ČESKÁ ZEMĚDĚLSKÁ UNIVERZITA V PRAZE
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Katedra geoenvironmentálních věd

MOŽNOSTI ODSTRAŇOVÁNÍ STARÝCH EKOLOGICKÝCH ZÁTĚŽÍ V SRBSKU

POSSIBILITES OF REMOVING OLD ENVIRONMENTAL DAMAGES IN SERBIA

BAKALÁŘSKÁ PRÁCE

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ZADÁNÍ BAKALÁŘSKÉ PRÁCE

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pro: Strahinja Mladenovič

obor: Aplikovaná ekologie

Název tématu: Možnosti odstraňování starých ekologických zátěží v Srbsku

Název tématu v anglickém jazyce: Posibilities of removing of old environmental damages in Serbia

Zásady pro vypracování:

Student se ve své práci zaměří na problematiku starých ekologických zátěží v Srbsku. Cílem zpracování bakalářské práce je vytipování starých ekologických zátěží v Srbsku a jejich sanace. Student popíše jejich hlavní rizika uvedených SEZ, zhodnotí jejich významnost a pokusí se navrhnout v rámci vlastní části možná sanační řešení s využitím zkušeností z praktických sanačních operací, které se provádějí nejen v Srbsku, ale i v České republice případně v EU, uvede výhody a nevýhody jednotlivých sanačních technologií.

Práce bude rozdělena do těchto částí:

1) Úvod a cíle práce; 2) Přehled SEZ a hlavních sanačních zásahů; 3) Staré ekologické zátěže v Srbsku; 4) Návrh sanačních opatření; 5) Závěr; 6) Literatura.

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Bláha K. (1994): Metodika hodnocení zdravotních a environmentálních rizik, MŽP ČR.

Bedient P.B., Rifai H.S., Newell C.J. (1994): Ground Water Contamination, Transport and Remediation.– Prentice Hall, Englewood Cliffs, New Jersey.

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V Praze dne 7. 10. 2010

Declaration

I declare that this bachelor thesis was written by me and me alone, merely using the cited sources. I agree with the loan of my work and its publication.

In Prague, 30.4.2012 Strahinja Mladenović

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Abstract: The objective of this thesis was collecting information about main ecological damages (burdens) in Republic of Serbia, their description and recommendation for possible remedial techniques. The most contaminated sites are in City of Belgrade, Pančevo, Bor, Kragujevac and Lazarevac. Municipal landfill Vinča is main dumping site in capital city of Serbia, Belgrade. Oil refinery, Fertilizer Factory and Chemical plant are major problems for Pančevo environment. Kragujevac still fights with burdens connected with NATO bombing of the automobile industry. The largest copper mine in Serbia is situated in Bor and it has huge influence on health of local people, but on nature as well. Every ecological burden is explained in separate chapters. Remedial methods of old environmental damages (mentioned above) are explained in separated as well in the chapter "Recommendation of main remedial methods". Personal photos and videos of the thesis author are attached in chapter "Photo Gallery" and CD as well. Multimedia includes environmental burdens in City of Bor and Belgrade's landfill. Chapter "Conclusion and Discussion" deals with, which main factors were the causes of the burdens and how it can improve in general.
Keywords: Serbia, ecological damages, landfill, coal and copper mining, oil pollution, remediation methods

Abstrakt: Cílem této práce bylo shromažďování informací o hlavních ekologických zátěží v v Srbsku, jejich popis a doporučení možných sanačních metod k jejich odstranění. Nejvíce kontaminovaných lokalit jsou ve městech Bělehrad, Pančevo, Bor, Kragujevac a Lazarevac. Městská skládka Vinča je hlavní komunální skládka v hlavním městě Srbska, Bělehradě. Rafinerie ropy, výroba hnojiv a chemická továrna jsou hlavní environmentální problémy pro životní prostředí města Pančevo. Kragujevac stále bojuje se zátěží spojených s NATO bombardovaní automobilového průmyslu. Největší důl mědi a zlata v Srbsku se nachází v Boru, a to má obrovský vliv na zdraví lidí, kteří tam bydlí, ale na přírodu taky. Každá ekologická zátěž je vysvětlena zvlášť v samostatných kapitolách. Sanační metody starých ekologických zátěží (viz výše) jsou vysvětleny samostatné v kapitole "Doporučení hlavních sanačních metod". Osobní fotografie a videa autora jsou uvedeny v kapitole "Fotogalerie" a na CD také. Multimédia obsahuje obrázky a videa ekologických zátěži z Boru a Bělehradu. Kapitola "Závěr a diskuse" se zabývá, které hlavní politické a ekonomické faktory byly příčiny ekologických zátěží a jak se tyto zátěže mohou zlepšit všeobecně.
Klíčová slova: Srbsko, ekologické zátěže, skladka, těžba uhlí a mědi, ropné znečištění, sanační metody

Acronyms

BAT – Best Available Technology

BOD5 – Biological Oxygen Demand (5 days of incubation at 20 ℃)

cca. – circa

COD – Chemical Oxygen Demand

DEPB – Department of Environmental Protection of the City of Belgrade

DNAPL - Dense Non-Aqueous Phase Liquid

EDC - 1.2 – dichloroethane

EPS – Elektroprivreda Srbije (Electric Power Industry of Serbia)

EU – European Union

ha – hectare

HIP – Hemijska Industrija Pančevo (Chemical Industry of Pančevo)

ISO - International Organization for Standardization

MCL – Maximum concentration limit

MŽP ČR – Ministry of the Environment of the Czech Republic

NATO - North Atlantic Treaty Organization

NIS – Naftna Indrustrija Srbije (Serbian Oil Industry)

NOx - mono-nitrogen oxides NO and NO2

PAH - Polycyclic Aromatic Hydrocarbons

pH - measure of the acidity or basicity of an aqueous solution

PP – Power Plant

RTB – Rudarsko Topioničarski Basen (Copper Mining and Smelting Complex)

SO2 - Sulfur dioxide

TENT – Termoelektrana “Nikola Tesla” (Power Plant “Nikola Tesla”)

TPP – Thermal Power Plant

USA – United States of America

USEPA – United States of America Environmental Protection Agency

WWII – World War Two

WWTP – Wastewater Treatment Plant

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1. Introduction and Objectives

After WWII, Yugoslavian industry started to rapidly improve. Oil refineries, mining casts, car industry were economic pioneers of Yugoslavia. Economic sanctions in 1990's have brought many problems, but most of them which were visible are connected with nature degradation. New millennium brought new hope for people of Serbia and its environment as well.

This bachelor thesis gives a look at most contaminated sites and old ecological burdens in Republic of Serbia. In next chapters, I tried to describe the most contaminated sites in Serbia and old environmental burdens which are priority to be rehabilitated and recommendations of main remedial techniques which are already done or should be taken at those areas. Some of them include practical remediation technology, while some of them include upgrading of an old one or installing new and modern facilities instead of outdated.

1.1 Serbia and its environmental situation

Main former political, economical, educational and cultural leader of former Federal Socialist Republic of Yugoslavia with its population of 7 million people, nowadays Republic of Serbia as democratic country takes big role in south-eastern Europe and Balkan Peninsula. Serbia takes surface of 88,361 km^2 and it's one of the largest countries on Balkans. Serbia is a democratic country and comprises two autonomous provinces: Vojvodina on the north and Kosovo on the south. City of Belgrade is the capital of Serbia, with a population of cca. one and half a million; Belgrade is the country's administrative, economic and cultural centre (Mitchell, 2010).

Republic of Serbia is often described as "the crossroad between the East and the West", because of its position in southeastern Europe. Land roads and railways of Morava Valley are one of the easiest ways to travel to Greece and Asia Minor. Danube river is the most important water transport route for Serbia since connects it with some significant western countries (Mitchell, 2010). Serbia is democratic parliamentary republic, member of UN and it's pretending to become a member of European Union until 2015 (Serbian Government, 2012).

By UNEP (2004), many of Serbia's environmental problems and damages are related to its historic legacy of a centrally planned economy and historical remains of more than fifty years of rule by communist regime (1945–2000) which were not very concerned with environmental protection. A focus on heavy industrialization in combination with price controls and subsidies created inefficient and wasteful natural resources use.

1.2 Objectives

The primary objective of this thesis is the marking of Serbian environmental "hot spots" and ecological burdens, their description and proposition for sanitation and remediation, eventually restoration of threatened ecosystems. Other important objectives of this study is to evaluate hot spot's significance and as it was mentioned, suggest the possible solution for its remediation and redevelopment with own practical experience in sanitation operations which are carried out not only in Serbia, but also in the Czech Republic and EU, indicating the advantages and disadvantages of various remediation technologies.

The expected benefits of this thesis is a general view on the main environmental damages in Serbia and their sanitation, generally finding long-term solution for those kind of problems and further defining their impact on the environment.

2. List of old environmental damages

2.1 Environmental damages (burdens)

Old ecological burden is a serious contamination of geological environment, groundwater or surface water that was caused by improper handling and managing of hazardous substances in the past (oil, pesticides, chlorinated and aromatic hydrocarbons, heavy metals, PCBs etc.). Observed contamination will be considered as an old ecological burden only if the agent contamination doesn't exist or is unknown (Havrlant 1998).

According to MŽP ČR (2012), contaminated sites can be varied types - it can be a landfill, industrial and agricultural facilities, retail establishments, non-secure storage of hazardous substances or areas affected by mining minerals.

There are many environmental damages caused by different factors, but I will mention few important causers, such as:

- Basic Industry
- Oil and petroleum refineries
- Mines
- Landfills (inadequate waste management)

(Havrlant 1998).

These pollutants are the biggest environmental causers in Republic of Serbia as well (WHO, 2010).

2.1.1 Basic Industry

The degradation of soil and pollution of ground and surface waters began as soon as industry began producing manufactured goods and wasting liquids and solid matter simultaneously. If we define pollution as that certain amount of industrial contamination that causes interference with the best usage of the receiving water, we can probably agree that this type of pollution did not begin before twentieth century. Basic industries such as power and food production, dairy, textile, cannery, and paper, which produce goods important for life, were the first to face the pollution problems. (Nemerow, 2006)

2.1.2 Oil and petroleum refineries

Potential environmental issues associated with petroleum refining include the following:

- Air emissions
- Wastewater
- Hazardous materials
- Wastes
- Noise pollution

(Cheremisinoff, 2002).

Air emissions includes exhaust gas and flue gas emissions (carbon dioxide (CO2), nitrogen oxides (NOX) and carbon monoxide (CO)) in the petroleum refining sector result from the combustion of gas and fuel oil or diesel in turbines, boilers, compressors and other engines for power and heat generation. Flue gas is also generated in waste heat boilers associated with some process units during continuous catalyst regeneration or fluid petroleum coke combustion (Cheremisinoff, 2003).

According to Parkash (2003), the largest volume effluents in petroleum refining include “sour” process water and non-oily/non-sour but highly alkaline process water. Sour water is generated from desalting, topping, vacuum distillation, pre-treating, light and middle distillate hydrodesulphurization, hydro cracking, catalytic cracking, coking and thermal cracking.

Sour water may be contaminated with hydrocarbons, hydrogen sulfide, ammonia, organic sulfur compounds, organic acids, and phenol. Process water is treated in the sour water stripper unit (SWS) to remove hydrocarbons, hydrogen sulfide, ammonia and other compounds, before recycling for internal process uses, or final treatment and disposal through an onsite wastewater treatment unit (Parkash, 2003).

According to Meyers (2004) in his handbook about refineries, petroleum refining facilities manufacture, use, and store significant amounts of hazardous materials, including raw materials, intermediate / final products and by-products. Spent catalysts result from several process units in petroleum refining including the pre-treating and catalytic reformer; light and middle distillate hydrodesulphurization; the hydrocracker; fluid catalytic cracking (FCCU); residue catalytic cracking, butanes iso-merization; the dienes hydrogenation and butylene hydro-iso-merization unit; sulfuric acid regeneration; selective catalytic hydrodesulphurization; and the sulfur and hydrogen plants. Spent catalysts may contain molybdenum, nickel, cobalt, platinum, palladium, vanadium iron, copper and silica and/or alumina, as carriers. In addition to spent catalysts, industry hazardous waste may include solvents, filters, mineral spirits, used sweetening, spent amines for CO2, hydrogen sulfide (H2S) and carbonyl sulfide (COS) removal, activated carbon filters and oily sludge from oil / water separators, tank bottoms, and spent or used operational and maintenance fluids. The principal sources of noise in petroleum refining facilities include large rotating machines, such as compressors and turbines, pumps, electric motors, air coolers (if any), and heaters. During emergency depressurization, high noise levels can be generated due to high pressure gases to flare and/or steam release into the atmosphere.

2.1.3 Mines

The environmental impact of mining includes erosion, formation of sinkholes, loss of biodiversity, and contamination of soil, groundwater and surface water by chemicals from mining processes. In some cases, additional forest logging is done in the vicinity of mines to increase the available room for the storage of the created debris and soil. Besides creating environmental damage, the contamination resulting from leakage of chemicals also affects the health of the local population. Mining companies in some countries are required to follow environmental and rehabilitation codes, ensuring the area mined is returned to close to its original state. Some mining methods may have significant environmental and public health effects (Grujic, 1998).

2.1.4 Landfills

In his handbook Cheremisinoff (2003) mentions that, in a larger environmental sense, landfills emit methane gas, which is a more dangerous greenhouse gas than carbon dioxide. Air emissions are typical problem on landfills everywhere. Some gasses, like methane can be controlled and used as a biogas. One of the most common problems with landfills reported was a leakage of hazardous materials. Even the most well-built and monitored dumping site will probably leak and the ground water will become contaminated. A large amount of household and industrial waste works its way into landfills and then finds its way into the water. Despite all rules and laws, there is no secure and clean landfill.

3. City of Belgrade

Belgrade is the capital and largest city of Serbia. The city lies at the confluence of the Sava and Danube rivers, where the Pannonia Plain meets the Balkans. It has an urban population of 1.2 million, while the metropolitan area has more than 1.7 million people, making it one of the largest cities of Southeastern Europe (Mitchell, 2005).

According to DEPB (2010), Belgrade has been paying special attention to the environmental protection for three decades now. In 1974, the City Committee for Town Planning and Environmental Protection was formed whereby the work and monitoring of the status in this area were organized for the first time within the authorities of the City of Belgrade. The Secretariat for Environmental Protection, as a separate body to engage in operations entrusted by the legislation was set up in 1990. The quality of environmental protection is monitored on a continuous basis. Each year, there are prepared certain programs of control of the quality of air, the quality of drinking water and public drinking fountains, surface waters, as well as the programs of testing of the levels of radioactivity, pollution of soil and measurements of the level of communal noise. The protection of the area of water catchment is provided through the plans and projects of physical development and their implementation.

3.1 Landfill Vinča

Belgrade has one and only landfill site which receives waste from the entire city and its surrounding area. The site is situated just outside the city next to a small village called Vinča. The site is located in a tributary valley of the River Danube and extends to about 70 ha in area. The waste infill is up to 60 meters deep in places with two active tipping faces. There is no leach ate or gas management on the site. The site itself is unlined with a small stream flowing through its centre to the River Danube about 1.5 km away (Aleksandar Raca, XI. 2010, in verb).

The "Vinča" landfill was established in 1978. as one of several municipal landfills. Since the 1990-ies the "Vinča" landfill has been the only operating landfill servicing the Belgrade Metropolitan area, the biggest city in Serbia, with cca. 1,5 million inhabitants in the larger-city area. The total average amount of solid wastes deposited in the landfill is estimated to be 1100 tons/day. The landfill site is not lined and the tributary flows through the centre of the site-in some places directly under the mass of refuse. No consideration has been given to the protection of ground waters, surface runoff or drainage. Local authorities plan to expand the landfill by 1.3 km2. Chemical analysis was performed on the samples and the temporal variation of several parameters was monitored including pH, COD, chlorides, sulfates, nitrates, ammonia nitrogen, hardness, and heavy metals. The COD and pH were related to the biological activity within the landfill and the results indicated differences between the samples due to waste age (Ćalić & Ristić, 2006).

Ćalić and Ristić (2006) continues, the concentrations of heavy metals, sulfates, nitrates, chlorides and ammonia nitrogen in the leachate were low, indicating their initially low amount in landfilled waste or their flushing with moisture contributing to a reduction in their concentrations.

The leachate coming out of the base of Vinča landfill site was extremely organic rich and evidence of its strength could be observed from its point of egress all the way to its eventual dilution in a freshwater lagoon adjacent to the River Danube. The mud is anoxic and the vegetation has been killed off by the strength of the leachate. The majority of mollusks and gastropods in the path of the leachate flow, as it fanned out across the lagoon muds, had been killed. The ground had a crusty coating of metal salt deposits (Ćalić and Ristić, 2006).

According to Ćalić and Ristić (2006*),* Vinča site had not been used for the disposal of hazardous industrial waste, but it was the disposal point for considerable quantities of steel and other scrap metals. This iron based leachate was photographed (see Chapter: Photo Gallery) at one of many such effluent egress points around the site. Unfortunately the site was used for the disposal of the entire city's medical waste and this was an extremely hazardous and high risk practice.

More about soil degradation and water pollution of Borska River see Chapter: Photo gallery or CD.

4. City of Bor

Bor is a city located in eastern Serbia, with one of the largest copper mines in Europe and it has been a mining centre since 1904. It is the administrative center of the Bor District of Serbia. Population of Bor is approx. 40 000. Copper mining is the key basis of Bor's economy and the effects of decreased production can be seen all over the town (Opstina Bor, 2011).

4.1 RTB Bor

Main environmental problems of City of Bor, caused by RTB Bor are:

- Air pollution
- Soil and land degradation
- Contaminated industrial wastewater
- Industrial landfill containing PCB materials
  (Markovic & kol, 2003)

The main source of air pollution with SO_2 gas, heavy metals in PM and aero sediments is the Copper Smelter Plant within the RTB Bor which has been working in Serbia for more than century (Tasic at al, 2010). Every year, every tone that is processed by RTB Bor plants emits 2.25 kg of heavy metal-contaminated particulate matter (PM), 5.3 – 19.6 kg of arsenic, 6.27 – 25.11 kg of lead, 4.86 – 7.99 kg of zinc (Ilic et al, 2011).

According to Tasic & kol. (2010), other important high figures, such as sulfur dioxide (SO_2) and mercury are reportedly emitted to the atmosphere. Their values were 170000 to 250000 t of SO_2 and 1.6 t of mercury per year.

Open cast mining has caused severe land and soil degradation soil degradation in the area. Failed open cast slopes have cause the collapse of local buildings and pose a significant local safety threat. The dust from mining, smelting and waste has degraded approximately 1,300 hectares of fertile land that would otherwise be suitable for farming. Open cast mine pits also become convenient dumping places for all type of wastes that can release leachate into the soil and contaminate surrounding land and watercourses. The regular discharge and dumping of solid wastes downstream of Bor, particularly at the confluence of the Bor and Timok rivers, has degraded other agricultural land in the area. Total affected surface of damaged soil in Bor estimated at some 25,500 ha, which constitutes 60% of all agricultural soils, and resulting in the figure of 0.5 ha of damaged soil/capita (Tar 2007 ex. LEAP Bor, 2003).

Large basins around Bor used to stock the flotation sludge and other toxic liquids with its high heavy metal and sulphuric acid content are also seriously polluting the local Borska and Krivelj rivers. Heavy metal content in rivers far exceeds permitted levels. There are also fears that the dams of the Veliki Krivelj tailing pond (almost 200 million m^3) will break due to their poor state of repair. The tailing pond is sited in the river bed itself, diverting the waters. Such a catastrophe would cause a major ecological disaster reaching as far as the Danube delta in Romania. (Panias, 2007).

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Panias (2007) continues about industrial waste dumping sites located nearby the city has a huge depth of waste. It is estimated that the first of these sites contains about 21 200 m^3 of sulphidic waste, while the sulphidic waste volume of the second accounts for more than 31 800 m^3. Dissolved heavy metals or sulfates, or both, are released from the dumping sites into the environment, causing serious and long lasting contamination in soil, surface- and groundwater.

More about soil degradation and water pollution of Borska River see Chapter: Photo gallery or CD.

5. City of Pančevo

Pančevo is a city located in the southern part of Vojvodina, just 15 km northeast from Belgrade. In 2002, the city had a total population of 77 000. It is the administrative center of the South Banat District. Pančevo is also the most important port on the Tamiš and Danube River, which flow near the city. It is also the economic and cultural centre of South Banat and one of the most important and biggest industrial centers in the Republic of Serbia (City of Pančevo, 2011).

5.1 Industrial Complex

Industrial complex of Pančevo includes three huge companies:

- Oil Refinery of Serbia – NIS Pančevo (privatized by Gazprom)
- Pančevo Petrochemical Plant (HIP Petrohemija)
- Pančevo Fertilizer Factory (HIP-Azotara)
  (Kaisarevic et al., 2009).

5.1.1. Oil Refinery of Serbia (NIS - Pančevo)

NIS refinery produces: gases; gasoline, jet fuel, aromatics, kerosene, diesels, fuel oils and feedstock for the petrochemical industry. The refinery has a maximum processing capacity of 4.8 million tones of crude oil per year (NIS, 2010). According to Savić (2011) the refinery is currently undergoing a $306 millions modernization program that will enable it to produce Euro 5-quality petrochemical products.

Key environmental problems of Pančevo are:

- Oil discharges into wastewater canal and Danube and Tamiš River (Kaisarevic et al, 2009)
- Soil and groundwater pollution from Industrial Complex (Milić et al, 2009)

- Excess emissions to air, particularly of sulfur dioxide and particulate matter (Karadžić & Popović, 2007)
- NATO bombing consequences, table 1. (Gopal & Deller, 2002)

5.1.2 Pančevo Petrochemical Plant (HIP)

The HIP Petrohemija manufacturing complex occupies 241 ha in the industrial zones of Pančevo. The complex comprises 7 facilities, some of those are an ethylene plant; high and low density polyethylene plants, chloral-alkali electrolysis plant, a PVC plant, and a wastewater treatment plant. The complex is able to produce approximately six hundred thousand tones of petrochemicals per year, including basic chemical and polymer products such as polyethylene gas and water pipes (HIP[a], 2012).

According to Kaisarević et al. (2009) key environmental damages caused by HIP are: wastewater treatment plant receives effluents and inadequate monitoring over input is often causing that process failures and receiving water is getting contaminated (graph 1.) , sludge lagoon is a big threat to the soil and groundwater (contamination by chlorinated solvents), then inadequate storage and disposal of waste (chemicals, asbestos-containing materials, PCB, mercury sludge). The most visible pollution from all is the air pollution where air emissions exceed limits, especially benzenes, toluene, xylene which is shown in graph 2. (Ugrinov & Stojanov, 2011).

5.1.3 Pančevo Fertilizer Factory (Azotara)

The Pančevo Fertilizer Factory, called Azotara which belongs to HIP industrial complex occupies 127 hectares and includes five operational facilities which were constructed in 1959 and grew to become Yugoslavia's leading producer of mineral fertilizers. At its peak, the factory produced between 1,200-1,400 tones per day of calcium ammonium nitrate and 300 tones per day of urea as well as large quantities of NPK (nitrogen-phosphorus-potassium) fertilizer, ammonia, ammonium nitrate, nitric acid and nitric solutions, compressed gases and de-mineralized water. The plant wastewater is connected with the Danube River by a two-kilometer long navigable canal that enables the transport of raw materials and products. Process and cooling water is abstracted from the navigable canal by a pumping station. (Azotara, 2012).

During the Kosovo conflict in 1999, the plant was hit twice by bombing. The major concern at this plant is the spill of over 2,100 metric tons of 1,2-dichloroethane and 250 metric tons of ammonia into the wastewater canal. Little bit more than a half of the material spilled into the waste canal via the sewer system while half of it spilled onto the soil surface. (Gopal & Deller, 2002). By the USEPA (2004) 1, 2-dichloroethane is a DNAPL, which means that it does not mix with water, is heavier than water, and therefore will sink.

For the most important problems of this company which pollute environment can be marked:

- Disposal of untreated wastewater into the wastewater canal
- Air pollution from nitrogen oxides and ammonia
- Inefficient use of abstracted water for cooling and firewater. (Kaisarević et al. 2009)

6. City of Kragujevac

Kragujevac is the largest city of the District of Šumadija and the 4th biggest city in Serbia. The total population is cca. 180 000. Kragujevac has been an important industrial, cultural and trading centre in Serbia for over two centuries. The industry of Kragujevac is best known by its cars production and weapons manufacturing. The former state-owned “Zastava automobiles” was founded in 1950’s and produced the well known, Yugo brand of vehicles (Grad Kragujevac, 2012). Zastava was sold to Fiat - Italy in 2008, with Fiat planning to invest around 700 million Euros into the company now renamed as Fiat Serbia (BBC, 2009).

6.1 FIAT Cars (Ex-Zastava) Complex

Main environmental damages in Kragujevac could be ecological management duties for industrial complex’s facilities are not clearly defined, waste landfills are accessible to public and children, release of untreated wastewater to the Lepenica river, petroleum tank depository is next to the river and there is a big potential to leak and create a contamination, improper storage of PCB-containing apparatus and PCB-contaminated places, air pollution from power plant (UNEP, 2004).

The industrial complex “Zastava Cars” creates different types of solid waste, including, toxic waste (scrap steel, textile scraps, and used PCB capacitors) which represent an important and serious problem in the City of Kragujevac. Probably, the concrete surface in the Industrial Complex is contaminated with PCBs, due the huge location of Complex there was a place to temporarily store PCB-contaminated waste after NATO bombing in April 1999. Approximately 500 tones of hazardous waste is stored in the drums (with 210-liter volume) which contain waste lacquers, paints, solvents, thinners, adhesives, etc. (UNEP, 2004).

Big amount of waste (including hazardous waste, concrete, brick, steelwork, pipe work, asbestos insulation, damaged asbestos cement sheets, rubber) from locations destroyed during the NATO bombing of the “Zastava” complex has been stored near the residential area of Kragujevac. The site was not under control and it was a possible danger for local residents and children because of easy access to the site (UNEP, 2004). Most important problem was the leakage of PCBs, chromium and nickel, mostly into the groundwater and soil. Research made at University of Kragujevac shows that the exposure to pollutants in uterus affects genetic information of fetus and increases micronuclei values in their body cells (Milosevic-Djordjevic et al. 2005).

Air emissions in Kragujevac represent important damage and pollution as well. Air monitoring in 2002 shows that, soot concentrations were higher than the limit value (10-38 $\mu g/m^3$,50 $\mu g/m^3$ annually), SO_2 concentrations were between 22 and 111 $\mu g/m^3$ per month, 50 $\mu g/m^3$ per year. The “Zastava Cars” complex had completed construction of a wastewater collection and central pre-treatment system in 1999 but due to bad economical situation in the state and the war in Kosovo had just started wastewater collector has never been put into working process. Wastewater from some plants has been discharged (with and without primary treatment) directly into the Zdraljica and Lepenica River. Other wastewaters were processed at Kragujevac central WWTP for final treatment before being discharged into the Lepenica River. (UNEP, 2004)

7. Lazarevac Town

Lazarevac is a town and one of Belgrade's municipalities located in central Serbia. It is situated cca. 55 km south from Belgrade near river Kolubara. Close to the town there is a coal-fired thermal power station "Kolubara A" which is one of the most important and the biggest supplier of the electricity in Serbia. It is the part of EPS group and one of the TENT power stations (LEAP Lazarevac, 2006). "Kolubara A" has a number industrial operations, like a open-pit mine, thermal power plant for electricity produce, production of mining equipment, a lignite coal production and processing facility, a brick factory and a civil engineering company (Lazarevac, 2011). Lignite from Lazarevac area is having an average calorific value of 7 500 kJ/kg. Open-pit mines at the Kolubara basin produces around 75 percent of lignite of Serbia and it's a supplier for a few thermal power plants in Serbia (EPS, 2012). Total produce of lignite in Kolubara basin is 28 million tones and it comes from four open casts (UNEP, 2004).

7.1 Lignite Processing Complex and Power Plant "Kolubara"

Main environmental damages in Lazarevac municipality are caused by "Kolubara". Most important ones are improper treatment of wastewater from coal and ash and air pollution from lignite processing and transport, see table 2. (LEAP Lazarevac,2006).

Objects in Industrial Complex "Kolubara" are concentrated pollutants and they can be controlled. All facilities and equipment in this Complex are in function 24 hours for 350 days. The unit's effluent is discharged, along with effluent from the power plant, into the small stream Belicanka or an artificial canal Crne vode and then transported to the Kolubara River, which is already highly burdened and in excess of applicable water quality limits. Data about wastewater quality you can see in table 2. As you can see in the table 2. effluents are typically very high in suspended particles, dissolved organics, relatively low in biological oxygen demand, high in phenolic and contain a range of heavy metals, which is not shown in the table. Some of the industrial wastewater is produced by thermal material processing. Every 2 years cca. 10 m^3 is released into the canal which leads to the

Kolubara River. Other industrial wastewater is created from open casts, especially in drainage process and there are not data about quality of those wastewaters since they are directly released into the Pestan River. For a technological working of the power plant, every year around 3.7 million m^3 of Kolubara river water is taken. Some of that water is after processing, together with ash, transported to the industrial landfill. From there is either brought back to the industrial processing or a very small percent is released in the stream Turija. Industrial landfill is a big threat to the close environment since pollutes groundwater in that area (LEAP Lazarevac, 2006).

Kolubara Industrial Complex while processing coal produces certain air emissions which represent serious environmental damage not only for Lazarevac municipality, but for the whole country. Some of air emissions includes carbon oxides, phenol, odors, ash, particulate matter, SO_2 and NOx, and they are a primary and main source of complaints from the community of Lazarevac. Since 1987, some of the gases are monitored every year and it includes phenol, SO_2, NOx, ash and particulate matter. Phenol, SO_2 and NOx concentrations are somewhat within applicable limits, particulate matter and ash concentrations typically exceed the limit value. Transportation is next big air pollutant since cca. 35 000 trucks transport 250 000 tons of lignite per year (data for 2002). The train railway is frequently used for coal transporting and train engines burn lignite fuel and cause few localized air pollution from their exhaust gases (LEAP Lazarevac, 2006). Lignite from the Kolubara Basin produces SO_2 concentrations in the range of 2,300 - 2,700 mg/m^3 and NOx concentrations between 70 - 190 mg/m^3 The TPP's precipitators have a particulate removal efficiency of around 95%. NOx emissions are in the value of the permitted limits. Dust from the stack and fly ash landfill, however, exceeds permitted limits (UNEP, 2004).

Dried lignite storage site often causes air emissions of dust, ash and smoke by itself. Ash is then mixed with water and transported via a pipeline to a fly ash landfill. The fly ash landfill is located approximately 3 km from the power plant. The landfill occupies approximately 20 ha and has a depth of cca. 12 m and it has a volume of 2.4 million m^3. During the winter the fly ash dumping site is covered partly with water. However, during hot summers the landfill dries out and wind starts to move dust around. Dust and ash are then the major source of complaints from a neighboring houses and towns. An old fly ash landfill has been remediated with 25 centimeters of subsoil and has been re-vegetated with grass or wheat. TPP

“Kolubara” generates recycled wastes (fly ash waste and waste oils), contaminated soil (deposited in the fly ash landfill) and general waste (UNEP, 2004).

8. Recommendation of main remedial methods

Remedial methods are practical actions that are used for decontamination and removal of the general pollutant components of the environment. It includes bioremediation, soil restoration, solid waste management, water and wastewater treatment, industrial waste and water treatment and noise and air pollution monitoring and cleanup. Treatment methods are divaded between soil, surface, water and grounwater rehabilitation. Then, we consider results between chemical, biological and physical treatment actions (Hamby, 2000).

8.1. Belgrade – Landfill Vinča

Exist severe methods for a remediation of old landfills: paper.Landfill capping, landfill mining, in situ vitrification, subsurface cutoff walls and in situ vapour stripping. Capping presents a technique which should block contaminated landfill area with surface, therefore protecting close environment from hazardous contents and limit transport of toxic materials from the landfill. Important is that cap must stop infiltration of all surface water into the landfill inside, Important is that cap must stop infiltration of all surface water into the landfill inside and reduce landfill leachate and contamination of groundwater. Capping system contains 3 layers: upper vegetative soil layer, drainage layer, low permeability layer made of a synthetic material covering 60-cm of compacted clay (Vasudevan et al, 2003). On the clay layer, at least 20 cm of the humus layer should be filled in order to grass can grow. Recommended type of plants to revegetate is family Fabacae. This family should support other plants to grow and increase the soil quailty and to stop erosion as well. Plants should be seeded 3-5 months after filling finil soil layer on the landfill. Recommended trees to be seed are Silver Linded (*Tilia tomentosa*) and Black Locust (*Robinia pseudoacacia*). To minimize the quantity of landfill leachate canals must be build to divert surface water from higher slopes and water from near springs. Temporary ring canals must be build around the landfill to divert water from landfill slopes. Drainage system for the rapid evacuation of leachate from the landfill should be build in the level of local erosive base at not used landfill field, with a condition of substrate permeability not greater than 10-5 cm per sec. Control of quality and quantity of water should be performed in facilities for their treatment. Groundwater should be controled by piezometers, while surface water should be controlled at the main area of the Danube river and Osljanski stream. Wastewater treatment unit should contain bio-filter ($V=300m^3$), pumping station unit and sedimentation clarifier ($V=600\ m^3$) (Regulacioni plan, 2002).

8.2. Bor – RTB Bor

In order to improve environment and life quality in Bor region, following goals were stated by Local Environmental Plan:

- **Air quality**: Reduce SO_2 emissions in 2 steps:
    1. Start production of sulfur acid in sulfur acid plant using sulfur dioxide from the smelter complex as a raw material and find a partner in trading; search for a market where it can be sold. Improving management processes in the City of Bor and introduce new environmental management systems and ISO 14000 standards (family of standards related to environmental management) (LEAP Bor, 2003). BHP

    2. Rebuilding of pipeline, that connects sulfur acid plant and smelter complex. Changing old and defect technology and systems in the chemical plant. Reconstruction of old gas pipeline, to reduce gas emissions to the environment. One of the technical options how to decrease SO_2 in Bor is using new BAT technologies in metallurgical industrial complex. Emissions could be decreased by 90% (LEAP Bor, 2003).

- **Water quality**: Decrease water consumption in industry (up to 40%) and in households (up to 20%), conservation of surface waters from mining processing and households wastewaters, Bioremediation of polluted rivers (rivers were downgraded into open wastewater collectors). To complete these goals, following actions should be taken: Construction of water storage reservoir for supply of the whole City, replacement of old asbestos pipes, introducing new system for riverbed management according to EU guide, education of population and RTB management of the reasonable use of water. Next step should be starting hydrometallurgy technologies for refining mining wastewaters in order to increase mining income (LEAP Bor, 2003). Construction of a concrete wall along mined lanes and cavities and channeling wastewater into an underground reservoir has showed useful results (Bian et al, 2010). In case of degraded rivers, using Inductively

Coupled Plasma Atomic Emission Spectrometry technique and bioreactors could decrease concentrations of metals in polluted rivers (Jackson et al, 2009).

8.3 Pančevo

8.3.1 Pančevo Petrochemical Plant (HIP)

ENACON Company from the Czech Republic together with the company Dekonta installed and managed groundwater sanitation systems. During first year of the processing of this remedial technology, a total of 170 t of dichloroethane were exploited from the polluted area (Enacon, 2012). Remediation technique contain simultaneous pumping of groundwater and EDC phase from multifarious wells, EDC gravity “break-up” and groundwater treatment with water vapor in the stripping procession, where evaporation is carried out, followed by liquefaction (to turn something into the liquid state) of EDC in exchangers. Temperature of the treated groundwater is then decreased in the exchangers, where in order to save energy costs, but before it heats untreated groundwater before starting the stripping procession, and then it is pumped back into the environment (HIP[b], 2012).

Continue the groundwater monitoring in and around the Petrohemija industrial complex. Design and create chemical and waste storage facilities which will include secondary containment. In case of air emissions, important is to decrease SO_2 and PM emissions from the industry boilers by replacing heavy oil with natural gas. Keep performing the EDC rehabilitation and search for the potential solution for in situ bioremediation of residual contamination places (UNEP, 2004). Inside its complex, Petrohemija has a modern industrial waste water treatment plant system. Before entering into main WWTP, industrial waste water is first collected and set through pretreatment processes, then is drained by sealed sewer system. This includes also atmospheric and surface water and sewage as well. Drained water goes through two processes of treatment. Primary treatment includes equalization, neutralization, flocculation and flotation, while secondary (biological) includes biofiltering and activated sludge. Both of the processes are performed separately from each other. In the Water Treatment Plant part of the treatment are dehydration and stabilization of separated sludge as well. Quality of the water is monitored and controlled before entering the Water Treatment Plant and at the discharge into the channel which leads to the Danube and as well as 50 meters upstream and downstream of the discharge into the Danube. After the whole treatment process, the waste water from Petrohemija doesn't have any effect on the Danube ecosystem. Petrohemija has a good organized and created waste management program, which decreases the waste impact on the environment. The plan contains in detail the measures and processes used in waste collecting, sorting, storage and disposal (HIP[c], 2012).

8.3.2 Oil Refinery of Serbia (NIS - Pančevo)

Reducing emission of PM into the atmosphere is done by reconstructing the Refinery facilities in 2011. There was an upgrade of 4^{th} new level of filtrating gas emissions from the Refinery, so called FSS (Fourth Stage Separator). This upgrade will be more safe and reliable, since it will decrease emission of PM into the Pančevo environment. To protect groundwater and rivers around Pančevo, new industrial harbor should be build and should include complete reconstruction of the oil reservoir, installing the part for recuperation of the gas fraction. This process will also eliminate the air pollution during transferring oil derivates from reservoir to ships (NIS, 2011). To prevent soil pollution, new technologies need to be installed at the Refinery complex. To remediated already contaminated soil, corrective actions need to be taken, especially soil remediation and other rehabilitation techniques (NIS, 2011). Alternative to expensive and traditional remediation technologies could be phytoremediation (use of special plants to rehabilitate soils, surface and ground water). It is considered to be more environmentally friendly and cheaper (Kirk et al., 2005). Costs of phytoremediation are 5 times less than excavation and incineration (Zhang at el., 2010 ex. Rock and Sayre, 1998). Groundwater remediation could be treated by in-situ rehabilitation which includes with oxidation treatment involving the injection of chlorine dioxide solution into the aquifer where pollutants included more than 80 organic compounds containing 14 mutagens. This treatment showed that most of the contaminants which contained 5 mutagens were decomposed and 19 new products didn't contain any carcinogen. The petroleum concentration in groundwater level was decreased by 60%. It is more than clear that desorption of organic contaminants from aquifer media significantly and positively affected the groundwater quality during this remediation process (Kun et al., 1998).

8.3.3. Pančevo Fertilizer Factory (Azotara)

Building a new WWTP and new closed system for cooling water inside the Azotara complex will have positive effects on environment. Considering that the cooling water which is discharged into the canal represent 88% of all wastewater from the Azotara, on the one hand this dramatically reduces the amount of waste water that enters into the waste channel and on the other side in the channel will be a significant concentration of the nitrate compounds which will improve the water eutrophication. In addition, reduced amounts of waste water in the channel will enhance sedimentation of the suspended matters. The introduction of a closed cooling-water system in the fertilizer factory includes the introduction of wastewater treatment unit, primarily to remove nitrogen from the wastewater. One possible solution for this problem involves the construction of common WWTP facilities for treatment of municipal wastewater from the area and industrial wastewater from Fertilizer Plant. As a technological process, this is a good solution because the municipal wastewater could provide a sufficient amount of organic matter that would improve biological purification of the nitrogen and phosphorus from waste water (LEAP Pančevo, 2005).

8.4 Kragujevac

8.4.1 FIAT Cars (Ex-Zastava) Complex

Project's objectives were to reduce health risks for factory workers, to avoid further cross-contamination and to pack and store waste properly so that it could be transported in the future UNEP, in close cooperation with the "Zastava" car factory and the University of Kragujevac's Institute of Chemistry, started implementation of the project in December 2001. Contaminated layers of concrete/soil were removed and packaged, accompanied by verification of decontamination. New soil/concrete layers and anti-static epoxy resin was placed over the concrete. The clean-up target was to reduce PCB concentrations in the remaining material/ soil to less than 50 mg/kg. This target was reached and thereafter the soil was covered with concrete and epoxy layers. Damaged transformers and debris caused by the conflict were also removed. A total of 135 tons of hazardous waste resulting from clean-up activities was characterized, properly packed, labeled, temporarily stored and later transported and incinerated abroad. These activities have allowed reuse of the affected part of the paint hall. The work was completed in August 2002 (UNEP, 2004)

Clean-up program considered all recognized old ecological burdens in Ex-Zastava Complex (including the current level of emissions and a list of the most vulnerable areas, necessary action to sanitation, amount of material costs and time required for implementation planned activities).. Actions that are perceived to be necessary, as defined in the Clean-up program were the relocation of the approximately 2,000 tons of waste paints, export 6-pyralene oil transformers, removal of hazardous and nonhazardous waste generated during cleaning of certain locations in the Complex. As an activity that is also recognized as essential was the reconstruction and WWTP from production process - "Katak". The plant was completely rebuilt and it is ready for acceptance and pre-treatment of the wastewater from the production process before entering into the recipient stream, during which certain regulations are respected to protect the environment (LEAP Kragujevac, 2010).

In 2001 (two years after NATO bombing), project was signed between the "Zastava Cars" and the UNEP. Project included replacement of the damaged transformers, polluted concrete removal and sand contaminated with PCBs removal, as well as adding a new layer of concrete in the "Zastava Complex" and export of hazardous waste. All waste was assorted, properly prepared and packaged for safe transportation and sent to further waste treatment. Once when decontamination projects were completed at locations within the company, there was a need for implementation of special projects dealing with the examination of the sediment samples, surface water and water wells and the examination of the possible content of PCBs in the Complex area and along the river Lepenica (LEAP Kragujevac, 2010).

Results were compared with allowed values according to the provisions of the quality of drinking water and it was concluded that the studied samples do not contain PCBs and PAH over the allowable MCL values. There were set 6 piezometers (at a depth of 8 meters), made the three structural holes (at depth of 6 meters), and followed the level of groundwater and surface water levels at Lepenica and Ždraljica river. The results of the content PCBs indicated, that PCB concentrations in sediments at the locations of the factory are relatively low and it can be concluded that the greatest amount of contaminated soil, water and material was removed during decontamination projects implemented under the supervision of UNEP (LEAP Kragujevac, 2010).

8.5 Lazarevac Town

8.5.1 Lignite Processing Complex and Power Plant “Kolubara”

According to LEAP Lazarevac (2006), “Kolubara” planned to provide following actions:

- installation of purification system for waste gases and vapors from the process of coal drying,
- evaluation of waste from production processes,
- raising the green zone around the Industrial Complex,
- the improvement and harmonization of air quality monitoring with EU directives.

Plan for environmental protection by PP “Kolubara” includes following activities: reconstruction of the electrostatic unit A5, building facilities for desulphurization, implementation of protection measures for the ash landfill, a change of ash transport technology with a new, environmentally friendly sollution and disposal of ash (ratio of ash : water = 1 : 1, very dense hydromixture), raising the green protective area around the coal stockpiles and improvement of the air quality (LEAP Lazarevac, 2006).

Open pits of Kolubara that occupy a great territory, causing a number of environmental problems related to revitalization of degraded areas after coal mining. These pits cover flat land areas, parts of the valley and alluvial plains with a high quality agricultural land. In order to solve this problem, actions related to the creation of the revitalization projects of the degraded land and an application of the designed solutions need to be taken (LEAP Lazarevac, 2006).

According to UNEP (2004), there are recommendations for rehabilitation of Kolubara Power Plant site which will avoid accidental fires at the lignite stockpile which is dry. Other recommended methods which will improve site condition could be creating a grass cover at he ash depository zone to decrease resuspension and regular monitoring of nearby groundwater to control potential migration of contaminants. Reducing SO_2 amd PM emissions by renewing plant technology is an important step in improving environment. Useful solution is to search for possible reuse of ash as building construction material, so less of it would be stored at depository site and spread around in summer when is dry and warm.

9. Discussion and Conclusion

In last few decades Serbian environment was a subject of the neglect what brought Serbia to a not optimistic position. Environment was always left aside, it was never on a prior list and it was the last one to take care of. The cost has been paid and results of it are visible almost at the every step: contaminated groundwater, rivers, streams, soil, polluted air and in general reduced nature quality; these environmental burdens are all consequences of bad and uneducated management of the Serbian Industry.

As we could see, most of the old environmental burdens were created by Industry, mostly Oil Refineries and Mining Complexes. Some of burdens are products of unreasonable waste management. Those plants, factories, mining casts were very important factor, not just for Serbian, but also for ex-Yugoslavian centrally planned economy. They were very successful in communism era of Yugoslavia and made huge production and profits in that time. To satisfy people needs, communist government needed to maintain low prices on energy and other natural resources (wood, coal, water) and environmental services (waste management, water supply, heating). This all resulted in nature degradation, since to make people wishes come true, Yugoslavian Government needed to continue to use nature's products as much as they could.

The final straw in environmental degradation started in 1990's when Yugoslavia separated into six smaller countries using force and wars. This politics of Serbian, Croatian and Bosnian leaders didn't bring any good to people of those countries. It didn't bring any good to the environment as well. It just left more contamination, this time from grenades, guns and bombs. Serbian economic failure in 1990's after UN sanction caused more problems since necessary investments in environment were not taken.

Next on the list of politicians was conflict in Kosovo and NATO bombing of Serbia. Like in case of “big” Yugoslavia separation, Kosovo conflict brought only pessimism and sadness. NATO bombs not only that brought deaths of thousands of people, but also did a final shot to the Serbian nature. Primary aim of NATO troops was to bring Serbian economy to the end and it was a successful mission, but it had enormous consequences to the Serbian environment. Ironically, most of the investments into environment after the war were coming from the Western states, who were also taking a part in NATO action in Serbia.

New millennium brought new hope to Serbia and more investments from EU and USA after a democratic revolution in 2000. Some major projects in environmental fields were done and some still wait to be finished. Most of the problems which were created in NATO bombing were reduced or remediated to the end with help of UN environmentalists. Major problem to continue nature rehabilitation, again, is economic situation of the country, but it is more than sure that more ecological actions are taken every year.

Important step in environmental policy of Serbia is education of the people. Unlikely their Slavic brothers in Czechoslovakia or USSR, Serbian people lived economically well in the time of communism, but when that finished, they were not interested not even to their close environment. That’s why is from huge importance to teach new generations about this problem. It is important to show people how to treat their waste, to save water and energy, because all of that will later on have impact on the nature. That’s why municipality’s environmental departments should be supported to build awareness and promote sustainable consumption patterns.

It is important to encourage industry to be more economic efficient and to use more clean energy to prevent pollutions, by decreasing hazardous wastes and using more green energy. New environmental strategies, laws and rules in cooperation with EU directives should be done in order to reduce potential nature degradation. Following the example of the Czech Republic and their creating environmental management techniques, Serbia can even benefit from pollution. Many research papers and case studies from foreign and Serbian experts and scientists can be found online on major science web pages. That shows that intellectual and scientific class in Serbia is interested to solve those environmental problems. That also encourages many young students to study more about this important field.

Field trips to the City of Bor and Landfill Vinča showed that nothing yet has be done to stop environmental pollution. Damages are still there, more visible year by year. According to the words employed in City Sanitation Company of Belgrade, new projects to remediate landfill and stop leachate are not on the sight. Environmental burdens created by Mining and Smelter Complex of Bor are more than worrying and process of treating wastewaters should be started as soon as possible, because condition of Borska river is extremely low (Photos from Landfill Vinča and Mining Complex in Bor are available in the chapter “Photo Gallery” or CD attached to the thesis).

A lot of things still need to be done. In this work, I only mentioned important pollutants of Serbian environment. Regional landfills need to change small municipal, severe cities still wait for new and modern WWTP, since most of them are still using the old ones. New technology need to be introduced to reduce air and noise pollution as well. But as I said, most of the problems are economic nature, which are later on reflecting into ecological. Nature pays the costs, of unpaid bills of Serbian industry and inefficient politics towards environment and has to stop as soon as possible.

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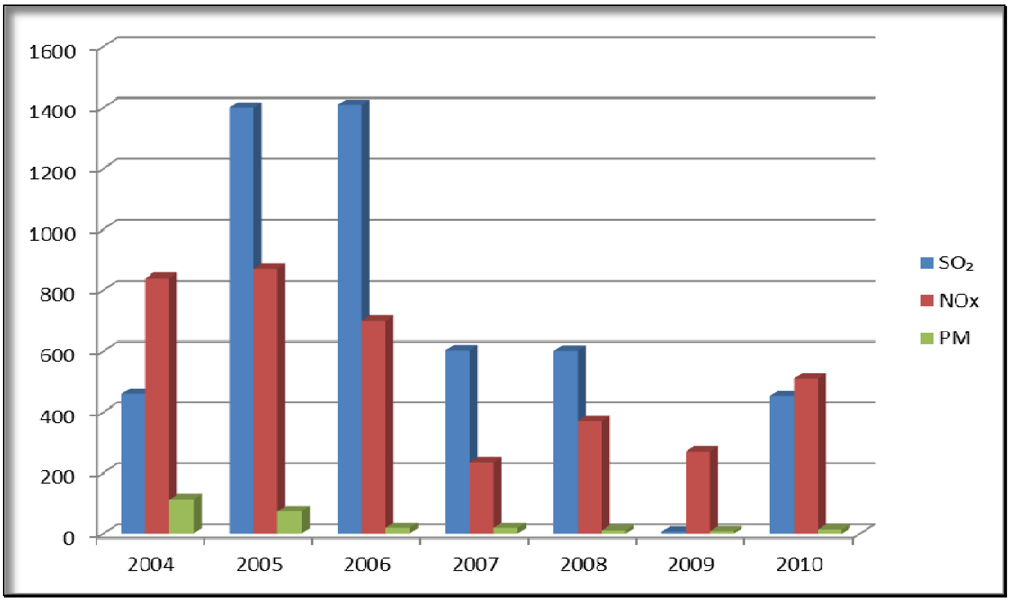
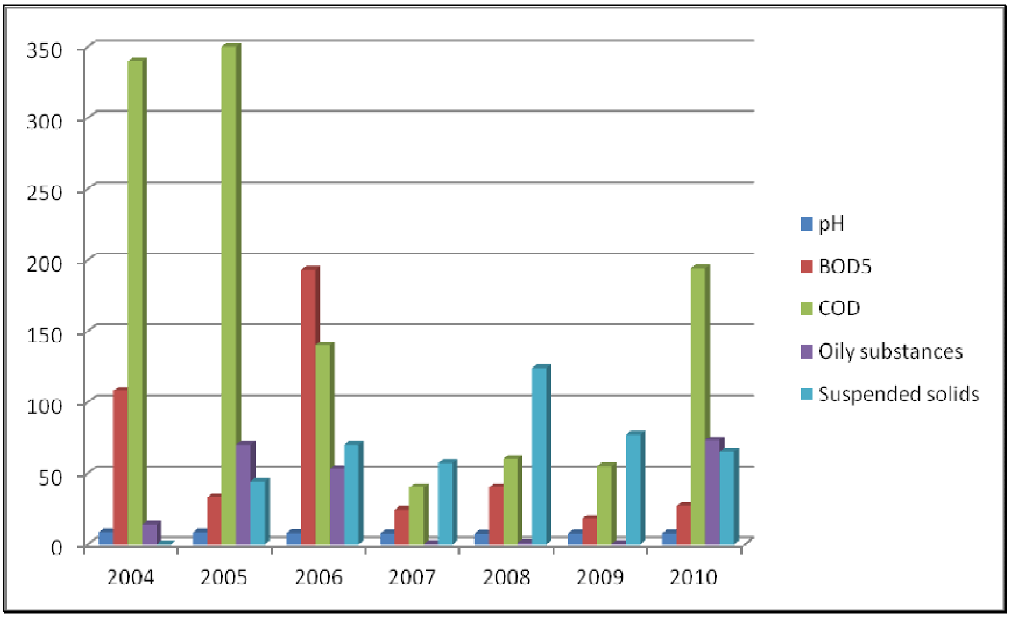


Graph 1. – HIP Petrohemija, Emissions of polluting substances into the air t / year (source: http://www.hip-petrohemija.com/corporate-responsibility/ecological-responsibility/air-emissions.116.html).



Graph 2. – HIP Petrohemija, Pollutant emissions into the water t / year. (source: http://www.hip-petrohemija.com/corporate-responsibility/ecological-responsibility/water-emissions.117.html).

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Substance	Location	Amount Released (tons)	Emission Route
Ammonia	HIP Azotara	250	Waste channel
Calcium ammonium, nitrate, phosphates, potassium chloride	HIP Azotara	250	Most burned, some into channel
Crude Oil	HIP Azotara	150	Most burned, some into channel
Vinyl chloride	HIP Petrohemija	460	Burned
EDC	HIP Petrohemija	2100	½ to channel, ½ to soil
Mercury	HIP Petrohemija	8	97% to soil, remains to channel
Sodium Hydroxide	HIP Petrohemija	100	Soil and waste channel
Ethyl propylene	HIP Petrohemija	1900	Burned
Crude oil and derivatives	NIS Oil Refinery	85000	95% burned, rest spilled into soil

Table 1. - Summary of pollutants released as a result of the 1999 bombing in Pančevo (source: Dopal & Deller, 2002).

Parameters	Sites where samples were taken				
	WWTP		Kolubara river		MCL
	before	after	**before**	after	
COD [mg/l]	1094,83	646,6	2,75	14,2	12
BOD_5 [mg/l]	918,73	561,87	2,33	12	4
Suspended particles [mg/l]	5078,33	161,07	13	44	30
Phenol particles [mg/l]	0,807	0,038	<0,001	0,002	0,001
pH	-	-	7	7,6	6,5-8,5

Table 2. – Pollutants released into Kolubara, before and after treatment in WWTP (source: LEAP Lazarevac, 2006).

Photo gallery

Photo 1. – Map of Serbia (www.serbia.embassyhomepage.com)

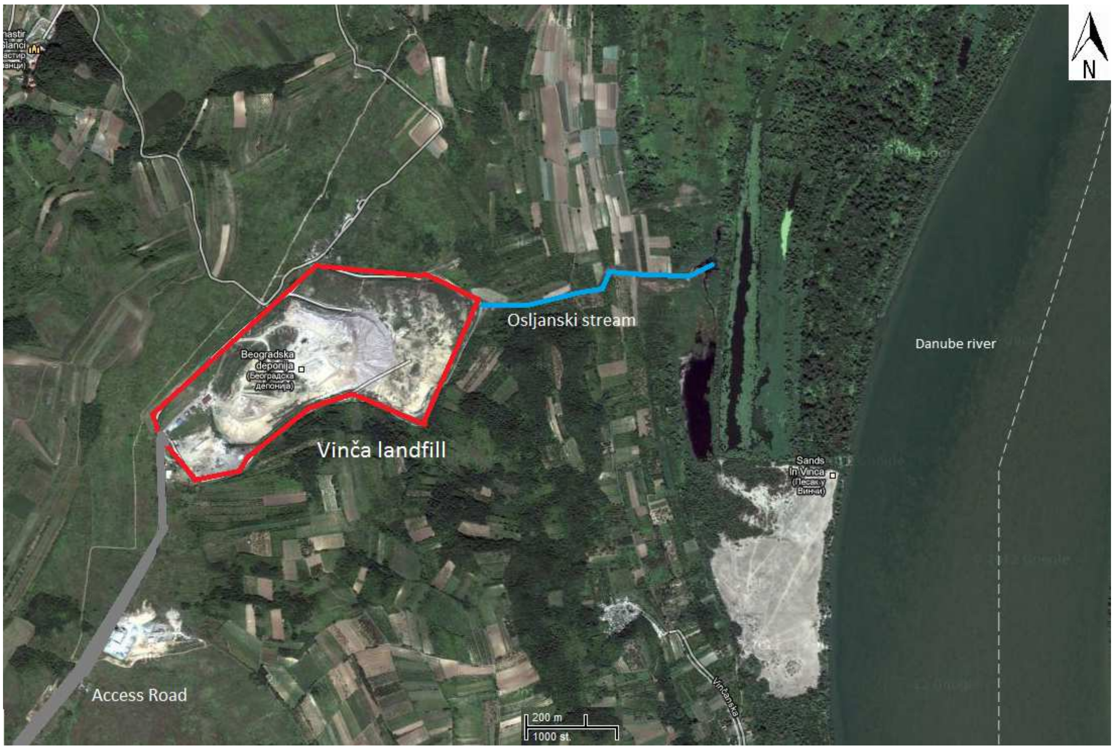

Photo 2. – Landfill Vinča, Belgrade (source: www.maps.google.com).

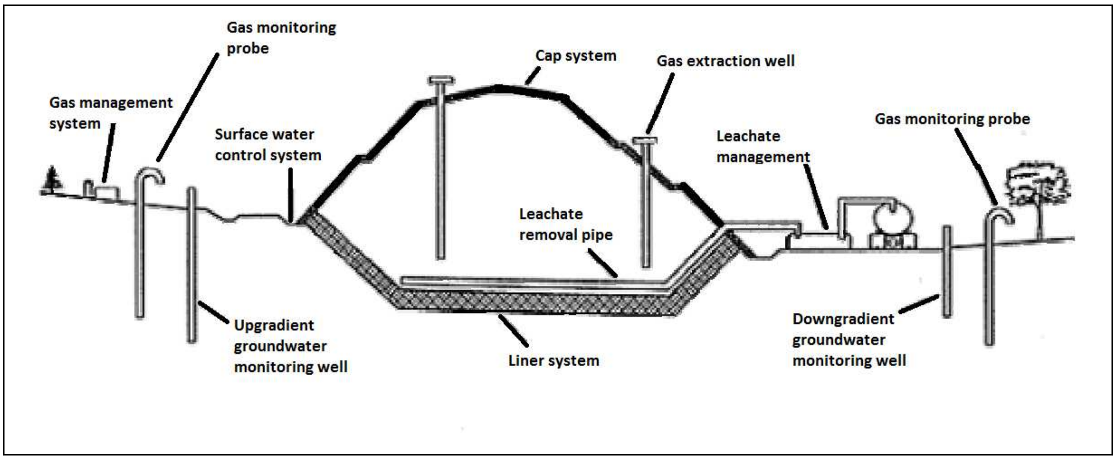

Photo 3. – Scheme of State of Art landfill, credit: Paul C. Rizzo
(source: Vasudevan et al, 2003).

Location: Borska River, Bor, Serbia
GPS: from +44° 3' 45.85", +22° 7' 50.72" to +44° 1' 48.80", +22° 12' 29.43"
Description: Soil degradation and water pollution caused by RTB Bor
Date: 18.03.2011.
Author: Strahinja Mladenović

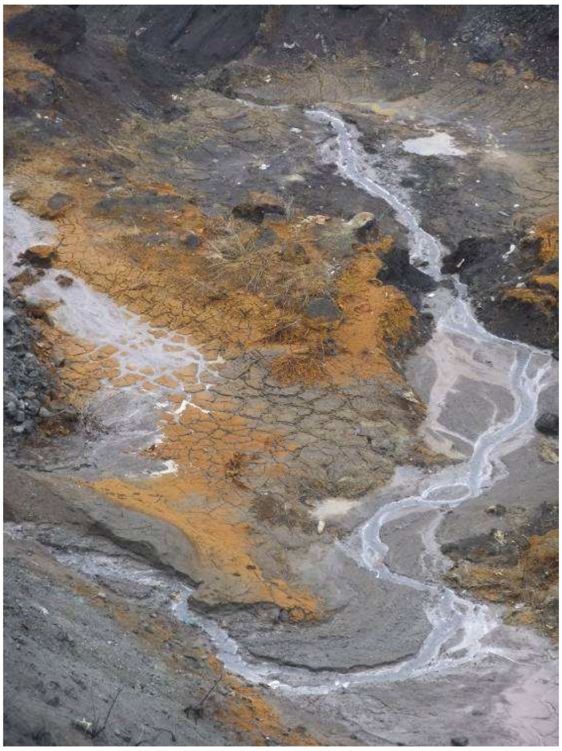

Photo 4. – Pond tailings and wastewater in Bor

Photo 5. – Borska river upstream

Photo 6. – Author (Strahinja Mladenović) at the tailings of Bor Mining complex

Photo 7. – Borska river dowstream, flooded area

Photo 8. – Degraded vegatation near Borska river, downstream

Photo 9. – Low water quality of Borska river

Location: Borska River, Bor, Serbia
GPS: from +44° 3' 45.85'', +22° 7' 50.72'' to +44° 1' 48.80'', +22° 12' 29.43''
Description: Soil degradation and water pollution caused by RTB Bor
Date: 22.04.2012
Author: Strahinja Mladenović

Photo 10. – Artificial lake at tailings, Bor

Photo 11. – Input drainage canal next to artificial lake

Location: Municipal Landfill Vinča, Belgrade, Serbia
GPS: +44° 47' 10.29'', +20° 35' 45.51''
Description: Belgrade's municipal landfill, waste treatment
Date: 16.11. 2010
Author: Strahinja Mladenović

Photo 12. – Wastewater with no treatment at Vinca Landfill

Photo 13. – Wastewater leasing from landfill, input canal, november 2010

Location: Municipal Landfill Vinča, Belgrade, Serbia
GPS: +44° 47' 10.29", +20° 35' 45.51"
Description: Belgrade's municipal landfill, waste treatment
Date: 23.04. 2012
Author: Strahinja Mladenović

Photo 14. – Wastewater leaching from landfill, no drainage systém.

Photo 15. – Wastewater leaching from landfill, input canal, april 2012.

Photo 16. – Waste treatment at Belgrade landfill

Photo 17. – Belgrade Landfill Vinca, panoramic view.

Photo 18. – Industrial complex in Pančevo.

Photo 19. - Novo Miloševo – New disposal site at NIS Oil Refinery (source: www.nis.rs)

Photo 20. - Remediation of the old environmental burden at oil fields of NIS (source: www.nis.rs)

Photo 21. - Cleaned sedimentation tank after disposal of oil sludge in the Pancevo Oil Refinery (before) (source: www.nis.rs

Photo 22. - Cleaned sedimentation tank after disposal of oil sludge in the Pancevo Oil Refinery (after) (source: www.nis.rs