82] Dimitrakopoulos D, Vasileiou E, Stathopoulos N, Dimitrakopoulou S. Estimation of the qualitative characteristics of post mining lakes in different lignite fields in Greece. Mining Meets Water – Conflicts and Solutions, 2016, pages 219-226. https://www.imwa.info/docs/imwa_2016/IMWA2016_Dimitrakopoulos_229.pdf

[83] Worlanyo A, Jiangfeng L. 2021. Evaluating the environmental and economic impact of mining for post-mined land restoration and land-use: a review. Journal of Environmental Management, vol. 279. https://doi.org/10.1016/j.jenvman.2020.111623

[84] Bylak A, Rak W, Wojcik M. 2019. Analysis of Macrobenthic Communities in a Post-Mining Sulphur Pit Lake (Poland). Mine Water and the Environment, vol. 38, pages 536-550. https://doi.org/10.1007/s10230-019-00624-2

[85] Rümmler F, Ritterbusch D, Schiewe S, Fullner G, Erschließung Neuer Ressourcen Für Die Sächsische Fischerei Durch Maränenbewirtschaftung Von Tagebaurestseen. Sächsische Landesanstalt für Landwirtschaft, 2005, vol. 10, pages 54-151. https://scholar.google.com/scholar?cluster=13617635564909910641&hl=pl&as_sdt=0,5

[86] McCullough Ch, Schultze M, Vandenberg J. 2020. Realizing Beneficial End Uses from AbandonedPit Lakes. Minerals, vol. 10, p. 133. https://doi.org/10.3390/min10020133

[87] Carlino A, McCullough C. 2019. Modelling the long-term water balance of a pit lake with recreational end uses. In Proceedings of the Fourteenth International Conference on Mine Closure, Perth, Australia, 3–5. https://papers.acg.uwa.edu.au/p/1915_110_Carlino/

[88] Schultze M, Rinke K, Brode E, Benthaus F. 2019. Wasserqualität in Als Speicher Genutzten Tagebauseen. Wasserwirtschaft, vol. 109, pages 38–41. https://www.springerprofessional.de/wasserqualitaet-in-als-speicher-genutzten-tagebauseen/16693014?fulltextView=true&doi=10.1007%2Fs35147-019-0040-8

[89] Dokulil M. 2013. Environmental Impacts of Tourism on Lakes. Eutrophication: Causes, Consequences and Control, vol. 2, pages 81-88. DOI 10.1007/978-94-007-7814-6_7

[90] Wagner T, Erickson L. 2017 Sustainable Management of Eutrophic Lakes and Reservoirs. Journal of Environmental Protection, vol. 8, pages 436-463. https://doi.org/10.4236/jep.2017.84032

[91] Salerno F, Viviano G, Carraro E, Manfredi E, Lami A, Musazzi S, Marchetto A, Guyennon N, Tartari G, Copetti D. 2014. Total phosphorus reference condition for subalpine lakes: A comparison among traditional methods and a new process-based watershed approach. Journal of Environmental Management, vol. 145, pages 94-105. https://doi.org/10.1016/j.jenvman.2014.06.011

[92] Oliver S, Corburn J, Ribeiro H. 2019. Challenges Regarding Water Quality of Eutrophic Reservoirs in Urban Landscapes: A Mapping Literature Review. International Journal of Environmental Research and Public Health, vol. 16. https://doi.org/10.3390/ijerph16010040

[93] Davidson K, Gowen J, Harrison P, Fleming L, Hoagland P, Moschonas G. 2014. Anthropogenic nutrients and harmful algae in coastal waters. Journal of Environmental Management, vol. 146, pages 206-216. https://doi.org/10.1016/j.jenvman.2014.07.002

[94] Mendiondo E. 2014. Global Review of Lake and Reservoir Eutrophication and Associated Management Challenges. https://pdfs.semanticscholar.org/ea08/890880ff40186f28dbbc463c72dd1f48f1bf.pdf

[95] Smith V. 2003. Eutrophication of Freshwater and Coastal Marine Ecosystems a Global Problem. Environmental Science and Pollution Research, vol. 10, pages 126-139. https://doi.org/10.1065/espr2002.12.142

[96] McNeary W, Erickson L. 2013. Sustainable Management of Algae in Eutrophic Ecosystems. Journal of Environmental Protection, vol. 4, pages 9-19. https://doi.org/10.4236/jep.2013.411A002

[97] Dokulil M, Herzig A, Somogyi B, Voros L, Donabaumc K, Mayd L, Nigese T. 2012. Winter conditions in six European shallow lakes:a comparative synopsis. Estonian Journal of Ecology, vol. 63, pages 111-129. doi: 10.3176/eco.2014.3.01. http://real.mtak.hu/27066/1/DokulilM_etal_OA.pdf

[98] Yuan Y, Locke M, Bingner R, Rebich R. 2013. Phosphorus losses from agricultural watersheds in the Mississippi Delta. Journal of Environmental Management, 2013, vol. 115, pages 14-20. http://dx.doi.org/10.1016/j.jenvman.2012.10.028

[99] Kozlov A, Koposova N, Uromova I, Krotova E, Matveeva A, Polyakova N, "The Level of Ecological and Hydrobiological Indicators in the Cheboksary Reservoir," Environment and Ecology Research, Vol. 9, No. 5, pp. 235 - 241, 2021. DOI: 10.13189/eer.2021.090504.

[100] Smith V, Tilman G, Nekola J. 1999. Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems. Environmental Pollution, vol. 100, pages 179-196. https://doi.org/10.1016/S0269-7491(99)00091-3

[101] Turgeon P. 2012. Monitoring Recreational Waters: How to Integrate Environmental Determinants. Journal of Environmental Protection, vol. 3, pages 798-808. DOI: 10.4236/jep.2012.328095

[102] Phillips M, Solo-Gabriele M, Piggot A, Klaus J, Zhang Y. 2011. Relationships between sand and water quality at recreational beaches. Water Research, vol. 45, pages 6763-6769. https://doi.org/10.1016/j.watres.2011.10.028

[103] Sabino R, Rodrigues R, Costa I, Carneiro C, Cunha M, Duarte A, Faria N, Ferreira C, Gargaté M, Júlio C, Martins M, Nevers M, Oleastro M, Solo-Gabriele H, Veríssimo C, Viegas C, Whitman R, Brandão J. 2014. Routine screening of harmful microorganisms in beach sands: Implications to public health. Science of The Total Environment, vol. 472, pages 1062-1069. https://doi.org/10.1016/j.scitotenv.2013.11.091

[104] Font T, Lloret J. 2014. Biological and Ecological Impacts Derived from Recreational Fishing in Mediterranean Coastal Areas. Reviews in Fisheries Science & Aquaculture, vol. 22, pages 73-85. https://doi.org/10.1080/10641262.2013.823907

[105] Cooke S, Cowx I. 2004. The Role of RecreationalFishing in Global Fish Crises. BioScience, vol. 54, pages 857-859. https://doi.org/10.1641/0006-3568(2004)054[0857:TRORFI]2.0.CO;2

[106] Pope K, Powell A, Harmon B, Peeg M, Chizinski Ch. 2017 Estimating the number of recreational anglers for a given waterbody. Fisheries Research, 2017, vol. 191, pages 69-75. http://dx.doi.org/10.1016/j.fishres.2017.03.004

[107] Lewin W-Ch, Arlinghaus R, Mehner T. 2006. Documented and Potential Biological Impacts of Recreational Fishing: Insights for Management and Conservation. Reviews in Fisheries Science, vol. 14, pages 305-367. https://doi.org/10.1080/10641260600886455

[108] Gavriletea M. Environmental Impacts of Sand Exploitation.Analysis of Sand Market. Sustainability, 2017, vol. 9. https://doi.org/10.3390/su9071118

[109] West A, Nolan J, Scott T. 2016. Optical water quality and human perceptions: a synthesis. Wires water, vol. 3, pages 167-180. https://doi.org/10.1002/wat2.1127

[110] Rahmonov O, Szczypek T, Pirozhnik I. 2019. Ecological and recreational and tourist functions of small anthropogenic reservoirs in post-industrial landscapes. Acta Geographica Silesiana, vol. 13, pages 13-25. http://hdl.handle.net/20.500.12128/12025

[111] Hall C, Härkönen T. 2021 Lake tourism: an introduction to lacustrine tourism systems. Accessed on 31.03.2021 at 00:48. http://www.microlinkcolleges.net/elib/files/undergraduate/Tourism%20&%20Hotel%20Management/Lake%20Tourism%20(2006).pdf#page=17

[112] Lantsova I, Grigor’eva I, Tikhomirov O. 2005. Geoenvironmental Problems of Recreational Use of the Ivankovo Reservoir. Water Resources, vol. 32, pages 107–113. https://click.endnote.com/viewer?doi=10.1007%2Fs11268-005-0015-2&token=WzMwNjExNjAsIjEwLjEwMDcvczExMjY4LTAwNS0wMDE1LTIiXQ.FxOuQBq8OnVIbigEYDIfg5uW0iQ

[113] Asplund T. 2000. The effects of motorized watercraft on aquatic ecosystems. University of Wisconsin, Madison. http://www.trpa.org/wp-content/uploads/2010-WI-Dept-of-Natural-Resources_UW-Boats-effects-on-ecosystems.pdf Access 30.03.2021