FACTA UNIVERSITATIS
Series: **Working and Living Environmental Protection** Vol.11, N° 2, 2014, pp. 129 - 143

ACCIDENT PREVENTION IN SEVESO FACILITIES: EXAMPLE OF THE COPPER FLOTATION PLANT IN BOR

UDC 614.8: [622.34:622.765(497.11 BOR)

Emina Mihajlović, Lidija Milošević, Jasmina Radosavljević, Ljiljana Živković, Miomir Raos

Faculty of Occupational Safety in Niš, University of Niš

Abstract. *In the near future, sustainable development of mining will inevitably be a part of raising environmental awareness. When Serbia joins the EU, the mining industry will have to abide by the European ecology standards and legislation, with which it is currently in the process of harmonization. This will primarily protect the population living in mining areas from large-scale accidents, as well as from the existing pollution sources.*
Pollution of the town of Bor began more than a century ago when industrialist Đorđe Vajfert was granted the excavation concession, as he hoped he would find gold there. Instead, he found copper, which was first extracted by the French. Since then, the development and survival of the town have depended on copper mining, which necessarily degraded the environment.
For the purpose of harmonizing the environmental legal regulation of current copper production and, above all, reducing the risk of large-scale accidents, the Centre for Occupational and Environmental Risk Management of the Faculty of Occupational Safety in Niš has prepared the Report on the Safety of Flotation Plant Bor at the request of Copper Mine Bor, a subsidy of RTB Bor (Mining and Smelting Complex Bor). The Report is essentially a study defining the operation objectives and principles of Seveso facility operators for risk control against chemical accidents.
The purpose of this study was to improve the implementation of accident prevention principles at the Flotation Plant Bor.
This paper presents the parts of the study that pertain to prescribed preventive procedures and measures against accidents due to hazardous materials that are present during flotation. It covers the following aspects: facilities, equipment, piping, machinery, tools, repositories, and the flotation tailings pond; analysis and assessment of the effectiveness of the system of occupational safety and fire and explosion safety; assessment of impact on employees, the surrounding population, and buildings, and the possible harmful environmental impact; assessment of unwanted event incidence; and determination of vulnerable zones.

Key words: *copper flotation, determination of vulnerable zones, accident prevention measures*

Received October 13, 2014 / Accepted December 30, 2014
Corresponding author: emina.mihajlovic@znrfak.ni.ac.rs
Faculty of Occupational Safety in Niš, Čarnojevića 10A, 18000 Niš, Serbia
Phone: +381 18 529 745• E-mail: emina.mihajlovic@znrfak.ni.ac.rs

1. INTRODUCTION

Flotation Plant Bor, with all its facilities and buildings, is located in the Municipality of Bor, in the central part of Eastern Serbia (Figure 1).

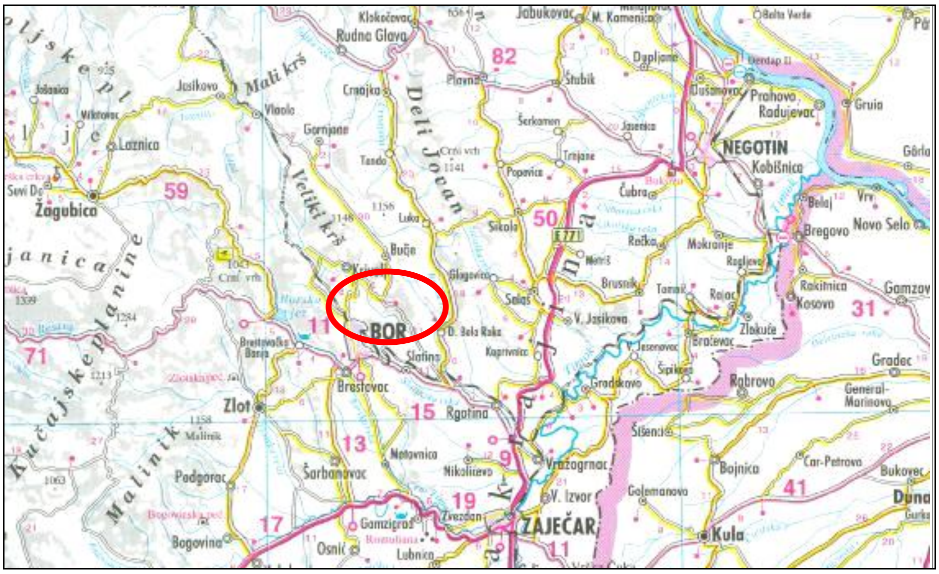


Fig. 1 Map of wider area of Bor

Municipality of Bor incorporates 13 urban and 13 rural administrative units. According to the 2011 census, the territory of Bor is 856 [km^2] and is inhabited by 33,328 people. Although it is surrounded by tall mountains, the town of Bor only rises 378 [m] above sea level.

Flotation Plant Bor covers an area of 1 276 809 [ha] within the RTB Bor industrial complex, and is located 800 [m] to the northeast of downtown Bor. It comprises flotation facilities and a tailings pond (Figure 2) [1, 2, 3, 4].

The area surrounding the RTB Bor complex, i.e. the flotation plant, comprises the following:

- ore body H and gangue dump to the north;
- residential buildings, ca. 460 [m] to the west and southwest;
- old desiccated tailings dump to the south and
- tailings pond dam and the Bor River valley to the northeast.

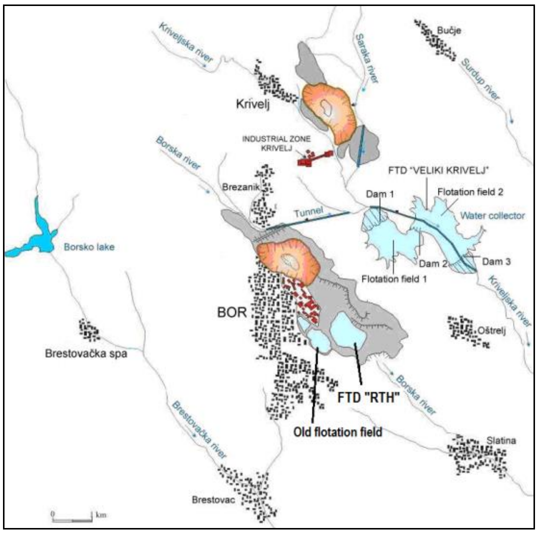


Fig. 2 Flotation Plant Bor site plan

Every building belonging to Flotation Plant Bor is earthquake resistant (up to nine degrees of earthquake intensity), which is satisfactory for this area.

The land area belonging to the flotation plant contains no landslides.

The mean annual air temperature in Bor and the surrounding areas is +10.7 [°C] according to the meteorological station of the Copper Institute Bor, whereas the mean monthly temperature is the lowest in January, +0.4 [°C], and the highest in July, +22.9 [°C].

According to the meteorological station measurements, there are no pronouncedly strong winds in the area, which is why production never halts. Winds during dry periods can raise dust deposits in the tailings pond.

The most frequent air currents in and around Bor are northwest and east winds. South winds follow directly behind, whereas north winds are the least frequent. Wind frequency is shown in Figure 3.

The amount of precipitation is measured at the Bor meteorological station and the mean monthly values are given in Table 1.

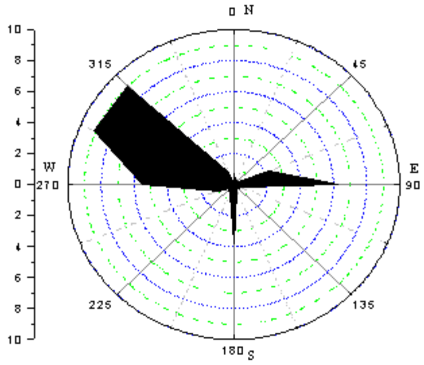


Fig. 3 Wind rose for Bor and the surrounding area

Table 1 Mean precipitation [mm/m^2] for Bor

Month	Mean value
January	40.2
February	40.2
March	26.1
April	45.7
May	62.4
June	66.1
July	45.1
August	62.2
September	40.2
October	59.8
November	50.0
December	45.0
Annual total	588.0

Heavy showers during summer and snowmelts create torrents, which erode the slopes of the dumps. Protective embankments have been built to prevent contamination of the surrounding soil by tailings deposits.

Flotation Plant Bor is situated in the Bor River valley (Figure 2). Testing of the Bor River water quality was performed near the village of Rgotina. The monitoring revealed a change in the organoleptic properties of the water, i.e. the water occasionally exhibited noticeable colouring and odour. Water quality was most often Class III or IV but sometimes also NC (not classified).

In terms of the presence of hazardous and harmful substances, there were increased concentrations of iron (Fe) (Class III/IV and NC), manganese (Mn), copper (Cu) (NC), zinc (Zn) (Class III/IV and NC), cadmium (Cd) (Class III/IV), nickel (Ni) (Class III/IV and NC), and phenol index (class III/IV).

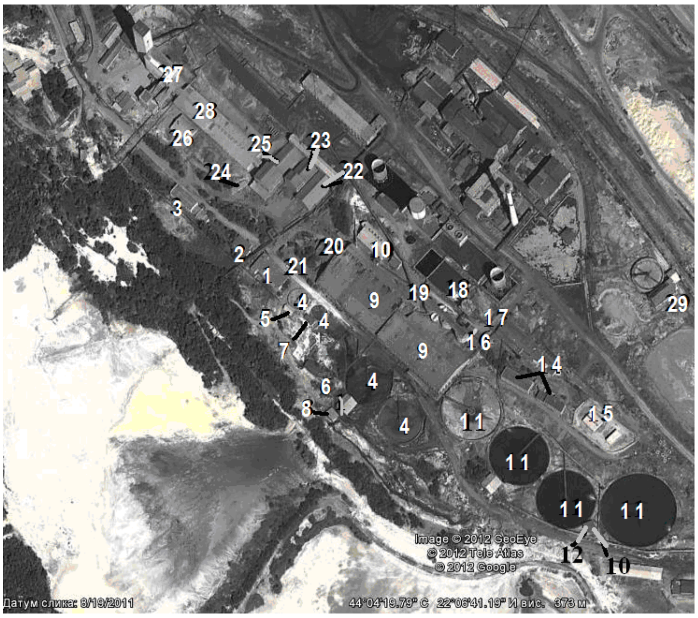
Based on these findings, the Bor River water quality was deemed unsatisfactory regarding its colour, pH value, and suspended particulate matter.

As regards groundwater contamination, there is no available specific data.

The problem of flood protection in the tailings pond at ore body H, which was at risk of dam failure, was considered for the first time in 2010. Across the world, dam failures in tailings ponds are not uncommon. According to the records of the International Commission on Large Dams, nearly 20 [%] of floods in tailings ponds are caused by dam failures due to earthquakes, 16 [%] by dam overflows, and about 23 [%] by unstable slopes.

2. Facility Description with a Site Plan

Flotation Plant Bor is situated within the RTB Bor industrial complex, which comprises several production units, each containing a group of facilities, such as the foundry, the smelting plant, the electrolysis plant, the power plant, and the flotation plant. Figure 4 shows the facilities located within the Flotation Plant Bor.



1. Administrative offices
2. Mess hall
3. Bathrooms
4. Thickeners, out of order
5. Garage
6. Pumping station 3
7. Pumping station 4
8. Pumping station 4a
9. Flotation building
10. Substation
11. Operational thickeners
12. Pumping station 6 + Pumping station 5
13. Pumping station J
14. LPF (leaching – precipitation – flotation)
15. Repository for reagents
16. Ball mill bunkers
17. Water tower
18. Water pool
19. Oil repository
20. Machine workshop
21. Electrical workshop
22. SIF (semi-industrial facility)
23. Spare part repository
24. Executive offices
25. Crushing
26. Repository for electric spare parts
27. Ore bunkers: A, B, and C
28. Copper filtration
29. Pyrite filtration (out of order)

Fig. 4 Site plan of Flotation Plant Bor

In the narrow sense, Flotation Plant Bor comprises the following facilities: crushing plant, flotation plant, repository for reagents, water tower, pumping stations, water pools, thickeners, and filtration plant. Facilities at the Flotation Plant Bor, including all mining facilities in this technological line, such as transport roads, lines, and power installations, are built compactly, i.e. they are placed close to one another. From the perspective of protection against accidents, this is an unfavourable circumstance, since a fire or a chemical accident could spread quickly across the entire flotation plant.

2.1. Description of the RTH tailings pond

The oldest disposal site for flotation tailings in the Bor mines is the Old Tailings Pond (Figure 2). The Old Pond contains ca. 28-30 [Mt] of tailings over the area of 57.60 [ha]. It is adjacent to the town of Bor and comprises two smaller fields that formed in the Bor River Valley. It was used until 1987. Today, the pond is dried and almost completely vegetation free, which is why dust emission from the dry pond surface toward the town of Bor is a serious and evident environmental problem. The biggest accident related to the Old Pond occurred in 1960, when the dam failed after heavy precipitation, which caused the tailings to spill on the farming land in the Bor and the Timok river valleys and thus contaminate it.

Nowadays, the RTH (Serb. rudno telo H – ore body H) tailings pond is used to dispose of flotation tailings from the Flotation Plant Bor (Figure 2). The RTH tailings pond contains 50-60 [Mt] of tailings over the area of 86 [ha], with copper content of ca. 0.20 [%]. The nearest residential building is 660 [m] away.

From the technological process perspective, the flotation tailings pond is a necessity, but from the environmental perspective, it is an environmental hazard.

Dams and embankments of the RTH tailings pond are hydro-technical facilities built with hydrocyclone-separated sand. When these surfaces are dry, strong winds cause the aeolian erosion of dust and its diffusion into the environment [5].

2.2. Description of the technological process in terms of chemical accidents

The technological process contains the following stages:

1. Crushing and screening;
2. Milling and sorting; and
3. Flotation (flotation in a narrow sense, thickening with filtration, water supply, and disposal of flotation tailings).

Basic flotation of copper mineral from the pit ore yields two products:

- copper concentrate, which is hydraulically transported to the filtration plant, and
- final tailings, which are deposited in the RTH tailings pond.

After thickening and filtration, the copper concentrate is transported to the smelting plant for further processing.

The final flotation tailings are transported gravitationally through a channel to the thickener. The thickener contains clean water, which is then pumped into the process water pools located above the flotation plant.

In RTH, the tailings are separated into the left and the right pipeline branch. These pipelines service the hydrocyclones on Dam 1, Dam 2, and the embankment between the two dams. Dams and embankments are built and further elevated with hydrocyclone-separated sand, while the overflow with fine sludge particulates is discharged into the tailings pond reservoir. The sludge fraction is used to build beaches, whose purpose is to control the position and shape of the deposit reservoir of the RTH tailings pond [1, 2, 3, 4].

3. INVENTORY OF HAZARDOUS MATERIALS

Flotation Plant Bor contains the following hazardous materials (Table 2):

1. reagent D-250, present in the flotation plant in the amount of 10 [t] and used as a foaming agent;
2. reagent KEX, present in the flotation plant in the amount of 10 [t]; and
3. flotation tailings, discharged into the tailings pond in the amount range of 1,000, 000-2,500,000 [t/year].

Table 2 Hazardous materials in the Flotation Plant Bor

No.	Trade name of hazardous material	IUPAC name	CAS	UN
1.	Reagent D-250 foaming agent	Triethylene glycol monobutyl ether	143-22-6	2369
2.	Reagent KEX	Ethylxantic Acid	140-89-6	3342
3.	Flotation tailings	-	-	3390

3.1. Properties of hazardous materials

Table 3 shows the basic properties of reagent D-250 and Table 4 shows the basic properties of reagent KEX.

Table 3 Basic properties of reagent D-250

IUPAC name:	Triethylene glycol monobutyl ether
Chemical formula:	$C_{10}H_{22}O_4$
CAS number:	143-22-6
Molecular mass:	206.2793 [kg/mol]
UN	2369
Colour:	Yellow to brown, dark yellow
State of matter:	Liquid
Health effects:	Eye irritant on contact
Chronic exposure:	Causes eye irritation
pH value:	4-7
Ignition temperature:	156 [°C]
Autoignition temperature:	330 [°C]
Acute oral toxicity:	LD50 > 5000 [mg/kg]
Acute skin toxicity:	LD50 > 2000 [mg/kg]
NOAEL	50[mg/kg]

Table 4 Basic properties of reagent KEX

IUPAC name:	Ethylxantic Acid
CAS number:	140-89-6
UN	3342
Chemical formula:	$C_3H_50S_2K$
LD50:	308 [mg/kg]
Acute effects:	Toxic for upper respiratory tract, skin, and eyes; potentially toxic for blood, nervous system, liver, and gastro-intestinal tract
Precautions:	Keep away from heat. Keep away from ignition sources. Emptied containers are fire hazards.
Odour:	Unpleasant odour, similar to carbon disulphide
Molecular mass:	160.3 [kg/mol]
Colour:	Light yellow
Specific weight:	1,558 [kg/m^3]

The total amount of deposited waste in the RTH tailings pond is 58,192,578 [t].
The annual amount of deposited waste in the RTH tailings pond is ca. 1,103,800 [t].
Chemical composition of the tailings is given in Table 5.

Table 5 Results of chemical analysis of RTH tailings

Parameter (%)	RTH tailings
Cu	0.14
S	0.80
Fe	3.63
SiO_2	-
Al_2O_3	66.00
CaO	1.28
MgO	2.71
Zn	1.33
Na_2O_3	1.16
K_2O	1.19
Pb	0.020
Zn	0.008
Te	0.004

3.2. Properties of hazardous materials generated by accidents

In the event of a chemical accident in the Flotation Plant Bor, reagents and flotation tailings are the hazardous materials expected to be spilled; in the event of a fire, the products of reagent combustion would constitute such hazardous materials [6] (Table 6).

Table 6 Hazardous materials in the event of accident

No.	Trade name of hazardous material	Transformation products in a chemical accident	Toxicological properties of products
1.	Reagent D-250	CO_2, CO, H_2O, N_2	toxicity
2.	Reagent KEX	CO_2, CO, H_2O, N_2, SO_2, SO_3, KO_2	toxicity
3.	Flotation tailings	Same hazardous materials as before the accident	corrosivity and toxicity

4. Hazard Identification

Identification of hazard source requires that the following aspects be determined:

- system “weak points”;
- causes of events relevant for risk assessment; and
- sequence of events.

“Weak points” in the system are instances in the work process that are considered to be the most common potential cause of an initial accident event from a construction-technical, technological, or organizational perspective.

Critical points of the Flotation Plant Bor, in which large-scale accidents could occur, are the following:

- repository for flotation reagents;
- transporters of reagents to the mixer;
- flotation cells;
- concentrate thickener;
- tailings thickener;
- tailings transport pipeline;
- tailings pond dams; and
- tailings pond itself.

An overview of possible accident events in relation to the critical points is shown in Table 7.

Table 7 Weak points in the technological process

Production stages	Hazardous material	Accident
Storage	Reagent D-250; Reagent KEX	Outflow, spillage, fire
Transport of reagents to the mixer	Reagent D-250; Reagent KEX	Outflow, spillage, fire
Flotation cells	Flotation pulp	Outflow, spillage
Thickening	Concentrate	Outflow, spillage
Transport of tailings	Flotation tailings	Outflow, spillage
Tailings pond	Flotation tailings	Spillage
Tailings dam	Flotation tailings	Flood wave

5. Representation of a Possible Accident Development – Scenario

A possible accident development, i.e. scenario, is determined based on a completed hazard identification (in particular the possible failures) and an event analysis.

The analysis of possible failures in the Flotation Plant Bor included in this study encompasses all pieces of equipment and devices in the flotation system. This paper reviews the two worst possible accident scenarios: fire and spillage in the reagent repository and dam failure in the tailings pond.

Despite the safe and efficient protection implemented at the Flotation Plant Bor, one has to assume the possibility of an accident, the effects of which could be manifested in the installations and facilities, as well as within and outside of the Flotation Plant Bor complex.

5.1. Fire effects modelling in the reagent repository

To model the effects of fire, we used ALOHA and CAMEO software suites. We made the calculation for the worst possible scenario – spillage and fire in the reagent repository. The model is based on the amount of 20 [t] of reagent D-250. This reagent was selected because its physicochemical parameters are well known, whereas the majority of KEX reagent parameters required for the calculation were not available. We did the calculation based on the atmospheric temperature of 15 [°C].

Figure 5 shows the zone in which a fire can occur if there is an ignition source present together with reagent D-250 vapours. The hazardous concentration level at which a fire can occur if an ignition source is present extends to 90 [m] of the spillage point.

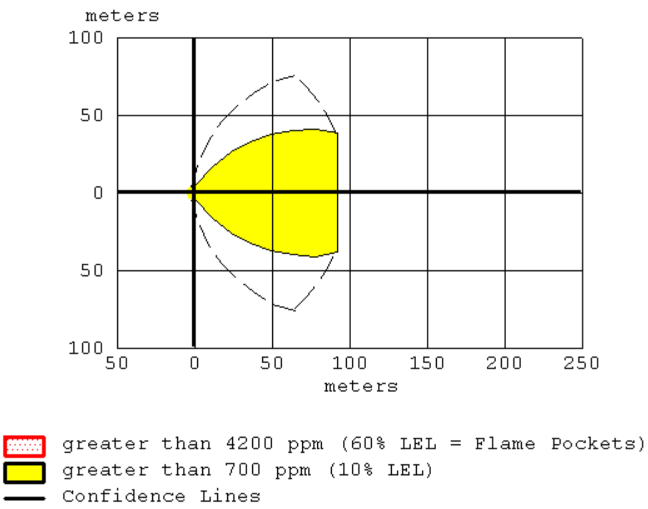


Fig. 5 Zone vulnerable to fire

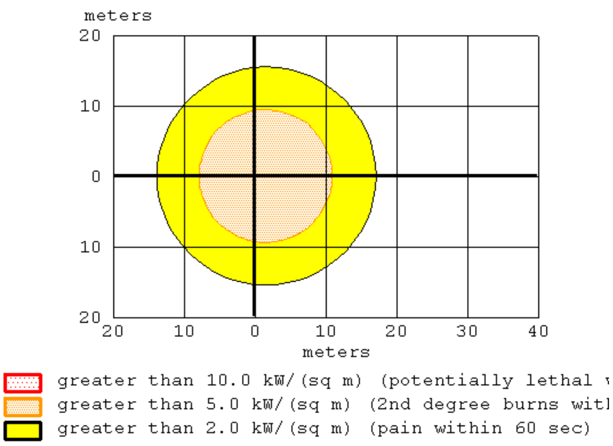


Fig. 6 Vulnerable zone in the event of fire

There are three possible hazard zones in the event of fire (Figure 6):

- (lethal) zone 1, which, in this case, can occur only in direct contact with the flames;
- zone 2, in which humans can suffer second degree burns; it covers a 10 [m] radius around the fire; and
- zone 3, in which humans can suffer minor burns, pain, and irritation; it covers an 18 [m] radius around the fire.

Hazard zones are found only inside the repository.

5.2. Modelling of toxicity effects due to vapour and aerosol propagation without a fire

Figure 7 shows the vulnerable zone for the worst case scenario of spillage of the entire amount of reagent in the repository and vapour dispersion without a fire. The dashed line represents windward vapour propagation.

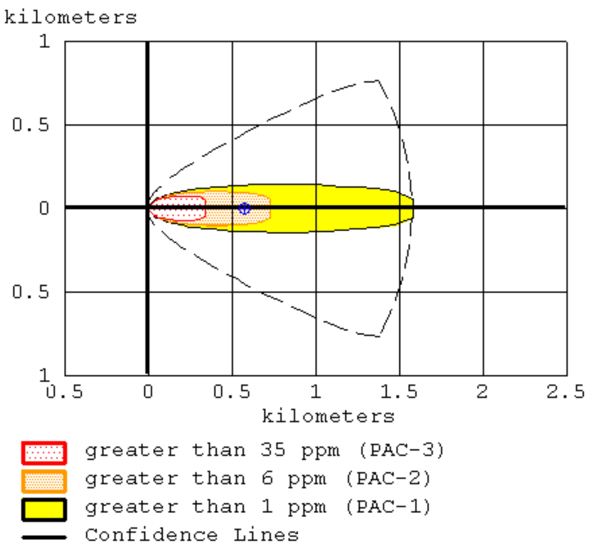


Fig. 7 Vulnerable zone due to reagent spillage without a fire

Figure 7 indicates the following:

- Vapour concentration of 1 [ppm] can reach the distance of 1.6 [km] windward. In a small number of people, this concentration level can cause mild and transient respiratory irritation.
- Vapour concentration of 6 [ppm] can reach the distance of 750 [m] around the reagent repository with the expectancy of eye and respiratory irritation in most people. However, these effects are transient. Although this concentration level can reach the area beyond the flotation plant complex, it is not life threatening.
- Vapour concentration of 35 [ppm], which can seriously affect human health, would be found within the Flotation Plant Bor complex no further than 300 [m] from the repository.

5.3. Modelling of effects of dam breach and tailings spread

Risk of damage or collapse of dams in the RTH tailings pond is due to several circumstances:

- construction technology, which is such that new layers completely or partially lie on relatively weak supporting layers from a previous layering cycle, which in turn reduces structural stability;
- dams are constructed with materials without a clay core, so the overflow water level is high, and insufficient drainage could lead to damage or collapse of the dam;
- poorly dimensioned or neglected derived structures could cause dam overflow during heavy precipitation;
- a stronger earthquake would be devastating to dams made of tailings material;
- downstream dam slopes are not protected against erosion and
- monitoring does not offer the possibility of automated warning.

This study analyzes two possible scenarios pertaining to potential dam breach in the RTH tailings pond. The dam collapses in the northern area of the tailings pond in the first scenario and in the western area in the second. In both scenarios, the dam collapses due to a strong earthquake, for which the probability of occurrence in the Bor area is once every 500 years.

Scenario 1 – This scenario pertains to a dam failure in the northern area of the tailings pond, in case of which the flood wave moves towards the old open pit.

Water level elevation in the tailings pond at the moment of the dam breach is 375.50 [mamsl]. We assumed that the dam collapses in only 10 [min]. We opted for such a short period to obtain a higher level of certainty of calculation results for downstream area flooding. The collapse occurs over the entire height of the dam and over the length of 30 [m].

Another assumption for the purpose of our calculation is that the water from the tailings pond flows out through the dam breach, whereby "breach" refers to a rectangular opening. Calculation of the outflow uses a curve of the total water volume in the tailings pond, which amounts to 750,000 [m^3].

Scenario 2 – This scenario stipulates a dam failure in the zones along the southern and western areas of the tailings pond.

A wave formed by dam collapse in the southern area of the pond would be completely retained in the depression next to the road/rail embankment.

If the total volume of water from the RTH tailings pond (750,000 [m^3]) flowed into this depression, water level elevation would be 309.0 [mamsl]. This elevation is at the same time the initial condition for the calculation of the embankment breach. Upon our on-site visit, we established that the depression was filled with water up to 292.50 [mamsl], so we decided to use this elevation as the lowest embankment collapse elevation.

The cause of the collapse is the overflow of the embankment crown and its erosion. The volume of the depression is larger than the total volume of water from the tailings pond, but the overflow could be caused by the embankment crown subsidence and deformation due to static or dynamic load (external water pressure, filtration, or earthquake). Identically to scenario 1, we assumed that the embankment collapses due to a breach in its body, over the length of 30 [m] and in only 10 [min], in order to preserve a high level of certainty of the results.

The calculation includes the Bor and the Bela old river valley beds (up to the village of Vražogrnac), but the results presented refer only to the section of the Bor River from the collapsed embankment to the confluence of the Bor and the Krivelj rivers. This is due to the fact that the peak of the flood wave at the confluence is lower than the one obtained by the calculation of the Veliki Krivelj dam collapse.

5.4. Vulnerable zone width

The width of the vulnerable zone, or hazard zone, is determined based on the results obtained from accident impact modelling. In the event of:

a) fire and explosion, the width is a maximum of 90 [m], windward;
b) release and spread of gases and vapours, the width is a maximum of 300 [m], windward; and
c) release and spread of liquids from the tailings pond, the width is 8.3 [km] × 500 [m] in the direction of the village of Slatina.

The wave in scenario 1 floods the area about 1 [km] in length between the tailings pond and the old open pit. The travel time of the wave front from the dam to the open pit entrance is ca. 4 [min]. The average wave velocity is 17 [km/h]. The time of occurrence of the highest flow rate at the old pit entrance is ca. 13 [min]. Such a short period seriously limits the possibility of early warning and completely prevents any measures of timely protection of material property in the afflicted area.

Based on the results of hydraulic calculations, we determined the boundaries and the highest flooding elevations in the observed area, as shown in Figure 8.

The results show that, in the event of dam failure in the northern area of the tailings pond, 9.3 [ha] of land between the dam and the open pit entrance would be flooded, with the highest water level elevation of 346.33 [mamsl]. This area does not contain any residential buildings or important infrastructure, only the industrial facilities of RTB Bor. Nevertheless, the water from the tailings pond (with a certain amount of tailings) would end up in the old open pit, which would create negative economic and environmental impact.

In scenario 2, the flood wave created by the dam collapse in the western area of the RTH tailings pond would pose a threat to the road and the railway adjacent to the pond. According to this scenario, the wave would end up in the depression south of the pond. Under the pressure of water, there is also high expectancy that the road/rail embankment delineating the depression would collapse, which would block both the road and the railway, and that the water would flow out of the depression and into the Bor River valley, thus endangering the village of Slatina.

The results indicate that the highest flow rate at the entrance into the village of Slatina reaches ca. 720 [m^3/s], whereas at the exit it decreases to ca. 300 [m^3/s].

The flood wave front would reach Slatina in about 6 [min] from the embankment collapse, whereas the peak of the wave would reach the village in 10 [min]. The wave front would exit Slatina in 18 [min], whereas the peak would exit it in 25 [min].

The flood wave reaches the confluence of the Bor and the Krivelj rivers in 36 [min], the peak in 47 [min]. The velocity of wave propagation indicates that there is very little time from the moment of embankment collapse to warn and evacuate the residents of Slatina. These actions must be taken the moment the hazard of imminent dam failure in the RTH tailings pond has been ascertained.

According to the calculation results, the maximum water level elevations along the observed 8.3-[km] section range from 192 [mamsl] to 270 [mamsl]. The maximum water level elevations in the village of Slatina range from 218 [mamsl] to 243 [mamsl]. The greatest depth in the profile of the collapsed embankment is ca. 7 [m]. The depth decreases further downstream, reaching 4 to 3 [m] in Slatina and 3 to 2.5 [m] between Slatina and the confluence of the Bor and the Krivelj rivers.

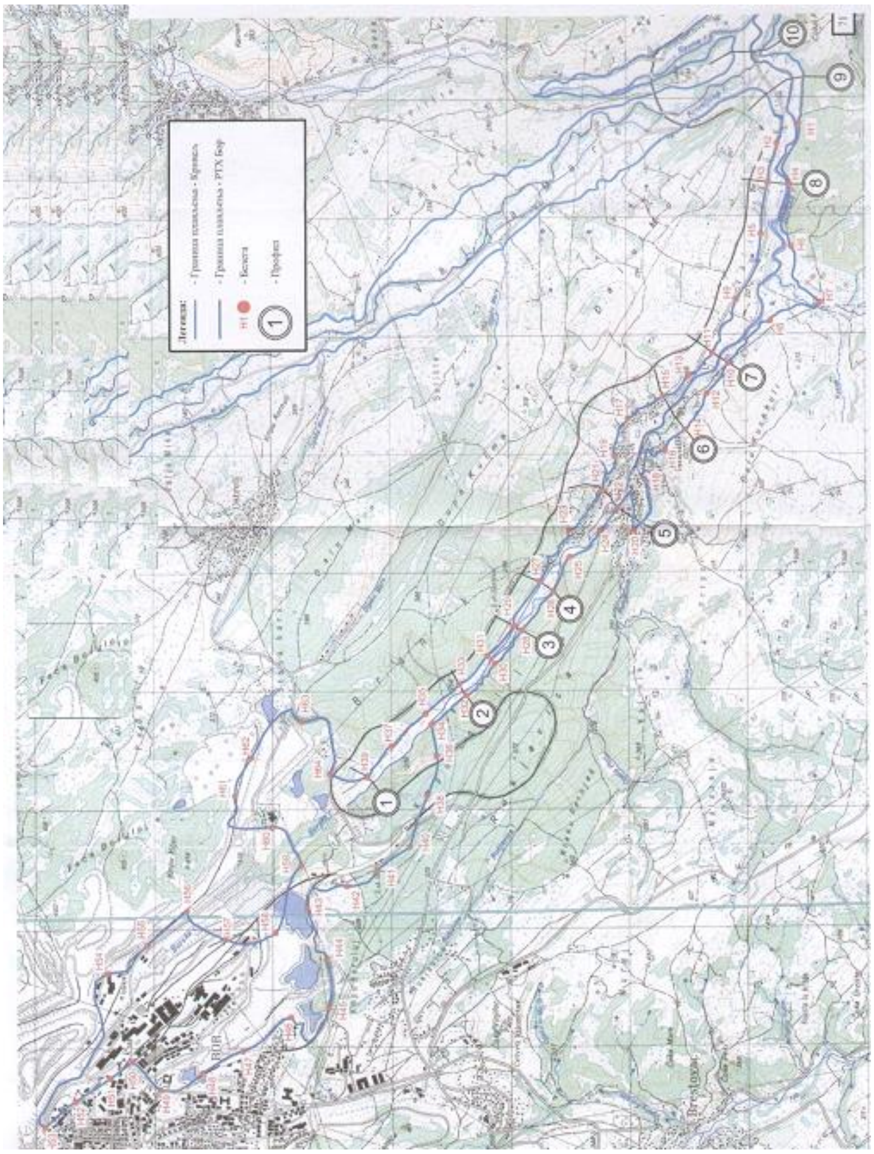


Fig. 8 Flooding zone of the RTH tailings pond

6. Vulnerability Analysis

6.1. Number of workers in the facility/complex

Depending on the accident, the number of endangered workers is as follows:

- fire in the reagent repository – a maximum of two workers that could be present in the repository (immediate evacuation required);
- reagent spillage and evaporation – 214 workers in the complex in danger of slight irritation (immediate evacuation required); and
- RTH dam failure on the northern side – in the event of dam failure in the northern area of the tailings pond and the formation of a flood wave, 9.3 [ha] of land between the dam and the open pit entrance would be flooded over the length of 1 [km]. This area does not contain any residential buildings or important infrastructure, only the industrial facilities of RTB Bor. This event is potentially life threatening for 214 workers in the complex, so immediate evacuation is required.

6.2. Number of people outside the complex

In the event of dam failure in the western area of the RTH tailings pond and the formation of a flood wave, 1,500 residents of the village of Slatina would be endangered, as well as the Bor-Rgotina road and the Bor-Zaječar railway line.

In this case, the optimal evacuation time for the residents of Slatina would be 5 [min].

7. Conclusion

The potential chemical accident at the Flotation Plant Bor and the worst case scenario of dam failure in the western area of the RTH tailings pond might be classified as a level 4 accident – the impact of the accident can extend to the entire region.

Should that occur, it is essential to establish a monitoring and alert system for the dam of the RTH tailings pond in Bor. Population in threatened areas and the staff of the municipal centre in Bor should be promptly notified on the occurrence of a flood wave.

To provide this function, the monitoring and alert system should contain the following:

- monitoring network;
- dam subcentre;
- main subcentre in the dispatch centre;
- operations centre in Bor;
- alarm stations in the threatened areas;
- telecommunication system; and
- notification and warning signs in the threatened area.

This system should be an integral part of a unified monitoring and alert system, which is accomplished by integration into the system of the operations centre in Bor.

Boundaries of threatened areas should be clearly marked so that the people in those areas could be aware of the boundaries and know which area they are supposed to leave in the event of a flood wave, by choosing the shortest and the best routes. The boundaries should be marked with noticeable delineators placed within the area of mutual visibility. The delineators should be white with a 5-[cm] wide red strip and minimum 140 [cm] tall. This would enable timely evacuation of the endangered people.

Acknowledgement. *The research reported in this paper was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia within the projects No. III-43014 and No. TR-33035.*

REFERENCES

1. *Main mining project for pit copper minin*g, Copper Institute in Bor, January 1997.
2. *Supplemental mining project for the servicing of the Bor pit*, (1998), Copper Institute in Bor.
3. *Main mining project for copper mining in the Bor pit until K235 m*, Copper Institute in Bor, December 2006.
4. *Main mining project for slag excavation from the technogenic deposit "Slag Depot 1*", (2006), Verification of the technological process of obtaining the concentrate and elevation of the RTH tailings pond in Bor to k +378 for the annual yield of 1.200.000 tonnes of slag; Mining and Metallurgy Institute Bor.
5. *Annual report on the auscultation of RTH tailings pond from September 2010 to August 2011*, (2011) Mining Institute, LLC, Belgrade.
6. *Fire protection plan*, (1987), Occupational Safety Institute "May 1", Niš.

PREVENCIJA UDESA KOD SEVESO POSTROJENJA NA PRIMERU FLOTACIJE RUDE BAKRA U BORU

Održivi razvoj rudarske proizvodnje, u bliskoj budućnosti, neizbežno mora da prati jačanje ekološke svesti. Sa ulaskom naše zemlje u Evropsku Uniju rudarska proizvodnja će morati da poštuje ekološke standarde i zakonsku regulativu koja je u fazi usklađivanja sa evropskim zakonodavstvom. Na ovaj način stanovništvo u rudarskim područjima biće zaštićeno pre svega od udesnih događaja većih razmera, kao i od postojećih izvora zagađenja.

Zagađenje Bora počelo je pre više od jednog veka sa koncesijama koje je dobio Đorđe Vajfert za iskopavanje u nadi da će naći u ovom području zlato. Našao je bakar, sa čijim iskopavanjem prvo počinju Francuzi. Do današnjeg dana razvoj i opstanak ovog grada zavisi od proizvodnje bakra koja neminovno vodi do degradacije životne sredine.

U cilju usklađivanja zakonske regulative postojeće proizvodnje sa stanovišta zaštite životne sredine, a pre svega u cilju smanjenja rizika od udesa većih razmera Centar za upravljanje rizikom u radnoj i životnoj sredini Fakulteta zaštite na radu u Nišu, je za potrebe RTB Bor Grupe, Rudnici bakra Bor uradio Izveštaja o brzbednosti pogona Flotacije "Bor". Izveštaj o bezbednosti za flotaciju „Bor" je studija koji definiše ciljeve i principe delovanja operatera seveso postrojenja, radi kontrolisanja opasnosti od hemijskog udesa.

Svrha ove studije je sprovođenje principa prevencije udesa u slučaju pogona Flotacije „Bor".

Ovim radom prikazani su delovi iz studije koji se odnose na propisane postupke i mere prevencije udesa od opasnih materija koje su prisutne tokom tehnološkog procesa flotacije, uključujući: objekte, opremu, cevovode, mašine, alate, skladišta i flotacijsko jalovište, analizu i ocenu delovanja sistema zaštite na radu, zaštite od požara i eksplozija, procenu mnogih posledica na zaposlene, stanovnike, objekte i životnu sredinu u neposrednom okruženju i moguće štetne uticaje na radnu i životnu sredinu, procenu učestalosti neželjenih događaja kao i proračun povredive zone.

Ključne reči: *flotacija bakra, proračuni ugroženih zona, mere za sprečavanje udesa*