Scientific and environmental aspects of the industrial heritage

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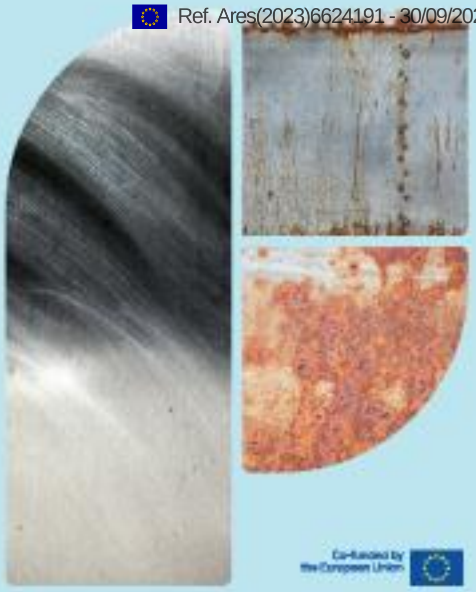

FASIH
Future Art Science
Industrial Heritage

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About FASIH

The FASIH project focuses on the interdisciplinary art and science research of the industrial and cultural heritage by detecting, exploring and evaluating architectural achievements and intangible processes that have marked modern history of Belgrade, Rijeka and Trbovlje. FASIH is a regional cooperation that, in conjunction with scientific research and new media, seeks to connect contemporary models of revalorisation and revitalisation of the industrial heritage. Using IT and novel technological tools, the project aims to provide new approaches to promoting the value of the cultural, scientific and industrial heritage of the region, shared in the context of a global, sustainable European future.

Executive Summary

Environmental aspects of the industrial heritage and scientific background of the technological advancements in Belgrade, Rijeka and Trbovlje in the late 19th and early 20th century.

Keywords

Industrial heritage; Factory; Power plant; Paper production; Coal; Electricity; Water and industry; Natural environment; Natural vegetation

1. Scientific background of the technological advancements in the late 19th and early 20th century

1.1 Industry in South-East Europa

The process of industrialization began in England, the United States, and Switzerland between 1790 and 1820; in Austria, Belgium, France, Russia, Sweden, and Germany between 1820 and 1860; in Denmark, Greece, Italy, Japan, and the Netherlands between 1860 and 1890; and after 1890 until the 1930s it developed in South America, Australia, and China.

The Habsburg Monarchy recognised the advantages of industrial production and trade and was omnipresent with policies and decisions that confirmed this. On the other hand, the whole territory is unevenly developed, so that a large part of the territory is devoted to agricultural production. Development is linked to the manufacture of various products, most of which are closely related to the construction of railroads. Globally, progress is associated with the metal industry and mining. Also important is the trade network that the state successfully develops for the placement of various products in world markets. There are great differences in the development of individual sectors and, in general, the potential for the development of industrial production.

1.1.1 Industry in Serbia

During the 19th century, Serbia was an agricultural country with initial development of industry, which was building an economic system, institutions and the direction of the economic policy. There were numerous reasons for the low level of the economic development, but the economic heritage of the Ottoman Empire and (semi) dependent character of the state were crucial.

Until World War I, textile, food, cement, brick, chemical, metal, leather, timber industry, etc., have all developed. Mills were constructed going through all the phases of industrialisation, from water power, turbines and steam, to petroleum and electric drive. Until the start of the war, the foundations of the industry on the territory of Serbia had been set, several decades had passed from the primitive workshops to modern factories, and the created industrial centres had remained during the 20th century as well.

Although industry was developing during the 1920s, it was still not possible to speak of a developed modern society with all its features: the growth of the secondary and tertiary sectors, the expansion of the urban lifestyle and the independent development of science and technology. True rapid industrialization started after World War II.

1.1.2 Industry in Croatia

The industrialization of the regions that make up today’s Croatia is very different. On the one hand, there are regions that exploit the potential of the development of production and trade and are closely linked to the construction of the railroad, while others are dedicated to agricultural production. Craft and manufacturing industries do not have the conditions to become industrial everywhere. Cities like Zagreb, Sisak, Rovinj, Rijeka

and Osijek stand out, where specific industries are developing - metal foundries, grain industry, tobacco processing, fish processing, wood industry.
The systematic development is highly influenced by the agricultural system and the predominantly agricultural production, as well as by the illiteracy of the population, especially until the beginning of the Second World War.

1.1.3 Industry in Slovenia

As a part of the Habsburg Monarchy, Slovenia's industry developed with limited economic initiative as the region was not as developed as others were in the Monarchy. The primary centre of economic activity was Trieste, which served as the most important port of the monarchy, extending its influence into the Slovenian hinterland. The Austro-Hungarian Empire initiated industrialization by constructing the Suedbahn (Southern Railway) between Vienna and Trieste from 1840 to 1857, which connected the heartland to the port and beyond. This railway, running practically across all of Slovenia, was the lifeline of industrialization, while areas not along its path saw a decline in influence. Towns and cities along the railway experienced rapid growth, especially those directly connected to it, like Maribor. Both Maribor and Zasavje remained vital industrial hubs throughout the 20th century in both Slovenia and Yugoslavia. Alongside with Croatia, Slovenia was one of the more developed parts of Yugoslavia both during the period between two world wars, as well as after World War II.

1.2 Belgrade, Rijeka, Trbovlje in the late 19th and early 20th century

1.2.1 Belgrade and Power Plant Power and Light

Electric lighting in Belgrade was introduced in 1883 with the construction of the first municipal power plant near the Danube, primarily for illuminating the town and meeting its industrial needs. This marked the moment when Belgrade acquired a modern electric power plant, providing electric lighting for the streets and homes of the city. The operations of this power plant were halted on May 14, 1933, as the new plant by the Danube with significantly greater production capacity was already operational.
Special attention was given to selecting the location for the new power plant to ensure an adequate water supply for cooling purposes. Unlike the first municipal power plant, the new facility was built along the Danube, providing sufficient water for the power plant's operation and coal transportation by water. The Power and Light thermal power plant complex was built between 1930 and 1932 and consisted of four buildings: the main power plant building housing the boiler room, machinery hall, distribution installation, coal crushing devices, and coal supply; two buildings for the water station on the harbour channel. One building contained water pumps, while the other had screens for mechanical water purification. Water was supplied to the power plant from the water station through two pipes.
With the construction of the Power and Light Power Plant, a low-voltage distribution network for AC power supply was put into use for the first time. As the largest facility of its kind in Belgrade between the two world wars, it represented the foundation for the city's electric power system and contributed to its significant improvement. The test run of the plant was at the end of 1932, when it took over the function of the first, old

municipal power plant, and was shut down in 1969 due to its deteriorated condition and has since been out of use and function.

1.2.2 Rijeka and Hartera

At the end of the 18th and the beginning of the 19th century, Rijeka was a small town with great production potential. The harbour in the centre of the city in the Rijeka riverbed (additional materials on urbanistic characteristic of the area are at artandscience.rs/en/fasih), the construction of roads connecting the city with the inland, and tax concessions for trade through the port of Rijeka are the first steps towards production and attraction of foreign investment. The establishment of a direct Hungarian administration in Rijeka brings capital and political will to promote production and sales, and the positive environment is an invitation to various industrialists from Great Britain, Italy, France, Hungary and Austria to come to the Rijeka plants.

Figure 1: Rječina
(https://lokalpatrioti-rijeka.com/)

Figure 2: Hartera
(https://lokalpatrioti-rijeka.com/)

In the first half of the 19th century, the trade in rags became extremely important for paper production. Rags were transported overland from the Rijeka hinterland to the port, and in 1821 paper production began in Rijeka's mills. The entry of the British merchant Walter Crafton Smith and the French industrialist Charles Maynier into the Rječina paper mill in 1827 marked the beginning of its golden age. The factory is modernized, the flow of the Rječina is regulated, canals are built to fully utilize the potential of water, and as early as 1833 a steam engine is delivered, the first of its kind in this part of Europe. Products such as fine postal, office and royal paper, the production of paraffin matches and cigarette paper were exported all over the world. In the eighties of the 20th century, cigarette paper production in Rijeka covered seven percent of the world market. After 1990, paper production was discontinued.
For detailed chronological development of the Paper factory more materials available at artandscience.rs/en/fasih.

1.2.3 Trbovlje and Power plant

Places with coal deposits have become important economic centres, which also applies to Trbovlje. The coal deposit largely contributed to the fact that the Vienna-Trieste railway ran through Trbovlje. The railway got a stable source of fuel to power the steam locomotives, and it enabled the mine to transport coal easily. Along with water, coal was the primary source of electricity production.

The first, very small, power stations were placed in the immediate vicinity of coal mines, and they powered mine elevators, ventilators, and pumps. The new power plant was opened in March 1915. The power plant was enlarged in several stages. Even before the Second World War, there were complaints from lower-lying cities along the Sava, primarily Zagreb, about the pollution of the river. Production peaked after World War II. The high level of sulphur that leaked into the surroundings had severe consequences for the vegetation in the Sava valley and also in more distant places. As part of the remediation program, a high chimney was built, which discharged the smoke above the inversion layer and partially solved the pollution problem. After 1990. mines were slowly being closed. In 2015. the power plant was decommissioned.

More materials about this chapter available at artandscience.rs/en/fasih.

1.3 Scientific and technological impact

1.3.1 Water and industry

Water played a significant role in shaping industry during the 19th and 20th centuries. The availability and management of water resources had a profound impact on the early growth and development of various industries during this period. Waterwheels were a vital source of mechanical power for early industrial processes. Waterwheels were used to drive machinery in textile mills, sawmills, grain mills, and various manufacturing facilities. Water had an important influence on the production of electricity. On the one hand, it was absolutely necessary for the production and cooling of steam that drove the dynamo, on the other it was used as a direct source of energy for the hydroelectric power plants.

Furthermore, water was used for the transport of coal and other essential resources to power plants and factories and it was used to transport toxic waste away from power plants and factories. The high level of sulphur, coal dust, and other toxic chemicals left over from the production of industry goods such as paper that leaked into the surroundings had severe consequences for the environment and the whole ecosystem.

1.3.2 Coal, electricity, and the environment

Coal was the driving force behind the first industrial revolution, the primary energy source for the great industrial production boom of the 19th century. Places with coal deposits have become important economic centres with strong railway connections. The railway got a stable source of fuel to power the steam locomotives, and it enabled the mine to transport coal easily. The relationship between coal and electricity, or coal mining and electricity production, was similarly reciprocal. The steam engine was used to run generators which powered different essential machinery.

Along with water, coal was the main source of electricity production, and at the same time, electricity powered many of the machines in the mines. Power stations were placed in the immediate vicinity of coal mines, and they powered mine elevators, ventilators, and water pumps. Coal power plants produced large amounts of coal dust, and toxic smoke filled with sulphur which poisoned air, soil and water.

Coal-fired power plants emit a range of air pollutants, including sulphur dioxide (SO2), nitrogen oxides (NOx), particulate matter, and volatile organic compounds. These pollutants can have detrimental effects on human health and the environment. SO2 and NOx, for example, can lead to acid rain, which harms ecosystems, damages buildings, and contaminates water bodies. Coal power plants release pollutants that contribute to the formation of ground-level ozone, a major component of smog.

Coal power plants use water for cooling purposes, and this water is subsequently discharged back into rivers, lakes, or oceans, albeit at elevated temperatures. This thermal pollution can disrupt aquatic ecosystems and harm fish and other wildlife. Additionally, the release of toxic heavy metals, such as mercury and lead, from coal combustion can contaminate water bodies, posing risks to aquatic life and human health when consumed in fish. The disposal of coal ash, a waste product of combustion, can also pose risks to land and groundwater if not managed properly.

For more details about Trbovlje and Power and Light Power Plant read Coal, electricity, and environment in Trbovlje and Power and Light Power Plant.

1.3.3 Paper production

In the first half of the 19th century, the trade in rags was one of the more interesting domestic crafts of the poorest regions. Rags become an important trade item, the price of which is relatively high, and they are the only raw material for paper production. Rags or rags are different types of linen and hemp fabrics that are no longer used and were mechanically turned into pulp in water mils. The pulp was finally pressed and turned into paper.

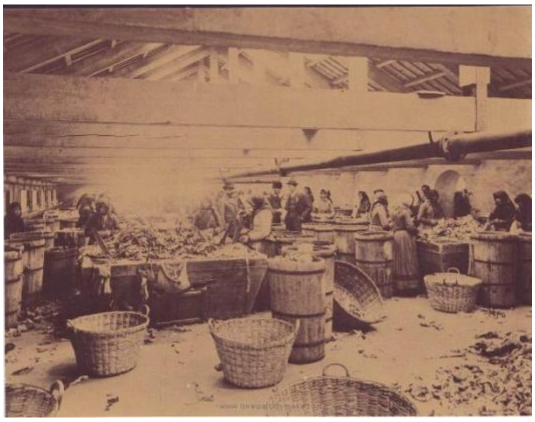

Figure 3: Rags (https://lokalpatrioti-rijeka.com/)

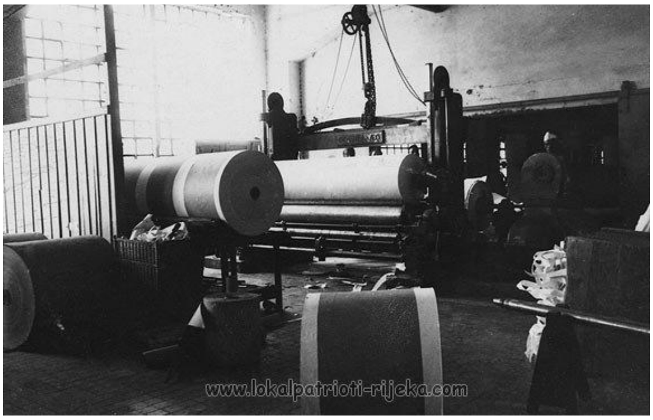

Figure 4: Machines (https://lokalpatrioti-rijeka.com/)

The rag-based paper was relatively expensive therefore factories turned to the manufacture of cheaper wood-based "pulp" paper mostly based on hemp fibbers. This process was improved with chemical pulping using sulphuric acid and calcium bisulphite treatment. From this point, printing and writing paper became easily available at a reasonable price.

While other mills had to have a water treatment plant to prepare the water, the Hartera paper factory had its water provided by nature, coming from three karst wellsprings on the right bank of the Rječina. The spring water was of high purity and of the appropriate hardness for papermaking, and it came with a particular blend of calcium and magnesium carbonate which made it particularly suitable for the manufacture of high-grade rolling paper, in addition to other high-grade rag and cellulose based papers.

For more details on paper production in Hartera read Rijeka - Paper factory and Hartera - a blend of location, resources, and circumstances.

2 Environmental aspects of the industrial heritage

Industrial development in all three urban centres, Rijeka, Belgrade and Trbovlje, brought economic progress, new knowledge, technologies, intelligence, social development and financial development to the people living in these areas. During the historical peaks of this industries, they also brought heavy impact with long-term consequences to the natural environment, living organism including humans.

2.1 "Hartera" paper plant and natural environment (Rijeka; Croatia)

2.1.1 Geography and geology of the broader area

The city of Rijeka is the largest Croatian port, the third-largest city in the Republic of Croatia, and the administrative centre of the Primorje-Gorski Kotar County. It is located in western Croatia, on the northern coast of the Kvarner Bay. The Kvarner area is a partially enclosed channel in the Adriatic Sea, situated between the Istrian peninsula and the Vinodol-Velebit coast. It primarily consists of tectonically deformed and karstified Mesozoic to Cenozoic carbonate rocks (Pikelj & Juračić, 2013). The city of Rijeka is situated on rocks approximately 95 million years old, belonging to the geological period of the Cretaceous. During the Cretaceous, the Adriatic Carbonate Platform (ACP) - a vast plateau that encompassed the present-day area of the Rijeka region - was surrounded by a deep sea, parts of the vast Tethys Ocean. It was located about twenty degrees south, at approximately 25° North latitude, and was moving northward and north-eastward towards present-day Europe. The area of Istria, Croatian Littoral, Gorski Kotar, Ogulin region, and parts of Lika that were situated in the north-western part of the Adriatic Carbonate Platform (ACP), during the Cretaceous, resembled today's Bahamas. During that time, dinosaurs roamed the area that is now Istria (Klepač et al.,2012.).

In the wider area of Rijeka, in addition to Cretaceous rocks, there are also Eocene-age rocks and Quaternary sediments. Triassic and Palaeozoic layers, which are quite widespread in neighbouring areas, are covered by younger deposits. Cretaceous layers appear as limestones, dolomites, and limestone or dolomite breccias, while Eocene clastic deposits consist of marls composed of limestones, slates, sandstones, conglomerates, and limestone breccias. The thickness of the marl deposits is 400-600 meters (HGI, 2009).

From a hydrogeological and engineering geological perspective, this entire area is divided into the carbonate, highly permeable karst unit, and impermeable marl deposits. The most significant watercourse of the Croatian Littoral is the Rječina River. It has a length of only 18.7 km, with an elevation difference of 325 meters between its source and the mouth. A strong spring located at the foot of the Gorski Kotar mountains drains underground water from a vast karst hinterland and has been used for water supply for a full century. In the middle course of the river, there is a dam and reservoir, and the waters of the Rječina are also utilized for electricity production (Prodan et al., 2012). The Rječina Valley is part of the Rijeka epicentral seismic area, where earthquakes with magnitudes up to M = 6 on the Richter scale have been recorded over the past two millennia (Herak et al., 1996.).

Figure 5: A view towards Rijeka

2.1.2 Natural vegetation of the broader area

Despite its coastal location along the Adriatic, the Northern Adriatic region biogeographically belongs to sub-Mediterranean floral region. This classification arises from several factors, including its relatively high annual precipitation, approximately 1500 mm, lower winter temperatures, the influence of the strong winter wind known as the bora, as well as its positioning at the northern boundary of the Mediterranean. Consequently, the classic evergreen vegetation typical of Mediterranean areas, featuring species like holm oak (Quercus ilex), green olive tree (Phyllirea latifolia), strawberry tree (Arbutus unedo), common myrtle (Myrtus communis), and mastic tree (Pistacia lentiscus), to name a few, is primarily found in sheltered and spatially rather restricted refugial sites.

The predominant climazonal vegetation here – the vegetation developed under general influence of the climate without anthropogenic influences - however, consists of forest stands populated by downy oak (Quercus pubescens), flowering ash (Fraxinus ornus), European hop hornbeam (Ostrya carpinifolia), and oriental hornbeam (Carpinus orientalis), forming the broad-leaves forests of the association Aristolochio-Quercetum pubescentis carpinetosum orientalis. The initial stage of degradation in these forests leads to stands primarily featuring oriental hornbeam and Jerusalem thorn Paliurus australis. Continued degradation results in the formation of floristically diverse, rocky Karstic grasslands, with the sedge Carex humilis being a dominant species within the Carici humilis-Centaureetum rupestris association. Note that almost all non-forested vegetation, including species rich rocky and dry grasslands, are man-made.

However, in areas that have undergone complete degradation, as most of the urban areas, vegetation is characterized by the prevalence of garlic cress (Peltaria alliacea), European stonecrop (Sedum ochroleucum), and certain therophytes - any (annual) plant which survives unfavourable seasons in the form of seeds only.

In the (sub)Mediterranean climates, the most unfavourable conditions plant experience during the summer draught.

2.1.3 The impact of the paper factory on the natural environment

The river Rječina is a short karst river, 19 km long, with a catchment area of 246 km2. Although Rječina is the most abundant river in the water area of the Primorje-Istria basins, it is characterized by significant seasonal fluctuations in accordance with the Mediterranean distribution of rainfall throughout the year. During these fluctuations, the maximum water flow is recorded in winter months, while the minimum occurs in summer. Therefore, during the summer months, anthropogenic chemical and physical impacts have the potential for a stronger effect on this river.

The negative impact of the operating Hartera factory on the natural environment, particularly on the Rječina River and its ecosystem, was multiple and significant, increasing with the intensity of operations and complexity of production processes.

In the initial period of operation, when the factory was still a paper mill, it used old rags as raw material, with low production capacity and a small number of employees. During this period, the impact of its operations on the flow of the Rječina River was relatively small, while the water was contaminated with (pathogen) microorganisms and organic compounds from dirty old rags.

In 1827, with the entry of the British merchant Walter Crafton Smith and the French industrialist Charles Maynier into the paper mill on the Rječina River, its "golden period" or rather, a dark era for the Rječina River, began. After taking over the factory, the new owners invested in its modernization, regulating the flow of the Rječina River and constructing canals to redirect water from the river for the utilization of hydrostatic energy, production processes, or the needs of the steam engine that was launched in 1833.

Following a major flood in 1852, a new canal was built, and the factory continued to develop technologically, adding two new steam engines, which put additional pressure on the Rječina River. At the turn of the century, the greatest efforts were directed towards ensuring sufficient energy for production processes and the use of a new raw material for paper production, cellulose. Paper production from cellulose became a more profitable process but had a stronger negative impact on the environment, particularly in terms of pollution and contamination with various chemical compounds.

According to S. Zrnčević (2019), the wastewater generated in all segments of the production chain of paper production is a mixture of about 240 to 250 different elements and compounds such as nickel, copper, chromium, lead, sodium, nitrogen, phosphorus, sulphur and their compounds, biologically non-degradable organic compounds, fatty acids, as well as chlorinated resins, phenols, and hydrocarbons. Many of these compounds are known to be acute or chronic toxins for both humans and animals. In addition, these waters are characterized by high electrical conductivity, relatively high or low pH values depending on the process used, turbidity, and intense odour. In the past, paper bleaching was mainly done using chlorine compounds, which led to the formation of toxic chlorinated compounds and acidification of water. Due to their complex composition and proven toxicity, wastewater from the pulp and paper industry represents a serious threat to aquatic ecosystems as well as the environment as a whole. Thermal pollution of water, resulting from the discharge of process wastewater at higher temperatures, can also have a multiple impact on aquatic organisms. Sudden temperature changes occurring near the discharge can cause immediate death (lethal effect) or induce stress and physiological disturbances (sublethal effects). Warmer water contains less dissolved oxygen, accelerates the metabolism of living organisms, and depletes oxygen faster, resulting in reduced oxygen concentration. This changes the living conditions of the habitat, gradually eliminates organisms that require more oxygen, and triggers anaerobic degradation of dead organic matter. The problem with process wastewater from the pulp and paper industry is also related to its coloration. Paper industry contributes to the coloration of water by using synthetic dyes to suppress the yellowish colour of paper (optical brighteners) or produce coloured paper. Even low concentrations of dyes in water (> 1 mg dm-3) are intensely visible. The presence of dyes in natural waters reduces water quality, disrupts the aesthetics of ecosystems, and prevents the penetration of light into deeper water layers. This disturbs photosynthesis, resulting in reduced oxygen concentration and lower productivity of the aquatic environment. Many dyes and their degradation products are carcinogenic, mutagenic, and/or toxic to organisms. Due to their high chemical and thermal photostability, dyes persist in the environment for a long time and disrupt metabolic processes in the cells of microorganisms, plants, and animals present in the ecosystem.

In the first half of the 20th century, a highly modern thermal power plant with a capacity of 3200 HP was built in the Rijeka Paper Factory, which polluted the air with coal combustion by-products during electricity production.

At different stages of its operation, the Rijeka Paper Factory also mechanically affected the flow of water in the Rječina River. Additionally, the reduction of river water flow due to water use in various production processes leads to the upstream intrusion of saltwater in the estuarine area, altering the living conditions and species composition in that part of the river.

2.1.4 Hartera paper plant today – natural features of an abandoned industrial site

Hartera, once an industrial complex now abandoned, is dominated by urban flora consisting of ruderal plant species. These species, often annual, employ an r-strategy for survival, characterized by a high growth rate but low survivability, meaning they produce many "cheap" offspring. In contrast, K-selected species, typically prevalent in climazonal vegetation types (representing the final stage in vegetation succession for a given climate and period), exhibit a low growth rate but high survivability, producing fewer but "expensive" offspring.

Abandoned sites as Hartera former plant area, and ruderal sites, are largely taken over by adventive, often invasive species. Since the available spaces and roles in ecosystem (ecological niches) at these sites are not occupied, once highly urbanized and disturbed sites represent spaces where newcomers find their place to grow. Many of these alien plant species turn out to be invasive ones at their new habitats.

Notably, in close proximity to these industrial sites, well-preserved flora and vegetation thrive in more or less natural areas. These serve as a species pool and offer significant potential for recolonizing the abandoned industrial sites.

2.2 Thermal power plant "Snaga i svetlost" and natural environment (Belgrade; Serbia)

2.2.1 Geography and geology of the broader area

Belgrade, the capital of Serbia, is located in Southeast Europe, on the Balkan Peninsula, at the confluence of the Sava and the Danube Rivers. It covers an area of 3227 km² of which almost 276.6 km² includes rivers and riparian land. The wider area of the city of Belgrade is mainly covered by thinner or thicker Quaternary deposits of various genesis (alluvium, river-marsh sediments, river terraces, deluvial-proluvial deposits, loess-paleosoil sequences, etc.). Below the Quaternary cover, there is a complex of Miocene and pliocene sediments of different thickness formed during the evolution of the Pannonian Basin and its southern rim. In the base of Neogene formations, there are the older rocks mostly built of various post-Triassic formations (diabases, serpentinized peridotites, radiolarites, clays, argiloshists, limestones, sandstones, spilites, andesites, etc.) (Marinović and Rundić, 2020.). From a geotectonic point of view, the Belgrade city area includes the southern margin of the Pannonian Basin, northern parts of the Vardar Zone (Tethys oceanic domain) and the Serbo-Macedonian Massif. The primary morphological relief of the Belgrade city area results from the tectonic movements that occurred during the Palaeogene and early Neogene. The turbulent tectonic activity was accompanied by volcanism, which lasted until the end of the Miocene. Volcanic landforms created during this period are not preserved in the territory of Belgrade, instead igneous rocks from that period. (Ilić et al., 2016.) The Pleistocene sequence in Serbia is represented by stratigraphically complex deposits of various origins. Of them, loess, alluvial, lacustrine and cave deposits are the most widespread, and well researched. Loess deposits from the vicinity of Belgrade are part of the southern margin of vast loess cover of the Pannonian lowland. In some places, the loess reaches the depth of over 30 meters. Here are numerous localities with Pleistocene vertebrate remains in cave and alluvial deposits, including numerous remains of mammoths (Dimitrijević, 1997.)

2.2.2 Natural vegetation of the broader area

Counterintuitively, the Thermoelectric Plant “Snaga i svetlost” area in Belgrade receives an annual precipitation of only 600-700 mm, significantly less than the North-western Adriatic's Hartera region, which is located along the coast and on the climatological fringes of the Mediterranean. However, despite its drier climate, TE Snaga i svetlost experiences much colder conditions, characterized by a typical continental climate featuring dry and hot summers, as well as colder and longer winters with precipitation distributed more evenly throughout the year. In a manner akin to the North-western Adriatic, this area is also significantly affected by a strong winter wind known as the Košava.

The climazonal vegetation in this region consists of thermophytic continental broadleaved forests featuring Hungarian oak (Quercus frainetto) and Turkey oak (Quercus cerris), forming the forest association Quercetum frainetto-cerris. Successional stages in vegetation towards complete degradation encompass low-standing forests with common lilac (Syringa vulgaris) and oriental hornbeam (Caprinus orientalis - the alliance Syringo-Carpinion, shrub vegetation with dwarf Russian almond (Prunus tenella) and Jerusalem thorn (Paliurus australis) - the alliances Pruno tenellae-Syringion and Paliurion moesiacum, and finally, dry grasslands and pastures with species like sedge species Carex humilis, grass species Chrysopogon gryllus and Danthonia alpina, to name just a few, from the Chrysopogoni-Dantonion alpinae alliance. Beyond this, rocky grasslands with a prevalence of fescue species like Festuca valesiaca can be found, ultimately giving way to completely ruderal and anthropogenic vegetation.

2.2.3 The impact of the “Snaga i svetlost” power plant factory on the natural environment

The power plant "Snaga i svetlost" (Power and Light), which operated in Belgrade from 1893 to 1933, holds a significant place in the social and architectural history of Belgrade and is now a cultural monument of the

Republic of Serbia. During its operation, "Snaga i svetlost" supplied the majority of Belgrade's electricity needs, enabling the development of the electrical grid, electrification, and the economic and social development of the city.

The construction of the power plant itself had a significant impact on the natural environment and landscape. It required the use of 10,000 m^3 of concrete, 700 tons of iron, and 560 tons of steel structures, which all had a notable environmental footprint during their production. For the needs of the power plant, a harbour, a coal storage area measuring 140 m in length and 58 m in width with a storage capacity of 38,000-55,000 tons of coal, and a complex of buildings were constructed along the river.

In addition to coal transportation, the water of the Danube River was used for a large part of the production processes. Since the Danube River is a large lowland river in its lower course when it flows through Belgrade, it is already subjected to significant human influences, pollution, and contamination. These influences have relatively less significance on the living world of the Danube.

The power plant operated using domestic lignite coal as the fuel source, with a calorific value of 2,000 to 2,200 kcal/kg, which was transported by railway from the mines in Kostolac, over 50 km away.

The impact of substances generated by the combustion of coal and other fossil fuels in power plants is the greatest problem for the natural environment and human health.

Power plants are thermal energy facilities that produce electric energy through the combustion of fuel. During fuel combustion, depending on the type (chemical composition) of the fuel and the combustion technology used, various types of organic and inorganic substances are emitted into the environment, which are a mixture of greenhouse gases, ash, and slag. Power plants are a significant source of environmental pollution. The most important indicators of the impact of power plants on the environment are the emissions of sulphur oxides, nitrogen oxides, carbon dioxide, carbon monoxide, and particulate matter (ash and soot). Sulphur dioxide (SO2) is one of the major air pollutants generated by the combustion of sulphur oxides, while nitrogen monoxide (NO), nitrogen dioxide (NO2), and nitrous oxide (N2O) are produced by the combustion of nitrogen oxides (Mikić A., 2020).

It is known that the problem of environmental pollution is most prevalent in coal-fired power plants, where the combustion releases harmful greenhouse gases such as carbon dioxide, nitrogen oxides, sulphur oxides, chlorofluorocarbon gases (CFC compounds), and methane (CH4), which pose a significant danger to the life and health of living organisms. Some of these pollutants cause cancer, disrupt reproduction and the normal development of children, damage the nervous and immune systems, and can worsen asthma. Additionally, they contribute significantly to climate change.

Today, in the operation of power plants, efforts are being made to reduce the extremely negative impact of these facilities on nature and the environment by using higher-quality fuels and various processes in the production and treatment of gases before their release into the environment. However, power plants in Belgrade, Serbia, and the entire so-called Western Balkans area are major air polluters on a global level. According to a report by the Centre for Research on Energy and Clean Air (CREA) and Greenpeace (Ciuta et al. 2021), the today operating Nikola Tesla coal-fired power plants, located about 30 kilometres from the city centre of Belgrade, in the suburban municipality of Obrenovac, rank ninth on the list of the world's largest sulphur dioxide polluters, while Serbia as a whole rank at 18th in the world.

Coal-fired power plants in the Western Balkans continue to seriously endanger the environment in the countries of the region, as well as the European Union, as they caused premature deaths of at least 19,000 people between 2018 and 2020, including more than 10,000 in EU countries. This conclusion was presented

in a report on the joint website of the environmental protection associations CEE Bankwatch Network and the Centre for Research on Energy and Clean Air (CREA). European Union countries are still the main buyers of exported electricity produced in Western Balkan power plants, although it represents only 0.3% of the total electricity consumption, its production is the source of nearly half of the air pollution on the European continent. According to calculations by analysts from these organizations, in the EU territory, 10,800 people died in the past three years due to air pollution from power plants, while 6,500 died in the Western Balkans.
In 2020 alone, coal-fired power plants in Bosnia and Herzegovina, Serbia, North Macedonia, Montenegro, and Kosovo emitted two and a half times more sulphur dioxide (SO2) than all other such power plants still operating in the EU. At the same time, they released 1.6 times more particulate matter into the air than what was stipulated in the national emission reduction plans (NERP) for the period from 2018 to 2020. The total three-year costs incurred by the affected countries due to air pollution are estimated to be between 25.3 and even 51.8 billion euros.

2.2.4 Power Plant "Snaga i svetlost" today – natural features of an abandoned industrial site

Like Hartera, once an industrial complex now abandoned, "Snaga i svetlost" is dominated by urban flora consisting of ruderal plant species. These species, often annual, employ an r-strategy for survival, characterized by a high growth rate but low survivability, meaning they produce many "cheap" offspring. In contrast, K-selected species, typically prevalent in climazonal vegetation types (representing the final stage in vegetation succession for a given climate and period), exhibit a low growth rate but high survivability, producing fewer but "expensive" offspring.

Figure 6: "Snaga i svetlost" today

Abandoned industrial sites, and ruderal sites, are largely taken over by adventive, often invasive species. This is even more pronounced with the "Snaga i svetlost" ex-power Plant that with Hartera, as the Snaga i svetlost" is situated on bank of highly trafficked Danube, just by a small port. Ports and railroads are known means of alien species entry points.

2.3 Thermal power plant Trbovlje and natural environment (Trbovlje; Slovenia)

2.3.1 Geography and geology of the broader area

Trbovlje is Slovenia's tenth-largest town, and the seat of the Municipality of Trbovlje. It is located in the valley of a minor left tributary of the Sava River in the Central Sava Valley in central-eastern Slovenia. During the Jurassic (~150-200 million years ago), central Slovenia was submerged under a deep sea, depositing thick layers of slab limestones with cherts, mudstones, and marls. In the Cretaceous (~65-145 million years ago), the Southern Alps and Central Slovenia were under deep marine conditions. Towards the end of the Cretaceous, Slovenian and Croatian Istria emerged as mainland, leading to limestone weathering and the formation of bauxite from red karst soil. Before the sea finally retreated, it briefly deepened again, forming flysch marls and sandstones. These formations now make up the fertile soil of the Vipava and Pivka valleys, the Brkini area, and the coastal region. After a rather long continental period in central Slovenia, larger peat basins were formed in the Middle Tertiary (Oligocene), in which coal and marl layers were deposited. These include the coal deposits at Trbovlje. Due to the subduction of the African plate under the Eurasian plate, strong volcanic activity began in the in the Oligocene (~23-34 million years ago). The ash from the volcanoes formed tuff deposits on the mainland and the sea. In the middle of the Miocene seawater once again flooded the Štajerska and Dolenjska areas and the limestones and marls with bivalves, gastropods, corals and sea urchins date from this period. In the quarry southwest of Trbovlje, a tooth of Carcharocles megalodon, one of the largest prehistoric sharks ever, was found (Mikuž, 1999.). In the Pliocene, tectonic activity began again. During this time Slovenia was mostly a plateau. Due to the long-lasting uplift of limestone and dolomite areas, karstification and the relocation of rivers below the surface occurred. At the beginning of the ice ages, large depressions were formed on long faults. The rivers deposited gravel and sand from the glacial areas into these depressions (Vrabec et al., 2009).

2.3.2 Natural vegetation of the broader area Geography and geology of the broader area

Trbovlje is situated in a small valley in central-eastern Slovenia and the climate here is continental one, with cold winters and not so hot summers, but with relatively high precipitation. The climazonal vegetation of Trbovlje area is European hornbeam deciduous forest (ass. Asaro-Carpinetum betuli). The initial stage of degradation in these forests leads to stands with blackthorn (Prunus spinose), and continued degradation results in the formation of dry mesophilic grasslands of Festuco – Brometea vegetation class. Completely degraded sites here are occupied by stands of Sedo-scleranthetea vegetation class, with prevailing ruderal continental species. On sites with dolomite bedrock, which ensures more thermophytic conditions for plants, that is not so rare in this area, climazonal vegetation includes stands with pine species (Pinus sylvestris and P. nigra).

Since Trbovlje valley is a relatively small and closed valley, surrounded by mountains and going in the direction that is opposite to that of the bigger Sava valley, the influx of the new species is probably significantly lower than it is the case in Rijeka or Belgrade. In biological sense, this can be linked to isolation and elevated degree of extinction, lower degree of both immigration and emigration, genetic drift and other effects to the biodiversity of closed environments that can lead to impoverishment of biodiversity. In this sense, the ecological communities in Trbovlje valley are possibly even more sensitive and more prone to endangerment by human impact.

2.3.3 The impact of the Power plant Trbovlje on the natural environment

The Trbovlje power plant is also burning coal to acquire electric energy, similar to Snaga i svetlost in Beograd used to in the past, but its impact on natural environment is less pronounced due to modern, up to times technologies and working under more strict legislations and environmentally more conscious society in Slovenia and European Union.

Širca (2000) showed that the influence of the Trbovlje Power Plant on the thermal state of the river Sava was not significant, as the whole Sava hydropower plants chain together with Trbovlje Power Plant might increase the temperate at nuclear Power Plant Krško by about 1°C in typical extreme conditions. The Trbovlje Power Plant 2 increases the river temperature from 0.16 (in November) up to 0.35°C (in September) with annual average of 0,22°C.

The results of this spatial analysis of the correlation between respiratory diseases in children from Zasavje region and air pollution showed a statistically significant positive correlation in the effect of the average annual SO2 concentration (Kukec et al. 2014.).

According to Kukec at al. (2013), the Zasavje region (or simply Zasavje), situated in the central Slovenia, consists of the Zagorje, Trbovlje and Hrastnik municipalities and is considered to be one of the most polluted regions in the country. For example, in 2008 the highest 10 concentrations of inhalable particulate matter with a diameter of 10 microns or less (PM10) were measured in urban areas polluted by traffic (Maribor, Ljubljana), industry (Trbovlje, Zagorje ob Savi) and individual heating devices in winter (Zagorje ob Savi). Most exceedances of the daily PM10 limit values were recorded in Zagorje ob Savi (107) and Trbovlje (73). The Zasavje region encompasses three narrow valleys placed more or less perpendicularly to the larger Sava river valley. One of the main features of Zasavje are coal mines, which are presently being exhausted and in the closing phase. On the other hand, the Sava river valley has for decades been one of the main Slovenian railway arteries. Consequently, many different centres of heavy industry were placed in Zasavje, among others one of the biggest steam power plants in Slovenia. The power plant, as well as cement, glass, chemical, and other industries, are mainly situated at the junction of the Zagorje, Trbovlje and Hrastnik valleys with the Sava valley. Ever since its establishment, the local industry has had an enormous impact on the environment. Due to the geographical and meteorological characteristics of the region, the impact of pollutants is even stronger. Wind direction and speed in the Zasavje mountainous terrain vary considerably. The predominant wind directions are north and south- east, while south-west, north-east winds are much less represented. The average wind speed in all directions is very low - very rarely do winds blow at speeds above 10 m s-1. Temperature inversions are frequently present in winter and autumn in the lower points of the valleys. Both animals and plants frequently suffer the consequences. Recent environmental studies have shown extensive pollution of plants with SO2 and fluorides, lichen with cadmium and lead, roe deer with cadmium and mercury, and air with PM10.

The most important pollution in the past was caused by sulphur dioxide (SO2) and particulate matter (PM). However, according to the latest report of the Environmental Agency of the Republic of Slovenia (EARS), SO2 levels have greatly improved, and the national legally-defined maximum values are exceeded only exceptionally (in the period 2000-2010, the average annual concentration of SO2 reduced from 22 µg m-3 to 6 µg m-3).

The prevalence of chronic respiratory diseases (CRD) and frequent acute respiratory symptoms (FARS) was related to the level of outdoor air pollution in the local environment (low, moderate and high pollution areas), 2.02-times higher odds for FARS were registered in high pollution areas in comparison to low pollution areas. The study confirmed a significantly higher prevalence of CRD and FARS in children living in high pollution areas of Zasavje. (Kukec et al. 2013)

Research done 16 years ago (Pogačnik 2007), emphasized the importance and possible environmental impact of the Thermal power plant Trbovlje waste that has to be treated accordingly. Coal fly ash from electrostatic precipitator and slag are the by-products of electricity production. In most cases by-products are either dumped at suitable repositories or used otherwise. The Trbovlje thermal power plant at that time used coal from the Trbovlje-Hrastnik mine and coal fly ash as well as slag has been dumped at the existing repository pile Prapretno. The same repository has also been used for gypsum which occurs as a by-product in the process of elimination of sulphur from smoke gases. The Prapretno pile of waste products affected mostly the quality of air with the dust particles being transported into it and thus, indirectly, precipitations, soil and vegetation are also affected. The wind plays a major part by spreading dust particles in the surroundings. The consequences are most felt by residents of Prapretno and Plesko who demand a more careful and environmentally friendly handling of this waste. The Trbovlje plant has taken numerous measures in this respect, such as moistening the surface of the dump, diminishing the amounts of dumped material at the expense of selling it for further use and abiding by the laws regulating the mode of disposing of such waste.

2.3.4 Damaged natural relationships at industrial sites

The term "biodiversity" is often quite abstract and, consequently, prone to misinterpretation. Typically, we assess biodiversity quantitatively and qualitatively, but the interpretation is often complex and counterintuitive. Although counting the number of species per unit area or time is the most common approach to "measuring" biodiversity, one of the most accurate and reliable ways to assess biodiversity both qualitatively and quantitatively is by examining biological interactions.

A simple four-word taxonomy categorizes relationships among organisms into four types: (a) selfishness, where one organism benefits at the expense of another (+ / -); (b) cooperation, where both organisms benefit (+ / +); (c) altruism, where an organism acts to benefit others at the expense of its own well-being (- / +); and (d) defiance, where the relationship harms both organisms (- / -). Note that these relationships, which are readily recognized in natural biological systems, are not to be directly transposed to the human society. The diversity of these relationships serves as a robust indicator of ecosystem health. While abandoned and ruderal sites often exhibit high species diversity, this diversity is typically unsustainable because the diversity of relationships between organisms tends to be low.

Lichens are complicated symbiotic organisms whose thallus consists of various groups of fungi, green algae, or cyanobacteria. Such a community functions as a novel organism with specific properties. The photosynthetic activities of algae and cyanobacteria lead to the production of organic compounds, while fungi provide mechanical protection, accumulate moisture and nutrients.

Figure 7: Lichens are used as bioindicators of air quality

In this way, lichens, as a group of organisms heavily reliant on beneficial interactions, provide an illustrative example. Epiphytic lichens are used for following the heavy metal input into the environment, since they accumulate them, and for the assessment of general pollution, since they start to decay in polluted areas. In lichens, the cooperation between green algae and fungi (a lichen thallus primarily comprises one or several different fungal species) is commonly referred to as symbiosis, although this relationship is intricate and sometimes misunderstood. In many lichen species, this cooperation is rather fragile and can be disrupted by various environmental stressors, notably air pollution. Certain sensitive lichen species exhibit structural changes in response to air pollution, including reduced photosynthesis and bleaching. Pollution can also lead to the death of lichen algae, discoloration, reduced growth of the lichen fungus, or complete lichen mortality. It's no surprise that (especially sensitive) lichen species are generally absent in heavily air-polluted areas influenced by heavy polluters as TE Snaga i svetlost and Hartera. Although strong measures have been undertaken to reduce the environmental impact of Trbovlje plant, especially pollution of the air, it is not probable that the lichen communities have recovered completely in Trbovlje valley and its surroundings, based on conclusions of the similar situation research (Poličnik & Batič, 2007).

2.4 Conclusion

Although we all tend to romanticise past, especially golden times of industries that helped our cities and towns grow and develop, we should be aware that those “golden times” were actually very dark ages for nature and environment that still cast a shadow to our present and the future. Were those times really utopian or actually dystopian ones and is the future without re-operating this industries dystopia or actually utopia? Human society, a society of only one animal species, is only a part of bigger, broader and stronger natural systems and we should be aware of this.

Literature

[1] Ciuta, I., Gallop, P., Myllyvirta, L., Pehchevski, D., Uusivuori, E. (2021) Comply or close. How Western Balkan coal plants breach air pollution laws and cause deaths and what governments must do about it. CREA & CEE bankwatch Network. 1-50

[2] Dimitrijević, V. (1997). Upper Pleistocene mammals from cave deposits of Serbia.

[3] Herak, M., Herak, D., Markušić, S. (1996.): Revision of the earthquake catalogue and seismicity of Croatia, 1902-1992. Terra Nova, 8, 86-94.

[4] HGI, 2009. Geološka karta republike Hrvatske 1:300,000. Hrvatski geološki institut, Zagreb.

[5] Ilic, M., Stojković, S., Rundić, Lj., Calic, J., Sandić, D. (2016). Application of the geodiversity index for the assessment of geodiversity in urban areas: an example of the Belgrade city area, Serbia. Geologia Croatica. 69. 325-336.

[6] Klepač, K., Velić, I., Vlahović, I. (2012). CD ROM Geološka građa riječke regije, Prirodoslovni muzej Rijeka.

[7] Kukec, A.. Zaletel - Kragelj, LJ., Farkaš - Lainščak, J., Eržen, I., Herakovič, A., Božnar, M. Z., Mlakar, P.; Grašič, B., Zadnik, V. (2014): Health geography in case of Zasavje: linking of atmospheric air pollution and respiratory diseases data. Geografija zdravja na primeru Zasavja: povezovanje podatkov o onesnaženosti ozračja in boleznih dihal. Acta geographica Slovenica, 54-2, 345–362

[8] Kukec, A., Farkaš, J., Eržen, I., Zaletel - Kragelj, LJ. (2013) A prevalence study on outdoor air pollution and respiratory diseases in children in Zasavje, Slovenia, as a lever to trigger evidence-based environmental health activities. Arhiv za higijenu rada i toksikologiju; 64:9-22

[9] Pikelj, Kristina & Juračić, Mladen. (2013). Eastern Adriatic Coast (EAC): Geomorphology and Coastal Vulnerability of a Karstic Coast. Journal of Coastal Research. 29. 944-957. 10.2307/23486562.

[10] Marinovic, Dj., Rundić, Lj. (2020). Depth geological relations of the wider area of Belgrade - based on the wells and geophysical data. Geoloski anali Balkanskog poluostrva. 81. 1-32. 10.2298/GABP201030009M.

[11] Mikić, A. (2020): Tehnologija zaštite okoliša u elektranama. Završni rad. Sveučilište Josipa Jurja Strossmayera u Osijeku, Fakultet elektrotehnike, računarstva i informacijskih tehnologija Osijek

[12] Mikuž, V. (1999). The great-teeth shark Carcharocles megalodon (Agassiz) also from Middle Miocene-Badenian beds above Trbovlje, Slovenia. Geologija, 42(1), 141–149. https://doi.org/10.5474/geologija.1999.008

[13] Poličnik, H., Batič, F. (2007) Ali stanje lišajske flore že kaže na spremembo kakovosti zraka v Šaleškid olini po izgradnji čistilnih naprav v termoelektrarni Šoštanj? Zbornik gozdarstva in lesarstva 82, 15–23

[14] Pogačnik, M. (2007) Vplivi odlagališča elektrofiltrskega pepela Termoeletrarne Trbovlje na okolje. Diplomsko delo. Univerza v Ljubljani, Filozofska fakulteta, Oddelek za geografijo.

[15] Širca, A. Toplotna obremenitev Save dolvodno od Trbovelj – Thermal Load of the Sava River Downstream from Trbovlje. Acta hydrotechnica 18/20 (2000), 83-95, Ljubljana

[16] Vivoda Prodan, M., Benac, Č., Žic, E., Jagodnik, P., Dugonjić Jovančević, S. (2012). Past and present geohazards in the Rječina Valley. Hrvatske Vode. 20. 105

[17] Vrabec, M., Šmuc, A., Pleničar, M. & Buser, S. (2009): Geological evolution of Slovenia – An overview. – In: Pleničar, M., Bojan, O., Novak, M. & Pirc, S. (eds): The Geology of Slovenia. – p. 23–40, 17 fig.; Ljubljana (Geološki zavod Slovenije).

[18] Zrnčević, S. (2019) Obrada industrijske otpadne vode iz proizvodnje celuloze i papira. Hrvatske vode 27/110, 317-342