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Chapter 11

SITES IN THE REPUBLIC OF SLOVENIA POLLUTED BY HEAVY METALS: STRATEGY AND ACTIONS PLANNED IN THE AREA

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Abstract: In the Republic of Slovenia there are five large sites polluted with heavy metals. The largest one is the waste disposal site of a lead and zinc mine in the northern part of the country, Next in size is the waste and tailings disposal site of the world’s second largest mercury mine. Both mines are now closed. The other three sites are smaller than those described above. They are as follows: the tailings disposal site of a uranium mine; the waste disposal site of an ironworks; and the waste disposal site of an aluminum processing plant. The article will present up-to-date data on the quantities of disposed wastes as well as measurements of some parameters connected with harmful effects on the environment and human health. Hazardous heavy metals from mines are monitored in the soil, flowing waters, groundwater and in the air. In some cases they are also monitored in some vegetables and human tissues and organs. The results of blood analysis for the content of heavy metals for mine workers and general population will be presented for two mining towns. On the largest sites, i.e. the waste disposal site of the lead and zinc mine and the waste disposal site of the mercury mine, some remediation activities are in progress. The results will be presented in graphs and tables.

Key words: Republic of Slovenia, heavy metals, polluted sites, disposed waste, measurements.

1. INTRODUCTION

In the Republic of Slovenia, with a surface area of over 20,000 km², there are five larger sites with increased levels of heavy metal pollution. This condition is the result of heavy metal mines or heavy metal processing at all five sites as follows: the waste disposal site of the lead and zinc mine at Mezica; the waste and tailings disposal site of the mercury mine in Idrija; the tailings disposal site of the uranium mine at Zirovski Vrh; the waste disposal site of the Jesenice ironworks; and the waste disposal site of the aluminium processing plant in Kidricevo.

In addition to these sites, there are another ten disposal sites containing waste from industries that are partly unregulated and represent a severe burden for the environment. These waste disposal sites are filled with various kinds of waste materials originating from various industrial branches. In these waste disposal sites measurements of leaching and measurements of emissions into the air are performed. In Slovenia, there is only one regulated active waste disposal site of harmful and hazardous waste materials. This is Metava in Maribor.

In addition to the active waste disposal sites there exists also a series of waste disposal sites that have arisen because of inadequate disposal of waste materials from industry in the period from 1950 to 1990. These waste disposal sites are: the disposal sites of acid tar in Pesnica, Studenci and Bohova near Maribor; the disposal site of industrial waste materials Globovnik near Ilirska Bistrica; the disposal site of red mud and ashes from the aluminium processing plant in Kidricevo; the disposal site of waste casting sands in Crnomelj, the area contaminated with PCB (polychlorinated biphenyls) in the surroundings of Semic.

This article presents data on the quantity of disposed waste at these sites, heavy metal concentrations in the waste, migration of these metals into the environment and the detected harmful
effects on humans. Values of individual monitoring parameters measured in each of these components of the environment are presented in the form of tables. The evaluation of values of the measured parameters corresponds to the maximum allowable quantities of these substances in the environment according to Slovenian legislation.

2. **FIVE SITES POLLUTED WITH HEAVY METALS**

The five sites polluted with heavy metals – Figure 1 – developed through the long centuries or decades respectively of the operation of mines and/or metal foundries: The mercury mine in Idrija operated for more than 500 years, the zinc and lead mine in Mežica for more than 300 years, the ironworks in Jesenica for more than 200 years. Therefore there are several disposal sites around these locations. In the past, the dumping of waste materials was spontaneous and occurred where some land was at disposal. The five disposal sites were unregulated and unprotected. With meteoric water metals washed away from the tailings and wastes, today it is recognized that a huge quantity of mercury from the disposal site of tailings near the the mercury mine in Idrija has migrated to the Adriatic Sea.
2.1 Waste Disposal Site of the Lead and Zinc Mine at Mezica

Tailing dumps represent a great burden for the environment because of their number and size. Tailing was dumped into valleys and partly on the slopes in the vicinity of the mine.

These tailing dumps are not planned; there are 31 of them in the mine area, spreading over 100 km². The estimated amount of tailing is around 20 million tons; the dump area is around 400,000 m². The tailing represents carbon material (mainly limestone and dolomite) with traces of ore and metal remains – the lead content is up to 3.8 %, zinc from 0.65 % to 7.7 %. The dump area is full of water, with numerous streams and springs, and even drinking water sources, as is evident from Table 1 (Presecnik, 2003).
The content of heavy metals in mine-waste landfills is continuously measured in tailings and leachate, and the content of natural radionuclides are periodically checked in tailings (uranium, radium, thorium).

At the Mezica mine, waste was created at first only because of extraction and the processing of ore in the smelting plant. After 1965, waste was also created as a result of the manufacturing of lead used in lead batteries. After 1989, the creation of waste was only the result of processing secondary materials.

According to Slovenian legislation, waste is dangerous if the values of zinc exceed 10,000 mg/kg; that is why seven of the old dumps are categorized as dumps with hazardous waste, and it is thus necessary to analyze out-going fluids constantly. According to data about the production of refined lead and the amount of created waste (scoria, gypsum, brick, hard rubber which amounts to about 5,763 tons of waste from 15,000 tons of pure lead) in the old dumps, it was calculated to be about 20 millions tons of waste.

At that time, tailings were used for several purposes. Because of the appropriate grange and structure of the material, people removed it and used it for filling up sinking in the mine or even in construction of residential housing, for maintaining roads, etc. Usage of this material was the cause for analyses of contamination by natural radionuclides. Due to the dolomite basis, the content of radionuclides in tailings is relatively low, as shown in Table 2.

Table 1. Zinc content in old dumps in the mine area

<table>
<thead>
<tr>
<th>Name</th>
<th>% Lead</th>
<th>% Zinc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zerjavska halda</td>
<td>0.85</td>
<td>3.24</td>
</tr>
<tr>
<td>Stoparjeva halda</td>
<td>0.80</td>
<td>2.86</td>
</tr>
<tr>
<td>Andrejeva in Lukrecija halda</td>
<td>0.66</td>
<td>0.56</td>
</tr>
<tr>
<td>Halda na Zackovih peskhi</td>
<td>3.84</td>
<td>7.67</td>
</tr>
<tr>
<td>Hildegardina halda</td>
<td>1.12</td>
<td>4.45</td>
</tr>
<tr>
<td>Terezija halda</td>
<td>1.95</td>
<td>3.96</td>
</tr>
<tr>
<td>Terezija podkop halda</td>
<td>1.95</td>
<td>3.96</td>
</tr>
<tr>
<td>Srce halda</td>
<td>1.35</td>
<td>3.17</td>
</tr>
<tr>
<td>Fridrih halda</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Igreceva halda</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Kavsakova halda</td>
<td>0.15</td>
<td>0.65</td>
</tr>
</tbody>
</table>

Table 2. Content of radionuclides in tailings

<table>
<thead>
<tr>
<th>Location</th>
<th>226Ra (Bq/kg)</th>
<th>238U (Bq/kg)</th>
<th>232Th (Bq/kg)</th>
<th>40K (Bq/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separation Zerjav</td>
<td>10</td>
<td>10</td>
<td>1-3</td>
<td>10</td>
</tr>
<tr>
<td>Tailing Kavak</td>
<td>10</td>
<td>10</td>
<td>1-3</td>
<td>10</td>
</tr>
<tr>
<td>Pit Topla below Peca</td>
<td>30</td>
<td>30</td>
<td>4</td>
<td>74</td>
</tr>
<tr>
<td>Scoria from Zerjav</td>
<td>6</td>
<td>6</td>
<td>2.8</td>
<td>25</td>
</tr>
</tbody>
</table>

2.2 Rehabilitation Program for Closure of the Mezica Mine

With the adoption of the Gradual Mine Closure Act (the Act Ensuring Part of the Funds Necessary for the Gradual Closure of the Mežžica Lead and Zinc Mine, Official Gazette of the Republic of Slovenia No 5/88) mining operations started to be wound up. At the end of 1994 the last wagons of ore were brought from the mine for separation. As part of the closure, remediation programmes were drawn up for restoration of areas where residues from ore smelting had been deposited and where mine tailings had been dumped. One of the major remediation projects was the rehabilitation of the silt that had been released into the Meza River upon separation of the ore. In the 1980s the introduction of rehabilitation measures saw the start of silt disposal in abandoned parts of the mine. The remediation projects can be divided into three areas:

- rehabilitation of gangue heaps and landslips,
- protection of drinking water sources,
– correctly and safely arranged disposal of mine waste.

Gangue heaps are areas where mine tailings and residues from the separation process have been deposited. Remediation provided drainage of these areas and recultivatation (planting and fences) with the planting of various plant species that should prevent erosion and the threat of tailings landslips. Problems arise primarily where people have located residential buildings or gardens and they cannot be systematically recultivated using one single methodology. There the tailings are flushed out by meteoric water, and this allows heavy metals to migrate into the groundwater. A full remediation of the existing gangue heaps and tailings dumps will also cover the preparation of new disposal sites and the transfer of the tailings together with the polluted ground from the old sites to a new one.

The remediation of drinking water sources served to protect accesses to potable water. The realistic prospects of rehabilitation in terms of protecting groundwater constitute primarily the covering of disposal sites, providing for the capture of underground water and the capture and treatment of leach water. Control and maintenance of these elements must also be carried out after recultivation of the disposal sites and gangue heaps.

The greatest difficulties are involved in the rehabilitation of wastes, both those from the pit and those left from ore smelting. In the production of 15,000 tons of lead, around 5,700 tons of waste is generated. A landfill site has been constructed for this waste.

2.3 Waste and tailings disposal site of the mercury mine in Idrija

The mercury mine in Idrija belongs to the greatest Hg mines in the world. Some 70 % of the ore is cinnabar and 30 % is native mercury. In the past the content of mercury in the ore was essentially higher. The greatest production, 820 tons of mercury, was reached in 1913. In the past the yield of winning was low, up to 75 % till 1948 and approximately 90 % after 1961. The burnt cinnabar was disposed near the devices. During a period of 500 years, over 12 mio tons of the ore were dug up and 153,000 tons of mercury were won, out of which 4,500 tons have contaminated the environment between Idria and the Gulf of Trieste (Dizdarevič, 2001). During the operation of the mine the emissions in the atmosphere were approximately 7 to 10 tons yearly. During the operation of the mine in the seventies the concentrations in the air were very high. They decreased, however, at the time of reduced operation, and today they are increased only at the mine ventilators and heaps of tailings. In the soil in the area of Idrija the concentration of mercury is very high (Gosar et al. 1997). The mine waters, rich in mercury, flew into the river Idrija, and increased concentrations of iron and sulphate as a result of burning the ore are visible in the river Idrija still today. Thus, the mercury in the river Idrija is a result of the atmospheric deposition, sweeping away the soil and erosion of burnt remainders of the ore, which is reflected in high concentrations in the river, river sediments and the Gulf of Trieste. At the moment the mine is in the final phase of closing. (As the five hundredth anniversary of operation approached, the mine of Idrija, just when experiencing the greatest extension and technological and economical top, came to a crisis: with the awaked ecological consciousness in the world omitting of heavy metals and their replacement with substances more friendly to the environment and human being was started.) The procedure for closing the mine started in 1996 and it will definitely be completed in 2006.

The procedure for closing works can be divided into three steps:

1. Filling of mine objects (galleries, shafts, gravity-feed pipes, working sites given up) with pneumatic dyke and the use of lean concrete.
2. Injecting of inaccessible areas of old ore bodies. If necessary, also inaccessible galleries and blind shafts are injected with a special injecting mass. Reinforcing of coagulated dykes and destroyed stoneware by injecting is technically-technologically and also financially a very demanding part of closing the mine of Idrija. In 1991 a test-injecting on the third floor was performed. The injecting blend. 44 % of electro-filter ashes, 6 % of lime and 50 % of water. With this blend the required hardness (2 Mpa) was exceeded. Because of green movement protests against using electro-filter ashes, the composition of the blend was changed to 40 % of grounding dust of dolomite meal, 20 % of cement and 40 % of water. Up until the end of
1997, 8,620.95 m of injecting boreholes were made in 11,194.00 m$^3$ of injecting mass were pushed into them.

3. In the final step, single floors are gradually poured with water under constant control of the closing works.

In 1995 the production of ore in the mine and its processing in the smelter was stopped. The standpoint was adopted that the separation and one rotation furnace would be preserved as a monument while other objects would be destroyed and the place ecologically remedied. In order to prevent the evaporation of mercury the complete area was covered with a one-meter layer of uncontaminated material. A landfill for the ecologically most polluted material was arranged on the lower part of the chimney stack. The bottom of the landfill was covered with a layer of clay and a drainage for meteoric waters was made. 7,180 m$^3$ of material polluted with native mercury was put into the landfill and covered with 710 m$^3$ of humus.

Although at the time of active mining of Hg in Idrija emissions of Hg into the environment were great, there are not many data on the past contamination at disposal. Systematic investigations of the influence of Hg on the environment have been started only in the last ten years. Before, the main concern was above all the protection of miners and inhabitants of Idrija from toxic action of Hg vapours. In this period two workshops were organized on the subject Hg in Idrija and the articles were published in two collections of scientific papers (Miklavcic, 1999). In our presentation we wish to summarize in short some important results of the investigations in the recent years.

2.3.1 River transport – entry of Hg into the rivers and sea

The hydrology of the Idrija and Soca river and of the Gulf of Trieste is important for understanding the transport and distribution of mercury in the river basin and the gulf. The quantity of atmospheric precipitations in the river basin of the Idrija and Soca rivers is high and varies strongly. Due to the configuration of the area the erosion is rather great; however, the transport of particles is limited because of the dams on the Soca river (Doblar, Plave, Solkan) – Figure 2.
The hydrology of the Soca river is well known on the Slovenian side (Solkan) with the average overflow of some 100 m$^3$/s with two expressive seasonal peaks: the longer one in the spring because of melting of snow in the Alps, and the shorter but stronger one, due to atmospheric precipitation, in the autumn.

In 2003 a repeated assessment of the transport of the suspended material and mercury in the river system Idrijca/Soca was made that took into account the average seasonal flows and extreme phenomena. It is known that the majority of mercury is transported with the suspended material in the time of extremely high flows, which, as a rule, occur in this river basin at least once a year.

Detailed estimations of the definite entry of Hg into the Gulf of Trieste are uncertain and most probably underestimated. For instance, from the date of 1997 for the 5-year period of waters the estimation of the average entry of the suspended materials amounted up to 365 g/m$^3$, while the data from year 2002 for the measurements made at the time of moderate and low waters show variations between 4.6 and 20.3 g/m$^3$. On the basis of all the data known up till now the quantity of yearly entry of suspended materials into the Gulf of Trieste from the Soca is estimated to 150,000 tons.

After 1990 some measurements of Hg in water, both the dissolved and bound share, were made. Concentrations of monomethyl mercury, which is the most important form of Hg as regards the environmental and sanitary aspects, were also measured. The measurements have confirmed the fact that the largest quantities of Hg are transported with suspended particles. The measurements show a great variability of Hg concentrations, which is connected with the flow, hydrometeorologic parameters and sites. The Hg values mentioned in several reports and between <10 and up to 80 mg/kg of the suspended material. In 2002, when systematic measurements in moderate and low
waters were carried out, the values varied between 1 and 4.5 mg/kg of sediment. The share of the methylated Hg is 0.2 to 3 % of the total Hg. The quantity of the average yearly entry of Hg over the Idrijca river is 1500 kg. Anyway, it should be mentioned that occurrences of extreme events (large flood waves) can be essentially more fatal. Namely in a period of 5- to 10-year waters, great quantities of Hg can enter the waters, as was the case in November 1997, when at the time of the flood wave in the course of 8 days, the river Soca brought 4700 kg of mercury into the Gulf of Trieste.

Transport with the Soca is the far most important transport into the gulf. It makes 1.5 ton yearly, out of which 99.5 % is in a suspended form. The dissolved methyl mercury represents only 1.5 % of the total dissolved mercury in the transport. The great majority of the mercury brought in settles at the bottom of the Gulf of Trieste and remains there durably deposited (Operative program, 2004). An important result of the assessment of the mass balance indicates especially that the Soca is the main sorce of the anorganic mercury, while the main source of MeHg in the Gulf of Trieste is the sediment.

2.4 Remediation Program for Closure of the Idrija Mercury Mine

In 1987, a decision was adopted on the closure and the complete and permanent cessation of production at the Idrija mine. At the same time a decision was adopted regarding rehabilitation of the consequences of mining operations. Upon the decision being taken, a plan was drawn up in the same year for the conversion of part of the Idrija pit for tourism purposes. In view of the geological make-up of this area, the Idrija pit is separated into lower and upper sections. The lower section is composed of hard sedimentary rock. Owing to settling and surface slides above the upper section of the pit, which was caused by many years of intensive excavation, reinforcement works are being carried out – infilling of all pit levels in permocarbon shale, infilling of all shafts in this part of the pit, shoring up of uncompromised dykes by injection, filling the empty spaces above the dykes and injecting of destroyed mine pillars between excavations.

The urban area of Idrija is characterised by its mining history. Ore was smelted on the surrounding slopes, and the yield from this process was in the majority of cases below 50 %. The residues of smelting were dumped in the direct vicinity of the location where the heating and smelting of ore was carried out. The locations of unsmelted residues of rock and ore became mixed with the smelted residues. Thus there are known to be residues that in individual locations contain more than 80 tons of mercury. In the past these residues were used to build up first the immediate surroundings of the smelters and in this way the necessary work surfaces were created. Later various unwanted holes and morphological anomalies in the area of the town and its immediate surroundings were filled in. The dumping of smelter residues in the area of the town continued even in the 1950’s and up to 1960. Owing precisely to the use of smelting residues as road-building base and aggregate, residues containing Hg are now found spread over a very wide area.

2.5 Tailings disposal site of the uranium mine at Zirovski Vrh

In Slovenia there are four locations where radioactive waste is disposed. This waste has been generated chiefly by the research, healthcare and industrial activities. The waste is kept in temporary storage facilities, whose technical features are not appropriate for the storage of the type of waste deposited. The largest volume of waste was generated primarily by a uranium mine and coal-fired power station (coal, ash) and aluminium processing plant. These locations are in the vicinity of Zirovski Vrh (uranium mine); Sostanj (coal-fired power station); Kidricevo (aluminium processing plant); and Kocevje (from other origins).

Slovenia used to have active uranium mine – Zirovski Vrh; it is now in the phase of closure and remediation of the landfill. There are now two landfills for radioactive waste from past mining activities and the processing of uranium ore:

- The first contains tailings produced in the uranium ore processing plant. This landfill covers an area of 4 hectares and contains around 600,000 tonnes of material containing 80 g U₃O₈/t and 8.6 Bq/kg Ra-226,
The second contains waste with red mud from ore processing. It contains around 1,500,000 tonnes of material with an average content of 70 g U₃O₈/t and total radioactivity of 15,200 GBq.

Radioactive waste is also produced by other industrial activities, primarily certain non-uranium mines, coal-fired power stations (coal ash), and aluminium and phosphate factories. This waste contains uranium and thorium levels higher than natural concentrations in the environment. These landfills are located in Sostanj, Kidricevo and Kocevje, and each covers several hectares. All five radioactive waste landfills, including those from non-uranium industrial sectors, are shown in Figure 3.

Figure 3. Shows the locations listed above.

2.6 Remediation Program for Closure of the Zirovski vrh Uranium Mine

The plan for the permanent arrangement of the tailings site of mine gangue envisages the transformation of the tailings body, primarily reducing the inclines, in order to increase the stability of slopes and reduce erosion. All surfaces will be covered with a suitable selection of grass. Emissions of radon and the intrusion of water into the tailings will be prevented through the installation of several layers of covering made from natural materials. The total thickness of the layers will be around 2 m. The project prioritizes natural materials and native plants, since they are more durable in the long term. A rainwater drainage system through channels will remove surface water in a controlled manner. A peripheral channel will protect the tailings from the threat of flood water. The Jazbec stream, which represents the biggest flooding threat, will be redirected along a new course around the tailings. Rainwater creates a groundwater stream in the tailings that for the most part flows out via a system of drainage pipes into a settlement pond, where it is cleared and also partly cleaned of uranium. Part of the groundwater stream that is not provided with a drainage system to the settlement pond flows out through drainage laid along the bottom of the infilled little valley and at the bottom of the gangue heap it flows into the stream. Another part of the groundwater stream, however, flows through a fissure in the rock base of the tailings and infiltrates the groundwater in the rock base,
Contaminated Soils-Heavy Metals

thereby polluting it. This groundwater stream flows through a system of fissures into small springs and ponds below the tailings and above the Todrac stream.

As we have already mentioned, special attention was paid to stabilization of the subsidence 50 m deep under the tailings. Around 7 million tons have slowly slipped down the lateral slide plate at a speed of less than 1 mm a day. Construction of wells and a tunnel with two shafts has achieved adequate stability.

The plan for the permanent arrangement of the tailings site of hydrometallurgical gangue envisages the transformation of the tailings site, especially a visible reduction of inclines towards the north and west. This will increase the stability of the slopes and reduce the threat of erosion. All surfaces will be covered with a suitable selection of grass. Emissions of radon and the intrusion of water into the tailings will be prevented through the installation of several layers of covering made from natural materials, with a total thickness of around 2 m. The project prioritises natural materials and native plants, since they are more durable in the long term. A rainwater drainage system through channels will remove surface water in a controlled manner. A peripheral channel will protect the tailings from the threat of water. The course of the nearby stream will be regulated by reinforced banks in order to prevent any erosion of the ground towards the tailings.

The only anticipated environmental impact from the pit structure after its closure will be the water flowing from the pit. Concentrations of uranium will be below the permitted and authorised value of 0.25 mgU/L, and the activity of radium-226 will be below 60 Bq/m³.

After execution of the closure works, the tailings will affect the surroundings by air and water. By covering the material, the speed of the gamma radiation dose will be practically reduced to the level of the surroundings, i.e. below 0.15 µGy/h. Emissions of radon-222 through the surface of the tailings will be a source of environmental impact via the atmosphere. The speed of emissions will be below 0.1 Bq/m²s. This permitted limit value was established by the Slovenian Health Inspectorate. Owing to the reduced intrusion of surface water into the tailings, there will be reduced contamination of intrusion water and in particular reduced outflow. The permitted limit values are below 0.51 mgU/l for uranium and below 40 Bq/m³ for radium-226.

The impact of the Borst gangue heap on the surroundings via the atmosphere will be less than that of the Jazbec tailings. The reason for this is the higher situation of the Borst tailings above the temperature inversion boundary. Following installation of the covering, emissions of radon-222 will be below 0.7 Bq/m²s. By covering the material, the speed of the gamma radiation dose will be practically reduced to the level of the surroundings. The covering will also prevent the intrusion of rain and surface water into the tailings and the leaching of contaminants from the tailings. Gradually the outflow of drainage water will be reduced and stopped.

Taking into account all sources and paths of impact, the annual effective dose for critical population groups will be below 0.3 mSv, and probably between 0.1 and 0.2 mSv. For inhabitants further away in the Sora valley it will of course be even less, once all the envisaged mine closure works have been completed.

2.7 Waste disposal site of the Jesenice ironworks

The iron industry in Jesenice goes back to 1530: The first smeltery was opened in 1868. Since then, the smeltery waste (scoriae) has been deposited in the immediate vicinity of the foundry. The present state is alarming because all heavy metals are washed away into the underground water. The floor, where the waste was been deposited, is contaminated with antimony, copper, zinc, chrome, manganese, lead and dioxins.

At the time of greatest production, the foundry deposited some 10,000 tons of scoriae every year; scoriae are actually inert, the only problem are heavy metals. It was estimated that on the disposal sites in the surroundings of ironworks there are some 1,600,000 tons of waste from ironworks.

The present needs for the disposal sites are some 250,000 tons for the coming years of operating of the smeltery and rolling mill. It is foreseen that yearly some 8700 m³ of place would be needed.
2.8 Remediation Plan of Waste Disposal Site of the Jesenice Ironworks

According to the local authorities the plan of remediation was made long years ago. Main activities in this plan are: monitoring of leaching water from disposal site, cleaning of leaching water before releasing in the river, monitoring of soil (periodically) and to set grass and some other plants on the site. Although the ironworks is due to lead remediation in reasonable period that are many problems with timing. The reason is a lack of money.

2.9 Waste Disposal Site of the Aluminum Processing Plant in Kidricevo

The building of the aluminum processing plant in Kidricevo was started in 1942 during the Second World War. In 1954 the trial production of the plant for the production of metallurgical bauxite was started, and at the end of the same year also the aluminum processing plant. Production increased annually and with it waste materials, both gaseous and solid, that were deposited on the disposal site inside the factory. The total production of metallurgical bauxite till 1991, when this plant was closed, amounted to some 3.4 mio tons. The total production of aluminum from 1955 to 2004 was slightly less than 2.6 mio tons.

During the described production a great number of waste materials were created. The following represent the greatest burden on the environment:

- fluorides - approx. 1,150 tons yearly,
- tar – approx. 90 tons yearly,
- remainders of cathodes - approx 2,500 tons yearly, and
- tailings of the bauxite ore, from which aluminum was leached – red mud - - 140,000 to 170,000 tons yearly.

Ash represents a special inert waste, namely as an energy supplier coal was used for years and 60,000 to 70,000 tons of ash were produced yearly. Since 1991 approx. 6.5 mio tons of red mud have
been produced. This mud contains alkaline metals. It is deposited on a disposal site of some 42 hectares (1 ha is 10,000 m²). The alkaline metals were washed into the underground water and came so also in the sources of drinking water.

2.10 Remediation of Waste Disposal Site of the Aluminum Processing Plant in Kidricevo

In 1986 the expertise for remediation of the red mud disposal site was prepared and in 1991 trial remediation of the disposal site was started. The expertise showed that at the contact with the sandy floor the layer of red mud had penetrated half a meter deep and the ground got choked with mud. Thus, under the deposit site a layer was formed that has a very low permeability.

The trial surface was divided into four parts, in which four different kinds of revitalization were carried out. With revitalization they tried to limit the influence of red mud on the environment, namely dusting and first of all trickling of meteoric waters through the layers of red mud and herewith transporting of alkaline metals and other toxic compounds in the groundwater.

To the first part or field of 15,000 m², first uncontaminated soil was carted and uniformly distributed, and then some 3000 young trees were planted, Scotch pine, Austrian pine, common spruce, larch and maple.

On the second field of 10,000 m², 5000 m³ of coal ash was carted and grass was sowed on it. Measurements showed that in one year pH of the surface decreased from 9.9 to 8.5.

The third trial field of 10,000 m² was covered with grass. The fourth trial field, also 10,000 m² large, was covered with the mud from the purifying plant for waste technological and communal waters and sowed with grass.

The results of these trial makings green showed that the most successful possibility of revitalization is covering with a layer of soil and planting of young trees. In this way the alkalinity of the surface of red mud is decreased and meteoric waters are retained in a great extend. Up till now some 200,000 m² of the disposal site - approximately one half of the total surface - has been successfully planted with trees and grass.

3. WORKING INDUSTRIAL WASTES LANDFILLS

In Slovenia there are 10 industrial wastes landfills and one disposal site for hazardous wastes. All site are shown on Figure 5.
Table 3. Shows quantities of wastes on individual of mentioned landfill or disposal site

<table>
<thead>
<tr>
<th>Activity</th>
<th>Name of the landfill/disposal site</th>
<th>Type of waste</th>
<th>Quantity (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DG (On Figure 6 – 1)</td>
<td>Landfill of solid wastes in Zepina</td>
<td>Inert and nonhazardous wastes</td>
<td>220</td>
</tr>
<tr>
<td>DJ (On Figure 6 – 2)</td>
<td>Landfill of industrial wastes in Novaki</td>
<td>Inert and nonhazardous wastes</td>
<td>3087,5</td>
</tr>
<tr>
<td>DJ (On Figure 6 – 3)</td>
<td>Disposal site in Polzevo</td>
<td>Inert wastes</td>
<td>5790</td>
</tr>
<tr>
<td>DC (On Figure 6 – 4)</td>
<td>Disposal of leather working industry in Smartno - Rakovnik</td>
<td>Nonhazardous wastes</td>
<td>4095,2</td>
</tr>
<tr>
<td>DE (On Figure 6 – 5)</td>
<td>Landfill of industrial wastes in Paloma</td>
<td>Nonhazardous wastes</td>
<td>10584</td>
</tr>
<tr>
<td>DJ (On Figure 6 – 6)</td>
<td>Landfill of metallurgical slag and crushed plastics in Mezica</td>
<td>Inert and nonhazardous wastes</td>
<td>1220</td>
</tr>
<tr>
<td>DJ (On Figure 6 – 7)</td>
<td>Tailings disposal site of the lead and zinc mine in Ravne</td>
<td>Inert and nonhazardous wastes</td>
<td>30284</td>
</tr>
<tr>
<td>DJ (On Figure 6 – 8)</td>
<td>Tailings disposal site Javornik of the Jesenice ironworks</td>
<td>Inert and nonhazardous wastes</td>
<td>28950</td>
</tr>
<tr>
<td>DJ (On Figure 6 – 9)</td>
<td>Ash disposal site of the aluminum processing plant in Kidricevo</td>
<td>Inert wastes</td>
<td>1283,1</td>
</tr>
<tr>
<td>DJ (On Figure 6 – 10)</td>
<td>Landfill of industrial wastes in Ruse</td>
<td>Inert and nonhazardous wastes</td>
<td>4475,7</td>
</tr>
</tbody>
</table>

Legend of designations for activities:
DG – Manufacture of chemicals, chemical products and man-made fibers
DJ – Manufacture of metals and metal products
DC – Manufacture of leather and leather products
DE – Manufacture of pulp, paper, cardboard, paper and cardboard products, printing

Table 4. Type and quantity of industrial wastes produced in different activities for the year 2000

<table>
<thead>
<tr>
<th>Activity</th>
<th>Quantity of all wastes of industry in the year 2000 (tons)</th>
<th>Quantity of wastes in bigger industrial factories in the year 2000 (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA</td>
<td>141.151</td>
<td>11.601</td>
</tr>
<tr>
<td>CB</td>
<td>43.033</td>
<td>0</td>
</tr>
<tr>
<td>DA</td>
<td>126.066</td>
<td>84.576</td>
</tr>
<tr>
<td>DB</td>
<td>5.141</td>
<td>406</td>
</tr>
<tr>
<td>DC</td>
<td>16.195</td>
<td>426</td>
</tr>
<tr>
<td>DD</td>
<td>61.226</td>
<td>0</td>
</tr>
</tbody>
</table>
Contaminated Soils - Heavy Metals

In recent years the quantity of waste materials from industry has been decreasing due to the discontinuation of the operation of some mines (the lead and zinc mine in Mežiča is in the phase of closing, as is the mercury mine in Idrija); the change of technologies in some industrial branches (ironworks in Jesenice, aluminium processing plant in Kidricevo); and the removal of certain industrial activities to Asia.

In Slovenia there is only one regulated harmful waste disposal site, that is Metava (on the Figure 5, marked with 11). This waste disposal site was built in 1984. Its total capacity is 95,000 m$^3$. For the waste materials deposited on this site there is a list of kinds, quantities and analyses of assay of individual harmful substances. There prevail scoriae from the aluminum factory containing ammonia compounds, casting sands (containing phenols), remaining of dyes and varnishes (containing various organic solvents) and metallic oxides and slimes (containing chrome, nickel, copper and zinc compounds).

Table 5. Shows the quantities of landfilled wastes from 1984 to 2000 on disposal site for harmful and hazardous wastes Metava near Maribor

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity (m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984</td>
<td>755</td>
</tr>
<tr>
<td>1985</td>
<td>2531</td>
</tr>
<tr>
<td>1986</td>
<td>1520</td>
</tr>
<tr>
<td>1987</td>
<td>1696</td>
</tr>
<tr>
<td>1988</td>
<td>957</td>
</tr>
<tr>
<td>1989</td>
<td>1525</td>
</tr>
<tr>
<td>1990</td>
<td>1327</td>
</tr>
<tr>
<td>1991</td>
<td>1034</td>
</tr>
<tr>
<td>1992</td>
<td>1065</td>
</tr>
<tr>
<td>1993</td>
<td>1047</td>
</tr>
<tr>
<td>1994</td>
<td>536</td>
</tr>
<tr>
<td>1995</td>
<td>547</td>
</tr>
<tr>
<td>1996</td>
<td>530</td>
</tr>
<tr>
<td>1997</td>
<td>375</td>
</tr>
<tr>
<td>1998</td>
<td>549</td>
</tr>
<tr>
<td>1999</td>
<td>588</td>
</tr>
</tbody>
</table>

Legend of designations for activities:
CA – Quarrying of energy producing materials
CB – Mining and quarrying except energy producing materials
DA – Manufacture of food products, feeding stuffs, verages and tobacco
DB – Manufacture if textiles and textile and fur products
DC - Manufacture of leather and leather products
DD – Manufacture of wood and wood products
DJ - Manufacture of metals and metal products
DK – Manufacture of machinery and equipment
DL – Manufacture of electrical and optical equipment
DM – Manufacture of transport equipment
DN – Manufacture of furniture and other processing equipment
4. OMITTED WASTE DISPOSAL SITES

The omitted disposal sites of harmful waste from different industrial branches arose between 1950 and 1990, because of inadequate and uncontrolled disposing of harmful waste from industry. Today they represent an extraordinary danger for the environment. Special technical solutions are required for these old burdens and in some places their remediation has already been running. These disposal sites are:

- a) the disposal site of acid tar in Pesnica, Studenci and Bohova near Maribor (Figure 6, designation of disposal sites 1, 2, 3),
- b) disposal site of waste materials arisen in the production of organic acids (tartaric acid, lactic acid, citric acid) in Globocnik near Ilirska Bistrica (Figure 6, designation of the disposal site is 4),
- c) disposal site of red mud and ashes from the aluminium processing plant in Kidricevo (Figure 6, designation 5)

Some similar waste disposal sites from the past have already been remedied. However, there still exists a series of so-called »illegal waste disposal sites« that have been discovered by inspection services. In most cases, the persons responsible for these disposal sites are unknown or cannot be found, therefore legislation has been passed that allows for such sites to be remedied from budget funds designated for environmental protection.
4.1 Short Survey and Characteristics of the Mentioned Old Waste Disposal Sites

Ad 4a) On the disposal sites of old acid tar in Pesnica, Studenci and Bohova in years 1955 to 1985, the remainders from the reworking of used motor industrial oils with sulphuric (VI) acid were deposited. The sites were badly selected, namely ground water was leaching in which increased deposited tar levels. The remediation of these disposal sites was started in 1986 and was divided into three steps. As of now, two of these steps have been carried out, namely, works for the protection of disposal sites, the purifying plant for leakages and waste waters was built up – one purifying plant for the three disposal sites. Up till now nearly 5500 m$^3$ of the liquid waste phase has been processed, and some 500 tons of oil and 500 m$^3$ of waste water polluted with tar were removed. It was important that the liquid layers of the waste materials were removed as they risked overflowing into the environment.

Ad 4b) At the end of the 1950s, waste materials arising from the production of organic acids, such as the tartaric, lactic and citric acid, were deposited on the disposal site of communal waste materials in Ilirska Bistrica. In 1965, the disposal site for these waste materials was sited at Globovnik near Ilirska Bistrica. The disposal site operated for 25 years and during this period 120,000 to 150,000 m$^3$ of waste materials were deposited. The status of the omitted disposal site is poor. Although covered with soil and strewing materials, it is exposed to emissions and is washed out with meteoric waters into the near brook. The polluted waters contain increased concentrations of individual elements, such as bromine, calcium, mercury, potassium. Remediation is foreseen in the following decade.

Ad 4c) The omitted disposal site of red mud and ashes in the area of the aluminium processing plant in Kidricevo represents a risk because of the pollution of underground waters. The washing away of individual substances with the meteoric water threatens the underground waters which represent the source of drinking water in that area. The substances that were analysed in the underground waters are characteristic for the substances that remain in the red mud after the production of aluminum from boxite. These substances are: alkaline elements, aluminium, iron, cyanides, fluorides, vanadium and mineral oils. The remediation of this disposal site has been running for some years already, however, it will not be finished before 2015.

5. CONCLUSIONS

In the “Slovene National Program of Environmental Protection”, adopted by the National Assembly of the Republic of Slovenia in 1999 and in the Waste Management Strategy of the Republic of Slovenia, the gradual elimination of old burdens of the environment is foreseen, i.e. remediation of the described contaminated disposal sites. In most of the described locations, it was already started ten or even twenty years ago, and in some of them even earlier.

This remediation has been running relatively satisfactorily above all on the disposal site of the uranium mine at Zirovski vrh and also on other locations where radioactive wastes were deposited.

Also the remediation of disposal sites at heavy metals mines, i.e. in Mezica (Pb, Zn)) and Idrija (Hg) has been running for years, albeit slower than expected and as required by the inhabitants in the affected surroundings.

The running of the remediation of the waste disposal site of the Jesenice ironworks has been faster than the above mentioned remediations.

The remediation at the waste disposal site of the aluminum processing plant in Kidricevo has been running very poorly or extremely slowly respectively. Also the remediation of the omitted old disposal sites such as:

- disposal site of acid tar in Pesnica, Studenci and Bohova,
- disposal site of waste from the production of organic acids in Ilirska Bistrica, and
- disposal site of red mud in the area of the aluminium processing plant in Kidricevo has been running very, very slowly and at some locations, it has been previously predicted that it would come to an ecological catastrophe – disposal site of acid tar in Pesnica.
REFERENCES

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