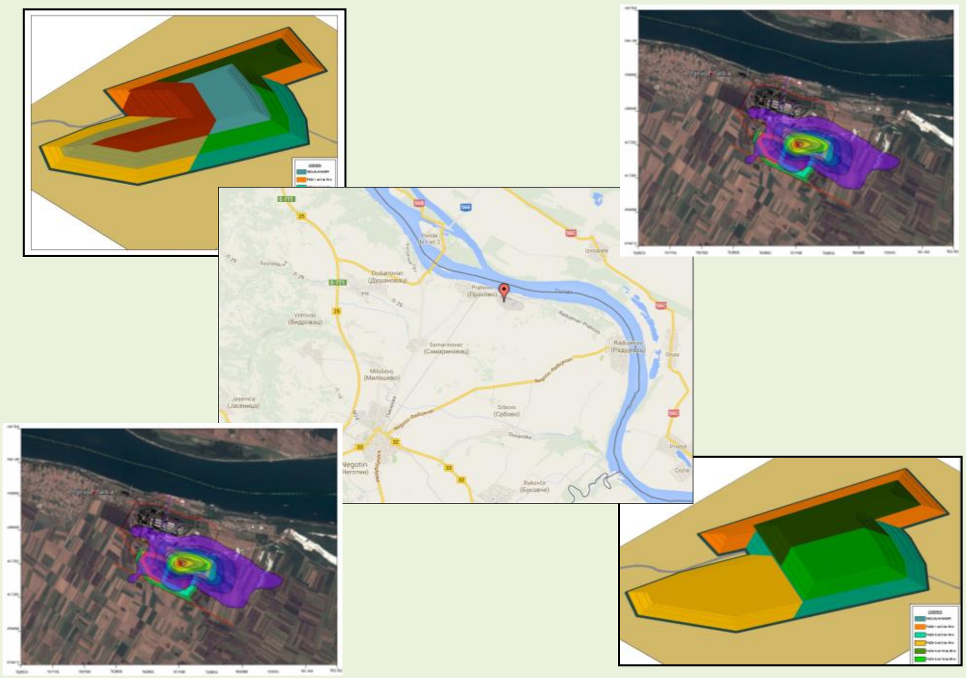
**ELIXIR PRAHOVO,** INDUSTRIJA HEMIJSKIH PROIZVODA DOO, PRAHOVO

# THE ENVIRONMENTAL IMPACT ASSESSMENT STUDY ON THE PHOSPHOGYPSUM STORAGE



**Belgrade, March 2015**

**University of Belgrade, Faculty of Mining and Geology**

Elixir Prahovo
Industrija hemijskih proizvoda

**ELIXIR PRAHOVO INDUSTRIJA HEMIJSKIH PROIZVODA DOO PRAHOVO**

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**Study prepared by:**


**Faculty of Mining and Geology**
**University of Belgrade**
**Djušina 7, 11000 Belgrade**
**The Republic of Serbia**


**Belgrade, March 2015**

**ELIXIR PRAHOVO DOO PRAHOVO**
**Radujevački put bb, 19330 Prahovo, Serbia**

# THE ENVIRONMENTAL IMPACT ASSESSMENT STUDY ON THE PHOSPHOGYPSUM STORAGE


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# INTRODUCTION

ELIXIR PRAHOVO INDUSTRY OF CHEMICAL PRODUCTS LTD PRAHOVO is a large chemical complex which used to be well-known for production and processing of phosphorous components, manufacturing of washing and cleaning products, fluorine chemistry, manufacturing of water purification agents, plant protection products, production of fodder additives and phosphorous salts. However, this company had always been recognized for production of mineral fertilizers and phosphoric acid.

IHP – Industry of Chemical Products Prahovo was established in 1960 as the superphosphate factory, i.e. it was a chemical section of the metallurgical complex of Bor basin. Since then, IHP had expanded its capacities and product range so that in 1968 and 1978 started to operate factories for production of phosphoric acid.

The consortium formed by University of Belgrade Faculty of Mining and Geology and University of Belgrade Faculty of Civil Engineering developed the conceptual design of the phosphogypsum storage for ELIXIR PRAHOVO INDUSTRY OF CHEMICAL PRODUCTS LTD Prahovo.

In this conceptual design is developed technology of formation of a new storage at the entire location which the company plans to purchase and allocate for the new storage. It has been planned utilization of the entire area in stages and, accordingly, this design includes division on stages and planning of “permanent” infrastructural facilities which will be used at the storage during its entire operational life, of around 34 years (without any placement of phosphogypsum on the market and changing of factory’s capacity). The division of space by stages is not geometrical, but is conditioned with the investor’s abilities to provide (procure) certain parts of the planned location.

The phosphogypsum storage will be developed through stages. From the aspect of the occupied surface, utilization will unfold in 3 stages, and in relation to the occupied volume in 8 stages. The first three stages implies occupation of the entire planned surface and overbuilding to elevation +18 m, while the following three stages include overbuilding to elevation + 36 m. The seventh and eighth stage include overbuilding of the phosphogypsum storage to the final height of 50 m. The area intended for the storage is defined with prepared planning acts, which have been adopted by the Commission for Plans and Municipal Council.

The subject of this document is the Environmental Impact Assessment Study on the Phosphogypsum Storage, for which Ministry of Energy, Development and Environmental Protection of the Republic of Serbia prescribed scope and content of the study with Decision No. 353-02-511/2014-05 of 10.04.2014.

The Environmental Impact Assessment Study on the Phosphogypsum Storage was done in accordance with the following legislation:

- Law on Environmental Protection (Official Gazette of RS, No. 135/2004, 36/2009, 36/2009 – state law, 72/2009 – state law and 43/2011 – the Decision of the Constitutional Court);
- Law on Strategic Environmental Impact Assessment (Official Gazette of RS, No. 135/04, 88/10);
- Law on Environmental Impact Assessment (Official Gazette of RS, No. 135/04 and 36/09);
- Law on Integrated Environmental Pollution Prevention and Control (Official Gazette of RS, No. 135/04);

- Law on Waters (Official Gazette of RS, No. 30/10);
- Law on Air Protection (Official Gazette of RS, No. 36/2009 and 10/2013);
- Law on Nature Protection (Official Gazette of RS, No. 36/2009 and 88/2010);
- Law on Ratification of Convention on Environmental Impact Assessment in a Transboundary Context (Official Gazette of RS, No. 102/07);
- Law on Confirmation of Convention on Transboundary Effects of Industrial Accidents (Official Gazette of RS, No. 42/09);
- Law on Protection against Environmental Noise (Official Gazette of RS, No. 36/09, 88/10);
- Regulation on noise indicators**,** limiting values and methods for estimation of noise indicators**,** annoyance and detrimental effects of environmental noise (Official Gazette of RS, No. 75/10);
- Regulation on limit values of pollutants in surface and ground waters and sediments, and deadlines for reaching thereof (Official Gazette of RS, No. 50/2012);
- Regulation on limit value emissions of pollutants in the air (Official Gazette of RS, No. 71/10, 6/11 – amendment);
- Regulation on definition of a list of projects for which an impact assessment is mandatory and a list of projects for which might be required environmental impact assessment (Official Gazette of RS, No. 114/08);
- Regulation on monitoring conditions and air quality requirements (Official Gazette of RS, No. 11/10);
- Regulation on systematic soil quality monitoring program**,** indicators for assessment of risk of soil degradation, and methodology for development of remediation programs (Official Gazette of RS, No. 88/2010);
- Rulebook on contents of the Environmental Impact Assessment Study (Official Gazette of RS, No. 69/2005);
- Rulebook on limit values**,** immission measurement methods**,** criteria for establishing the measurement points and data recording (Official Gazette of RS, No. 54/92 and 19/06);
- Regulation on permitted noise level in the environment (Official Gazette of RS, No. 54/92);
- Rulebook on parameters of ecological and chemical status of surface waters and parameters of ecological and chemical status of groundwaters (Official Gazette of RS, No. 74/2011);
- Rulebook on Reference Conditions for the Types of Surface Waters (Official Gazette of RS, No 67/2011);
- Rulebook on methodology for chemical accident hazard assessment and the environmental pollution risk with the preparation and mitigation measures (Official Gazette of RS, No. 60/94);
- Law on Planning and Construction (Official Gazette of RS, No. 72/2009, 81/2009 – amendment, 64/2010 – the Decision of the Constitutional Court, 24/2011, 121/2012, 42/2013 – the Decision of the Constitutional Court, 50/2013 - the Decision of the Constitutional Court and 98/2013 - the Decision of the Constitutional Court)

# 1. PROPONENT DETAILS

In accordance with the Law on Environmental Impact Assessment (Official Gazette of RS, No. 135/04) and the Rulebook on the contents of the Environmental Impact Assessment Study (Official Gazette of RS, No. 69/2005), in this section of the Environmental Impact Assessment Study of the Phosphogypsum Storage is provided proponent details.

| | |
|---|---|
| **Organisation** | Elixir Prahovo Industrija hemijskih proizvoda<br>**ELIXIR PRAHOVO INDUSTRIJA HEMIJSKIH PROIZVODA DOOPRAHOVO** |
| **Name of individual** | Manager Strahinja Golubović |
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| **Company identification number** | 07309783 |
| **Tax Identification Number** | 100777129 |
| **Description of activity code** | Production of fertilizers and nitrogen compounds |

# 2. DESCRIPTION OF LOCATION PLANNED FOR PROJECT IMPLEMENTATION

## 2.1. Physical characteristics and geographic location

Prahovo is located in Negotinska Krajina in the peripheral northeastern part of Serbia. It is a village in Municipality of Negotin, County of Bor. The geographic location of Negotinska Krajina and, consequently, of Prahovo is important because of proximity of the Danube River. The fundamental regional attribute is its location on the banks of the Danube, the border region toward the Republic of Romania and proximity of the state border toward the Republic of Bulgaria. The local attribute of Prahovo is defined with its central position in relation to villages: Radujevac, Samarinovac and Dušanovac. Prahovo is an industrial settlement of a compact type located 9 km from Negotin. It is situated, approximately, at +60 masl, on the right bank of the Danube River. The railway and modern road connects it with larger towns. It occupies an area of 1,957 ha.

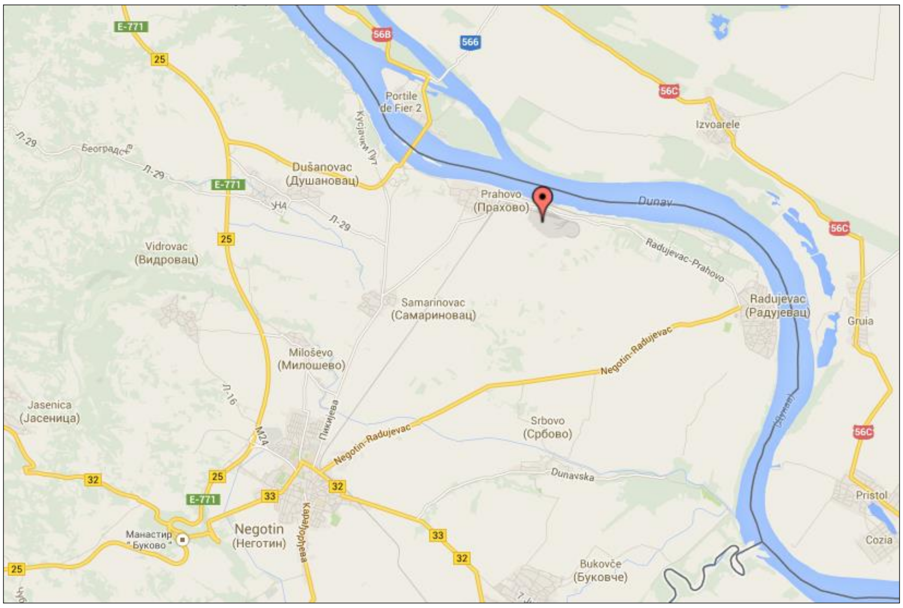



Fig.2.1 Map with Prahovo's location

The industrial and commercial complexes: IHP Prahovo, Jugopetrol facilities Prahovo, Prahovo Port, Inland Waterway Shipping Krajina and Đerdap Hydroelectric Power Plant are located in the area and surrounding of Prahovo.

The area belongs to the Negotin sheet in eastern Serbia, between $44^{0}$0' and $44^{0}$20' North latitude and $44^{0}$0' and $44^{0}$20' East longitude, relative to Greenwich.

The company "Elixir Prahovo Industry of Chemical Products Ltd Prahovo" is situated near the bank of the Danube River, by the Prahovo port, in Cadastral Municipality Prahovo. Apart from road and rail transport the proximity of the port also provides, inland waterway transport for the complex.

The chemical complex in Prahovo occupies around 135 ha, i.e. 95 parcels, of which 13 is partially occupied, while the remaining number is fully occupied. The largest part of the area occupies the industrial complex Elixir Prahovo Ltd. Prahovo, which is located at the Cadastral parcel No. 2300. The remaining occupied parcels are for the purpose of accessory facilities of the complex Elixir Prahovo Ltd. Prahovo. It ought to be noted that the project anticipates occupation of the new parcels besides the ones already occupied (Appendix 1).

The location of the complex Elixir Prahovo Ltd. Prahovo (Fig.1) can be positioned in relation to the following benchmarks:

- workers settlement (a small group of residential facilities) adjacent to the complex boundary in the western direction;
- The Prahovo port, at the distance of around 200 m in the northern direction;
- NIS Jugopetrol – the fuel and oil warehouse, at the distance of around 1 km in the eastern direction;
- the Prahovo village, at the distance of around 1 km in the western direction;
- HPP Djerdap II, at the distance of around 3 km in the western direction;
- the phosphogypsum disposal site, on the river bank, at the distance of around 2 km in the eastern direction, with around 8 million tons of phosphogypsum from the period before privatization;
- the village Radujevac, at the distance of around 5 km in the southeastern direction and the village Samarinovac, at the distance of around 10 km in the southwestern direction;
- the capital Belgrade, at the distance of around 260 km.

In the northern part of Elixir Prahovo Ltd Prahovo complex are situated the asphalt road, industrial railway and the port at the Danube, which is owned by Krajina Company – it is the part of company Elixir Prahovo Ltd Prahovo. The Danube flows in a west-east direction, at around 100 m from the company's location and also forms the state border with the Republic of Romania.

The eastern part consists of undeveloped building land owned by the company Elixir Prahovo Ltd Prahovo, and for the time being local residents use this land for agricultural purposes. The operation unit of NIS Jugopetrol owns an area for storage of fuel and oil, located at distance of around 200 m from the outline of land owned by the company. The phosphogypsum storage, which is owned by the company Elixir Prahovo Ltd Prahovo, is situated around 2 km from the location, while village Radujevac is around 4 km away from the company in E-SE direction.

Fig.2.2 Satellite photo of the location of the complex Elixir Prahovo Ltd Prahovo

The110 kW substation and open land owned by IHP Prahovo are situated in the southern part of Elixir Prahovo complex. The local residents use this land for agricultural purposes. There is also agricultural land further away.

There is a small number of residential buildings, which were constructed in the previous period for workers of IHP Prahovo, the cemetery and open land. Further away, there is the railway and the village Prahovo at around 1 km from the complex. HPP Djerdap at the Danube is situated around 3 km away toward the west from the company's location.

The facilities situated in proximity of the location with company's production facilities are:

- NIS Jugopetrol – the fuel and oil warehouse is located around 200 m away east from Elixir Prahovo Ltd Prahovo company location. It represents the operational unit of the state owned enterprise NIS Jugopetrol. Fuel supply can be conducted via the Danube and road transport is also possible. This facility also is capable of performing supply of reservoirs for transport on the Danube.
- Hydro Power Station Djerdap on the Danube (Fig.2.3) is situated 3 km away west from the company's boundary. The power plants are adjacent and occupy the larger part of the river's main stream. Between them is the state border, so that each side easily operate and maintain its part of the system.

Fig.2.3 HPP Djerdap II, in background is seen Prahovo Port and Elixir Prahovo Ltd Prahovo

As a part of this Study the environmental impact assessment of the new phosphogypsum storage has been conducted at the entire location which the investor plans to purchase and assign for the new storage. Fig.1 shows the designed location of the new phosphogypsum storage. The total area which occupy the cassettes of the new phosphogypsum storage is 46.5 ha.

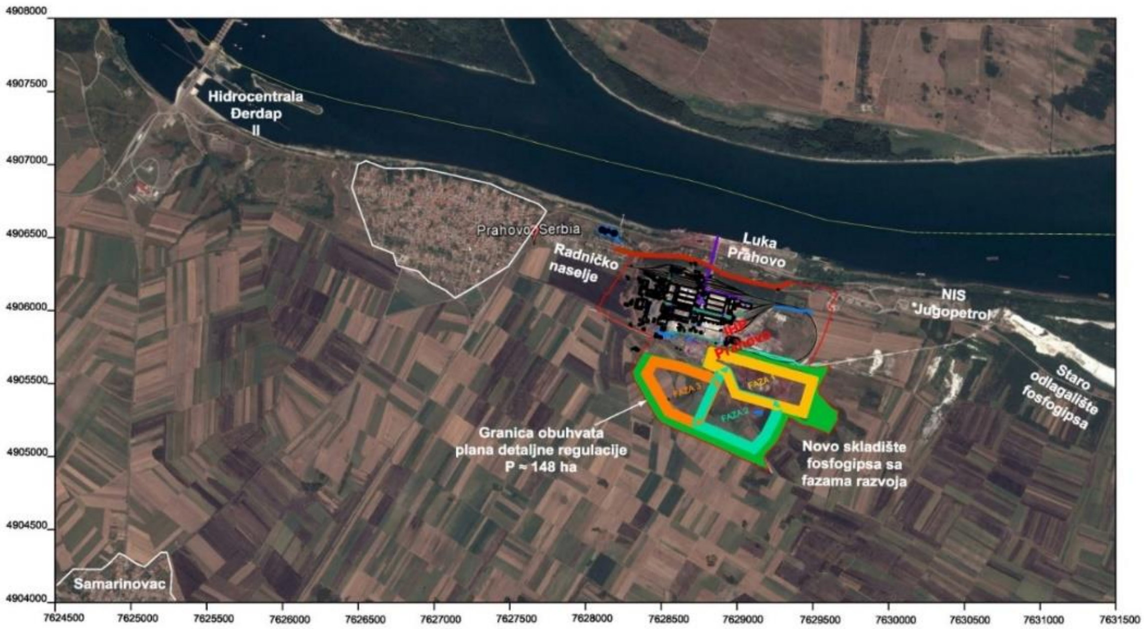



Fig.2.4 Industrial complex Elixir Prahovo with the location of the new phosphogypsum storage

The selected location is suitable because it is located on the land where had been disposed and later removed pyrite slag. The distance from the factory is not great, i.e. the length of transport pipeline varies from 1150 m to 1750 m. Furthermore, the location is favorable since it cannot be flooded. The Danube is located at a sufficient distance and at lower elevation for more than 20 m, while the groundwater level is 6-10 m below the terrain's elevation.

## 2.2. Soil characteristics

Pedological characteristics, i.e. soil types which are formed in the certain area are one of the most important factors for origination of vegetation (autochthonous or grown species). With a mutual impact of natural factors in the process of paedogenesis in the certain area occurs formation of various soil types and subtypes. Landscape, geological structure of the foundation and climate conditions crucially influence their spatial distribution. Such soils formed from lithosphere differentiate for their fertility, i.e. their potential for successful growth of plants which use water and nutrients. The following types of soil occur in Negotinska Krajina: alluvial soils (fluvisol), vertisols, chernozem (marsh dark soil; meadow black land), presented in Fig. 2.5.

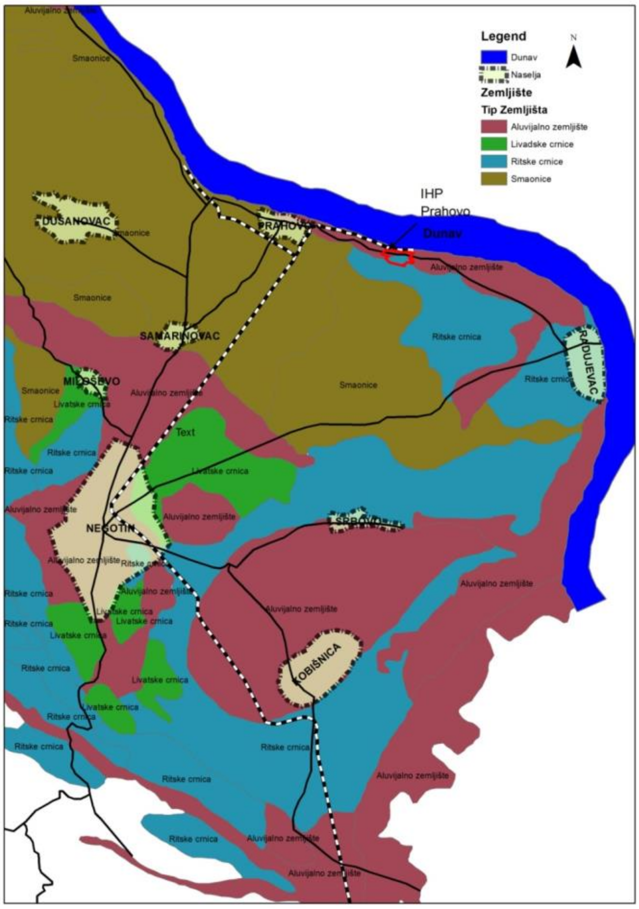



Fig.2.5 Section of the pedological map of Negotin and surrounding

Alluvial soils (fluvisol) are formed on alluvial deposits, hence the name since material which participate in its genesis originates from a river deposit. The alluvial plateau represents the most dynamic part of pedosphere. Due to the location it is under a continual impact of groundwater and flooding which brings the most diverse pedogenetic material, starting from very fine suspended particles to coarse sand and gravel. The deposition of material is a subject of certain rules, both in the direction of river flow and perpendicular to that direction. The coarsest material (proluvium) is retained in the upper parts of the stream, and the finest fractions of material in river deltas. The similar thing is with the deposition of material further away from a current, the coarsest material is deposited immediately along banks, and the finest fraction of material in pre-terraced parts, the furthest from a river bank.

The sedimentation process unfolds permanently, and due to this process occurs formation of alluvial soils. However, pedogenesis of alluvial soils is frequently interrupted so that in a flooding zone occur young alluvial formations. Occasionally, on higher parts or zones less exposed to flooding pedogenetic processes unfolds calmly and it is possible origination not only of young undeveloped alluvial soils, but also of mature soil formations with all transitions which precedes this stage. For its natural fertility it can be classified in the most valuable ones, but occurrence of sand and gravel decrease its value. From the aspect of mechanical compositions these soils are light ones, most frequently of sandy, sandy-loamy and less frequently of loamy character. Alluvial soils are originally characterized with grass and forest vegetation.

Alluvial soils (alluvial deposits) in the analyzed area cover significant surfaces along the larger currents such as the Danube and the Timok, as well as along the smaller ones. Considering that these soils are characterized with light mechanical composition mixed with mud and with good fertility, they are mainly used for growing vegetables, albeit there are also present areas under grass and forests.

Vertisols are characterized with deteriorated physical properties, heavy mechanical compositions and aggravated cultivation (possible only in semi-wet conditions). From the production aspect they have a lesser value than meadow soils. The parent substrate had a significant role in formation of this soil type. Tertiary, mainly very clayey sediments with various contents of calcium carbonates (CaCO3) are the most frequent substrate on which are formed vertisols. They are also formed on lighter sediments, but always with a sufficient content of montmorillonite clays.

The basic characteristic of vertisols are agglutinated structural aggregates and swelling, that is pronounced contraction and occurrence of prismatic structures and, therefore, they are named vertisols. Their name used among ordinary people in Serbia is connected with such soil properties. Vertisols belong to soils with the heaviest mechanical composition, clays to heavy clays. Vertisols cover large areas, particularly in plains, which have the greatest importance from the aspect of agricultural production. It is considered that they have a high potential fertility, but an unfavorable water and air regime poses a significant limiting factor. Melioration of vertisols is possible, mainly calcification with introduction of organic fertilizers and growing of perennial legumes (alfalfa) and grass and legumes mixtures. In the analyzed area are mainly grown arable crops, forages, fruits and rarely cereals.

Chernozem occurs in the region of Negotinska Krajina as marsh dark soil and meadow black soil.

Marsh dark soils occur in alluvial plains at somewhat higher locations, and also occur in individual, closed depressions, which have marsh character. For these soils is characteristic presence of water in the profile which level does not reach surface. Most frequently, it oscillates around 1 m, but also lower (to 1.5 m).

The parent substrate of marsh dark soils is altered loess or alluvial deposit. It is considered that relief (topogenic soils) has the main role in genesis of marsh dark soil. The autochthonous vegetation consists of wet (edaphic conditioned) forests, among which are very frequently represented ash and the English oak (*Quercus robur*) population, as a rule of good worthiness.

For marsh dark soils is characteristic, particularly if they occur in marshes, that they endure surface flooding. In alluvial plains surface water reaches marsh dark soils in branches of a river, and in marshes comes down from its peripheral parts. However, flooding remain on surface for various periods of time, but it is mainly absent on surface during vegetation period. Soil profile is saturated with water due to capillary rising, which is to large extent also the result of heavy mechanical composition of these soils. Because of abundance of moisture vegetation is exuberant, with an abundant production of organic mass.

In prevailing conditions of increased wetting and reduced influx of oxygen in a soil profile, larger share of organic mass is transformed in humus, more or less, of hydromorphic form. If anaerobes is strongly pronounced, the transformation of organic mass is lesser, and, therefore, can occur the peat formation process. On contrary, the humification process is very intensive and occur formation of a substantial humus-accumulative horizon, which in some cases can reach up to 1.0m. In one part this horizon originates with growing out of profile under impact of materials brought with flooding. The humus-accumulative horizon is the most pronounced part of marsh dark soil's profile, usually it is of pronounced black color due to hydromorphic humus origin. As for mechanical composition these soils are of heavy mechanical composition, with clayey or clayey loess character. These soils do not have clearly pronounced structure, it is usually reminiscent of the coarse-grained, but is polyhedral as a rule.

On the whole, marsh dark soils are characterized with favorable chemical properties. They result more from abundant supply with plant nutritive elements from flooding and groundwater, and less due to the mobilization process, i.e. humus mineralization. The reaction is natural to weakly alkali, while $CaCO_3$ content, with carbonated dark soils starts from the very surface and in lower parts can reach over 20%. Marsh dark soils can evolve in two directions. The one is toward development of the loess formation process, when groundwater is deeper as with marsh dark soils where flooding is ceased. The other direction is the pseudoglay formation process, in case of heavy mechanical composition on old river terraces.

Marsh dark soils are most frequently fertile soils due to their depth, physical and chemical properties, which are used as agricultural areas. However, difficulties occur during cultivation since it is usually required deep cultivation, due to limited filtration capacity.

Meadow dark soils occupy higher locations (loess terraces, loess plateaus, alluvial plains) in relation to marsh dark soils and are rarely exposed to flooding. The parent substrate of those soils is loess or redeposited loess rich with carbonate. Meadow dark soils are grouped in semi-hydromorphic soils due to relatively low groundwater level. These soils are also called "meadow chernozems" and it is thought that they most differentiate from chernozem in the lower part of C-horizon, particularly with deep meadow dark soils, where is not always present glay horizon. Hence, vegetation has significantly more pronounced impact on their genesis. The original vegetation, i.e. the autochthonous vegetation consisted of somewhat drier forest stands of English oak and common hornbeam, or alternatively of English oak, common hornbeam and ash. Meadow vegetation is of secondary character, originated after forest reclamation.

The primary pedogenetic process is humification and humization which unfolds in conditions of favorable moisture. The main share of water originates from precipitation, and the smaller one from groundwater. Additional wetting with groundwater provide an abundant development of ground flora and ample humus creation. The humization process mainly unfolds with penetration of the humus-accumulative horizon (A) into the parent substrate (C horizon). As a rule, G horizon is very deep and almost does not make the integral part of profile. There is no undecayed plant residues.

Meadow dark soils are deep soils with a thick humus-accumulative horizon, of average thickness 60-80 cm, sometimes >1 m. As for the mechanical composition they are somewhat lighter than mars dark soils, of loamy to heavy loamy mechanical composition, what is consequence of slower decay of primary minerals. Water and air properties are favorable, but are not always balanced. The water capacity is sometimes increased on the expense of the air capacity. Meadow dark soils are soils with moderate humus content (3.0-4.0%). The reaction is natural to weakly alkali, since meadow dark soils are mainly with high $CaCO_3$ content, albeit they are without carbonate along entire profile depth under forest vegetation. The content of nutritive elements (N, P and K) is average.

Nowadays, meadow dark soils are mainly used as agricultural land, although in alluvial plains are still preserved autochthonous forest vegetation of deciduous trees of the Fugaceae family from plain terrains.

The evolutionary development of meadow dark soils is pointed in two directions. In the higher parts of the terrain it is directed toward the cambisol formation process, while during more pronounced wetting they succumb to loess formation processes and, finally, to the pseudoglay formation process.

## 2.3. Geomorphological characteristics of the terrain

One of the specific characteristics of each facility is the morphology of terrain in which the facility is located. Morphologically, the terrain is plain with elevation differences of up to 20 m. The highest elevations in the wider area of the industrial complex Elixir Prahovo Ltd. Prahovo are located in the village Prahovo (64 masl). The lowest elevation of the analyzed terrain is located on the bank of the Danube River (34 masl). The lowest elevation of the phosphogypsum storage will be the elevation of the lower level of disposal site, which is planned at +46 m.

## 2.4. Geological characteristics

In such a large area the time of origination as well as origin itself are different. The locality of the oldest rocks, crystallized shales, sedimentary and volcanic rocks spreads from Tekija via Brza Palanka and Stubika to the village Metriša. In the “Old Era” this narrow belt of the oldest rocks represented only part of mainland in Negotinska Krajina.

The western part of Negotinska Krajina and Ključa originated prior to the “New Era”, i.e. prior to Tertiary. This area is named higher to make difference from Negotinska’s plain which is called the lower.

Magmatic rocks occupy large areas in East Serbia. Granites of the Paleozoic Era are represented in the region of Old Mountain (Stara planina in Serbian language) and between Deli Jovan, Velikog Krša and Stola. The spacious mass of gabbro is situated at Deli Jovan. Andesites are most represented rocks from magmatic rocks in East Serbia. Andesites, andesite and dacite-andesite tuffs occupy a vast area from Majdanpek on the north, to Knjaževac on the south. In andesites occur copper, magnetite, wolfram ore deposits, etc. around Bor and Majdanpek.

### 2.4.1. Geological characteristics

From the aspect of regional geology, Prahovo is located within a wide valley called “Negotinska Krajina”, which represents the part of the so-called area Carpatho-Balcanica. The company Elixir Prahovo Ltd. Prahovo was built on the Quaternary sediments of the river terrace of Pleistocene age, formed under impact of the Danube River. The observed area is virtually levelled (medium elevation ≈ 51 masl). The data on geological characteristics at the location of Elixir Prahovo Ltd. Prahovo are obtained on the basis of the Serbian basic geological map, as well as on the basis of data obtained by the previous conducted shallow exploration works at the location of the company.

Geological characteristics at the location of Elixir Prahovo Ltd. Prahovo are:

- Terrain surface – humified clay, of thickness 0.5-1.5 m;
- Loess and loess dust and clay with $CaCO_3$ concretions of average thickness which range 3.0-5.0 m;
- Clayey sand of average thickness of 1.0-3.5 m;
- Gravel which thickness is up to 4.0 m;
- Lacustrine gravel, sand and marls of thickness from 20 to 60 m;

Pliocene (Pl) sand and clays with sandstone partings of thickness over 150 m.

Drilling was performed in order to set up piezometers (internal designation P-1) in the industrial complex, north from the pyrite slag disposal (approximately 200 m north from the location of a future storage), presented in Fig.2.7. At this micro location has been defined the following lithological section:

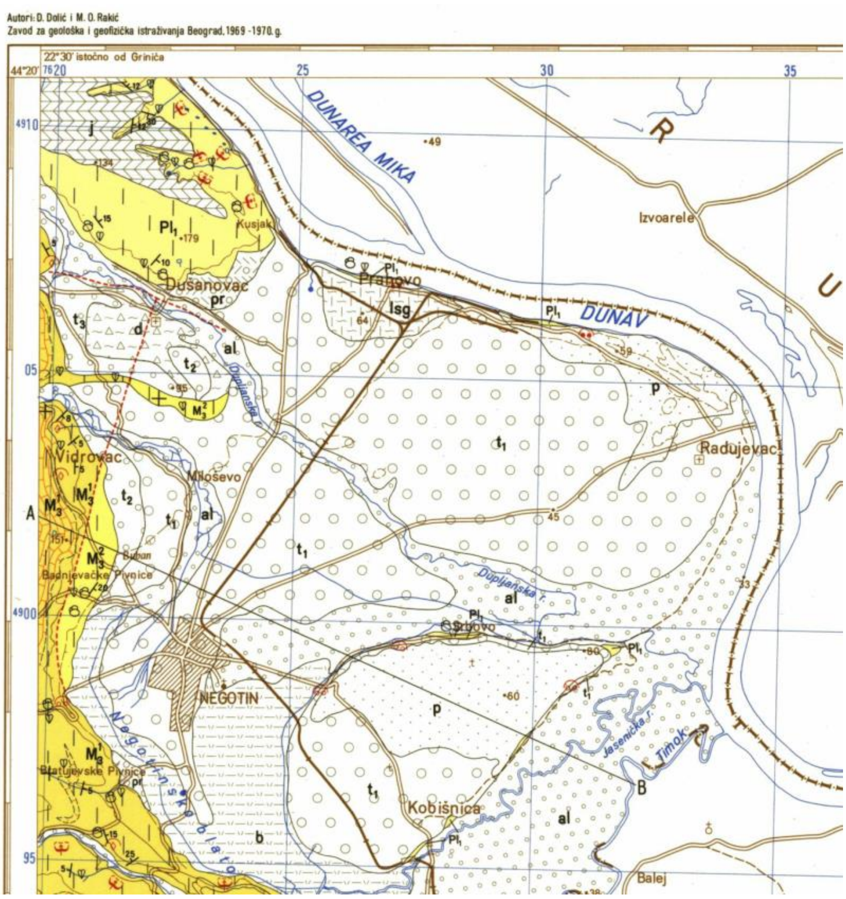



Fig.2.6 The detail from the basic geological map of Negotin and surrounding (1:100000)

*Legend: $t_1$ – town terrace; Isg – loess like gravel co-clays; p –live sand: $Pl_1$ – sands, clays and sandstones*

| | |
|---|---|
| 0.00 – 6.50 m: | **Sandy clay** of umber color, poorly consolidated; |
| 6.50 – 16.50 m: | **Gravel** of various size ranges, **fine-grained sand** with **clay** partings; |
| 16.50 – 20. 50 m: | **Gravel** of various size ranges; |
| 20.50 – 24.50 m: | Alteration of **gravel** and **marble clay**; |
| Below 26.0 m: | **Marble clay** of gray color. |

The static ground water level was measured after rinsing. It was $H_{st}$ = 6.85 m, measured from the top of piezometer pipe.


Fig.2.7 Location of piezometer (P1) in relation to the location of the future storage

The exploration works were performed during the summer of 2013 within the complex of IHP Prahovo and in the geological structure were ascertained dusty clays and sands, up to 8.0 m of depth.

The level of ground water was measured at the depth of around **GWL** ~ 7.40 m, i.e. **GWE** = 41 masl.

Geomechanical characteristics obtained with investigations of samples taken on the occasion of aforementioned investigations are presented in Table 2.1.

Table 2.1: Geomechanical characteristics of floor's samples

| **Parameter** | **Dusty clay** | **Dusty sand** |
|---|---|---|
| $\gamma$, kN/m$^3$ | 17.40 – 19.00 | 18.80 |
| $\gamma_{d,}$ kN/m$^3$ | 14.70 – 15.90 | |
| $\varphi$, | $22^o$ - $27^o$ | $24^o$ - $28^o$ |
| C, kPa | 10.0 - 20.0 | 0.00-5.00 |
| $N_{(SPT)}$, qr kPa | 3 - 6 =>qr= 5,280 - 9,516 | 6 - 7 => qr = 9,516 - 11,600 |
| $Mv_{(50-100),}$ kPa | 4,938 - 7,182 | 4,938 - 7,000 |
| $Mv_{(100-200),}$ kPa | 6,525 - 9,412 | 6,720 - 8,960 |
| $K_f$, m/s | 1.04 x $10^{-7}$ - 9.37 x $10^{-8}$ | 1.0 x $10^{-3}$ - 9.37 x $10^{-5}$ |

At the end of November 2013, control drilling (3 drillholes) was organized in the area of the future storage, Stage 1 and the geologist's report quotes the following:

The foundation of the investigated terrain, and wider, is formed from Pliocene (PL) sediments which occur at depths over 30 m in the facies of sand, fine grain gravel, clay and poorly bonded sandstones. Those sediments, for requirements of anticipation of the coaction of the future facility and the terrain, can be regarded as weakly compressible with Ms > 25000 kPa.

The Pliocene sediments at its floor consist of Quarterly sediments of various genesis, eolian-aquatic and alluvial-terrace sediments.

Quarterly sediments are established in the terrain floor in the entire exploration area. It covers Pliocene sediments and is developed in form of moor-terrestrial, loess like sandy clay ($gl^{pr}$[1]) of 4.5 m thickness, in which floor are situated dusts $Pr^P$ of 4-5 m thickness and facies of water saturated alluvial-terrace sediments of dusty sands, sands and gravel (P) of substantial thickness which exceeds 6 m. Those Quarterly sediments are covered with a thin layer of recent sediments of humified soil ($h^t$). On the basis of previous explorations the thickness of Quarterly sediments is estimated on 20-30m.

The recent sediments, filled ground and the recent layer of humified ground are situated above Quarterly sediments.

The groundwater level has been ascertained at depth of around 10.30 m, it is hydraulically connected with the Danube River and, therefore, it can be expected (during hydrological maximum) at depths of around 6 m, i.e. around elevation + 41 masl.

The review of the floor structure of the future storage is as follows:

- Humus reaches depth of 0.20 m and, at some places, 0.40 cm;
- To depth around 4.30 m, loess like sandy clay ($gl^{pr}$), medium plastic dusty clay;
- To depth around 6.50 m, weakly plastic dusty clay gradually transformed into dusty sand with increasing depth;
- From 6.50 m fine and medium sands and fine-grained gravel, in partings well compacted, partially clayey and poorly coherent to 8.50 m, and further down pure.

1 Original Serbian abbreviations

Tables 2.2, 2.3 and 2.4 show results obtained with investigations of taken samples.

Table 2.2: Characteristics of samples from the drillholes at the location of the storage

| Sample ID | Depth, m | Moisture, % | Density, $kN/m^3$ | Volume density, $N/m^3$ | | Grain-size distribution, % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Wet | Dry | -0.002 mm | -0.06+ 0.002 mm | -0.2+0.06 mm | -0.6+0.2 mm | -2+0.6 mm | -6+2 mm |
| B-2 | 1.50 1.80 | 23.2 | 26.14 | 19.2 | 15.5 | 13 | 73 | 10 | 3 | 1 | 0 |
| B-2 | 6.00 -6.30 | 25.0 | 26.60 | 18.8 | 15.1 | 4 | 84 | 12 | 0 | 0 | 0 |
| B-2 | 9.20 -9.40 | 21.6 | | | | 7 | 34 | 19 | 24 | 15 | 1 |
| | | | | | | | | | | | |
| B-8 F1 | 2.50- 2.80 | 19.5 | 26.07 | 19.6 | 16.4 | 13 | 71 | 9 | 5 | 2 | 0 |
| B-8 F1 | 5.60 -5.90 | 11.4 | 26.60 | 15.3 | 13.8 | 4 | 87 | 9 | 0 | 0 | 0 |
| B-8 F1 | 9.00 -9.20 | 23.5 | 26.60 | 18.3 | 14.8 | 5 | 83 | 11 | 1 | 0 | 0 |
| | | | | | | | | | | | |
| B-9 F1 | 2.50 -2.80 | 22.9 | 26.11 | 18.6 | 15.1 | 13 | 72 | 10 | 4 | 1 | 0 |
| B-9 F1 | 4.75- 5.00 | 26.0 | 26.25 | 18.2 | 14.5 | 10 | 84 | 4 | 1 | 1 | 0 |
| B-9 F1 | 8.50 | 27.5 | 26.28 | 19.2 | 15.1 | 9 | 81 | 9 | 1 | 0 | 0 |

Table 2.3: Characteristics of samples from the drillholes at the location of the storage

| Sample ID | Sampling depth, m | Angle of internal friction, ° | Cohesion, C $kN/m^2$ | Filtration coefficient, m/s | Compressibility modulus | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | 100-200 $kN/m^2$ | 200-400 $kN/m^2$ | 400-800 $kN/m^2$ | 800-1200 $kN/m^2$ |
| B-2 | 1.50 1.80 | 21 | 25.6 | | 10.363 | 11.203 | 14.934 | 18.754 |
| B-2 | 6.00 -6.30 | 24 | 9.7 | | 7.143 | 9.302 | 11.594 | 18.605 |
| B-2 | 9.20 -9.40 | | | | | | | |
| | | | | | | | | |
| B-8 F1 | 2.50- 2.80 | 22 | 22.0 | 6.0E-09 | 12.500 | 15.385 | 17.778 | 19.048 |
| B-8 F1 | 5.60 -5.90 | 26 | 9.5 | | 9.377 | 11.859 | 18.539 | 28.802 |
| B-8 F1 | 9.00 -9.20 | 25 | 8.7 | | | | | |
| | | | | | | | | |
| B-9 F1 | 2.50 -2.80 | 21 | 26.8 | | 13.904 | 15.497 | 17.391 | 19.151 |
| B-9 F1 | 4.75- 5.00 | 23 | 20.7 | 1.01E-08 | 8.783 | 9.975 | 12.289 | 15.508 |
| B-9 F1 | 8.50 | | | 4.03E-08 | 4.348 | 9.524 | 12.698 | 18.605 |

Table 2.4: Characteristics of samples from the drillholes at the location of the storage

| Sample ID | Sampling depth, m | Porosity | Porosity coefficient | Saturation degree | Atterberg limits | | | | Group symbol |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Liquid limit | Plastic limit | Plasticity index | Consistency index | |
| | | n, % | e | Sr. % | Wt% | Wp% | Ip% | Ic % | |
| B-2 | 1.50 1.80 | 40.5 | 0.682 | 90.8 | 47.8 | 24.1 | 23.8 | 1.0 | CI |
| B-2 | 6.00 -6.30 | 43.4 | 0.766 | 88.5 | 30.6 | 23.9 | 6.7 | 0.8 | ML |
| B-2 | 9.20 -9.40 | | | | | | | | SC |
| | | | | | | | | | |
| B-8 F1 | 2.50- 2.80 | 37.1 | 0.590 | 87.8 | 47.8 | 23.8 | 24.1 | 1.2 | CI |
| B-8 F1 | 5.60 -5.90 | 48.2 | 0.932 | 33.3 | 30.8 | 23.6 | 7.2 | 2.7 | ML |
| B-8 F1 | 9.00 -9.20 | 44.3 | 0.795 | 80.1 | 32.5 | 23.7 | 8.9 | 1.0 | ML |
| | | | | | | | | | |
| B-9 F1 | 2.50 -2.80 | 42.1 | 0.728 | 83.7 | 53.3 | 26.5 | 26.7 | 1.1 | CH |
| B-9 F1 | 4.75- 5.00 | 44.9 | 0.815 | 85.5 | 40.4 | 22.5 | 17.9 | 0.8 | CI |
| B-9 F1 | 8.50 | 42.6 | 0.744 | 99.0 | 36.0 | 19.7 | 16.2 | 0.5 | CI |

### 2.4.2. Area's hydrogeological characteristics

Quarterly sediments represent the most important hydrogeological unit in this area, of which are is formed the wide river terrace between the Danube and Deli Jovan Mountain. The Quarterly cover consists of the river terrace sediments (t1) and lacustrine sediments of Pleistocene age.

Hydrogeological characteristics at the site of IHP Prahovo have been obtained on the basis of available data. They are presented in the following text:

- Humified clay, loess and loess dust and clays and clayey sand – surface hydrogeological insulator (of average thickness 8 m);
- Fine-grained sand and gravel – the shallow aquifer (of average thickness 6 m);
- Lacustrine marl – deeper hydrogeological insulator (of average thickness 8 m).

The shallow aquifer is directly affected and hydraulically connected with the Danube River. The level of groundwater in the Prahovo area is most frequently located deeper than 10 m, below the surface level. These waters are not scooped for water supply. The direction of groundwater flow is conditioned with the Danube River, i.e. toward the river during the regime of low waters or toward the hinterland during period of high water. The aquifer is fed with infiltration of surface water of the Danube River and from the hinterland as well as with discharges and seeping from production processes at the location. The shallow aquifer is drained into the Danube River (during the period of low water) as well as with seepage into the deeper aquifer.

## 2.5. Hydrological characteristics of the Danube and water supply sources

The Danube River is located in the immediate proximity of the location (≈100 m), and its flow direction is toward the east. The data on flows on the Danube River at the Pančevo gauging station, for the period 1997-2000 are:

- maximum flow: approximately 7,400 $m^3$ (occurs most frequently in April);
- minimum flow: approximately 3,200 $m^3$ (occurs most frequently in September);
- mean flow: 5,326 $m^3$, in this region.

Deeper aquifer is used for the water supply of the wider area. The water source used for supply of drinking water (which consists of water-catchment springs and wells) for Prahovo village and the production facilities of Elixir Prahovo Ltd Prahovo is located 7 km away northeast from the company. It is expected that the direction of groundwater flow is conditioned with the Danube River, i.e. toward the river during the regime of low water or toward the hinterland during period of high water.

It has been planned to provide the supply of drinking water for the location of Elixir Prahovo Ltd from the water source Baroš of capacity 43 l/s. The technical conditions for connection to the PVC Ø 225 mm piping system exist at the location. The existing installations for sanitary water are in poor condition and it is required their reconstruction and replacement with the pipes of suitable material resistant to environmental impacts. It has been planned a full reconstruction of the pipeline system and its construction to the required locations in the complex. The minimal diameter of the sanitary water pipeline within the complex is Ø 50 mm, while the pipeline will be laid down at 1.0-1.2 m. It has been anticipated reconstruction of the new sanitary water pipeline in accordance with investor's future requirements. The all additional extensions will be dealt with in the projects defined in accordance with the relevant laws and regulations.

## 2.6. Seismologic characteristics

According to the seismic map of Serbia for the return period of 100 years, in the area of Prahovo can be expected the maximum earthquake of 8 degrees of Mercalli intensity scale.

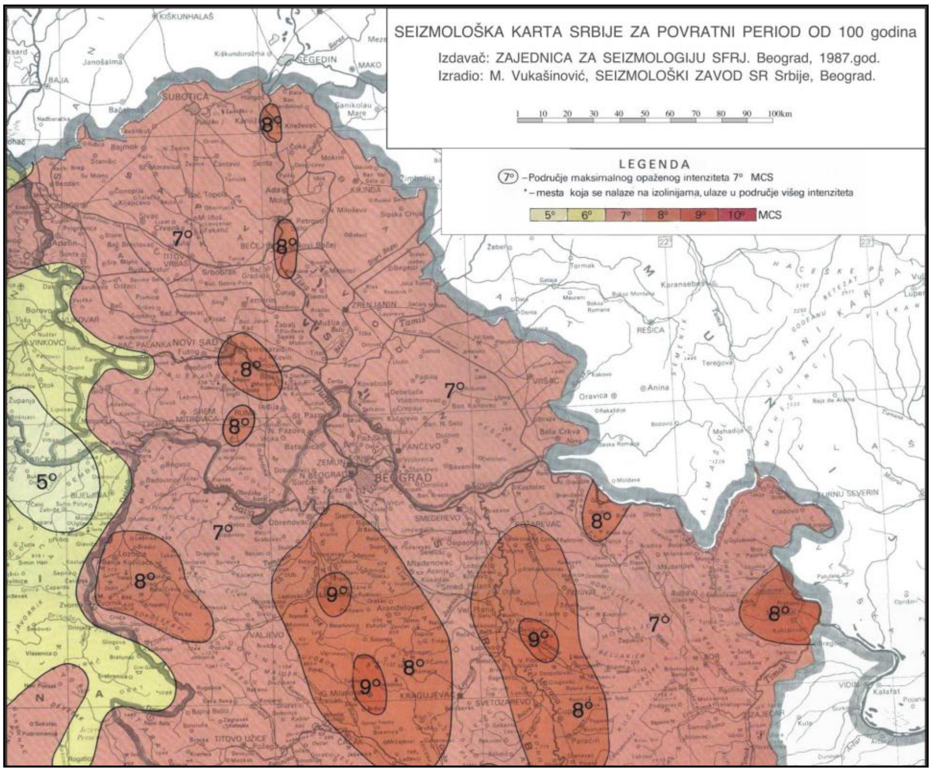



Fig.2.8 Seismic map of Serbia

## 2.7. Climate characteristics

Microclimatic peculiarities of the observed area are most frequently defined with dominant northwest and south winds, lower average temperatures (≈10 $^{o}$C) and proximity of aquatorium which conditions higher air humidity. Fig. 2.9 shows a wind rose for the period 2009-2013, the Negotin Meteorological Station.

The average monthly and annual air temperatures in Negotin in the period 1961-1990 and 1990-2000 are presented in Table 2.5 (excerpted from the paper by Andjelković, Živković, 2007).

Table 2.5: Average air temperatures ($^{0}$C) in Negotin in the period 1961-1990 and 1990-2000

| Month | January | February | March | April | May | June | July | August | September | October | November | December | Mean annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *T*61-90 | **-1.1** | 1.1 | 5.5 | 11.8 | 16.9 | 20.2 | **22.1** | 21.2 | 17.3 | 11 | 5.7 | 1.3 | 11.1 |
| *T*91-00 | **0.4** | 2.6 | 6.4 | 12.1 | 17.4 | 21.5 | **23.1** | 23.1 | 17.4 | 11.7 | 5.1 | 0.5 | 11.8 |

The average monthly and annual air temperatures in Negotin for 2012 and 2013 are presented in Table 2.6.

Table 2.6: Mean monthly air temperatures ($^{0}$C) in Negotin for 2012 and 2013

| Month | January | February | March | April | May | June | July | August | September | October | November | December | Mean annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2013** | 1.2 | 3.5 | 5.2 | 13.9 | 19.4 | 22.2 | 24.4 | 25.1 | 17.5 | 11.8 | 8.0 | 1.3 | 12.8 |
| **2012** | 0.9 | -4.2 | 9.7 | 14.4 | 18.1 | 24.4 | 27.2 | 25.7 | 20.7 | 13.7 | 7.9 | -0.7 | 13.2 |

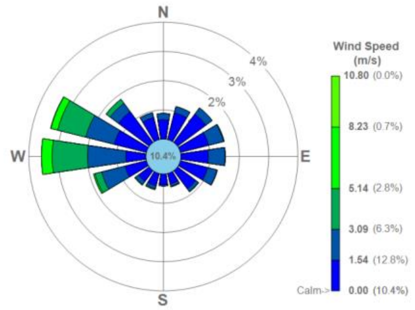
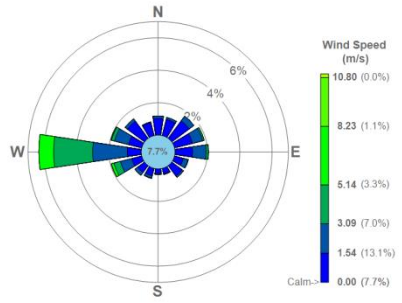
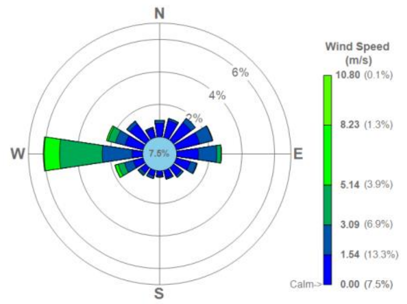
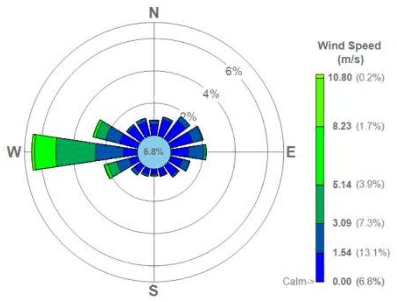
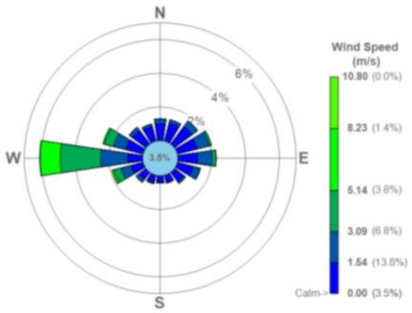
| Period | Wind rose | Period | Wind rose |
|---|---|---|---|
| *2009* |  | *2010* |  |
| *2011* |  | *2012* |  |
| *2013* |  | | |

Fig.2.9 A wind rose for the period2009-2013, the Negotin Meteorological Station

The area of Negotin is characterized with typical continental climate with average annual temperature between 11 and 12 $^{o}$C, the lowest temperatures in January and the highest in the period July-August. The annual temperature amplitude is ≤ 23.0 $^{o}$C, and over 50% of annual total precipitation occur in half of the year with summer. Duration of the drought periods is significantly longer than duration of rainy periods.

The average monthly and annual precipitation in Negotin in the period 1961-1990 and 1990-2000 are presented in Table 2.7 (excerpted from the paper by Andjelković, Živković, 2007). The average monthly and annual precipitation in Negotin for 2012 and 2013 are presented in Table 2.8.

Table 2.7: Average monthly precipitation in Negotin in the period 1961-1990 and 1990-2000

| Month | January | February | March | April | May | June | July | August | September | October | November | December | Annual value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *R*61-90 | 41 | 51.8 | 56.8 | 62.6 | **68.1** | 67.1 | 48.8 | **40.7** | 40.8 | 47.8 | 64.7 | 55.8 | 646 |
| *R*91-00 | 34.9 | **21.8** | 36.3 | 45.8 | 43.7 | 46.4 | 48.5 | 34.6 | 41.0 | 37.2 | 64.3 | **64.5** | 519.1 |

Table 2.8: Review of monthly precipitation in mm for 2013 and 2012

| Month | January | February | March | April | May | June | July | August | September | October | November | December | Annual value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2013** | 37.3 | 169.7 | 72.9 | 42.4 | 75.2 | 44.5 | 23.3 | 18.0 | 82.2 | 64.0 | 70.8 | 3.4 | 627.4 |
| **2012** | 57.2 | 53.7 | 0.5 | 64.9 | 108.0 | 31.0 | 27.0 | 1.2 | 6.8 | 45.3 | 40.5 | 89.7 | 435.6 |

It is interesting that the highest daily precipitation, since measurement began in Serbia, was recorded on 10.10.2015 in Negotin (211.1 mm).

## 2.8. Flora and fauna and protected natural assets

Negotinska Krajina is located in the utmost eastern part of the country. It occupies the area of over 100,000 ha, of which forests and forest soil occupy 32,200 ha, meadows 22,800 ha and cultivated fields 41,000 ha. The landscape consists of three separate entireties: Negotin's lowland, hilly plateaus and highland relief which consists of mountain ranges Deli Jovan and Miroč. The elevations range from 32 to 546 masl. Those natural and ecological characteristics, as well as rich and diverse flora and fauna created ideal conditions for breeding and development of all kinds of quarry.

The Municipality of Negotin is characterized with fertile soils suitable for agricultural production. The agricultural soils occupy around 65% of the municipal territory, while dominate cultivated fields, and then pastures and surfaces under vineyards and orchards.

The agricultural land as a natural resources is a comparative advantage of Negotin Municipality. Forests cover around one third of the municipal territory, of which the company "Srbija šume" manages 4,807 ha, through the Negotin forestry administration of Forestry Husbandry "Timočke šume", while 23, 222 ha of forests are private property (38% of the municipal territory). It has been recorded trend of increase of surface under forests because of depopulation of villages and abandonment of farming.

The areas under forests are mainly concentrated in west and northwest hilly parts of the municipal territory. The areas at the highest elevations are overgrown with beech forests, while oak forest are located in the overgrown areas at lower elevations. This region is characterized with relatively great diversity of tree species (beech, oak, common hornbeam, ash, willow, poplar), regardless on the forest function, i.e. used for production or protective purposes. Furthermore, within meadow vegetation is present a substantial number of medical plants (common wormwood, deadly nightshade, common yarrow, chamomile, common centaury, St John's wort, etc.) which are used as a raw material for production of drugs and cosmetic preparations. In some rural regions is preserved tradition of medical plants collection, but it is noticeable lack of processing facilities (drying chambers or extraction facilities) as well as institutional regulation of this activity.

The four hunting grounds are located in the municipal territory:
1. Deli Jovan is situated in the east part of Deli Jovan massif, its surface is around 5000 ha. The largest part is under forests (around 3,000 h, mainly beech forests), and the remaining part under meadows and pastures. This hunting ground is habitat for various quarry species, of which are most significant deer and wild boars.
2. Alija is situated in the area around villages Rogljevo, Mokranja, Rečka and Smedovac, it covers surface of around 2000 ha, of which forests cover 1,425 ha. There are bred the fallow deer and mouflon.

3. Vratna is situated in immediate proximity the village Vratna and Vratna Monastery, its surface is 1,350 ha. There are bred mouflon, deer and roe deer.
4. The hunting ground Negotinska Krajina covers surface of 96,423 ha and it is managed by the hunters association “Hajduk Veljko” Negotin. This hunters association owns a modern pheasant farm, of capacity 15,000 pheasant chicks and cooler for storage.

To the listed animal species in the quoted hunting grounds need to be added roe deer, rabbits, gray partridge, dabbling ducks, European turtle doves, wild pigeons, wolves, jackals, foxes, wildcats, weasels which can be encountered in this region.

According to the Regulation on Ecological Network of Serbia (Official Gazette, No 102/10) the Danube is ecological corridor of international importance which enables migration of plant and animal species between areas under protection and ecologically important locations. With the construction of HPP Djerdap and the impassable barriers created by the Djerdap dams, ichtio fauna of this part of the Danube has been significantly changed. This is particularly because Black sea’s migratory sturgeon cannot reach anymore its spawning area in the Djerdap region or upstream. It can be encountered the following species: European sturgeon, catfish, starry surgeon, Black sea shad, Caspian shad, the common nase, the common dace, the chub, carp bream, the common carp, the silver bream, the northern pike, zander, European perch, the freshwater eels, the asp, the huchen, the starlet.

The bird fauna is rich and diverse. It has been recorded presence of numerous species: auks, grebes, pelicans, waterfowls, cranes, marsh hens, woodcocks and gulls. Furthermore, in the vicinity of Djerdap there is the colony of small cormorants and of great cormorants, and there is also present little egret, gray heron, white and black stork. It has also been recorded the presence of a large number of ducks (mallards, widgeons, common teals, common pochards) and ten thousands of coots. Raptors are also well represented, but some of them are very rare such as: black kite, white-tailed eagle, Great Nicobar serpent eagle, lesser spotted eagle, golden eagle, etc.

In the area of the village Prahovo and its surrounding a diverse flora of autochthons or introduced character is formed and it is a result of corresponding natural conditions. Plant species characteristic for settlements are represented in Prahovo itself, while agricultural land is in the surrounding. That is understandable considering a traditional character of this region.

Coastal vegetation grows near the Danube River since there is plenty of moisture in soil. In the immediate surrounding fragmented forests (groves) can be also observed.

The protected species of flora and fauna have not been recorded in the said location.

## 2.9. Landscape

The area of Negotin’s Krajina is also known as the Negotin’s Lowland, which properly describe terrain configuration of this part of Serbia.

The lowland spread between the Danube and the Timok to the hilly slopes of Vidrovac-Badnjevo-Bratujevac, and further, above them, is spread the plain plateau to Deli Jovan Mountain and Stol Mountain, which separates this entire region from the other part of Serbia. As for elevations, it is the lowest region in Serbia, with average elevation 45-47 masl.

From a topographic aspect, the terrain is plain with elevation differences of up to 20 m. The highest elevations in the wider area of the industrial complex Elixir Prahovo Ltd. Prahovo is located in the village Prahovo (64 masl). The lowest elevation of the analyzed terrain in located on the bank of the Danube River (34 masl). The lowest elevation of the phosphogypsum storage will be the elevation of the lower level of disposal site, which is planned at +46 m.

The storage's location and its immediate surrounding virtually represent levelled area at elevation of around +47 masl, formed with the river action during the Pleistocene period when were formed Quaternary sediments.

## 2.10. Cultural property

Cultural and historical monuments with a special protection from the Republic Institute for Protection of Cultural Monuments are not recorded in the wider area of the investigated deposit

According to the available information on archeological sites in the said area, on the basis of archeological explorations conducted in 1975 (The Archeological Review, No. 17 for 1976 – Prahovo Factory Multilayered Site by M. and Dj. Janković, pg. 51-55) it has been ascertained existence of the multilayered archeological site which is in status of previous protection.

The detailed regulation plan prescribes measures and obligations which the investor has to undertake in case of encountering on archeological finding sites.

## 2.11. Population, concentration of residents and demographic characteristics

According to the results of 2011 census in the Municipality of Negotin, in 39 populated settlements and 13,906 households lives slightly more than 37,000 residents, i.e. 17,826 men and 19,230 women. Out of that number, 16,882 residents live in the town of Negotin , while other settlements have from 150 to 1500 residents. The larger villages are Bukovača, Vidrovac, Dušanovac, Jabukovac, Kobišnica, Plavna, Prahovo, Urovica and Štubik.

Prahovo is an industrial settlement of a compact type. It occupies the area of 1,957 ha. According to the census of 2011, the number of residents was 1,197, i.e. 577 men and 619 women. The total number of households is 434, while the average number of residents per household is 2.76.

Mainly Serbs (93.29%) live in Prahovo, while the minority includes Vlachs, Romanians, Montenegrins, Gypsies and Croats.

The average age of residents is 47.7. The diagram presented in Fig.2.10 a) clearly shows that most numerous age group is 60-64 years.

It is evident that during the period 1961-2011 was permanently present trend of decreasing population as it can be seen on the presented diagram, Fig.2.10 b).

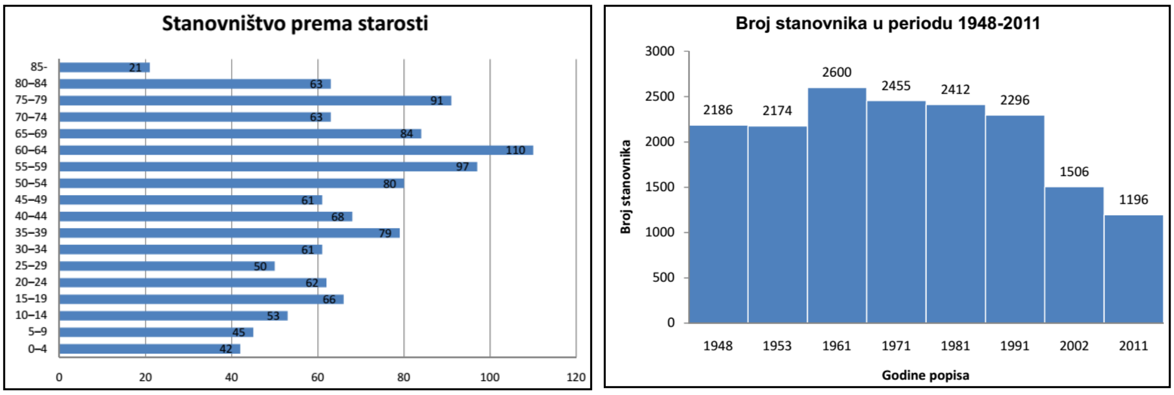



Fig.2.10 a) The number of residents according to the age group; b) The number of residents in the period 1948-2011

The local population is mainly employed in the processing, traffic, forest and agricultural industries.

As for the employment level in this region, it can be said that the employment rate reached significantly higher levels in the 1970s and 1980s than the employment figures at present, what is the consequence of social changes and transition process in the Republic of Serbia as well as economic crisis both in the region and in the world.

## 2.12. Existing infrastructure

The fundamental regional attribute is its location on the banks of the Danube, the border region toward the Republic of Romania and proximity of the state border toward the Republic of Bulgaria. The local attribute of Prahovo is defined with its central position in relation to villages: Radujevac, Samarinovac and Dušanovac.

A single-track railway Niš-Zaječar-Prahovo passes along the periphery of the area, Fig. 2.11. This railway covers distance of 184 km. The industrial railway connects the Prahovo Railway Station and the complex Elixir Prahovo Ltd. Prahovo. The industrial railway is owned by the company Elixir Prahovo Ltd. Prahovo and is used for local transport requirements.

The Port of Prahovo is located on the right bank of the Danube River and represents the last port in the territory of the Republic of Serbia. It is connected with roads and railways with other parts of the Republic of Serbia.


Fig.2.11 The part of Serbia's road network

The road network in the territory of Negotin Municipality consists of: magistral, regional and local road. The total length of road network in the municipal territory is 453 km, of which 345 km is modern roadway.

Prahovo is the industrial settlement located 9 km from Negotin, i.e. 260 km southeast from Beograd.

The local and regional road network connects Prahovo via Negotin with Bor, Majdanpek, Kladovo and the border crossings Vidin toward the Republic of Bulgaria and Djerdap toward the Republic of Romania.

The infrastructural facilities also include a certain number of electric power and telecommunication facilities of a broader socio-economic importance, among which stand out, first of all, a substantial number of 110/10 kV and 10/0.4 kV substations as well as optical fiber cables.

# 3. PROJECT DESCRIPTION

Phosphogypsum is separated as a by-product during production of phosphoric acid. The quantities of phosphogypsum are 3-6 times higher than quantities of acid which is produced as a main product. According to its properties phosphogypsum is similar to other gypsums industrially produced (ODG-gypsum from desulphurization of exhaust gases, citro gypsum from production of citric acid, etc.), with minor differences in relation to natural gypsum. Its applicability in industry and construction trade is well known. The issue related to the application is connected with produced quantities since they exceed by manifold quantities which can be applied in industry during the same period.

At present, Elixir Group Ltd uses the old phosphogypsum storage (Fig. 2), formed almost 50 years ago at the site located around 2.4 km from the factory. The old storage is formed on the terrace above the Danube River and occupies around 54 hectares, whilst the level of hydrotechnical regulation of the area corresponds to standards applied in 1960s. Its regulation and upgrading to the currently required legal and technical level is complicated and unprofitable. Because of that Elixir Group Ltd has started works on the establishment of a new storage at the more favorable location. The new site is more favorable since it is closer to the factory, what also provides lesser transport costs and easier organization. Furthermore, it is located at a sufficient distance from the Danube, what provides safer operation and reduce endangerment of the river. The conceptual design has worked out the technology for formation of the new storage at the entire location, which is planned for purchase and designated for the new storage.


Fig.3.1 The location of the old phosphogypsum storage

## 3.1. Description of provisional works on the project implementation

The first step in the storage formation is cleaning of the humus layer. After that leveling of the terrain to the elevation of storage's bottom planned at 46 masl is to be performed. The next anticipated stage is the cassettes development, including construction of: embankment, access road and perimeter canal.

After levelling and regulation of the cassette's bottom at 46.5 masl it is anticipated regulation of the cassette's bottom, what implies development of the mineral barrier of 0.5 m thickness, for the cassette's bottom stabilization In the first stage, which is primarily established in the area in which was deposited pyrite slag during last 50 years, as a geological barrier will used pyrite slag remains, which have been removed to elevation +47 masl.

On this layer is placed a watertight flexible line (high density polyethylene liner - HDPE 1.5 mm) in order to prevent seepage from the storage into groundwater. The liner will be placed on the bottom of a new storage to the perimeter canals, including also perimeter canals' bottom. In this way, it is prevented infiltration of water from the storage's area into groundwater. In the first stage the liner surface will be around 18 ha.

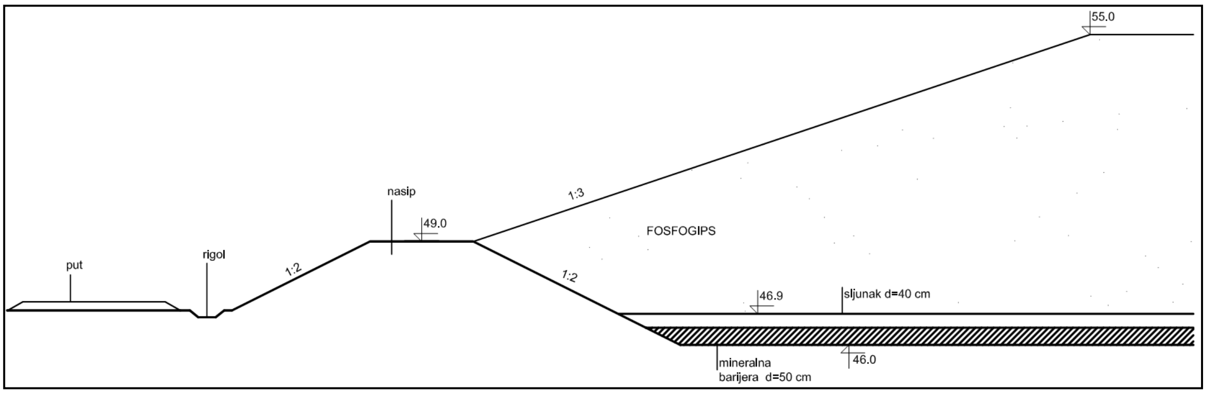



Fig.3.2 Starter dike and cassette's bottom

It is anticipated construction of drainage system on the cassette's bottom for reception of water is seeped through the storage. The drainage system consists of drain pipes laid down in square arrangement 40 x 40 m. The drain pipes are placed onto the mineral barrier layer over which is placed waterproof liner. The drain pipes are laid down onto liner into the 40 cm gravel filter layer. The drain pipe are discharged into the perimeter canal.

The dimensions of the drainage system are defined in the way that it is capable of receiving the total inflow of around 66 l/s, while the free water level in the drainage layer will not be increased for more than 40 cm. The maximum inflow into the drain pipes is around 6.7 l/s per length of 100 m. The drain pipe diameter of 175 mm, with bottom's slope of 0.15% has been adopted on the basis of water inflow analysis.

The starter dike is formed around the all storage stages with slopes 1:2 and to 3 m height in relation to the elevation of the storage's bottom (elevation 46.5 + 0.5 masl), i.e. + 50.0 masl. The temporary partition dikes will be formed between the cassettes from a single stage. The drainage canal and transport corridor are accommodated between the dike and the perimeter canal, which serves for collection of return water.

The perimeter canal is formed around the storage's cassettes for reception of filtration water from the storage during regular operation, but also for reception of discharge from precipitation. It has been anticipated construction of the canal so that it follows opening stages of the storage's new cassettes.

For the traffic and haulage of phosphogypsum from the storage will be partly used the old roads, and also the newly designed roads. In each stage, roads are dispositionally accommodated between the perimeter drainage canal and the perimeter canal. The all newly designed roads are 5 m wide. The elevation the road's crown is conditioned with the elevation of storage's bottom and it is situated at 47.5 masl, i.e. 50 cm above the elevation of filled terrain which spreads between the dike and the perimeter canal.

The reception drainage canal is anticipated between the perimeter dike and the road in the 1.5 m wide belt, on the storage's external side. The drainage canal is used for reception of filtration water from the storage and precipitation on the slopes of perimeter dike. The elevation of drainage canal's bottom is at 46.7 masl, i.e. 30 cm above elevation of the filled terrain which spreads between the dike and the perimeter canal. The drainage canal bottom is 50 cm wide, with slopes 1:1.

The perimeter dike serves for requirements of phosphogypsum storage formation. It has a multiple role since it:

- physically limits space in which will be deposited phosphogypsum;
- represents toe, i.e. foundation support of the storage which secures facility's static stability;
- protects the storage from external waters.

The perimeter canal construction dynamics follows the dynamic of storage's stages. In each stage, the storage is encircled with the perimeter dike, except in parts where is created physical connection between the cassettes of various stages.

The elevation of the dike's top is constant, i.e. 50.0 masl, that is 2.5 m above the filled terrain which spreads between the dike and perimeter canal and 3.0 m in relation to the elevation of the regulated cassette's bottom (47.0 masl). The width of dike on the top is 3.0 m with slopes 1:2.

The starter dike is made of a selected material from removed ground generated during leveling of the terrain to elevation of the storage's bottom at 47.0 masl. It is mainly dusty, sandy material with clay impurities, on the basis of geotechnical foundations and it makes this material suitable for construction of the perimeter dike. Insertion of material is going to be performed in 50 cm thick layers in an uncompact state. Spreading is performed by dredgers and compacting with rollers.

The pump station, of a chute type, has been anticipated in axis of the perimeter dike in the northwest corner of the cassette 1/1. It is required to accommodate two pumps of which one is operational and other serves as a backup pump.

## 3.2. Description of facilities and technology of phosphogypsum storage formation

It is necessary to provide a certain area for disposal of a by-product, i.e. phosphogypsum which is generated during phosphoric acid production in order to secure unimpeded unfolding of the production process. The new location, which presents the best and safest solution from the environmental aspect, is located partly in the existing industrial grounds, while will also include new areas. This spatial solution for phosphogypsum disposal inevitably imposed stage utilization of the entire area. The division of space per stages is not geometrical, but is conditioned with existing possibilities which are available for the investor to purchase individual parts of the planned location (Appendix 2 and Appendix 3).

### 3.2.1. Review of storage's stage overbuilding

The phosphogypsum storage will be developed in stages. From the aspect of the occupied surface, utilization will unfold in 3 stages, and in relation to the occupied volume in 8 stages. The first three stages implies occupation of the entire planned surface and overbuilding to elevation +18 m, while the following three stages include overbuilding to height of 36 m. The seventh and eighth stage include overbuilding to the final height of 50 m. Within the each stage operation is organized in several cassettes, 2 or 3. 15 cassettes will be formed.

Table 3.1: The number of cassettes per stages

| Operational stage | Number of cassettes |
|---|---|
| 1 | 3 |
| 2 | 2 |
| 3 | 2 |
| 4 | 2 |
| 5 | 1 |
| 6 | 1 |
| 7 | 2 |
| 8 | 2 |
| **Total:** | **15** |

The cassettes are formed in order to establish operational regime in which:

- one cassette is operational (there is performed storage of phosphogypsum);
- one cassette serves as a backup (it is prepared for reception of phosphogypsum and from there it dispatches phosphogypsum for the market),
- while one cassette is out of use (it is drained in order to enable overbuilding or extraction of phosphogypsum for the market)..

This kind of phosphogypsum storage development will condition overlapping of some stages.

Three cassettes will be formed only in the beginning (1/1, ½ and 1/3), while in all other cases the development of the next stage begins while the previous stage is still active.

The formation and utilization dynamics is developed for the most disadvantageous scenario when all quantities have to be stored since phosphogypsum cannot be sold on the market. If the investor provides sale of phosphogypsum developed dynamic is being changed and after “cleaning” of one cassette stockpiling is being done again in that empty space instead of activation of new cassettes. During extraction from the cassette particular attention ought to be directed in order to avoid any damage of geomembrane on the bottom and internal slope. The easiest way and best protection to achieve this is to stop extraction of phosphogypsum at height of 1 m from the bottom, i.e. at least 5 m from the internal slope of the starter dike.

The schedule of cassette utilization and overbuilding height in certain stages of operation are presented in Table 3.2.

Table 3.2: The operational schedule and overbuilding height per operational stages

| Operational schedule | Stage | Cassette | Overbuilding height, m |
|---|---|---|---|
| 1. | 1 | 1/1 | 14 (0-14) |
| 2. | | 1/2 | 14 (0-14) |
| 3. | 2 | 2/1 | 14 (0-14) |
| 4. | | 2/2 | 25 (0-25) |
| 5. | | 2/3 | 25 (0-25) |
| 6. | 3 | 3/1 | 25 (0-25) |
| 7. | | 3/2 | 14 (0-14) |
| 8. | | 3/3 | 14 (0-14) |
| 9. | 4 | 4/1 | 14 (0-14) |
| 10. | | 4/2 | 14 (0-14) |
| 11. | 5 | 5/1 | 32 (14+18) |
| 12. | | 5/2 | 32 (14+18) |
| 13. | 6 | 6/1 | 32 (14+18) |
| 14. | | 6/2 | 32 (25+18) |
| 15. | | 6/3 | 32 (0+32) |
| 16. | 7 | 7/1 | 38 (32+6) |
| 17. | | 7/2 | 38 (32+6) |
| 18. | 8 | 8/1 | 50 (38+12) |
| 19. | | 8/2 | 50 (38+12) |

Overbuilding is performed by means of 1.5 m high benches. The four benches of which each is 1.5 m high are joined and retracted inside the accumulation area for 3 m. Therefore, on each 6 m will be formed the path around cassette. The slope of each bench (V: H) is 1:3, while the slope of the formed storage is (V: H) 1:3.42.

Stage 1 implies activation of the two cassettes: 1/1 and 1/2, Fig.3.3. In this stage starts utilization and storage formation. The cassettes from this stage mostly occupy area of the former pyrite slag disposal dump. The entire foundation surface occupied in this stage is 18 ha, and cassettes’ surface is approximately equal, around 60,000 $m^2$. The space of this cassette is of irregular shape, and the shortest dimension (along which is determined possibility of overbuilding) is around 130 m. This shape and size are conditioned with available space and requirement to set up the cassette for disposal of ashes from the boiler-room in SW part of cassette 1/1 b beside the existing road. Because of the advanced construction method employed for overbuilding each next bench will be displaced into the space of storage from the all sides.

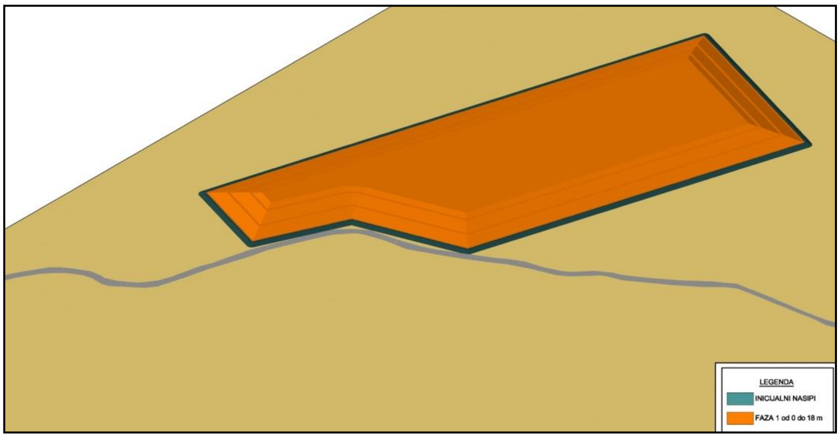



Fig.3.3 Development scheme of phosphogypsum storage in Stage 1

Utilization starts with construction of the starter dike, 2 m high around the both cassettes. The starter dike is constructed from material obtained from the borrowing source, with slopes 1:2. The partition dike between cassettes, of 3 m height with slope 1:1, will be built from phosphogypsum on the existing storage.

Table 3.3 shows utilization dynamics in Stage 1.

The access road in this operational stage represents road which is constructed around the entire occupied area. The earth road will be constructed around those cassettes, while the existing road will be used from the west and SW side. The earth canal is also constructed around cassettes. The drainage canal is constructed next to the starter dike around the both cassettes.

The underground suspension pipeline which leads to the storage passes through the corridor, along the west side of the road. When the pipeline reaches the partition dike it bifurcates. One route passes along the starter dike from the north and east side, and the other from the west and south side, in circle.

The pump station for return water, of a chute type, is set up within the profile of earth canal at the northwest corner of the future cassette 1/1, while the return water pipeline route follows the route of the suspension pipeline. The pipeline for return water is laid down underground all the way to the point where enters into the factory.

The area which occupy cassettes, drainage canal, road and canal is coated with waterproof geomembrane liner.

The storage area for ashes is formed in the southwest part of cassettes 1/1, immediately along the existing road. This road is also used for transport of ashes.

Stage 2 starts with activation of the cassette 2/1 when stored phosphogypsum in the cassette 1/1 reaches height of 15 m, Fig.3.4. The regulation of area around the cassettes from this stage and construction of starter perimeter dikes is performed concurrently, but their activation is shifted in stages. Firstly, is activated the cassette 2/1and then the cassette 2/2.

When the cassette 1/2 reaches its height of 15 m. The cassette 2/2 is activated when the Stage 1 reaches its height of 15 and further operation unfolds with utilization of the stage 1 and stage 2 cassettes, Table 3.3.

Table 3.3: Schedule of combined cassettes utilization

| Cassette | Overbuilding height, m | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/1 | 3 | 3 | 3 | 6 | 6 | 6 | 9 | 9 | 9 | 12 | 12 | 12 | 15 | 15 |
| 1/2 | 0 | 3 | 3 | 3 | 6 | 6 | 6 | 9 | 9 | 9 | 12 | 12 | 12 | 15 |
| 1/3 | 0 | 0 | 3 | 3 | 3 | 6 | 6 | 6 | 9 | 9 | 9 | 12 | 12 | 12 |
| 2/1 | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |

| Cassette | Overbuilding height, m | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/1 | 15 | 15 | 15 | 15 | 15 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| 1/2 | 12 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 18 | 18 | 18 | 18 | 18 |
| 1/3 | 12 | 12 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 18 | 18 |
| 2/1 | 0 | 0 | 0 | 3 | 3 | 3 | 6 | 6 | 6 | 9 | 9 | 9 | 12 |
| 2/2 | - | 0 | 0 | 0 | 3 | 3 | 3 | 6 | 6 | 6 | 9 | 9 | 9 |
| 3/1 | - | - | - | - | - | - | - | - | - | - | - | - | 0 |

| Cassette | Overbuilding height, m | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/1 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| 1/2 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| 1/3 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| 2/1 | 12 | 12 | 12 | 15 | 15 | 15 | 15 | 18 | 18 | 18 | 18 | 18 | 18 |
| 2/2 | 9 | 12 | 12 | 12 | 15 | 15 | 15 | 15 | 15 | 15 | 18 | 18 | 18 |
| 3/1 | 0 | 0 | 3 | 3 | 3 | 3 | 6 | 6 | 6 | 9 | 9 | 9 | 12 |
| 3/2 | - | - | - | - | 0 | 3 | 3 | 3 | 6 | 6 | 6 | 9 | 9 |
| 4/1 | - | - | - | - | - | - | - | - | - | - | - | - | 18 |

| Cassette | Overbuilding height, m | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3/1 | 12 | 12 | 12 | 15 | 15 | 15 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| 3/2 | 9 | 12 | 12 | 12 | 15 | 15 | 15 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| 4/1 | 18 | 18 | 21 | 21 | 21 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 27 | 27 | 27 | 27 | 30 |
| 4/2 | - | - | - | - | - | - | 18 | 18 | 21 | 24 | 24 | 24 | 24 | 27 | 27 | 27 | 27 |
| 5/1 | - | - | - | - | - | - | - | - | 18 | 18 | 21 | 21 | 21 | 21 | 24 | 24 | 24 |
| 6/1 | - | - | - | - | - | - | - | - | - | 18 | 18 | 21 | 21 | 21 | 21 | 24 | 24 |

| Cassette | Overbuilding height, m | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4/1 | 30 | 30 | 30 | 33 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| 4/2 | 30 | 30 | 30 | 30 | 33 | 33 | 33 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| 5/1 | 24 | 27 | 27 | 27 | 27 | 30 | 30 | 30 | 33 | 33 | 33 | 36 | 36 | 36 | 36 | 36 | 36 |
| 6/1 | 24 | 24 | 27 | 27 | 27 | 27 | 30 | 30 | 30 | 33 | 33 | 33 | 36 | 36 | 36 | 36 | 36 |
| 7/1 | | | | | | | | | 36 | 36 | 39 | 39 | 39 | 42 | 42 | 42 | 45 |
| 7/2 | | | | | | | | | | | | | | 36 | 39 | 39 | 39 |
| 8/1 | | | | | | | | | | | | | | | 36 | 39 | 39 |

| Cassette | Overbuilding height, m | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/1 | 45 | 45 | 45 | 48 | 48 | 48 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | Recultivation |
| 7/2 | 42 | 42 | 42 | 42 | 45 | 45 | 45 | 48 | 48 | 48 | 50 | 50 | 50 | 50 | |
| 8/1 | 39 | 42 | 42 | 42 | 42 | 45 | 45 | 45 | 48 | 48 | 48 | 50 | 50 | 50 | |
| 8/2 | 21 | 21 | 24 | 24 | 24 | 24 | 27 | 27 | 27 | 30 | 30 | 30 | 33 | 33 | Back-up |

**Note:** Active cassette is marked with green color the, the back-up cassette with yellow cassette that is drained, with red, while with blue color the stage which is completed. The back-up cassette implies construction of peripheral embankments after drainage, but its elevation is not provided in this table.

In this operational stage is provided contact of cassettes 2/1 and 2/2 from the north side with the stage 1 cassettes. In this operational stage the pipeline leads around both cassettes, with extension of the pipeline installed in the stage 1. The pipeline is set onto the crest of starter dike.

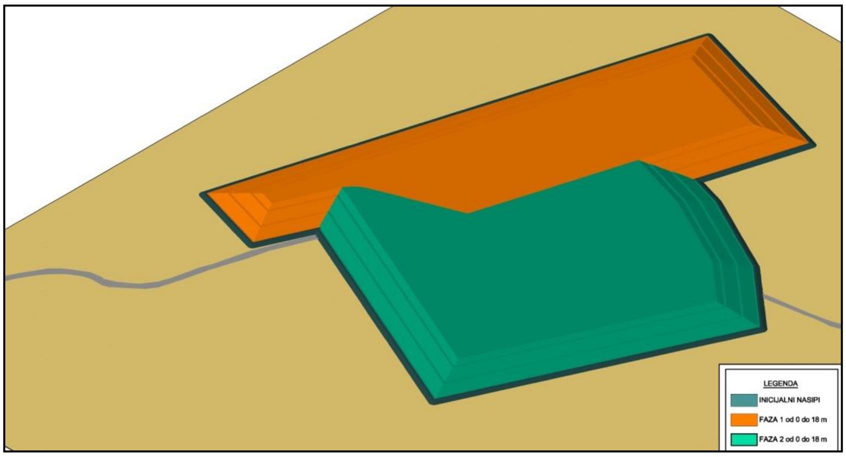



Fig.3.4 Development scheme of phosphogypsum storage in Stage 2

There is already the road from the north and partly from the east and west side which is extended around the stage 2 cassettes. The road from the south side of the stage 1, in the part of stage 2 cassette is cancelled.

The canal is extended around the stage 2 cassettes, while the south branch from the stage 2 is buried.

Stage 3 starts with activation of the cassette 3/1 when the cassette 2/1 is overbuilt to height of 15 m. The cassettes 2/2, 2/3, 3/1 and 3/2 are alternatingly overbuilt until the stage 2 cassettes do not reach elevation +18 m. At that moment stops utilization of the stage 2 cassettes, and it is continued with utilization of the stage 3 cassettes, Table 3.3.

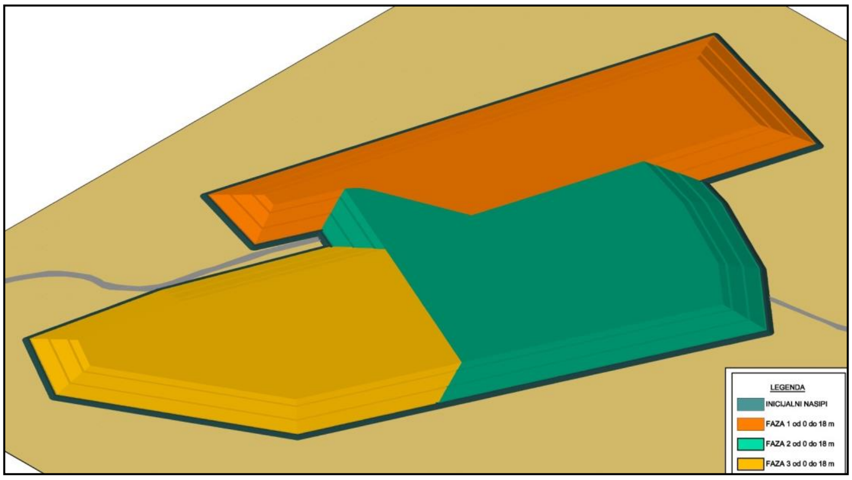



Fig.3.5 Development scheme of phosphogypsum storage in Stage 3

In this stage the cassettes are physically connected since the cassette 3/1 is backed on the west perimeter dike of the cassette 2/2. The suspension pipeline passes through the corridor and then continues along the existing road from the north side of cassette 3/2 around the cassettes. The pipeline from the east side is extended along the storage's south side.

The road is constructed around the west and south side of the stage 3 cassettes. The part of the perimeter canal between the cassettes 2/2 and 3/1 is buried, and the external canal is constructed following the road route.

The cassettes 3/1 and 3/2 can be overbuilt to height of 18 m. When construction reaches height of 12 m it starts activation of space from the stage 4, Fig.3.6. The Stage 4 mainly represents overbuilding of the stage 1 cassettes. It consists of two cassettes 4/1 and 4/2 and they can be overbuilt to height of 36 m. Therefore, with the stage 4 starts overbuilding of the occupied space from elevation +18 to +36 m.

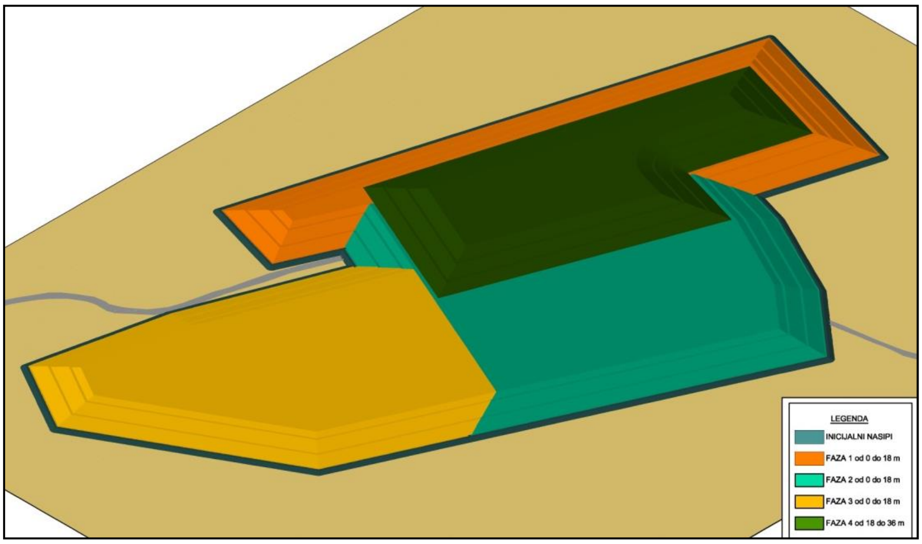



Fig.3.6 Development scheme of phosphogypsum storage in Stage 4

Since only two cassettes can be formed in the stage 4 it will be carried out combined utilization of the stage 4 cassettes, with the cassettes from the previous stage 3 and following stages 5 and 6, Table 3.3, in order to provide a proper utilization tempo. The suspension pipeline is already distributed and, therefore, it is only extended for the cassettes 4/1 and 4/2 from the nearest discharging points.

In this stage are completed the all infrastructural works around and on the storage (the starter dike is completed as well as the road, perimeter canal, lights, hydro insulation, drainage) and starts overbuilding of the occupied area.

Activation of the stage 5 cassette 5/1 starts when overbuilding of the stage 4 cassette reaches height of 24 m. The stage 5 consists of only one cassette, i.e. the cassette 5/1. The initial elevation of the cassette 5/1 is +18 m and the final +36 m. Overbuilding of the cassettes 5/1 is combined with the stage 4 cassettes and with cassettes from stages 6 and 7, Table 3.3.

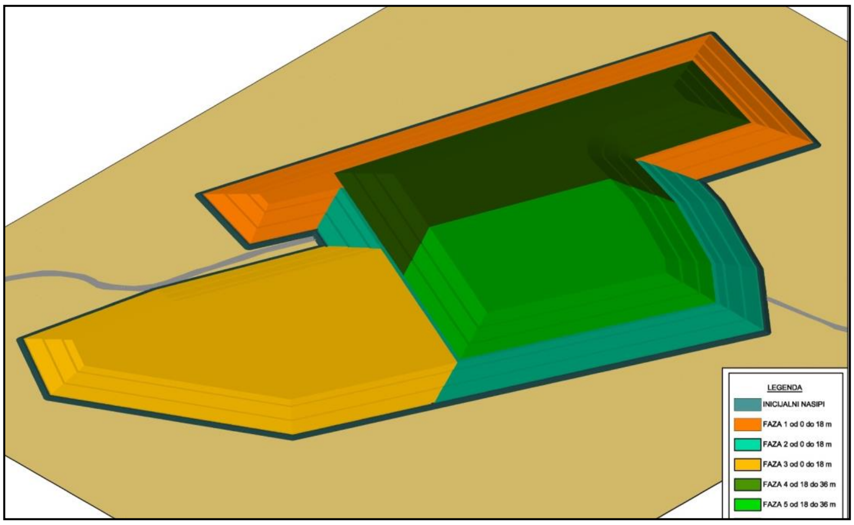



Fig.3.7 Development scheme of phosphogypsum storage in Stage 5

The activation of stage 6 cassette 6/1 starts when the cassette 5/1 reaches height of 21 m. The stage 6 consists of only one cassette. This cassette is formed from elevation +18 m in the space previously occupied with the cassettes 3/1 and 3/2.

In the stage 6, the newly established cassette is backed to the stored material from the stage 5 toward the east, while from the all other sides are perimeter dikes.

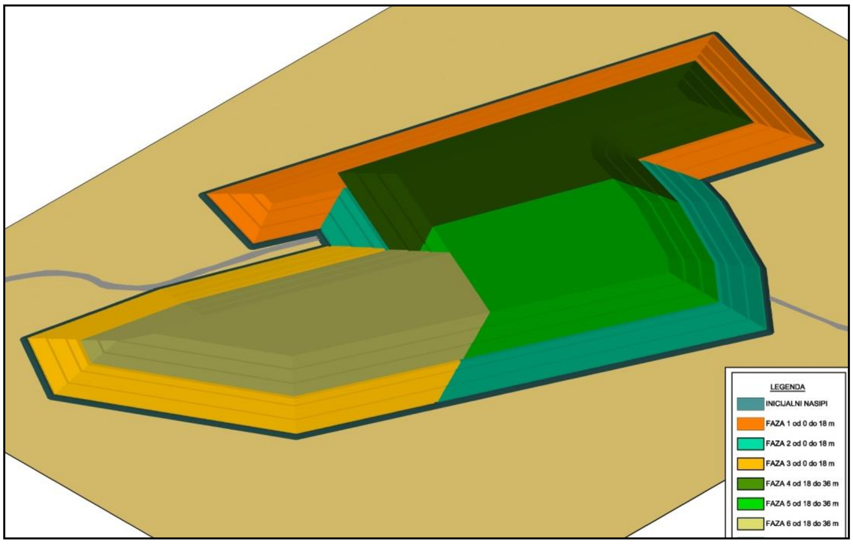



Fig.3.8 Development scheme of phosphogypsum storage in Stage 6

Activation of the stage 7 cassette 7/1 starts when the cassettes 6/1 and 6/2 reach height of 33.0 m. The stage 7 consists of two cassettes 7/1 and 7/2. They are established in the space of former cassettes from stages 1 and 2. This cassette is formed from elevation +36 to the finale elevation +50 m. In this stage the cassettes 7/1 and 7/2 occupy the entire available space. The perimeter dikes are constructed from the all sides.

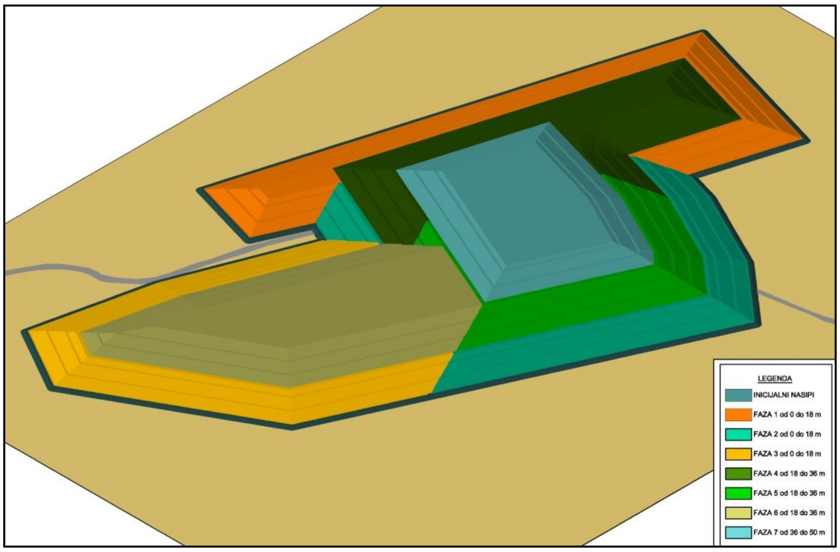



Fig.3.9 Development scheme of phosphogypsum storage in Stage 7

The final stage 8 is obtained with overbuilding of previous cassettes from stages 3 and 6. The stage 8 consists of two cassettes, i.e. 8/1 and 8/2. The cassette 8/1 is formed in the space for the former cassettes from stages 3 and 6, and the cassette 8/2 represents overbuilding of the dump for ash from the boiler-room. Geometrically, this stage can be overbuilt above the planned storage's height, but it will end up, according to the detailed regulation plan, at elevation +50 m and, therefore this stage has a transitional and back-up role, Fig.3.10 (the stage 8 without overbuilding of the ash dump) and Fig.3.11 (the stage 8 with overbuilding of the ash dump). Namely, the phosphoric acid factory ought to already have a new storage at a new location, or to expand the existing one, so that the back-up space will be situated at the location of a new storage.

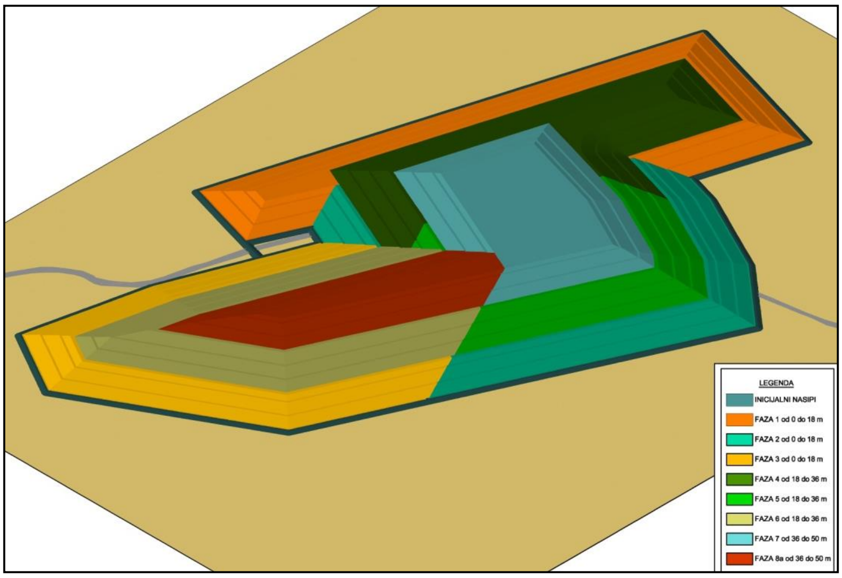



Fig.3.10 Development scheme of phosphogypsum storage in Stage 8, cassette 8/1

Depending on the phosphogypsum sale, possibility of provision of a new space for storage and for the ash dump, the investor will opt out to keep the ash dump location within the protected space of this storage or to transfer the ash dump when transfer the phosphogypsum storage. It is important to be underlined that the ash quantity is neglectable, around 2250 t/year, in comparison with the gypsum quantity.

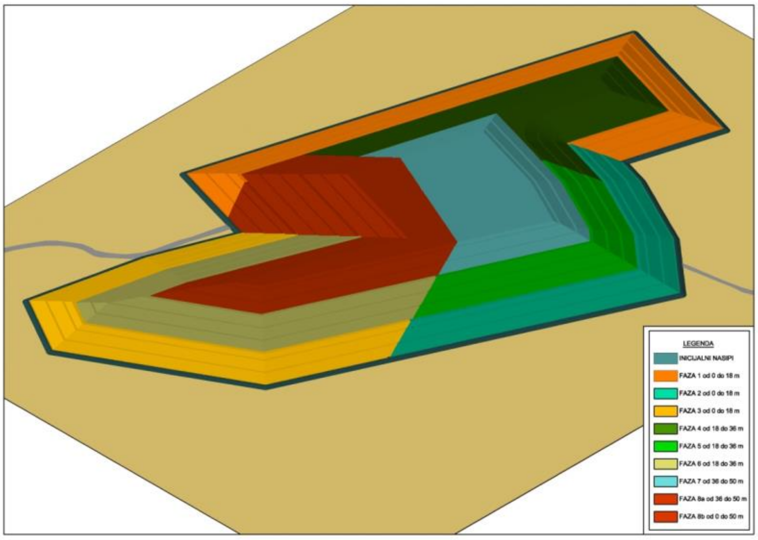



Fig.3.11 Development scheme of phosphogypsum storage in Stage 8, cassette 8/2

The utilization of the cassette 8/1 starts when the cassette 7/2 is filled up to elevation +39 m, and the cassette 8/2 to +42 m. In this stage a distributed circular pipeline is only extended to the location of discharging point.

### 3.2.2. Definition of the storage's zero elevation

The bottom of the future storage depends not only on terrain's elevations but also on the lithological composition of the surface soil layer and maximum (expected) level of groundwater in the analyzed location. On the basis of the survey and analyses it is defined that the maximal expected groundwater level is below 41.5 masl and, therefore, this elevation has been adopted as the elevation above which need to be constructed facilities at the storage.

In the Germen mining and industrial practice for the formation of area in which will be stored waste material, the bottom of storage facility is elevated for 1 m in order to avoid contact of stored material and capillary water, i.e. to prevent eventual mistakes in the estimates of maximum level. Hence, the minimum elevation of the bottom of future storage and the lowest elevation of the pump station is at 42.5 masl. The peripheral canal's bottom can be at 1 m higher elevation, i.e. +43.5 m.

Considering that the elevations of natural terrain are between +45 and +48 masl and that the thickness of organic layer ranges from 0.2 to maximum 1.5 m it has been adopted the elevation of cleared terrain at +46.5 masl. With this the bottom is raised above groundwater for at least for 5 m, and it is also achieved a certain mass balance between the quantities which will be stripped bellow the humified layer and the quantities which will be filled in the terrain which level is below 46.5 masl, understandably after clearance of the humified material.

The layer of material which represent a natural protection barrier will be placed on the storage's bottom, and considering that there is no material in the surrounding which can be rolled in to achieve filtration coefficient of $10^{-9}$ m/s its thickness will be therefore 0.5 m and the bottom on which will be placed geomembrane liner protection cover will be at 47.0 masl. At this elevation will be placed geomembrane liner protection cover of thickness 1.5 mm on which then is placed the 0.4 m gravel drainage layer and pipe drainage system. Hence, the stockpiling of phosphogypsum starts at 47.4 masl.

The starter perimeter dike made of material from the borrowing source needs to be constructed in order to start around cassettes. Its foundation will be at +47.0 masl, with net height of around 2 m (1.0 m will occupy mineral barrier and drainage gravel layer) and the dike crest will be at +50.0 masl. The review of those deliberations is provided in Table 3.4.

Table 3.4: Review of levels with terrain regulation

| | | |
|---|---|---|
| | | |
| 49 | | Crest of starter perimeter dike |
| | | |
| | | |
| 46,5 | | Top of rolled mineral barrier |
| 46 | Terrain level after cleaning | |
| 45,5 | Fuller from drainage | |
| | | |
| | | |
| 44,5 | Bottom of the perimeter canal | |
| | | |
| 43,5 | Bottom of the pump station | Storage's bottom |
| | | |
| 41,5 | Maximum expected level of ground water | |
| | | |

### 3.2.3. Filling and overbuilding technology used for storage formation

At least, 2 that is 3 cassettes are active in each stage. They have status of operational, backup or the cassette out of use. The principal schedule of status change per cassettes is provided in Table 3.4.

The each stage of storage filling is preceded with regulation of storage area. The regulation of storage area implies erecting of perimeter dikes, extension of pipeline and fullers and provision of backup space (observing principle that one cassette is filled, other is drained and one serves as backup).

Table 3.5: Principal schedule of status change – individual cassettes

| | Cassette 1 | Cassette 2 | Cassette 3 |
|---|---|---|---|
| Step 1 | Operational | Backup | - (does not exist) |
| Step 2 | Out of use | Operational | Backup |
| Step 3 | Backup | Out of use | Operational |
| Step 4 | Operational | Backup | Out of use |

Discharge of suspension is performed directly within the enclosed storage space. Discharge starts with filling of the canal (trench) which is situated immediately along the perimeter dike, and is continued with overflowing of suspension in the internal part of the storage space. In order to keep water, i.e. the settling pond, in the central part of the cassette around the each cassette is laid down a circular pipeline and installed one fuller at each 100-150 m. The fuller is the pipe of the same diameter as the pipes in the supply pipeline which free side is directed into the cassette's storage space. The change of discharge location is performed occasionally, on each 7 to 10 days. Directing of suspension into the storage area, i.e. toward some other fuller is performed with the blind pipe flange and ring system.

When the operational cassette is filled with phosphogypsum and purged water, discharge is transferred into the new (free, empty, backup) cassette. During first days after change of the cassette water will be quickly evacuated from the former operational cassette since there is no inflow of new water, and the drainage system and pump that empting the settling ponds are active. When the level in the former operational cassette is dropped discharge returns again in order to fully fill the storage space.

When the operational cassette is again filled it is then disassembled the pipeline and floating pump station. From that moment it becomes the cassette out of use and it starts complete draining via the drainage system and evaporation of water from the settling pond, if existing.

When the cassette out of use is drained it starts its overbuilding. Overbuilding is performed with the advanced method so that each next bench is retracted toward the center of the cassette. Overbuilding implies gradual erection of perimeter dikes in four 1.5 m steps. The previously stored phosphogypsum is used for construction of perimeter dikes, in the stage of overbuilding. Phosphogypsum is scooped with the bucket of a hydraulic dredge which span is 10 to 15 m from the part where used to be canal and is filled on the axis of the future dike. The external slope of each bench is 1:3 and the internal 1:2. When the cassette is overbuilt in four 1.5 m steps and reach its full height of 6 m the 3 m road remains on the crest and the next dike is retracted for that size.

For construction is used gypsum from the canal and above it since this gypsum is sufficiently wet and can be easily scooped, filled and spread on the axis of the next dike, while phosphogypsum which was deposited in the central part of the cassette is solidified and it is therefore hard to be excavated and spread. In each step the dike is constructed in 50 cm layers. The filled and spread material is compacted and shaped prior to placement of the next layer.

The overbuilding of dike is usually entrusted to the organization outside the company which uses the storage and which has a suitable mechanization.

### 3.2.4. Release of the phosphogypsum from the storage

The investor intends to sell maximum possible quantities of phosphogypsum and, therefore, the technology of development and overbuilding of the storage is adjusted accordingly.

The roundabout is provided for the access to the cassette which is being emptied and from there each cassette is accessible.

The selection of cassette which is to be emptied is defined with the cassette status. It is possible to organize that the backup cassette is emptied and, in some cases, the cassette which is out of use. Simultaneous filling and empting of the operational cassette has not been anticipated.

If phosphogypsum is released from the backup cassette then it is required to construct the passage for tracks and the loader in the outline of the dike which is most suitable for connection with the bypass road. The material is first taken from central parts of the cassette with continual and steady approach toward perimeters. The approach to perimeters can be done from the trench from which phosphogypsum was taken for construction of the perimeter dike. It is not allowed to take gypsum for sale from already formed perimeter dikes. If the cassette is deepened for more than 1.5 m on occasion of taking material (measure of one filling) it is possible to carry on with deepening, taking into account that scooping ought to be ended at least 1 m above the geomembrane liner protection cover. Furthermore, with deepening the permanent borrowing source ought to be expanded toward perimeters in order to form the “funnel” with list possible slope.

Loading of phosphogypsum ought to be done with a loader or a dredger. The bucket capacity depends on the truck’s capacity. This design does not envision procurement of loaders or trucks, but for this purpose hired equipment and crews are used if it is required.

### 3.2.5. Stockpiling of ashes and slag from the heating plant

In the area primarily occupied by the phosphogypsum storage will be separated area in which will be set up separate cassettes for stockpiling of ashes and slag (herein after “ash”) from the factory’s heating plant. The factory’s heating plant will use coal as a fuel. Coal will be procured at the local market.

Production of ashes in the heat plant is estimated on 5-6 t for 8-hour operation, i.e. 15-18 t per day. For estimated 150 net working days the total quantity of ashes will amount to around 2,250t/year. For deposition of those quantities of ashes it is required to provide the retention space of around 3,000 $m^3$/year, i.e. for the 40 year period, under conditions that ashes are not placed at the market, and this is the priority objective, it will be required the retention area of 120,000 $m^3$.

Ashes will be occasionally remove from the plateau near the heating plant and transport by trucks to the area for temporary stockpiling. The temporary stockpiling reflects the investor’s desire and intention to place the product on the market (sell, relinquish, donate) and in that way reduce space required for stockpiling and to replace sand as raw material used in construction trade and industry. The issue is related with the fact that placement on the market is most difficult to realize during winter months when production of ashes is the highest and, therefore, it is anticipated their stockpiling.

With the development of overbuilding technology for the phosphogypsum storage, for the most disadvantageous scenario which takes into consideration that there is no placement of phosphogypsum on the market, it has been anticipated to store ashes in the area southwest from the cassette 1/1, northwest from the cassette 2/2 and northeast from the cassette 3/1.

The second locations is functionally regulated area, it covers around 1.5 ha, i.e. around 16,000 $m^2$. In this way the space for stockpiling of ashes will be surrounded with stored phosphogypsum, and available quantities and stockpiling dynamics condition that the ashes cassette will be always lower and sheltered with phosphogypsum cassettes. It is important in order to prevent air pollution from the area designated for the stockpiling of ashes.

The cassette will utilize the all infrastructure (road, lighting, canals, etc.) constructed for the phosphogypsum storage. Regulation of the area used to store ashes will be identical to the regulation of the phosphogypsum area. The bottom and internal sides of the cassette will be covered with HDPE liner. It will be only drained space above the liner.

If there is no interesting party for to take it over ashes will be occasionally transported during the day light, from the heating plant to the storage area. For loading and transport will not be procured new equipment used specifically for that purpose but will be the equipment used on the investor's disposal, i.e. the loader and the truck at the time they are not in operation. Because of small quantities it is not planned to perform simultaneously transport with several trucks but instead transport will be occasionally performed with only one truck. The transport will be performed on the existing roads within the factory grounds to the storage facility and then the truck will travel on the so called traffic corridor, parallel with the west side of the cassette 1/1, and the existing road to the unloading location. Considering that the storage location will be covered with geomembrane and that will have drainage system for reception of precipitation, the storage's bottom will be protected with the phosphogypsum layer taken from the old storage or from the drained cassette of the new storage, but in order to avoid eventual damage to geomembrane the truck will perform unloading at the entrance in the ashes cassette. When the entire entrance area is filled with tipped ashes the loader will spread tipped mass, over which will pass the roller for better compacting. This will additionally reinforce the protection layer of geomembrane. In the next cycle, the truck will tip from the layer of previously distributed ashes and further to the end of the cassette. When the first 0.5 m layer of stored ashes is formed, overbuilding will be carried out, in the way that the truck will drive to the remotest part of storage facility and then successively retreating toward the initial part, by the entrance. Tipped ashes will be occasionally distributed with the loader and compacted with the available roller. In order to avoid elevation of dust, prior to distribution and rolling with will be wetted with water. Wetting will be performed with the cistern vehicle already on disposal to the investor. For wetting will be used "clean" water which will be sprinkled from the available cisterns. The exact technical details of spreading, wetting and rolling will be determined on the spot after the heat plant starts operations, i.e. after it is determined which coal will be used and conduct testing of produced ashes.

If production of ashes is followed with its placement on the market it will be formed the cassette with several layers of rolled ashes. In order to avoid jeopardizing of transport during overbuilding will be performed continual retracting of the deposited layers in relation to the external edge of the cassette, so that approach angle does not exceed $8^0$.

Because of the placement ashes will be preferentially excluded directly from the heating plant, and only in cases when the daily placement on the market exceeds the daily production ashes will be excluded from the cassette in which it is stored.

It will be always excluded the upper ashes layer, i.e. whenever it is possible it will be excluded ashes from tipped pile, i.e. ashes which is not distributed, wetted or rolled. If there are no obstacles, for further application, prior to loading ashes will be wetted with water in order to prevent local air pollution. The ashes loaded in the sidecar need also to be wetted with water before they are covered with awning.

The transport of ashes which is excluded from the heating plant and/or the storage ought to be performed with dumper trucks which sidecar is covered with adequate awning. It will be not allowed transport with an uncovered sidecar since such transport would inevitably lead to pollution of the ground around the storage and factory with spilled ashes.

## 3.3. Review of types and quantities of required energy, water and materials the stockpiling of phosphogypsum

Phosphogypsum is the industrial by-product formed during phosphoric acid production, in form of deposit which contains calcium sulphate and part of undecomposed minerals.

Its physical and chemical properties are similar to natural gypsum but they are not identical, while prefix “phosphor” points out that this gypsum is obtained from the phosphoric acid production.

Depending on qualities and compositions of input raw materials, phosphogypsum can some pollutants in traces, which does not have gypsum obtained from other sources (natural or generated with desulphurization of waste gases, etc.). The significant elements and compounds which are part of its composition include: fluorine, heavy metals, metalloids, rare earth elements, sulphuric acid, hydrofluoric acid and radioactive nuclides.

Phosphogypsum is acid due to the presence of phosphoric acid, sulphuric acid and fluorosilicic acid. It is easily dissolved in rainwater, in the same way as natural gypsum, but dissolution of phosphogypsum does not depend on pH value. If it is continually exposed to precipitations or high groundwater levels, in the phosphogypsum mass can develop canals and cavities.

The phosphogypsum properties depend on size of its particles, and for this characteristic it differentiates from natural gypsum. Phosphogypsum contains numerous fine particles. Because of this the specific surface of phosphogypsum particles is exceptionally large and, consequently, phosphogypsum dissolves much faster than the same quantity of natural gypsum.

Table 3.6 shows its chemical composition from the location of the industry of chemical products Elixir Prahovo Ltd Prahovo.

Table 3.6: Chemical composition of phosphogypsum

| Component | Content of Syrian phosphate (%) | Content of Togo phosphate (%)* |
|---|---|---|
| $SiO_2$ | 14,36 | 0,7 |
| $Al_2O_3$ | 0,094 | 0,15 |
| CaO | 26,15 | 32 |
| MgO | 0,023 | 0,01 |
| $Fe_2O_3$ | 0,33 | 0,1 |
| $K_2O$ | 0,0053 | 0,03 |
| $Na_2O$ | 0,103 | 0,01 |
| $SO_3$ | 42,7 | 45 |
| $P_2O_5$ | 4,09 | 1 |
| $TiO_2$ | <0,167 | |
| Incineration loss | 12,14 | |
| Moisture | | 19,2 |

*(data excerpted from the investor’s documentation)

The most dominant minerals in the analyzed samples were minerals from the gypsum group (gypsum anhydrate and basanite). Those minerals occur only in the form of fresh to moderately altered crystals. Quartz is significantly less present. From the accessory minerals have been determined salts (most likely halite (NaCl) and/or silvine (KCl) which only occur as euhedral crystal of octahedron shape and opaque minerals.

For given sample, phosphogypsum density was 2.36 t/m$^3$, and its bulk density was 800 kg/m$^3$. The volume density was 950 kg/m$^3$.

The water separation test, with prevented evaporation, demonstrated that 300 g of dry phosphogypsum bond 290 ml of water. Hence, each ton of phosphogypsum will bond around 0.96 t of added water.

With the stage overbuilding of the phosphogypsum storage in each stage is provided a certain retention space. In Table 3.7 are provided the volume of established retention space and approximate utilization time, under condition that the all quantities of phosphogypsum are stored, there is no sale and the capacity of facility for phosphoric acid production is constant.

The formation and utilization dynamics is developed for the most disadvantageous scenario when the all quantities have to be stored since phosphogypsum cannot be sold on the market. If the investor provide sale of phosphogypsum the developed dynamic is changed so after “cleaning” of one cassette stockpiling is done again in that empty space instead of activation of new cassettes.

The estimate is provided for the annual production of phosphogypsum of 460,000 t and the required storage space of 485.000 $m^3$. As for the stages they last from 1.6 years to 5.4 years, i.e. in the entire occupied area can be developed the storage which has capacity to store the all quantities of phosphogypsum, without sale or increase of capacity in the period of 25-29 years.

Table 3.7: Estimate of retention space per stages and utilization time

<table>
<tr><th colspan="2" rowspan="2">Stage of Development</th><th colspan="2" rowspan="2">Retention space volume, m<sup>3</sup></th><th colspan="4">Utilization time, years</th></tr>
<tr><th colspan="2">Maximum</th><th colspan="2">Average</th></tr>
<tr><td colspan="2">1</td><td colspan="2">2,390,150</td><td colspan="2">4,9</td><td colspan="2">5,5</td></tr>
<tr><td colspan="2">2</td><td colspan="2">2,605,171</td><td colspan="2">5,4</td><td colspan="2">6,0</td></tr>
<tr><td colspan="2">3</td><td colspan="2">2,060,277</td><td colspan="2">4,2</td><td colspan="2">4,8</td></tr>
<tr><td colspan="2">4</td><td colspan="2">1,370,219</td><td colspan="2">2,8</td><td colspan="2">3,2</td></tr>
<tr><td colspan="2">5</td><td colspan="2">1,174,702</td><td colspan="2">2,4</td><td colspan="2">2,7</td></tr>
<tr><td colspan="2">6</td><td colspan="2">1,215,872</td><td colspan="2">2,5</td><td colspan="2">2,8</td></tr>
<tr><td colspan="2">7</td><td colspan="2">790,678</td><td colspan="2">1,6</td><td colspan="2">1,8</td></tr>
<tr><td>8/1</td><td rowspan="2">8</td><td>360,101</td><td rowspan="2">960,994</td><td>0,7</td><td rowspan="2">1,9</td><td>0,8</td><td rowspan="2">2,2</td></tr>
<tr><td>8/2</td><td>600,893</td><td>1,2</td><td>1,4</td></tr>
<tr><td colspan="2">Total</td><td colspan="2">12,568,063</td><td colspan="2">25,7</td><td colspan="2">29</td></tr>
</table>

At the storage phosphogypsum is disposed in form of suspension, mixture of water and phosphogypsum. After discharge occurs the natural deposition of phosphogypsum particles under gravity force. Because of small density the particle size deposition will be slow and performed in the congested deposition regime. The settling pond will be simultaneously formed.

The settling pond will serve as a temporary retention for full clarification of water before it is returned to the factory. Considering that the settling pond is formed onto the surface of the operational cassette it represents the source for continuous feeding of the drainage system and saturation of the stored phosphogypsum layers. At the same time, it represents a major threat for storage stability. Because of that the settling pond has always to be maintained on the maximum possible distance from the internal edge of perimeter dikes, and in the worst case scenario that distance (so called beach) ought to exceed 30 m in relation to the all other dikes.

Locating of the settling pond into the cassette’s central zone and its movement toward and from (in relation do perimeter dikes) is performed with change of discharging locations and with maintenance of slightly funnel like section through the each cassette. The water from the settling pond is continually evacuated via the floating pump station. The floating pump station consists of pontoon on which is installed a horizontal pump for transport of dirty water. The pipeline configuration will be such the top of dike is contraflexure in which the transport regime is changed to the regime of gravitational transport of water toward the canal.

It is also of significance water separation through the drainage system on the bottom of the storage. In ideal conditions the drainage carpet is able to receive the entire quantity of technological water, but in real operative conditions, depending on storage's height and degree of choking in the drainage system it is expected that 20-50% of water will be separated through drainage. The drainage water ought to be "pure", without solid particles. In practice breach of suspended particles cannot be fully prevent and, therefore, it can be expected their presence in the water which returns to the factory.

In the continuous operation 240 $m^3$/h of technological water will be delivered to the storage, of which 160 $m^3$/h will return to the factory. The remaining 50 $m^3$/h remain in the storage as chemically bonded water or pore water. Clarification and cleaning of water will be performed within the operational cassette and with passage of infiltration water through the stored phosphogypsum toward the drainage system. Grains are not expected in that water, but in reality it is possible insignificant or small share of suspended particles. In the canal will be additionally provided deposition so that clarified water could be delivered to the pumps for return water in the factory.

In any case, it is convenient management's intention to extract the entire quantity, i.e. 240 $m^3$/h wherever it is possible and with that will be provided additional retention space.

Hence, it will be totally consumed 643,650 kWh/year and it provides for the annual phosphogypsum storage capacity normative 1.84 kWh/t of stored phosphogypsum.

In Table 3.8 is presented the list of power consumers.

Table 3.8: Estimate of retention space per stages and utilization time

| **No.** | **Consumer** | **Installed power, kW** | **Utilization degree, %** | **Operation time, h/year** | **Power consumption, kWh/year** |
|---|---|---|---|---|---|
| 1. | Pump for suspension (transport) | 132 | 0.8 | 4,800 | 506,880 |
| 2. | Pump for return water | 22 | 0.7 | 4,800 | 73,920 |
| 3. | Pump for water from the storage | 5.5 | 0.8 | 4,800 | 21,120 |
| 4. | Workplace lighting | 10 | 0.6 | 4,800 | 28,800 |
| 5. | Container heating (for workers) | 9 | 0.3 | 4,800 | 12,960 |
| | **Total** | | | | **643,680** |

## 3.4. Review of types and quantities of expected waste materials and emissions

The analysis of environmental impacts conducted for the requirements of this project takes into consideration potential environmental effects which are anticipated on the basis of implementation of the Best Available Technologies (BAT) in the designing stage and design development and the Best Management Practices (BMP) which are applied during construction and operation of the new phosphogypsum storage.

In order to define the design solution for the stockpiling of phosphogypsum within the framework of selected options, the issues related to the state in which phosphogypsum will be sent to the storage (wet or dry phosphogypsum) and the location of the future phosphogypsum storage have been taken into consideration. The detailed review of the investigated options is provided in Section 4 herein.

The problem connected with the state in which phosphogypsum will be stored at the storage is taken into consideration through two alternatives: dry (wet) phosphogypsum or in the form of suspension. One of the crucial disadvantages connected with the stockpiling of dry (wet) phosphogypsum are higher transport costs incurred by trucks used for the transport to the storage. Furthermore, this transport is less favorable from the ecological aspect. On the other side, the unfavorable requirements connected with the stockpiling of phosphogypsum suspension is, among other things, larger active space for stockpiling, and also continual maintenance of the back-up cassette in standby.

During designing of the phosphogypsum storage the two locations for establishment of the phosphogypsum storage were taken into consideration, more specifically, the overbuilding of the existing storage and formation of a new storage at a new location. The existing storage has some unfavorable characteristics: it is formed on the terrace above the Danube; the terrain is not technically regulated, i.e. there is no hydro insulation, the drainage system or the system for reception and return of water back to the factory.

As it has already been quoted, by means of techno-economic analysis has been selected the option of the stockpiling of phosphogypsum in the form of suspension as more favorable.

The suspended particles (mineral dust) can have environmental impact on air quality. The immission values of suspended particles, in certain natural conditions, can be above limit values prescribed for the residential areas.

The possibilities of unfavorable impacts caused by excessive noise in working environments exist in the all operational phases during the disposal and stockpiling of mineral raw materials and other materials. The sources of noise are construction machines for excavation, transport and ancillary works: drilling machines with compressors, loaders, bulldozers, trucks, tanker trucks, as well as crushers, mills, classifying screens, etc.

The danger from noxious impacts of vibration only exist in some phases, manly during operation of construction machines. These impacts are limited to the working environment.

During disposal and stockpiling of phosphogypsum problems might arise due to seepage below the storage in case the storage is not properly insulated. For example hydrofluoric acid which is present is phosphogypsum can dissolve silica minerals. $SiF_4$ is capable of forming via hydrolysis reaction $H_2SiF_6$ (fluorosilicic acid) in the drainage waters from phosphogypsum storage. The presence of fluorosilicic acid can cause dissolution of clayey soil at the bottom of the phosphogypsum storage. This can lead to rapid groundwater pollution if phosphogypsum is not properly stored.

The water erosion of phosphogypsum storage can create cavities and instability within the constructed dike and cause occurrence of surface wastewaters from the phosphogypsum storage, as well as the erosion around the pipeline system. The slopes at the phosphogypsum storage can be endangered due to erosion cause by heavy precipitations. The anticipated solutions in the conceptual design provide protection of soil and groundwater.

Considering that soil belongs to hardly renewable, limited natural resources, occupation and disturbance of soil represent the most significant conflict of industry with the surrounding. It has been planned stage formation of the new phosphogypsum storage at the location of the industrial complex. Thus, the stage 1 includes the area which is already owned by the company, while the stage 2 include degraded area of the existing pyrite slag disposal.

The problematics related to the occupation of surfaces required for construction of the phosphogypsum storage as well as all accessory facilities required for the process of disposal operation represent one of important parameters which is authoritative for the definition of relation between the storage and environment. The total area occupied with cassettes is 46.5 ha, of which 12.5 ha is already occupied, partly or completely, with deposited pyrite.

# 4. MAIN ALTERNATIVES TAKEN INTO CONSIDERATION

There is no dilemma during the storage planning and designing connected with existence or non-existence of the storage since domestic and foreign practice shown that sale of phosphogypsum, as a secondary raw material, is seasonal and, therefore, the storage is necessary.

The alternatives which are taken into considerations are issues related to:

- the form in which phosphogypsum will be delivered to the storage (dry or wet); and
- the location of the future phosphogypsum storage.

The issue connected for the phosphogypsum state in which will be stored is taken into consideration through the following options:

- as dry (wet) phosphogypsum; or
- in the form of suspension.

The stockpiling of wet (filtrated) phosphogypsum provides the following advantages:

- it is required smaller active space for stockpiling (lesser cassettes);
- easier maintenance of the geotechnical storage's stability;
- simpler manipulation of phosphogypsum in the period of loading from the storage for sale (or other alternatives).

The disadvantages which are faced in case of the stockpiling of wet phosphogypsum are:

- it is required reconstruction of the phosphogypsum filtration facility;
- it occurs loss of phosphoric acid (up to 4%) in the stored product;
- the transport to the storage by trucks is more expensive and is less favorable from the ecological aspect.

The stockpiling of phosphogypsum in the form of suspension provides the following advantages:

- it is not required reconstruction of the phosphogypsum filtration facility;
- it is increased recovery of phosphoric acid with utilization of return water from the storage;
- it is used hydraulic transport of phosphogypsum which is cheaper and from the ecological aspect more favorable;
- the factory acquired experience during many years in the utilization of hydraulic transport for phosphogypsum.

The disadvantages which are faced in case of the stockpiling of phosphogypsum in the form of suspension are:

- it is required larger active space for stockpiling, additionally, it is required to continually maintain the back-up cassette in standby;
- complicated maintenance of the geotechnical storage's stability;
- complicated extraction of phosphogypsum from the storage for sale (or for other alternatives).

The both options have pros and cons, however it has been selected the stockpiling option in the form of suspension as more favorable from the techno-economic aspect.

The two locations for establishment of the phosphogypsum storage have been taken into consideration during designing and planning:

- overbuilding of the existing storage; and
- establishment of a new storage at a new location.

The option of overbuilding of the existing phosphogypsum storage provides the following advantages:

- rational utilization of the occupied and degraded area;
- the existing transport system which connects the factory and the storage; and
- the established the technological process, i.e. transport and disposal adopted by the staff in charge for the storage utilization.

The disadvantages of the existing storage are:

- it is established at an unsuitable place, on the “terrace” above the Danube; and
- the terrain is not technically regulated:
    - it does not have perimeter dikes of required size;
    - it is without hydro insulation;
    - the drainage system is not provided;
    - it is not provided the system for reception and return of water back to the factory;
    - along the route from the storage to the Danube occurs large gullies due to breach of water and phosphogypsum, etc.

It can be concluded, on the basis of the aforementioned, that fitting and upgrading of the existing storage in accordance with current technical standards would be very complicated from the technical aspect (in some parts technically unfeasible) and very expensive. Therefore, its overbuilding is not justifiable. This storage is classified in the category of so-called historical polluters and, accordingly, it needs to be rehabilitated and closed in order to reduce environmental impact to the least possible degree.

The selection of the location for establishment of the phosphogypsum storage was aimed to provide that:

- it is as close as possible to the facility where phosphogypsum is separated, but, on the other hand, it does not jeopardize surrounding facilities, i.e. development of the entire industrial complex;
- the area is accessible for transport and discharge of suspension and transport of phosphogypsum which is purposefully placed on the market;
- are met the all technical and technological standards quoted in Serbian and EU legislation; and
- the available and required area is in ownership of the investor or can be purchased.

The terrain in immediate proximity of the industrial complex IHP Prahovo has been selected with combination of the quoted requirements. The part of that area (in the past) was used for disposal of pyrite slag and other tailings from the processes of IHP Prahovo, and the other part is agricultural land.

The selected location is suitable for the following reasons:

- Degraded soil used for deposition of pyrite slag, was directly jeopardized environment (air, water and soil) and after its removal the area will be cleaned in accordance with current technical and legal requirements, being converted to its purpose without jeopardizing environment, with which will be reduced occupation of the new areas for the stockpiling of phosphogypsum;
- The distance of the phosphoric acid factory is not demanding, i.e. the length of transport pipeline varies from 1150 m to 1750 m, what has positive impacts on transport costs, but it also facilitates organization of work at the storage;
- The area is accessible from the all sides. It facilitates transport of phosphogypsum to and from the storage and provides an easy control of vehicles which enter and depart from the storage facility;
- The location provides significant advantages:
    - It is situated on the sufficient distance from populated settlements;

- It does not jeopardize any infrastructural facilities;
- There is no protected properties or natural monuments;
- It is situated outside all sanitary protected zones;
- It is not susceptible to flooding since the Danube River situated at a sufficient distance and more than 20 m below (geodetically), whilst the highest groundwater level is 6-10 m below the natural elevation of the terrain, etc.

This location has some disadvantages which are connected with the fact that agricultural land is lost and, most likely, permanently converted to the industrial lot.

# 5. REVIEW OF ENVIRONMENTAL CONDITIONS AT THE LOCATION

In this section is provided the review of environment at the site and the surrounding of the planned design for the stockpiling of phosphogypsum at the factory grounds, i.e. Industry of Chemical Products Elixir Prahovo Ltd Prahovo.

## 5.1. Residents

When speaking of the residents and project impact on them it is first of all thought about socioeconomic aspect of that impact. The former experiences indicated that the only socioeconomic aspect was the one which always has, to certain extent and conditions, some benefits form the project development. It is another issue whether this benefit is always in accordance with the expectations of the community members, but nevertheless it is evident. In this case, a subjective character of realized benefit is far more pronounced than with other environmental aspects. Therefore it is difficult to achieve consensus regarding the issue of the project impact on residents, concerning the scope but also disadvantage of its impact.

According to data provided in the Section 2 herein it is obvious that this region of the Republic of Serbia and, first of all, the village Prahovo shares the same fate of all smaller towns and settlements particularly during last 20 years, although the similar trends were experienced even in the longer period.

As for the village Prahovo, according to the data obtained from the previous censuses it is evident that during the period 1961-2011 trend of decreasing population is permanently present . It can be seen on the provided diagram in Fig.2.10 b. It would be over optimistic to expect that this trend is significantly changed during the last three year, i.e. to record the upward trend.

The other issue of this small community is ageing population. The average age of residents is 47.4 years, while the group of people aged 60-64 is the most numerous.

It is well established fact that a potential strength of one nation is based on a numerous population but also in a substantial share of a younger age group. It is not case in this part of Serbia.

From that aspect, the quoted project can have an immediate impact on improved employment figures in this community and provision of similar economic conditions recorded in the 1970s and 1980s. The employment and regular incomes of residents in the community forms the basis for its prosperity in every aspect.

## 5.2. Flora and fauna

Unlike the issue of residents, it is relatively easy to establish consensus regarding a possible impact on flora and fauna. It is not always obvious to which extent this impact will be pronounced but, unfortunately it is always evident. The human presence itself at certain location changes original structure of flora and fauna. It is also the fact that this impact is not always negative or at least not to such an extent that prevent self-regeneration flora and fauna’s habitat. In other words, the coexistence of humans and surrounding flora and fauna is possible. Furthermore, it is an imperative for community, which to large extent or almost completely bears responsibility for its survival.

Negotinska Krajina, in which is situated the said project, is located in the utmost eastern parts of the country. It occupies the area of over 100,000 ha, of which forests and forest soil occupy 32,200 ha, meadows 22,800 ha and cultivated fields 41,000 ha. The areas under forests are mainly concentrated in west and northwest hilly parts of the municipal territory. The areas at the highest elevations are overgrown with beech forests, while oak forest are located in the overgrown areas at lower elevations. This region is characterized with relatively great diversity of tree species (beech, oak, common hornbeam, ash, willow, poplar)

The natural and ecological characteristics are one of preconditions for diverse flora and fauna.

The Municipality of Negotin is characterized with fertile soils suitable for agricultural production. The agricultural soils occupy around 65% of the municipal territory, while dominate cultivated fields, and then pastures and surfaces under vineyards and orchards.

The diversity of flora is the precondition for the diversity of fauna. It has been recorded presence of numerous species: auks, grebes, pelicans, waterfowls, cranes, marsh hens, woodcocks and gulls. There are also colonies of small cormorants and of great cormorants, little egrets, gray herons, and white and black storks. It has also been recorded the presence of a large number of ducks (mallards, widgeons, common teals, common pochards) and ten thousands of coots. Raptors are also well represented, but some of them are very rare such as: black kite, white-tailed eagle, great Nicobar serpent eagle, spotted eagle, golden eagle, etc. A large number of various species of woodcocks and gulls remain on the Danube banks, particularly during summer and at the beginning of autumn. It has been also recorded a large number of owls, European robins, tits, and numerous other species.

The fauna of large quarry is, first of all, limited on a certain number of hunting grounds (Deli Jovan, Alija, Vratna and Lovište) and it provides a certain degree of security from the aspect of preservation of this fauna (deer, wild boars, mouflon). To the listed animal species in the quoted hunting grounds need to be added roe deer, rabbits, gray partridge, dabbling ducks, European turtle doves, wild pigeons, wolves, jackals, foxes, wildcats, weasels which can be encountered in this region.

As for the said project site, in the village Prahovo and its surrounding is formed a diverse flora of autochthons or introduced character, what is the result of corresponding natural conditions. In Prahovo itself are represented urban plant species, while in the surrounding is agricultural land, what is understandable considering a traditional character of this region. The terrains with high moisture content, characteristic for the area near the Danube provided conditions for growth of coastal vegetation.

As for flora and fauna it is of utmost importance from the aspect of each project the fact that in the particular location are not recorded rare or protected species of flora and fauna, which could have a significant impact on scope and realization of the project.

Furthermore, regarding possibility and scope of a potential impact of the project on flora and fauna it ought to be underlined that this project mainly occupies devastated area, i.e. devastated agricultural land. The chemical industrial complex in Prahovo covers the area of around 135 ha, i.e. 95 parcels, of which 13 is partially occupied, while the remaining number is fully occupied. The largest part of the area occupies the industrial complex Elixir Prahovo Ltd. Prahovo. The remaining occupied parcels are in the function of accessory facilities of the complex Elixir Prahovo Ltd. Prahovo. The utilization of new agricultural land is anticipated only for a smaller part.

Scope and type of degradation depend on the source of degradation, i.e. whether it is plant itself, accessory facilities, pyrite slag disposal and likewise. However, the fact is that the existing flora and fauna in the immediate surrounding is adjusted to great extent to the conditions of changed natural habitat.

## 5.3. Soil

The following types of soils occur in Negotinska Krajina: alluvial soils (fluvisol), vertisols, chernozem (marsh dark soil; meadow black soil), presented in the Section 2, Fig. 2.5. Alluvial soils (fluvisol) are formed on alluvial deposits, hence the name since material which participate in its genesis originates from a river deposit. Alluvial soils (alluvial deposits) in the analyzed area cover significant surfaces along the larger currents such as the Danube and the Timok, as well as along the smaller ones. Considering that these soils are characterized with light mechanical composition mixed with mud and with good fertility, they are mainly used for growing vegetables, albeit there are also present areas under grass and forests.

Chernozem occurs in the region of Negotinska Krajina as marsh dark soil and meadow black soil. Marsh dark soils occur in alluvial plains at somewhat higher locations, and also occur in individual, closed depressions, which have marsh character. For these soils is characteristic presence of water in the profile which level does not reach surface.

For marsh dark soils is characteristic that they endure surface flooding. In the alluvial plains surface water reaches marsh dark soils in branches of a river, and in marshes comes down from its peripheral parts. However, flooding remain on surface for various periods of time, but it is mainly absent on surface during vegetation period. Soil profile is saturated with water due to capillary rising, which is to large extent also the result of heavy mechanical composition of these soils. Because of abundance of moisture vegetation is exuberant, with an abundant production of organic mass.

Marsh dark soils are most frequently fertile soils due to their depth, physical and chemical properties, which are used as agricultural areas. However, difficulties occur during cultivation since it is usually required deep cultivation, due to limited filtration capacity.

Meadow dark soils occupy higher locations (loess terraces, loess plateaus, alluvial plains) in relation to marsh dark soils and are rarely exposed to flooding. Meadow dark soils are grouped in semi-hydromorphic soils due to relatively low groundwater level. These soils are also called “meadow chernozems”. Nowadays, meadow dark soils are mainly used as agricultural land, although in alluvial plains are still preserved autochthonous forest vegetation of deciduous trees of the Fugaceae family from plain terrains. The evolutionary development of meadow dark soils is pointed in two directions. In the higher parts of the terrain it is directed toward the cambisol formation process, while during more pronounced wetting they succumb to loess formation processes and, finally, to the pseudoglay formation process.

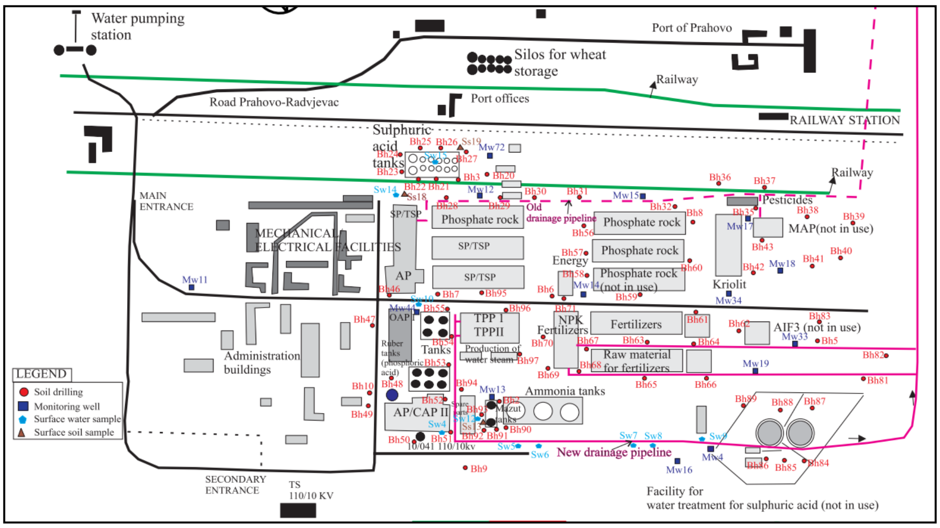



Fig.5.1 The sampling locations for the investigations of soil, surface water and groundwater (Source: Intergeo Environmental Technology)

The company INTERGEO Environmental Technology conducted, among other things, detailed soil investigation for requirements of the definition of existing environmental conditions. The results of those investigations demonstrated that there is contamination at several locations due to exceeding of normal values. The sampling locations for soil investigation are presented in Fig.5.1.

On the basis of the analysis of the results related to the soil quality it has been ascertained that remedial values are exceed for a certain number of parameters, Table 5.1.

Table 5.1: Review of parameters for which are exceeded remediation intervention values (Source: Extended environmental investigation phase II at the industrial *complex IHP Prahovo Fertilizer Factory in Prahovo, Serbia, 2008)*

| | **No. of investigated sample** | **Optimal value (mg/kg) per NDL** | **Action value (mg/kg) per NDL** | **Minimum recorded concentration (mg/kg)** | **Maximum recorded concentration (mg/kg)** | **No of samples which exceed action value per NDL** |
|---|---|---|---|---|---|---|
| pH | 237 | - | - | 3.72 | 11.70 | - |
| Arsenic (As) | 159 | 29 | 55 | n.d. | 79 | 3 |
| Copper (Cu) | 159 | 36 | 190 | 1.9 | 1100 | 5 |
| THP | 35 | 50 | 5000 | n.d. | 7800 | 5 |
| Aliphatic hydro carbonates | 37 | 50 | 5000 | n.d. | 7600 | 2 |
| Phthalates | 37 | 0,1 | 60 | n.d. | 1500 | 1 |

*NDL – New Dutch List

Additionally, it is also ascertained low pH value for soil with one sample, while with 13 samples is detected increased natural radioactivity, and at several locations are detected high values of fluorides, sulphates, nitrates and phosphates (they are not standardized).

The similar investigations, with the objective to define the existing environmental conditions in the chemical complex Prahovo, were conducted during 2012 by City Institute for Public Health, Belgrade. Works on installing 3 piezometers were performed for requirements of the investigation of the existing environmental conditions. The samples of drilled material for laboratory testing were taken during drilling, while the sampling depth depended on the depth at which was located the water bearing layer (the first meter, middle and the lower part). Besides the 9 (nine) samples from the drilled material, it was sampled and laboratory tested 8 more soil samples from the surface layer (h=20-30 cm) Fig. 5.2.

Fig.5.2 The sampling locations from surface soil layer

As sampling technique was used representative sample formation, scooping soil at 3 locations on surface of around 20 m$^2$ and with formation of one composite sample.

The laboratory analysis was used to test soil samples for most significant parameters of possible soil contamination in accordance with the represented technological processes and activity in this complex. The following parameters related to soil quality are investigated: pH value, moisture content (%), incineration loss, total phosphorous, sulphate, total nitrogen, fluorine, polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls **(**PCB)**,** total hydrocarbons (C10-C40), nitrophen and metals (Hg, Cd, As, Pb, Zn, Cu, Ni, total Cr, Mo and V). The results of laboratory analysis for the surface layers are provided in Table 5.2.

Table 5.2: Values of investigated parameters per sampling locations from surface soil layer

| | Unit | Loc. 1 | Loc. 2 | Loc. 3 | Loc. 4 | Loc. 5 | Loc. 6 | Loc. 7 | Loc. 8 |
|---|---|---|---|---|---|---|---|---|---|
| pH | | 4.8 | 6.8 | 6.0 | 4.7 | 5.9 | 2.1 | 3.7 | 4.7 |
| Total nitrogen | mg/kg | 2612.0 | 2209.0 | 2832.0 | 2440.0 | 2555.0 | 165.0 | 1690.0 | 3027.0 |
| Total phosphate | mg/kg | 2160.0 | 73900.0 | 13400.0 | 36200.0 | 6520.0 | 363.0 | 2060.0 | 19500.0 |
| Sulphate | mg/kg | 3568.0 | 2256.0 | 1373.0 | 3568.0 | 3568.0 | 2779.0 | 5086.0 | 3568.0 |
| Fluorine | mg/kg | 26.0 | 55.0 | 139.0 | 2933.0 | 114.0 | 8.4 | 1195.0 | 899.0 |
| Lead | mg/kg | 209.0 | 43.5 | 21.9 | 260.0 | 23.6 | 358.0 | 47.0 | 228.0 |
| Cadmium | mg/kg | 0.7 | 4.6 | 1.0 | 5.0 | 2.1 | 0.3 | 0.2 | 2.1 |
| Zinc | mg/kg | 78.2 | 209.0 | 97.3 | 377.0 | 162.0 | 14.8 | 4.9 | 114.0 |
| Copper | mg/kg | 2230.0 | 186.0 | 83.4 | 395.0 | 43.5 | 186.0 | 10.5 | 183.0 |
| Nickel | mg/kg | 43.4 | 28.7 | 32.9 | 20.7 | 29.2 | 1.6 | 1.3 | 19.5 |
| Total chrome | mg/kg | 48.4 | 100.0 | 46.9 | 70.9 | 38.9 | 4.8 | 6.1 | 45.5 |
| Arsenic | mg/kg | 43.0 | 42.2 | 14.9 | 97.6 | 6.3 | 40.9 | 3.2 | 41.5 |
| Vanadium | mg/kg | 97.7 | 84.3 | 40.2 | 52.8 | 25.7 | 6.1 | 2.1 | 32.6 |
| Molybdenum | mg/kg | 14.3 | 6.7 | 1.0 | 12.2 | 1.0 | 1.9 | 1.1 | 17.6 |
| PAC | mg/kg | 0.4 | 0.4 | 0.1 | 20.2 | 0.9 | 0.3 | 0.6 | 15.5 |
| $C_{10}$-$C_{40}$ | mg/kg | 64.9 | 114.2 | 60.2 | 1598.3 | 71.8 | 15.5 | 574.7 | 1303.4 |
| Nitrophen | mg/kg | 0.0 | 0.0 | 0.0 | 103.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| Legend: | (grey) | Exceeded limit value | | | | | | | |
| | (red) | Exceeded remediation value | | | | | | | |

**Note:** values for pH, total nitrogen, total phosphate and sulphate are not standardized, and for fluorides was standardized only the limit value.

For the interpretation of the results as a referential standard were used values prescribed with the Regulation on systematic soil quality monitoring program**,** indicators for assessment of risk of soil degradation, and methodology for development of remediation programs (Official Gazette of RS, No. 88/10).

On the basis of the expert processing of the results obtained by the soil investigation from the surface layer it has been ascertained the following:

- In the large number of soil samples it have been ascertained that limits are exceeded by some of the investigated parameters, according to the Regulation;
- The most frequently, deviation is related to existence of the content of some of heavy metals and total hydrocarbons (C10-C40), which are exceeded the remedial value at several locations;
- the presence of pesticide in increased concentrations (location No.4 in front of the nitrophen storehouse) has been ascertained in one soil sample. The nitrophen content in that sample is over 100 mg/kg, which is very high value;
- Concentrations of total nitrogen, total phosphates and sulphates reached very high values at some locations, albeit those values are not standardized;
- Soil`s pH value is mostly compromised at the location behind the sulphuric acid reservoir, where it is 2.1 pH;
- The significant concentrations of polycyclic aromatic hydrocarbons (PAH) are recorded only at two locations, i.e. the locations 4 and 8;

- In the investigated samples presence of polychlorinated biphenyls (PCB) and mercury has not been recorded, and generally observing the most significant contamination of the surface layer within the complex is recorded at the location No.4 To be more specific in front of the nitrophen storehouse between the concrete plateau and the railway, where have been ascertained the highest concentrations (in comparison to the all investigated samples) of a larger number of parameters: cadmium, zinc, arsenic, fluorine, polycyclic aromatic hydrocarbons (PAH), total hydrocarbons (C10-C40) and nitrophen. Besides, it is also recorded high content of lead, copper, chrome and phosphate (the second place in comparison to the values from the other locations).

The review of results for 9 soil samples from the drilled material is provided in Table 5.3.

*Table 5.3:* ***Review of recorded values for 9 soil samples from the drilled material***

| | **Unit** | **Location 1** | | | **Location 2** | | | **Location 3** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Sample 1** | **Sample 2** | **Sample 3** | **Sample 1** | **Sample 2** | **Sample 3** | **Sample 1** | **Sample 2** | **Sample 3** |
| pH | | 6,6 | 8,3 | 9,1 | 7,4 | 8,2 | 9,3 | 5,4 | 7,5 | 7,2 |
| Total nitrogen | mg/kg | 1549,0 | 1598,0 | 452,0 | 1434,0 | 2114,0 | 1099,0 | 890,0 | 623,0 | 343,0 |
| Total phosphorus | mg/kg | 584,0 | 434,0 | 184,0 | 1340,0 | 47,0 | 288,0 | 2300,0 | 711,0 | 624,0 |
| Sulphate | mg/kg | 1458,0 | 1093,0 | 1011,0 | 168,0 | 592,0 | 20,0 | 2079,0 | 7868,0 | 8487,0 |
| Lead | mg/kg | 14,9 | 10,2 | 3,0 | 16,9 | 9,9 | 4,6 | 3,1 | 5,8 | 3,9 |
| Cadmium | mg/kg | 0,0 | 0,0 | 0,0 | 1,2 | 0,2 | 0,0 | 1,8 | 0,0 | 0,0 |
| Zinc | mg/kg | 53,8 | 56,4 | 12,6 | 52,0 | 33,0 | 15,8 | 7,6 | 20,7 | 13,6 |
| Bakar | mg/kg | 20,4 | 17,2 | 4,7 | 23,8 | 14,4 | 6,4 | 4,0 | 9,3 | 6,3 |
| Nickel | mg/kg | 42,3 | 31,6 | 10,9 | 35,2 | 38,5 | 15,5 | 0,7 | 18,4 | 21,3 |
| Total chrome | mg/kg | 36,7 | 22,2 | 11,8 | 23,2 | 20,3 | 12,8 | 4,6 | 14,5 | 17,1 |
| Arsenic | mg/kg | 5,7 | 6,5 | 0,0 | 5,2 | 6,3 | 2,5 | 2,3 | 4,2 | 2,5 |
| Vanadium | mg/kg | 34,0 | 15,4 | 8,0 | 16,1 | 14,1 | 9,1 | 2,1 | 11,9 | 8,2 |
| Fluorine | mg/kg | 36,0 | 28,0 | 8,7 | 51,0 | 55,0 | 13,0 | 759,0 | 31,0 | 28,0 |
| $C_{10}$-$C_{40}$ | mg/kg | 23,5 | 10,9 | 16,2 | 0,0 | 0,0 | 13,1 | 32,7 | 29,5 | 18,7 |
| Legend: | | (grey) | Exceeded limit value | | | | | | | |
| | | (red) | Exceeded remediation value | | | | | | | |

**Note:** values for pH, total nitrogen, total phosphate and sulphate are not standardized, and for fluorides was standardized only the limit value.

On the basis of the results of soil investigations from the drilled material it has been ascertained the following:

- In a certain number of soil samples, limit values are exceeded for some of investigated parameters prescribed by the Regulation on the programme of the systematic monitoring of soil quality, indicators for risk estimate for soil degradation and methodology of development of remedial programme;
- Most frequently, the deviation is related to the increase of content of some heavy metals (nickel and vanadium in 8 samples, copper and cadmium in 2 samples) and total hydrocarbons (C10-C40 in 7 samples), which concentration at no locations have exceeded the remedial value;
- The concentration of total nitrogen, total phosphates and sulphates reached high concentrations, albeit they are not standardized;
- Soil pH value ranges from 6.6 to 6.9, which are characteristics for a normal soil composition.

The presence of pesticides, polychlorinated biphenyls (PCB), and mercury has not been recorded in the investigated samples.

Generally, the concentrations of the investigated parameters which are exceeded limit values in the soil taken from the drilled materials are significantly lower than concentrations recorded in the surface soil layer, and of particular importance is the fact no concentration has exceeded the remediation intervention values according to the prescribed standards of the valid regulation.

The significant frequency of increased values for vanadium, nickel and total hydrocarbons (C-10-C40) in the majority of samples, both from the surface layers and drillholes, point out to a diffusive arrangement of pollution sources and/or pollutants mobility.

## 5.4. Water

Physical and chemical analyses of groundwaters, surface waters and waste waters were conducted during the period 2008-2013 in order to define the quality of water within the holding of IHP Prahovo. They are presented in:

- The Study “Extended Environmental Investigations at Holding IHP AD Prahovo, Fertilizer Factory, Serbia” (INTERGEO Environmental Technology, 2008);
- The Study of Existing Environmental at Holding IHP AD Prahovo (Institute of Public Health, Beograd, 2012);
- The Draft “Strategic Estimate of Environmental Impact – the Plan of detailed regulation for the holding of chemical industry in Prahovo” (Company for Engineering, Consulting, Designing and Construction “SET” Ltd. Šabac, 2013).

In order to estimate a possible impact of the new phosphogypsum storage on water in this complex in the following text are presented certain data from the quoted material.

### Groundwaters

As a part of investigation of environmental factors, the company INTERGEO Environmental Technology conducted physical, chemical analyses of 16 groundwater samples during 2008. On the basis of those analyses it has been ascertained, in accordance with the New Dutch List (target, limit and remediation pollutant values in the New Dutch List[1] are identical as in the Regulation on the pollutant limit values in surface waters and groundwater and sediments and deadlines for their reaching (Official Gazette, No. 50/2012) that remedial values or limit values are exceeded with some samples for the certain number of parameters. The groundwater samples have pH values between 5.6 and 7.6, and only 3 samples had pH value below the limit pH value of 6.5. It has also been ascertained an increased concentration of fluorides, sulphates and nitrates in some samples, while the concentration of total phosphorous ranged from 1-500 mg/l (for surface waters the limit value for the currents class 2, the type 1 is 0.1 mg/l, class 3 - 0.2 mg/l, class 4 - 0.5 mg/l, and for class 5 >0.5 mg/l; while there is no limit value for groundwaters).

Table 5.4: Review of recorded values for 9 soil samples from the drilled material

| | No. of investigated samples | Target value[1/2] | [1]Remediation and limit value [2] | Minimum measured concentration | Maximum measured concentration | No. of samples which exceeds remediation* or limit** value |
|---|---|---|---|---|---|---|
| Arsenic (As). (µg/l) | 16 | 10 | 60 | 2 | 72 | 1* |
| Cadmium (Cd). (µg/l) | 16 | 0.4 | 6 | n.d. | 6 | 1* |
| Nickel (Ni). (µg/l) | 16 | 15 | 75 | 10 | 300 | 3* |
| Aliphatic carbon hydrides (mg/l) | 16 | 0.05 | 0.6 | n.d. | 18 | 2* |
| F (mg/l) | 16 | - | 1.5 | 0.18 | 370 | 15** |
| $SO_4$ (mg/l) | 16 | 25 | 250 | 59 | 1500 | 7** |
| $NO_3$ (mg/l) | 16 | 25 | 50 | n.d. | 150 | 1** |

*[1] NDL – New Dutch List;*
*[2] Regulation on the pollutant limit values in surface waters and groundwater and sediments and deadlines for their reaching (Official Gazette, No. 50/2012).*

[1] NDL

From the quoted study are singled out the results of physical and chemical analyses of three groundwater samples (Table 5.5), which are sampled at sites which are according to the sampling locations nearest to the phosphogypsum storage (Fig.5.3).

Table 5.5: Physical and chemical analysis of groundwater samples M274, Mw73, Mw45 (Fig.5.3), 2008

| Parameter | Mw74 | Mw73 | Mw45 | MAV or LV class II. type 1[1-3] | Remediation intervention values [1] |
|---|---|---|---|---|---|
| pH | 6.7 | 7.1 | 5.7 | 6.5-8.5 | |
| t. $^{o}C$ | 11.1 | 10.5 | 9.5 | | |
| Electro conductivity µS/cm | 1980 | 2150 | 1830 | 1000 | |
| $O_2$. mg/l | 6.65 | 6.9 | 6.9 | 5.0-7.0 | |
| F. mg/l | 10 | 8.4 | 11 | | |
| PO4. mg/l | 444 | 320 | 500 | 0.1 | |
| NO3. mg/l | 1 | 1 | 2 | 3.0 | |
| SO4. mg/l | 922 | 870 | 1500 | 100 | |
| TPH index C10-C40 | | | | | |
| As. mg/l | 0.035 | 0.029 | 0.047 | 0.01 | 0.060 |
| Pb. mg/l | <0.001 | <0.001 | <0.001 | | 0.075 |
| Cd. mg/l | <0.0005 | <0.0005 | <0.0005 | | 0.006 |
| Cr. mg/l | <0.005 | <0.005 | <0.005 | | 0.030 |
| Co. mg/l | | | | | 0.100 |
| Cu. mg/l | <0.005 | <0.005 | <0.005 | 0.040 | 0.075 |
| Mn. mg/l | 1.8 | 0.9 | 2.6 | 0.100 | |
| Ni. mg/l | 0.07 | 0.02 | 0.1 | | 0.075 |
| Hg. mg/l | <0.0002 | <0.0002 | <0.0002 | | 0.0003 |
| Ba. mg/l | <0.005 | <0.005 | <0.005 | | 0.625 |
| Zn. mg/l | 0.07 | <0.01 | 0.08 | | 0.800 |
| Mo. mg/l | <0.005 | <0.005 | <0.005 | | 0.300 |

*MAV – maximum allowable value; LV- limit value

[1] *Regulation on the pollutant limit values in surface waters and groundwater and sediments and deadlines for their reaching (Official Gazette, No. 50/2012);*

[2] *Rulebook on benchmark conditions for types of surface waters (Official Gazette of RS, No. 67/2011);*

[3] *Rulebook on the parameters of chemical and quantitative status of groundwaters (Official Gazette of RS, No. 74/2011)*

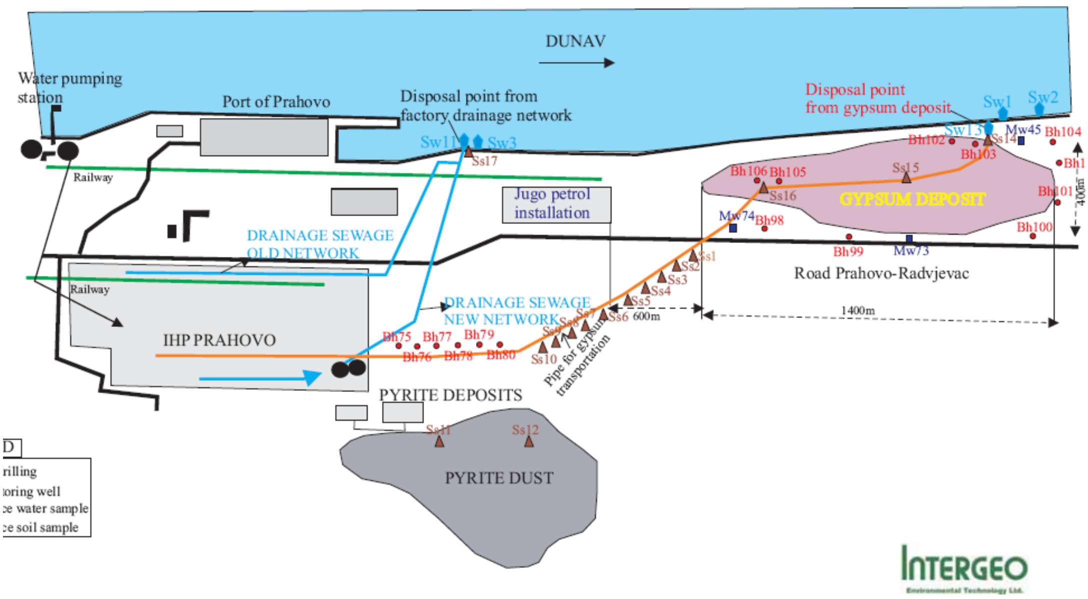



Fig.5.3 The sampling locations of soil (Ss), groundwaters (Mw74, Mw 73 and Mw45) wastewaters (Sw 11 and Sw 13 and surface waters (Sw3, Sw1, Sw2)

According to the obtained results those groundwater samples do not exceed remedial values standardized by the Regulation on the pollutant limit values in surface waters and groundwater and sediments and deadlines for their reaching (OJ of the RoS, No. 50/2012).

If it is commented on the quality of those waters on the basis of the stream standards method (the method based on the quality of recipient's water), according to the values of maximum allowable concentrations or limit values for the class 2 which is required class for the Danube as its possible recipient, at Prahovo's profile for a good ecological status, of a large plain river, with domination of a fine deposit – Type 1[1-3], then those two groundwaters are, according to electro conductivity parameters, of class 4, concentrations of phosphate and sulphates of class 5 (for class 5: $MAV_{phosphates}$ >0.5 mg/l; $MAV_{sulphates}$ >300 mg/l), arsenic - class 3, manganese - class 4 (MAV=1 mg/l) or class 5 (MAV >1 mg/L).

In the following text are provided physical and chemical analyses of the Danube, as well as the parts of the report of the Hydrometeorological Institute of Serbia on the quality of this river at the Prahovo's profile, which indicate that even the Danube was not of the required II class, for the river type 1.

City Institute of Public Health, Beograd also conducted the investigations of groundwater during 2012. It was performed sampling of groundwater from the installed piezometers in order to define water quality. The physical, chemical analysis of three obtained samples included the following parameters: temperatures, oxygen saturation, dissolved oxygen, pH value, electrical conductivity, dried remains, biochemical oxygen demand (BOD), ammonium, nitrates, chlorides, orthophosphates, total phosphate, sulphates, fluorides, suspended materials, polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), total hydrocarbons (C10-C40), pesticides, phenols and metals (Hg, Cd, As, Pb, Zn, Cu, Ni, Cr, Al, B Mo, V, Na, K, Mg, Ca, Fe and Mn).

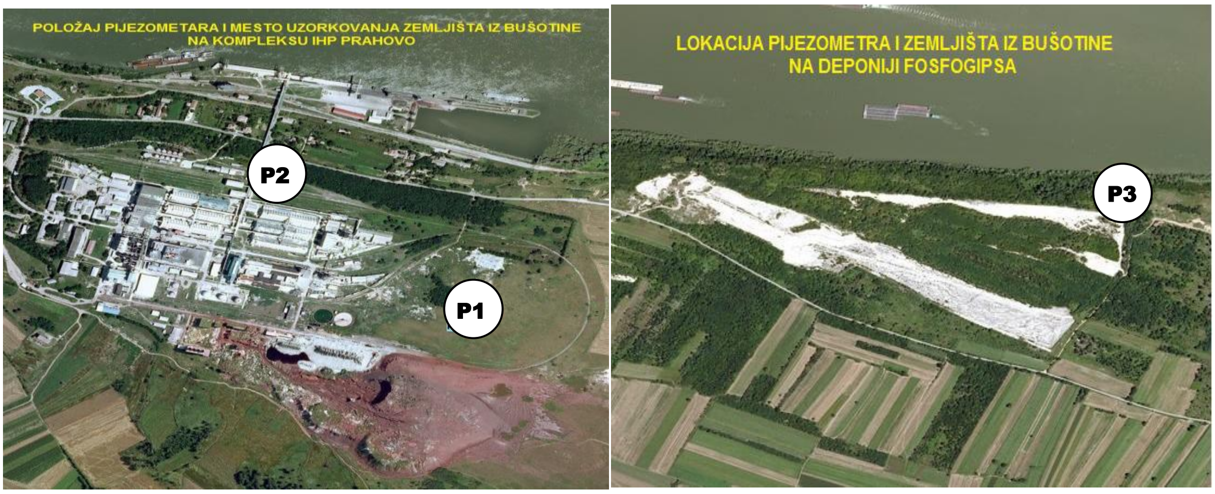



Fig.5.4 Piezometer locations at the complex and the phosphogypsum storage
(Piezometer locations and soil sampling locations from the drillhole at the complex of IHP Prahovo – P2 and P1; Piezometer locations and soil from the drill hole at the phosphogypsum storage- P3)

In Table 5.6 is provided one part of the results of physical and chemical analyses of groundwater from the three piezometers installed in 2012 (the parameters for which are legally standardized values.

On the basis of the obtained results of investigation of the three groundwater samples from the piezometers the following has been ascertained in the Study:

- "in no investigated sample concentrations of the investigated parameters have exceeded limit or remedial values of pollutant materials in groundwater as prescribed by the Regulation;
- the only recorded deviation is related to exceeding of ammonium concentration at the 2 locations in relation to the values for III and IV class of water, according to the Rulebook on the dangerous materials in water (OJ of SRoS, No.31/82)"

The general conclusion of the Study on Existing Environmental Conditions at the Holding of IHP Prahovo which was prepared during 2012 by City Institute for Public Health Belgrade states that contamination at some locations within the Holding of IHP Prahovo is not substantially impacted the groundwater quality.

Table 5.6: Physical and chemical analyses of groundwaters (2012)

| | Unit | Piezometer 1 | Piezometer 2 | Piezometer 3 | Water class Piezometer 3 according to parametru[1] | Remediation intervention values for some water parameters Piezometer 3 |
|---|---|---|---|---|---|---|
| pH value | | 8.40 | 8.20 | 7.30 | I | |
| Electro conductivity | µS/cm | 370.0 | 340.0 | 1990.0 | IV | |
| Dry residue - 105$^{O}$ C | | 253.0 | 223.0 | 1040.0 | | |
| Ammonia | mg/l | 0.92 | 0.09 | 4.5 | V | |
| $NO_2$ | mg/l | 1.44 | 0.44 | 4.4 | V | |
| $NO_3$ | mg/l | 0.38 | 0.06 | 9.3 | IV | |
| Sulphates | mg/l | 43.7 | 24.7 | 1134 | V | |
| $BPK_5$ | mg/l | 12.50 | 12.50 | 21.60 | IV | |
| Total phosphates | mg/l | 0.08 | 0.08 | 4.74 | V | |
| Potassium | mg/l | 2.06 | 1.83 | 3.58 | | |
| Bakar | mg/l | 0.01 | 0.00 | 0.02 | I-II | 0.075 |
| Zinc | mg/l | 0.01 | 0.01 | 0.05 | I-II | 0.800 |
| Arsenic | mg/l | 0.004 | 0.004 | 0.01 | 2-3 (class 2 LV=10 µg/l) | 0.060 |
| Lead | mg/l | 0.03 | 0.00 | 0.03 | I | 0.075 |
| Aluminium | mg/l | 0.07 | 0.18 | 3.73 | | |
| Fluorides | mg/l | 0.17 | 0.23 | 0.22 | | |
| Vanadium | mg/l | 0.001 | 0.001 | 0.01 | | 0.070 |
| Total pesticides | µg/l | 0.04 | 0.10 | 0.00 | | |

*[1] Regulation on the pollutant limit values in surface waters and groundwater and sediments and deadlines for their reaching (Official Gazette, No. 50/2012);*
*[2] Regulation on the programme of the systematic monitoring of soil quality, indicators for risk estimate for soil degradation and methodology of development of remedial programme (Official Gazette of RS, No.88/2010)*

However, we have provided comments on the quality of groundwater from the piezometer 3 in accordance with certain regulations[1, 2], considering that the water was taken from the present phosphogypsum storage which is without hydro insulation and in case of an industrial accident, for example burst of the pipeline or damaging of the liner at the future phosphogypsum storage it is possible that ground water quality would correspond to the quality of groundwater from the piezometer 3.

In Table 5.6, column 4 are provided water classes for some parameters, and in accordance with the Regulation on the pollutant limit values in surface waters and groundwater and sediments and deadlines for their reaching (Official Gazette, No. 50/2012)[1] for the type 1 of plain river, while in the column 5 are provided remediation intervention values for concentrations of standardized parameters from Table 5.6 for groundwater according to the Regulation on systematic soil quality monitoring program**,** indicators for assessment of risk of soil degradation, and methodology for development of remediation programs (Official Gazette of RS, No. 88/2010)[2]. It could be said that those parameters for which exist remediation intervention values of concentrations do not exceed concentrations of the standardized values (Cu, Zn, As, Pb, V). If the quality of water from the piezometer 3 would be commented as the quality of surface water, type 1, then it is noticeable that some parameters are of class 5 ($NH_3$, $NO_2^-$, what would point out to the pollution with nitrogen compounds, sulphates and total phosphates) and that water could not be discharged into that recipient as an effluent in relation to the quality of class 2 stream according to the stream standard method.

Generally, it can be said on the basis of results of the groundwater analysis in the surrounding of the phosphogypsum storage from 2008 and groundwater from the piezometer No.3, that are not exceeded remedial values standardized by Regulation on the pollutant limit values in surface waters and groundwater and sediments and deadlines for their reaching (OJ of the RoS, No. 50/2012).

**Surface waters**

The company INTERGEO Environmental Technology was conducted physical, chemical analyses of 12 water samples which are named “surface waters” during 2008, but, in fact, those were samples of wastewater: the drain canal (Sw4), in proximity of the new pipeline (Sw5-Sw10), the drain canal in proximity of the sulphuric acid reservoir (Sw15) and the wastewaters which can have a direct impact on the quality of water in the Danube River, as its recipient - wastewater from the factory’s drain network (total wastewater from the factory grounds – waste water collector, Sw11) and spillway of the present phosphogypsum storage (Sw13). Furthermore, the analysis of water from the Danube River was performed (Sw3), below the discharging location of the spillway of the phosphogypsum storage into the Danube River.

In Fig.5.3 are provided the wastewaters sampling locations Sw11 and Sw13 and the Danube (V). In Table 5.2 is provided description of sampling location and the major pollutants in the wastewater samples Sw4-Sw15, while Table 5.8 shows physical and chemical sample analyses Sw4-Sw15 and water samples from the Danube (Sw3 and Sw1).

In the Study prepared in 2008 . It has been concluded that in the majority of the investigated 12 wastewater samples, has low pH value (below pH 6.5), it is detected an increased content of sulphates and heavy metals (As, Cu, Ni, Cd, Cr), and in a smaller number of samples the increased total petroleum hydrocarbon (TPH) content is detected. Table 5.9 shows wastewater parameter values which exceeded remediation and limit values.

Table 5.7: Wastewater samples IDs, sampling locations and main polluters (2008)

| Sample | Sampling locations | Main pollutants |
|---|---|---|
| Sw4 | Drainage canal | -- |
| Sw5 | In proximity of the new drain pipeline | Low pH value, increased concentration $SO_4$, As, Cu, Cr, Cd |
| Sw6 | In proximity of the new drain pipeline | Low pH value, increased concentration F, $SO_4$, Cd, Cu, Cr, Zn |
| Sw7 | In proximity of the new drain pipeline | Low pH value, increased concentration F, $NO_3$, Cd ,Cu, Cr, Zn, Ni |
| Sw8 | In proximity of the new drain pipeline | Low pH value, increased concentration F, $NO_3$, As, Cd, Cu ,Cr, Zn, Ni |
| Sw9 | In proximity of the new drain pipeline | Mala pH value, increased concentration F, $NO_3$, $SO_4$, As, Pb, Cd, Cu, Cr, Zn, Ni |
| Sw10 | Drainage canal in proximity of the phosphoric acid reservoir | -- |
| Sw11 | Discharge location of drainage from the factory in proximity of the Danube | Low pH value, increased concentration a NO3, $SO_4$, TPH* |
| Sw12 | Wastewater from the fuel oil reservoir | Low pH value, increased concentration TPH, Zn |
| Sw13 | Overflow of the present phosphogypsum storage in proximity of the Danube | Low pH value |
| Sw14 | Drainage canal in proximity of the old drain pipeline | Low pH value, increased concentration F, SO4, As, Pb, Cr |
| Sw15 | Drainage canal of the sulphuric acid reservoir | Low pH value, increased concentration F, NO3, SO4, As, Pb, Cd, Cu, Cr, Zn, Ni |

** (TPH) total petroleum hydrocarbon – the term related to several hundred chemical compounds which originated from crude petrol*

Table 5.8: Physical and chemical analyses of water samples Sw1, Sw3-Sw15

| Parameter | Sw1 | Sw3 | Sw4 | Sw5 | Sw6 | Sw7 | Sw8 | Sw9 | Sw 10 | Sw 11 | Sw12 | Sw13 | Sw14 | Sw 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 7.4 | 7.5 | 7.8 | 3.2 | 2.9 | 2.8 | 2.6 | 2.8 | 6.7 | 2.3 ? | 6.5 | 6.2 | 2.4 | 2.5 |
| t, $^oC$ | 3.3 | 3.8 | 5.2 | 6.8 | 3.9 | 3 | 2.8 | 4.1 | 3.9 | 14.6 | 13.7 | 5.3 | 9.5 | 11.1 |
| Electro conductivity, µS/cm | 900 | 952 | 986 | 1881 | 5880 | 8400 | 8180 | 9980 | 1161 | 4520 | 1380 | 2100 | 2150 | 1890 |
| $O_2$, mg/l | 7.8 | 7.9 | 6.25 | 6.15 | 5.95 | 5.25 | 5.3 | 5.2 | 6.3 | 4.3 | 3.1 | 5.1 | 5.6 | 5.5 |
| F, mg/l | 0.69 | 0.92 | 1.7 | 1.4 | 26 | 140 | 9 | 75 | 1.4 | 0.71 | 0.45 | 0.28 | 32 | 28 |
| PO4, mg/l | 0.45 | 3.2 | 10 | 320 | 1.4 | 0.22 | 32 | 24 | 0.12 | 560 | 0.33 | 0.35 | 12 | 11 |
| NO3, mg/l | 7 | 8 | 9 | 9 | 37 | 100 | 76 | 70 | 11 | 140 | 5 | 6 | 28 | 32 |
| SO4, mg/l | 69 | 73 | 42 | 220 | 1800 | 9 | 10 | 3400 | 120 | 990 | 52 | 50 | 2900 | 19000 |
| TPH index, C10-C40 | <0.01 | <0.01 | | | | | | | | 0.9 | | - | | |
| As, mg/l | 0.001 | 0.002 | 0.001 | 0.009 | 0.001 | 0.002 | 0.55 | 0.32 | <0.001 | 0.002 | 0.001 | 0.001 | 0.006 | 0.51 |
| Pb, mg/l | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | 0.003 | 0.006 | 0.008 | <0.001 | <0.001 | <0.001 | <0.001 | 0.013 | 1.1 |
| Cd, mg/l | <0.0005 | <0.0005 | <0.0005 | 0.0076 | 0.022 | 0.058 | 0.063 | 0.06 | 0.0008 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 |
| Cr, mg/l | <0.005 | <0.005 | <0.005 | 0.062 | 0.08 | 0.14 | 0.23 | 0.25 | <0.005 | <0.005 | <0.005 | <0.005 | 0.01 | 3.6 |
| Co, mg/l | <0.005 | <0.005 | | | | | | | | | | - | | |
| Cu, mg/l | <0.005 | <0.005 | <0.005 | 0.43 | 19 | 34 | 28 | 66 | 0.068 | 0.052 | <0.005 | <0.005 | 0.021 | 5.1 |
| Mn, mg/l | <0.005 | <0.005 | <0.005 | 0.36 | 10 | 9 | 17 | 20 | 0.34 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| Ni, mg/l | <0.005 | <0.005 | <0.005 | 0.05 | 1 | 1 | 0.8 | 2 | 0.03 | 0.03 | 0.03 | <0.005 | 0.007 | 2 |
| Hg, µg/l | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| Ba, mg/l | 0.019 | 0.025 | 0.024 | 0.022 | 0.006 | 0.017 | 0.007 | 0.013 | 0.023 | 0.009 | 0.007 | 0.005 | 0.097 | 0.03 |
| Zn, mg/l | 0.72 | 0.8 | <0.01 | 0.48 | 8.1 | 15 | 11 | 24 | 0.25 | 0.62 | 0.95 | 0.28 | 0.16 | 15 |
| Mo, mg/l | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | 0.12 |
| PAH, µg/l | <1 | | | <1 | | <1 | <1 | | <1 | <1 | <1 | <1 | <1 | |
| PCB, µg/l | <1 | | | <1 | | <1 | <1 | | <1 | <1 | <1 | <1 | <1 | |
| HCH , µg/l | <1 | | | <1 | | <1 | <1 | | <1 | <1 | <1 | <1 | <1 | |
| Chlorobenzene µg/l | <1 | | | <1 | | <1 | <1 | | <1 | <1 | <1 | <1 | <1 | |
| Aliphatic hydrocarbons µg/l | <100 | | | <100 | | <100 | <100 | | <100 | 1200 | 1800 | <100 | <100 | |
| Chlorophenol µg/l | <10 | | | <10 | | <10 | <10 | | <10 | <10 | <10 | <10 | <10 | |
| Organochlorine pesticide µg/l | <1 | | | <1 | | <1 | <1 | | <1 | <1 | <1 | <1 | <1 | |
| Phenol, µg/l | <1 | | | <1 | | <1 | <1 | | <1 | <1 | <1 | <1 | <1 | |
| Phthalates µg/l | <1 | | | <1 | | <1 | <1 | | <1 | <1 | <1 | <1 | <1 | |

Table 5.9: Parameters for which are exceeded remediation or limit values with samples Sw4-Sw15 (Extended environmental investigation, phase II at the chemical industrial complex IHP and Prahovo Fertilizer Factory in Prahovo, Serbia, 2008)

| | **No. of tested samples** | **Target value[1,2]** | **Remediation intervention value[1] and limit value[2]** | **Minimum measured concentration** | **Maximum measured concentration** | **No. of samples which exceed remediation or limit value** |
|---|---|---|---|---|---|---|
| pH | 12 | - | - | 2.3? (Sw11) | 7.8 (Sw4) | 10 |
| Arsenic (As). (µg/l) | 12 | 10 | 60 | n.d. | 550 (SW8) | 5 |
| Cadmium (Cd). (µg/l) | 12 | 0.4 | 6 | n.d. | 63 (SW8) | 6 |
| Nickel (Ni). (µg/l) | 12 | 15 | 75 | n.d | 2000 (SW15. SW9) | 4 |
| Lead (Pb). (µg/l) | 12 | 15 | 75 | n.d. | 1100 (SW15) | 3 |
| Chrome (Cr), (µg/l) | 12 | 15 | 75 | n.d | 36000 (SW15) | 7 |
| Bakar (Cu). (µg/l) | 12 | 1 | 30 | n.d. | 66000 (SW9) | 6 |
| Zinc (Zn). (µg/l) | 12 | 65 | 800 | n.d. | 24000 (SW 9) | 6 |
| Aliphatic hydrocarbons (mg/l) | 12 | 0.05 | 0.6 | n.d. | 18 (SW11. SW12) | 2 |
| F mg/l | 12 | - | 1.5 | 0.28 | 140 (SW7) | 5 |
| SO4 mg/l | 12 | 25 | 250 | 9 | 19000 (SW15) | 6 |
| NO3 mg/l | 12 | 25 | 50 | 5 | 140 (SW11) | 5 |

*NDL – New Dutch List;*

[2] *Regulation on the pollutant limit values in surface waters and groundwater and sediments and deadlines for their reaching (Official Gazette, No. 50/2012).*

Considering that it is required to estimate within this study whether the new phosphogypsum storage will have impact on the quality of surface waters and groundwaters in case of industrial accidents, it is singled out the physical and chemical analysis of waste water which represents overflow of the existing phosphogypsum storage, Sw13 (Table 5.10).

As it has already been mentioned the existing phosphogypsum storage (Fig.5.5) is located 2.4 km from the factory on the Danube bank, in the area of villages Prahovo and Radujevac, in the natural depression. It spreads on around 56 ha. From the factory is transported phosphogypsum, which is a by-product from the phosphoric acid production, in the form of water suspension via the 2.4 km pipeline to the storage. The main problems is posed with the fact that storage does not have hydro insulation and, secondly, overflow as an effluent is directly comes down in the Danube through the storage's overflow dam. The sampling location of waste dump's overflow is presented in Fig.5.3. The waste dump is currently filled and its capacity is increased with elevation of the dike (addition of phosphogypsum). Occasionally, phosphogypsum water suspension causes breach of waste dump's periphery and, therefore occur seepage to the surrounding soil. At the moment, around 8,000,000 t of phosphogypsum is deposited in the dump.

Table 5.10: Physical and chemical analyses of overflow from the phosphogypsum storage (sample Sw13, 2008) and values of some parameters according to certain Regulations 1-3

| **Parameter** | **GVE**[1] | **Water class per parameter (LV)**[2] | **Remediation value** [2-4] | **Sw13** |
|---|---|---|---|---|
| pH | 6.5-9 | 6.5-8.5 (outside classes - VK) | | 6.2 |
| t. $^{o}$C | 30 | | | 5.3 |
| Electro conductivity µS/cm | | IV class (1500-3000) | | 2100 |
| $O_2$. mg/l | | II b class (5-6) | | 5.1 |
| F. mg/l | | | | 0.28 |
| PO4. mg/l | | IV class (0.2-0.5) | | 0.35 |
| NO3. mg/l | | III class (II class do 3) | | 6 |
| SO4. mg/l | | I-II class | | 50 |
| TPH index. C10-C40 | | I-II | | - |
| As. mg/l | 0.1 | I class (<5 µg/l) | 60 µg/l | 0.001 |
| Pb. mg/l | 0.5 | I class (<0.05) | 75 µg/l | <0.001 |
| Cd. mg/l | 0.1 | I class (<0.5 µg/l) | 6 µg/l | <0.0005 |
| Cr. mg/l | 0.5 | II class (25-50 µg/l) | 30 µg/l | <0.005 |
| Co. mg/l | | | 100 mg/l | - |
| Cu. mg/l | 0.5 | I class (5 µg/l) | 75 µg/l | <0.005 |
| Mn. mg/l | | I class (50 µg/l) | | <0.005 |
| Ni. mg/l | 1 | | 75 µg/l | <0.005 |
| Hg. mg/l | 0.05 | | 0.3 µg/l | <0.0002 |
| Ba. mg/l | | | 625 µg/l | <0.005 |
| Zn. mg/l | | I-II class (<2000 µg/l) | 800 µg/l | <0.28 |
| Mo. mg/l | | | 300 µg/l | <0.005 |
| PAH. µg/l | | | | <1 |
| PCB. µg/l | | | | <1 |
| HCH (hexachlorocyclohexane), µg/l | | | | <1 |
| Chlorobenzene, µg/l | | | 0.5-180 | <1 |
| Aliphatic hydrocarbons µg/l | | | | <100 |
| Chlorophenol, µg/l | | | 10 | <10 |
| Organochlorine pesticide, µg/l | | | | <1 |
| Phenols, µg/l | | I-II class (<1) | | <1 |
| Phthalates, µg/l | | | | <1 |

*[1] Regulation on emission limit values in waters and deadlines for their reaching (Official Gazette of RS, No. 67/11 and 48/2012);*
*[2]Regulation on the pollutant limit values in surface waters and groundwater and sediments and deadlines for their reaching (Official Gazette, No. 50/2012);*
*[3] Regulation on the programme of the systematic monitoring of soil quality, indicators for risk estimate for soil degradation and methodology of development of remedial programme (Official Gazette of RS, No.88/2010);*
*[4] New Dutch List.*

On the basis of the obtained results, considering the valid legislation it can be concluded that water from the storage's existing spillway (Sw13) is in accordance with the defined parameters for the class I and II (Table 5.10). The water is only in relation to nitrate of the III class, and for phosphates and electrical conductivity of the IV class. When the values of those parameters are compared the parameters in samples Sw11 ($PO_4$ 560 mg/l; $NO_3$ 140 mg/l) and Sw3 ($PO_4$ 3.2 mg/l; $NO_3$ 8 mg/l) with the values for samples Sw13 ($PO_4$ 0.35 mg/l; $NO_3$ 6 mg/l) and Sw1 ($PO_4$ 0.45 mg/l; $NO_3$ 7 mg/l) it can be said that, according to the stream standards methodology, water from the spillway of the present phosphogypsum storage does not have impact on the water quality in the recipient, i.e. the Danube River, for these parameters.

As for pH value of the water from the spillway of the phosphogypsum storage it is somewhat lower than the emission limit value, or limit value of 6.5, and according to that parameter it would be classified in the class V. However, the analysis of water from the Danube River, downstream from the discharge locations of this effluent indicated that pH value of water from the Danube River is 7.4 (Sw1, Table 5.8). Furthermore, if pH value of the wastewater from the collector, pH=2.3 (S211) and pH=7.4 of the water from the Danube River below the discharging of the collector's wastewater (Sw3)are compared, what is above the location of the phosphogypsum storage's spillway, and aforementioned pH values for Sw13 and Sw1, it is concluded that the storage's spillway does not have impact on the quality of water in the recipient for this parameter.


Fig.5.5 Location and view of the existing phosphogypsum storage IHP Prahovo

Finally, on the basis of the results it could be generally said that the wastewater from the collector Sw11 has the main impact on the quality of the water in the Danube River since at the measuring location Sw3 and Sw1 the water is classified in the V class for phosphate. However, it is observed that the Danube water significantly dilute the collector's wastewater, considering that the phosphate concentration is around 175 times lesser in the Danube's water (Sw3) than in the collector's water (Sw11) or in Sw1's water (below the inflow of water from the phosphogypsum storage).

It can be also said that the analyzed groundwaters, particularly those sampled around and at the phosphogypsum storage in 2008 did not have impact on the Danube's water quality.

The accredited organization, i.e. Institute for Quality of Work Environment and Surroundings "1st May" the joint-stock company Niš, was performed analysis of water during the zero state in order to investigate the quality of environmental factors. The similar investigations of water quality are performed by the accredited laboratory – Anahem from Belgrade. The sampling was conducted on 21.12.2012. The obtained results (available from the Strategic Estimate of Environmental Impacts – the Detailed Regulation Plan for the chemical industrial complex IHP Prahovo in Prahovo, 2013) are presented in Table 5.11 and 5.12.

Before the presentation of comments which is part of the quoted strategic estimate of impact we underline that the Danube is classified according to the Rulebook on referential conditions of surface water types (Official Gazette of RS, No. 67/11) in large plain rivers, domination of a fine deposit (Type1), and according to the Rulebook on parameters for ecological and chemical status of surface waters and parameters for chemical and quantitative status of groundwaters (Official Gazette of RS, No. 74/2011) in the II class for which limit values (LV and MAC) or pollutant materials are defined with the Regulation on the pollutant limit values in surface waters and groundwater and sediments and deadlines for their reaching (Official Gazette, No. 50/2012), and on the basis of that have been made some correction in Table 5.11 and 5.12 (values in brackets) in relation to the values provided in the Strategic Estimate of Environmental Impacts.

Table 5.11: Physical and chemical analyses of wastewater from the collector (0467 WW), the Danube's water upstream (0468 WW) and downstream (0469 WW) from the wastewater discharge site, October 2012

| **Investigated parameter** | **Detected value in sample** | | | **MAC[1]** |
|---|---|---|---|---|
| | **0467 OV** | **0468 OV** | **0469 OV** | |
| Temperature of water/air ($^oC$) | 15.6/20 ± 0.4 | 20.1/20 ± 0.4 | 20.3/20 ± 0.4 | Do 28 (33) |
| Water color (μm) | Without | Without | Without | Without |
| Water odour | Without | Without | Without | Without |
| Floating materials | Without | Without | Without | Without |
| pH values | 7.1 ± 0.02 | 8.0 ±0.02 | 7.95 ± 0.02 | 6.8 -8.5 (6.5-8.5) |
| Deposited material per IMHOFF-u (ml/l) | 0.4 ±3 % | 0.3 ±3 % | 0.3 ± 3 % | / |
| Suspended materials at 105 $^oC$ (mg/l) | 127 ± 18% | 29 ± 18% | 28 ± 15% | 30 (25) |
| Residue after evaporation at 105 $^oC$ (mg/l) | 426±5% | 128±5% | 132±5% | 1000 |
| Consumption KMnO4 (mg/l) | 52.6±15% | 10.9±15% | 11.21±15% | 12 (10) |
| Biochemical oxygen consumption $BPK_5$ (mg $O_2$/l) | 24.6±17% | 3.13±17% | 3.22±17% | 4 (5) |
| Chemical oxygen consumption (HPK from $K_2Cr_2O_7$) (mg $O_2$/l) | 131 | / | / | / (15) |
| Nitrates $NO_3^-$, as N (mg/l) | 0.15±10% | 0.29±10% | 0.32±10% | 10 (3) |
| Nitrates $NO_2^{-}$, as N (mg/l) | 0.016±8% | 0.007±8% | 0.009±8% | 0.05 (0.03) |
| Ammonium ion, $NH_4^+$ (mg/l) | 1.22±7% | 0.15±7% | 0.17±7% | 1 (0.3) |
| Chloride, $Cl^-$(mg/l) | 33.1±4% | 20.1±4% | 23.4±4% | / (100) |
| Sulphates, $SO_4^{2-}$ (mg/l) | >40±4% | >40±4% | >40±4% | / (100) |
| Phenols (mg/l) | /±6% | /±6% | /±6% | 0.001 |
| Detergents (as LAS) (mg/l) | 0.31±6% | <0.025±6% | <0.025±6% | 0.4 (0.2) |
| Oil and grease (mg/l) | <0.3±18% | <0.3±18% | <0.3±18% | 0.05 |
| Iron. Fe (mg/l) | 0.19±3% | 0.11±3% | 0.10±3% | 0.3 (0.5) |
| Chrome (total) (mg/l) | /±9% | /±9% | /±9% | 0.1 |
| Bakar. Cu (mg/l) | /±2% | /±2% | /±2% | 0.1 (0.5) |
| Nickel, Ni (mg/l) | /±2% | /±2% | /±2% | 0.05 |
| Cadmium, Cd (mg/l) | /±5% | /±5% | /±5% | 0.005 |
| Zinc, Zn (mg/l) | 0.06±6% | 0.04±6% | 0.04±6% | 0.2 (0.3-2) |
| Lead, Pb (mg/l) | /±3% | /±3% | /±3% | 0.05 |
| Dissolved oxygen (mg/l) | /±1.5 | 8.05±1.5% | 8.14±1.5% | Min 6 (min.7) |

*[1]MAC (maximum allowable concentrations) for the II class need to be values from the Regulation on the pollutant limit values in surface waters and groundwater and sediments and deadlines for their reaching (Official Gazette, No. 50/2012); In the column 5 in brackets are MACs adjusted according to the Regulation in relation to MACs presented in the Strategic Estimate of Environmental Impacts from 2013.*

Institute for Quality of Work Environment and Surroundings “1st May” the joint-stock company Niš, was performed analysis of wastewater samples from the collector (0467 WW) and the water samples from the Danube River upstream (0468 WW) and downstream (0469 WW) from the wastewater discharge location (0467 WW). In the report compiled by Institute for Quality of Work Environment and Surroundings it is written: *“The estimate of quality is made with comparison of the obtained results on the downstream sample from the Danube River, after inflow wastewater from the collector and its complete mixing and maximum allowable concentrations, indicators of the quality of II class river, to which the quoted water course belongs and which is the recipient of wastewater.”*

On the basis of the given analysis, the conclusion is that the quality of wastewater satisfies the provision from the Rulebook and regulations regarding the content of pollution parameters and therefore, the wastewaters can be discharged in the quoted recipient.

Table 5.12: Physical and chemical analyses of wastewater from the collector (total wastewater at the discharge point, sample 1), the Danube’s water upstream (2) and downstream (3) from the wastewater discharge site, December 2012

| **Investigated parameter** | **Detected value in sample** | | | **MAC[1]** |
|---|---|---|---|---|
| | **1** | **2** | **3** | |
| Color change | Yellow | Transparent | Transparent | |
| Presence and odour type | Without | Without | Without | |
| Visible waste materials | Without | Without | Without | |
| pH values | 8.3 | 8.2 | 8.2 | 6.5-8.5 |
| Electro conductivity, (µS/cm) | 560 | 362 | 366 | 1000 |
| Ammonium ion (mg/l) | <0.1 | <0.1 | <0.1 | 0.1 (0.3) |
| Nitrogen according to Kjeldahl (mg/l) | <0.05 | <0.05 | <0.05 | / |
| Dry residue at 180 $^oC$ (mg/l) | 460 | 270 | 320 | / |
| Suspended materials, (mg/l) | 180 | 56 | 68 | 25 |
| Sediment materials (ml/l) | <0.2 | <0.2 | <0.2 | / |
| Consumption $KMnO_4$ (mg $KMnO_4$/l) | 6.5 | 3.9 | 9 | 10 |
| Nitrates (mg N/l) | <0.005 | <0.005 | <0.005 | 0.01 (3.0) |
| Nitrites (mg N/l) | 8.6 | 8.4 | 9.7 | 3.0 (0.03) |
| Sulphates (mg/l) | 180 | 30 | 39 | 50 (100) |
| Chlorides (mg/l) | 19 | 16 | 16 | 50 (100) |
| Greases and oils (mg/l) | <0.1 | <0.1 | <0.1 | / |
| Detergents anions (mg/l) | <0.03 | <0.03 | <0.03 | 0.2 |
| Phenol index (mg/l) | <0.001 | <0.001 | <0.001 | 0.001 |
| HPK (mg/l) | 20 | 12 | 14 | 15 |
| $BPK_5$ (mg/l) | 5.8 | 5.1 | 5.9 | 4.5 (5) |
| Iron (mg/l) | <0.3 | <0.3 | <0.3 | 0.5 |
| Manganese (mg/l) | <0.05 | <0.05 | <0.05 | 0.1 |
| Nickel (mg/l) | <0.01 | <0.01 | <0.01 | / |
| Lead (mg/l) | <0.01 | <0.01 | <0.01 | / |
| Bakar (mg/l) | <0.04 | <0.04 | <0.04 | 0.04 |
| Chrome (mg/l) | <0.01 | <0.01 | <0.01 | 0.7 (0.05) |
| Cadmium (mg/l) | <0.0005 | <0.0005 | <0.0005 | / |
| Phosphorous, total (mg/l) | <0.01 | <0.01 | <0.01 | 0.2 |
| Dissolved oxygen | / | 12.7 | 12.8 | Min 7 |
| **Note:** | | | | |
| Sample No. 1 | Total wastewater at a discharge point | | | |
| Sample No. 2 | Surface water, the Danube, upstream | | | |
| Sample No. 3 | Surface water, the Danube. downstream | | | |

*[1]MAC (maximum allowable concentrations) for the II class need to be values from the Regulation on the pollutant limit values in surface waters and groundwater and sediments and deadlines for their reaching (Official Gazette, No. 50/2012); In the column 5 in brackets are MACs adjusted according to the Regulation in relation to MACs presented in the Strategic Estimate of Environmental Impacts from 2013*

We are of an opinion that the wastewater from the collector is not of the II class for the following parameters: suspended materials, biochemical oxygen demand (BOD), chemical oxygen consumed, concentration of ammonium ions, detergents. However, the quality of the Danube’s water upstream and downstream from the wastewater discharge location is, according to the results, of the II class except for suspended materials. Thus, it can be said that wastewater does not influence the quality of the recipient. As for the concentrations of oil and grease, the comments are not provided since it cannot be said whether the value <0.3 mg/l lesser than the value of maximum allowable concentration (MAC).

The authorized and accredited laboratory Anhem from Belgrade also performed analyses of wastewater samples, water from the Danube River upstream and downstream from the discharge location (sampling as of 21.12.2012). The results are presented in Table 5.12 in the Strategic Estimate of Environmental Impact – the Detailed Regulation Plan for the chemical industrial complex IHP Prahovo (2013), and the following comment on those results is provided:

The results of investigations indicate that concentrations of the all parameters, except suspended materials, BOD, and nitrates in the samples from the Danube River 100 m upstream and downstream from the inflow of waste water, are below maximal allowable concentrations prescribed by the Regulation. The difference in concentrations of the quoted parameters is insignificant and indicate that the wastewater from the factory does not substantially influence the quality of the River Danube.

According to the valid regulations the Danube at Prahovo has been classified in the II category water streams, i.e. the water quality should satisfy provisions for the II category of river waters. The flow regime is regulated with the operation of HPP Djerdap II, and it also has impact on the quality of river water downstream from the dam.

According to the report by Hydrometeorological Institute of Serbia, the quality of the Danube's water on the route from the dam to the border with the Republic of Bulgaria occasionally do not correspond to the prescribed quality from physical and chemical and microbiological aspect.

From the physical and chemical parameters deviations are recorded with the percentage of oxygen saturation, iron content as well as the content of hydrocarbons of petrol origin.
From the microbiological aspect, occasionally occur an increased titre of total coliform bacteria. The phosphate content is not standardized, but are occasionally detected high concentration of ortho-phosphates and total phosphorus.

Saprobiological investigations of the Danube's water quality pointed out to the presence of moderate organic pollution. In the water stream dominates bioindicators and mesosaprobic zones. In the all investigation periods was characteristic domination of centric and silicate alga, while during summer periods it was detected a significant presence of green alga.

However, our conclusion is that the results from Table 5.12 indicate that biochemical oxygen demand (BOD) values for the all three samples are above the maximum allowable concentration for the II class, and for this parameter the analyzed water belongs to the III class (5>BOD≤7). In fact, the Danube River has somewhat higher value than the maximum allowable value for the II class (5.1 mg $O_2$/l).

Those samples neither belongs to the II class for suspended materials, and it ought to be underlined that the Danube's water 100 m upstream from the wastewater discharge location was not of the II class (56 mg/l), and that the wastewater (180 mg/l) increased the concentration of suspended materials in the Danube's water downstream from the discharge location (88 mg/l).

As for nitrites and nitrates we are of opinion that it was made an erroneous review of MAC values or the results were commuted. If maximum allowable concentrations (MAC) were commuted, in that case in the water samples are increased nitrite concentrations (the all three samples are of the V class according to this parameter), what would point out to a resent pollution with nitrogen. However, it needs to be emphasized that the Danube was of the V class upstream from the discharge site. On the other hand, if the results were commuted then waters would be of the V class in relation to nitrates (the old or continual nitrogen pollution).

Finally, if the wastewater samples from the collector are compared which are analyzed during the period 2008-2012 it is noticed that the values of some parameters are substantially different (for example, pH), what can be explained with the fact that all production facilities in the complex worked or not worked in certain periods. Consequently, it had impact on the quality of wastewater which was discharged in the recipient, i.e. the Danube River. It has already been mentioned that the wastewater from the collector can influence the quality of the Danube’s water. However, most frequently the Danube’s water upstream from the wastewater discharge location for the collector was not, of the required II class, and the quantity of the Danube’s water has impact on a great dilution of wastewater and as a result, the quality of the Danube’s water downstream in relation to the water quality upstream from the inflow location is not substantially changed.

## 5.5. Air

With deposition of air impurities first of all of particles pollution onto the soil surface and their dissolution and rinsing into the deeper soil parts which can be brought into a direct connection to the quality of air and soil. Depending on chemical properties of deposited dust and its capability of dissolution the indirect connection between the deposited materials and surface waters, i.e. groundwaters can be realized. From that aspect, the knowledge of air quality represents a significant step in the process of protection of soil and water quality.

Institute for Technology of Nuclear and Other Raw Materials (ITNMS) was conducted during 2010 (May-September) investigations of the total deposited materials. The settlers were situated in the surrounding of storage area, at 14 locations on the distances from 500-2500 m.

On the basis of the data obtained with the investigation of granulometric characteristics of the deposited material, it can be assumed that from the storage’s surface occurs emissions of particles with diameter <μm. The proved negative effects of inhalation suspended particles mostly depend on particle size, scope of exposition (duration and concentration in air), but also on other factors (individual respiratory characteristics, age, sex, the state of health, etc.).

The impact of suspended particles is the result of their physical action on the respiratory system and the defensive reaction of the organism. In situations when it is case only about physical impacts, particle size is of great importance.

For the said location it is of importance a potential emission of micro particles in air, since those particles, unlike deposited material, stay in atmosphere for long periods and can be transferred to larger distances. In the concrete case the deposited materials are of primary importance for the agricultural areas in the surrounding, and to lesser extent for surface waters and groundwaters, while suspended particles could be transferred to larger distances, i.e. to the surrounding settlements. The impact on the employed staff in the complex need not to be neglected.

The investigations of total deposited materials were conducted by Institute for Technology of Nuclear and Other Mineral Raw Materials (ITNMS) during 2010 (in the period May-September). The precipitators were located in the surrounding of the storage area at 14 locations at distances from 500m to 2500 m.

During the period in which measurements were conducted total deposited materials only exceeded on two days limit values of 300 mg/m$^2$/24h.

During the measuring period, the deposited materials only exceeded limit values of 300 $mg/m^2/24h$ in two days. The quantity of dissolved and undissolved part varied, depending on the quantities of total deposited materials and the represented dissolved part was somewhat bigger with it.

During 2012, City Institute for Public Health, Belgrade was conducting sampling of ambient air for requirements of the definition of zero-state at the location of the primary school in Prahovo and in no case occurred exceeding of the limit values. The results of those measurements are provided in Table 5.13.

As it can be seen from Table 5.13, in no case occur exceeding of HF limit values for the II harmfulness class.

Table 5.13: Physical and chemical analyses of wastewater from

| Date | Sample No. | Investigated parameter HF($\mu g/m^3$) |
|---|---|---|
| 07.09.2012. | 12-09-7043 | <1.4 |
| 08.08.2012. | 12-09-7214 | <1.4 |
| 09.09.2012. | 12-09-7215 | <1.4 |
| 10.09.2012. | 12-09-7216 | <1.4 |
| 11.09.2012. | 12-09-7217 | <1.4 |
| 12.09.2012. | 12-09-7344 | <1.4 |
| 13.09.2012. | 12-09-7345 | <1.4 |
| 14.09.2012. | 12-09-7346 | <1.4 |
| 15.09.2012. | 12-09-7347 | <1.4 |
| 16.09.2012. | 12-09-7343 | <1.4 |
| 17.09.2012. | 12-09-7456 | <1.4 |
| 18.09.2012. | 12-09-7457 | <1.4 |
| 19.09.2012. | 12-09-7458 | <1.4 |
| 20.09.2012. | 12-09-7459 | <1.4 |

HF – Flour and its compound expressed as hydrogen fluoride

## 5.6. Radiological investigations

The radiological investigations were conducted on soil samples (more specifically, one sample from the surface layer and one sample from the drilled material), groundwater (one sample from each piezometer), NPK fertilizer samples and waste samples (20 samples). The testing was performed in the Laboratory for Protection from Radiation and Environmental Protection of Institute for Nuclear Sciences Vinča. On the basis of results it was ascertained the following:

- in the tested soil samples (from the surface layer and drilled material) it was not detected the presence of radionuclides above the prescribed limits for radioactive contamination;
- in the groundwater samples the measured values and activities are in accordance with the valid legislation;
- in one NPK fertilizer sample was recorded radioactivity; and
- in waste samples it was not recorded increase of radioactivity above prescribed limits.

## 5.7. Climate factors

As for climate factors, i.e. micro climate of a certain location and its predisposition to changes under impact of some project in case of IHP Elixir – Prahovo it is obvious it is not possible. The characteristic of the said project is such that is will not impact in any way change of climate factors at the location, both at macro and micro level. The eventual change of air currents, due to establishment of the phosphogypsum storage, would be of a very local character, more specifically in the immediate proximity of the storage. Accordingly, since climate characteristics are described in more details in the Section 2 herein, in the following text will be only provided a brief review of climate factors at the location.

Negotin is located in the plain surrounded with mountain ranges (Miroč, Crni Vrh and Deli Jovan) and the open area from the east and the south. It conditions a very specific climate in Negotin. Because of the hottest summer and coldest winters Negotinska Krajina represents the region East Serbia with most pronounced continental climate.

The seasons during year are clearly differentiated from the aspect of temperatures. According to the recorded temperatures the hottest month is July and the coldest February. Snow regularly occurs in the regions of East Serbia. Snow-cover is usually formed around 15 November at higher elevations, and at the lower around 1 December. In this part of East Serbia snow-cover is present the longest period.

As for precipitations, it can be said that rains are characteristic for springs, their maximum is recorded in spring months. The secondary maximum precipitations reach in a late autumn, and minimum during summer. However, although are recorded two precipitation maximums, annual precipitation sum ranges from 435 to 620 mm.

The west and northwest winds blow most frequently in the winter period. They start from the Homolje Mountains, and are invariably cold winds, which bring sudden and heavy precipitations. This wind is known as a katabatic wind and represents the most important wind during the summer period. This wind is most important for climate in Negotin and weather very frequently depends on it. During the winter period, the lowest temperatures are recorded in Negotin and, therefore, the name "Serbian Siberia''. A cold, southeastern wind known as "Košava", although of lesser intensity than a katabatic wind, is frequent in this area, causing snowfalls during several days. Those snowfalls are characterized with tiny snowflakes.

Having in mind character and scope of works in the said project, it is not expected their impact on climate factors, both in the immediate surrounding or further away from the industrial complex Elixir Prahovo Ltd. Prahovo.

## 5.8. Structures, immovable cultural properties, archeological sites and ambient units

The area under project is included with the Spatial Plan of Negotin Municipality and it is located within C.M. Prahovo. According to data from the real estate folios and the data from Republic Geodetic Authority the cadastral parcels within the scope of the subject plan are mainly privately owned or in mixed ownership, except cadastral parcels which represent municipal and local roads, which are in public ownership. The cadastral parcels are registered, according to land type, within the defined scope of the Plan as:

- land in the area designated for construction (occupies the north half of the defined scope and there is mainly situated the industrial complex);
- other land (there are mainly situated roads within the subject area;
- agricultural land (represented in the south parts of the area covered by the plan);
- forestry land (individual parcels within the south parts of the area covered by the plan).

A significant part of the subject area occupies the industrial complex Elixir Prahovo Ltd. Prahovo. The Spatial Plan of Negotin Municipality anticipates development and expansion of the industrial zone, and this is supported with the following facts:
- the whole southeast part of the area covered by the plan is occupied with the pyrite slag disposal;
- in the southwest part of the subject area is situated devastated agricultural land, which has already been purchased by legal persons;

- the consolidation area is defined south from the boundary of the area covered by the plan (the boundary of consolidation area is the road toward cadastral parcel no. 5481).

The quoted units are not systematically or compatibly distributed and there exists mismatch between the cadastral and factual status of roads within the defined area covered by the plan. The Spatial Plan of Negotin Municipality anticipates compilation of the General Regulation Plan which will define the aforementioned.

It should be emphasized that the operator has compiled the general regulation plan for its location which had been adopted in the Municipal Council and the following step is adoption on the session of Municipal Assembly of Negotin.

As for immovable cultural properties, classified as heritage monuments under the special protection regime by Institute for Protection of Cultural Monuments, it should be underlined that in the wider area of the subject locality those facilities have not been registered.

The similar situation is with ambient units of exceptional values, which also have not been registered in the zone of potential impact of the subject facility.

As for archeological sites, it has been ascertained existence of the multi-layered archeological locality, which is under status of previous protection, following the archeological explorations from 1975 (the Archeological Review No. 17 for 1976 – PRAHOVO FACTORY multi-layered locality by B and Dj. Janković, pg. 51-55). The Detailed Regulation Plan prescribes measures and obligations which an investor has to undertake in case if finds archeological sites.

## 5.9. Landscape

A significant landscape characteristic of some locality makes presence of the all or larger number of morphological elements: plateaus, wavy terrains, hills, mountains, etc.

From that aspect, it could be said that the wider are of the subject locality is characterized with certain number of those morphological elements. However, the nearby area is mainly characterized with the presence of plateaus. It is not therefore surprise why this region in which Negotinska Krajina is situated is known under name Negotin Lowlands. The word itself, lowland sufficiently describes terrain configuration in this part of Serbia.

From topography aspect, it is plain terrain, while elevation differences do not exceed 20 m. The highest elevation in the wider area of the project is located in the village Prahovo, more specifically +64 masl, and the lowest elevation is the Danube, at +35 masl.

In those conditions, each deviation from plain, in this case the phosphogypsum storage will make it, can disturb the existing landscape to certain extent. It is difficult to quantitatively determine that impact since impression created by landscape in the eyes of an observer is mainly abstract and subjective, and specific to the observer. However, it is possible with certain techniques, to some extent, reduce this visual disparity to a reasonable level.

## 5.10. Mutual relation of the quoted factors

The analysis and evaluation of the existing environmental condition as well as estimates of possible ecological risks which arise from this project, represent necessary steps both in the planning and designing process and in the feasibility analysis process. Furthermore, it provides the insight in justification for realization of significant projects from the aspects of society and economy.

The method for developing impact model, that is the model of mutual relation of some project and environmental segments, uses analytical and qualitative approach. The quoted approach is based on the selection of a certain number of relevant criteria for impact estimate and allocation of various importance to those criteria. It is expressed when are taken into account concrete spatial relations of the analyzed technique used for the stockpiling of phosphogypsum.

The analysis of mutual relations within the defined criteria matrix was performed by application of the methodological concept developed within Pollution Prevention by Design in Pacific Northwest National Laboratory (2003, by U.S. Department of Energy – DOE). The quoted methodological concept anticipates estimate of risk level for each individual impact of the analyzed technological system for the stockpiling of phosphogypsum. Besides the estimate of individual criteria will be performed estimate of the overall environmental impact of the phosphogypsum storage.

The risk level (R) of individual impact criteria is determined as multiplication of the impact scope caused by applied technique (I) and probability category of impact occurrence (P), i.e. R = I x P.

Within the quoted methodological concept probability categories are evaluated through three categories: no possibility (0), possible (1), probably (2). In Table 5.14 is presented evaluation of each individual impact from the defined criteria matrix according to the presented concept of risk level analysis as a function of impact level of the applied technology and probability category of impact occurrence. The summary level of risks from individual impacts of certain activities in the analyzed technological process on environment as well as the summary impact of the proposed technique for the stockpiling of phosphogypsum is determined with the sum of risk levels of individual activities, the three categories are differentiated: 0-2 low risk (0), 3-6 medium risk (1), and >6 high risk (2).

Table 5.14: Evaluation of mutual relations of elements contained in the analysis and estimate of risk level

| Kriterijum uticaja | Vazduh | | | | | | Površinske vode | | | | | | Podzemne vode | | | | | | Tlo | | | | | | | | | Buka | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aktivnosti | Prašina | | | Gasovi | | | Promene toka voda | | | Imisija zagađenja | | | Varijacije nivoa podzemnih voda | | | Imisija zagađenja | | | Pedološke promene | | | Promene korišćenja zemljišta | | | Imisija zagađenja | | | Nivo buke | | |
| | P | I | R | P | I | R | P | I | R | P | I | R | P | I | R | P | I | R | P | I | R | P | I | R | P | I | R | P | I | R |
| Čišćenje terena i uspostavljanje funksionalnog prostora | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Geološka ispitivanja | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Uspostavljanje servisa | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Izrada nasipa, drenažnog sistema i obodnih kanala | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Izrada hidroizolacije | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Faza uređenja i formiranja skladišta (faze 1-3) | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 1 |
| Faza nadogradnje i visinko povećanje kapaciteta skladišta (faze 4 – 8) | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 1 |
| Zatvaranje i rekultivacija radnog prostora | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1 | | | 0 | | | 0 | | | 1 | | | 0 | | | 1 | | | 1 | | | 1 | | | 1 | | | 1 | | |
| | 1 | | | | | | 1 | | | | | | 1 | | | | | | 1 | | | | | | | | | 1 | | |

| Kriterijum uticaja | Biološka zaštita | | | | | | Eko sistem | | | Pejzaž | | | | | | Stanovništvo | | | | | | | | | Kulturno i prirodno nasleđe | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aktivnosti | Efekti na floru | | | Efekti na faunu | | | Efekti na ekosistem | | | Morfološke promere terena | | | Zauzimanje površina i vzuelni uticaj | | | Efekti na infrastrukturu | | | Efekti na ekonomske aktivnosti | | | Efekti na zdravlje | | | Efekti na kulturno i prirodno nasleđe | | |
| | P | I | R | P | I | R | P | I | R | P | I | R | P | I | R | P | I | R | P | I | R | P | I | R | P | I | R |
| Čišćenje terena i uspostavljanje funksionalnog prostora | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Geološka ispitivanja | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Uspostavljanje servisa | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Izrada nasipa, drenažnog sistema i obodnih kanala | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| Izrada hidroizolacije | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Faza uređenja i formiranja skladišta (faze 1-3) | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| Faza nadogradnje i visinko povećanje kapaciteta skladišta (faze 4 – 8) | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| Zatvaranje i rekultivacija radnog prostora | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0 | | | 0 | | | 0 | | | 1 | | | 2 | | | 0 | | | 0 | | | 1 | | | 0 | | |
| | 0 | | | | | | 0 | | | 2 | | | | | | 1 | | | | | | | | | 0 | | |

It is necessary to be underlined that in Table 5.14 is presented the estimate of risk level caused by the technique used for the stockpiling of phosphogypsum in relation to environment. As it can be seen from Table 5.14 the high risk is ascertained for storage's impact on water, soil, flora and fauna at its site. Other impacts are classified in medium and low level risk categories.

The soil degradation in the area of the industrial complex IHP Elixir-Prahovo will inevitably occur during the stockpiling of phosphogypsum. At this moment, it is difficult to estimate duration of this impact, since this process depends on several factors. The fact is that after completion of stockpiling, i.e. with the formation of the final storage, the quoted negative impact can be reduced with the selected works on technical and biological recultivation. The biological recultivation includes activities which primary task is the formation of vegetative cover from autochthonous plant species.

# 6. DESCRIPTION OF POSSIBLE ENVIRONMENTAL IMPACTS OF THE PROJECT

The consequences caused by the natural environment adjustments to community requirements are most frequently unexpectedly because of a very sensitive balance of all ecological elements. The technogenic impact on the ecosystem with its reverse action to original initiators can cause new conditions and environmental effect and can have also an impact on humans.

The construction of the new phosphogypsum storage in the holding of Elixir Prahovo, Industry of Chemical Products Ltd., with all its characteristics, can influence on the quality of environment. The successfulness of each solution in the domain of environmental protection and improvement of environment implies comprehensive consideration and definition of all possible impacts. Accordingly, it is always set as a priority the obligation of definition of possible impacts in relation to the basic environmental media such as: air, water, soil, climate, flora, fauna, landscape, etc.

## 6.1. Identification of possible environmental impacts

The analysis of possible environmental impacts was conducted on the basis of potential effects which those impacts might have on the values of individual components, i.e. the ecosystem elements. The values – the ecosystem components are those aspects or elements of the existing environment which are considered valuable and significant from the aspect of potential effects of the said project.

Table 6.1 shows the results regarding the definition of field of activity of the said project both on physical and natural surroundings, and on socioeconomic aspects. The table shows to which scope the various components, i.e. project stages can have impact on diverse categories or, more specifically, environmental components during works at site preparation but also later in the stage of project realization.

The analysis of environmental impacts is connected for the requirements of this project takes into consideration potential environmental effects which are anticipated on the basis of implementation of the Best Available Technologies (BAT) in the designing stage and project development and the Best Management Practices (BMP) which are applied during construction and operation of the new phosphogypsum storage.

The environmental effects are classified in the following way:

- Physical surrounding – soil (physiography, geology and soil), water (surface and underground resources), air (climate, air quality and noise);
- Natural environment – aqueous and earth habitats;
- Socio-economic environment – the existing and planned utilization of land and resources and economic activities related to it.

Cultural environment – archeological, cultural characteristics and inheritance which includes any locations or cultural asset of historical importance which could be physically exposed to the project impact. This potential type of impact is not expected, on the basis of available information and will not be further taken into consideration.

Table 6.1 Potential Project - Environment Interaction Matrix

| PROJECT STAGES / COMPONENTS | ENVIRONMENT COMPONENTS | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PHYSICAL ENVIRONMENT | | | | | | | | | | | | | NATURAL ENVIRONMENT | | | | | SOCIOECONOMIC / CULTUROLOGICAL ENVIRONMENT | | | | | | | | | |
| | Air | | | Water | | | | | Soil | | | | | Natural ecologic system | | | | | Socioeconomic | | | | | | | Culturological | | |
| | Air quality | Other (dangerous materials | Noise | Surface water quality | Surface water quantity | Groundwater quality | Groundwater quantity | Other (dangerous materials) | Landscape / Topography | Rock massif | Ground | Other (dangerous materials) | Waste | Natural vegetation (in-situ) | Natural vegetation (outside location) | Natural habitat | Areas with protected natural assets | Other | Occupational health and safety | Residnets'health and safety | Land utilization (urban, industrial, residential) | Land utilization (rural, agriculture, forests) | Population / Employment | Social impact | Other | Cultural heritage | Historical / archeological heritage | Other |
| **STAGE OF SITE PREPARATION** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| • Terrain cleaning and establishment of functional space | ● | | ● | ● | | ● | | ● | ● | ● | ● | ● | ● | ● | | ● | | | ● | ● | | ● | ● | ● | | | | |
| • Geological investigation | ● | | ● | ● | | ● | | ● | | | ● | ● | ● | ● | | ● | | | ● | ● | | ● | ● | ● | | | | |
| • Establishment of service | ● | | ● | ● | | ● | | ● | ● | | ● | ● | ● | ● | ● | ● | | | ● | ● | | ● | ● | ● | | | | |
| **CONSTRUCTION AND UTILIZATION STAGE** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| • Construction of dike, drainage system and perimeter canals | ● | | ● | ● | | ● | | ● | ● | ● | ● | ● | ● | ● | | ● | | | ● | | | ● | ● | ● | | | | |
| • Installation of hydro insulation | ● | | ● | | | ● | | ● | | | ● | ● | ● | | | ● | | | ● | ● | | | ● | ● | | | | |
| • Storage regulation and establishment stage (stage 1 - 3) | ● | | ● | ● | | ● | | ● | | | ● | ● | ● | | | ● | | | ● | ● | | | ● | ● | | | | |
| • Overbuilding and increase of storage's volume capacity with height (stage 4 - 8) | ● | | ● | ● | | ● | | ● | | | ● | ● | ● | | | ● | | | ● | ● | | | ● | ● | | | | |
| • Closure and recultivation of work environment | ● | | ● | ● | | ● | | ● | ● | ● | ● | ● | ● | ● | ● | ● | | | ● | ● | | ● | ● | ● | | | | |

## 6.2. Analysis of impacts on air quality

Suspended particles which concentrations, under certain conditions can be above limit values prescribed for populated areas represent a significant, potential danger for air. The creation of a dispersive phase in air in the working environment is connected to a greater or lesser extent with the all designing technological process's phases.

The characteristics sources of air pollution with suspended particles are: a point source pollution (loaders, bulldozers), an air pollution line source (the roads in the industrial complex), surface (the surfaces on which are performed activities in the storage and disposal site). The primary sources include mining and construction equipment in operation, while the secondary sources include all active surfaces which under impact of wind emit in air a floating fraction from the deposited dust.

The total intensity of air pollution with suspended particles greatly depend on meteorological conditions, which averages that occasionally, in dry periods during the year it can represent a potential polluter of air in the environment where activities are performed.

Air pollution with exhausted gases generated by motors with internal combustion on loading, transport mechanization and ancillary machines is connected with emissions of the following gases: carbon monoxide CO, carbon dioxide $CO_2$, nitrogen oxides $NO_x$, sulphur dioxide $SO_2$, acrolien, etc. As for their intensity the pollutants as exhausted gases from mechanization used for the stockpiling of phosphogypsum are classified in small pollution sources. Therefore, they are not recorded as important causes of ecological threats in populated areas.

### 6.2.1. Standardized values

As a result of the necessity for estimate, analysis and reduction of the impact of certain air pollutants on the humans, flora and fauna and materials the legal standards for regulation of this field are adopted, first of all, the Law on air protection (Official Gazette of RS, No. 36/09 and 10/2013) and pursuant to this law the Regulation on monitoring conditions and air quality requirements (Official Gazette of RS, No. 11/2010). The Law on air quality regulates air quality management and defines measures, the organization and control method for implementation of air protection and air quality improvement as a natural asset of common interest which is placed under special protection. The monitoring conditions and air quality requirements are defined pursuant to this regulation. The air quality requirements are expressed through pollutants limit values in air, the upper and lower limits for the assessment of pollutants level in air, tolerance limit and tolerances values, dangerous concentrations for human health and the concentrations about which the public is informed, critical level of air pollutants, target values and national, long-term objectives related to air pollutants, deadlines to reach limit and/or target values, in case when those values are exceeded in accordance with the Law.

In accordance with the quoted regulation, in Table 6.2 is provided a systematized review: the averaging period, limit values, tolerance limit, tolerance values and deadlines for reaching limit values, of certain air pollutants.

Table 6.2: Limit values, tolerance levels and tolerance limit according to the Regulation on monitoring conditions and air quality requirements (Official Gazette of RS, No. 11/2010)

| | Averaging period | Limit value | Tolerance limit | Tolerance value | Deadline for reaching limit value |
|---|---|---|---|---|---|
| Sulphur dioxide | One hour | 350 μg/m$^3$ Not allowed to exceed more than 24 times per year | 160 μg/m$^3$, 43% of limit value | 500 μg/m$^3$ | 01.01.2016 |
| | One day | 125 μg/m$^3$ Not allowed to exceed more than 3 times per year. | | 125 μg/m$^3$ | 01.01.2016 |
| | Calendar year | 50 μg/m$^3$ | | 50 μg/m$^3$ | 01.01.2016 |
| Nitrogen dioxide | One hour | 150 μg/m$^3$ Not allowed to exceed more than 18 times per year. | 50% of limit value as of 01.01.2012 is reduced each 12 months for 5 % in order to reach 0% on 01.01.2021 | 225 μg/m$^3$ | 01.01.2021 |
| | One day | 85 μg/m$^3$ | 47 % of limit value as of 01.01.2012 is reduced each 12 months for 5 % in order to reach 0% on 01.01.2021 | 125 μg/m$^3$ | 01.01.2012 |
| | Calendar year | 40 μg/m$^3$ | 50% of limit value as of 01.01.2012 is reduced each 12 months for 5 % in order to reach 0% on 01.01.2021 | 60 μg/m$^3$ | 01.01.2021 |
| Suspended particle $PM_{10}$ | One day | 50 μg/m$^3$ Not allowed to exceed more than 35 times per year. | 50 % of limit value as of 01.01.2012 is reduced each 12 months for 10 % in order to reach 0% on 01.01.2016 | 75 μg/m$^3$ | 01.01.2016 |
| | Calendar year | 40 μg/m$^3$ | 20 % of limit value as of 01.01.2012 is reduced each 12 months for 4 % in order to reach 0% on 01.01.2016 | 48 μg/m$^3$ | 01.01.2016 |
| Suspended particles $PM_{2,5}$ | Calendar year | 25 μg/m$^3$ | 20 % of limit value as of 31.12. 2011 is reduced the following 01.01.2013 and then each 12 months for 3% to reach 0% on 01.01.2019 | 30 μg/m$^3$ | STAGE 1 01.01.2019 |
| | | 20 μg/m$^3$ | | 20 μg/m$^3$ | STAGE 2 01.01.2024 |
| Total suspended particles | One day | 120 μg/m$^3$ | | | |
| | Calendar year | 70 μg/m$^3$ | | | |
| Lead | One day | 1 μg/m$^3$ | | 1 μg/m$^3$ | 01.01.2016 |
| | Calendar year | 0,5 μg/m$^3$ | 100 % of limit value as of 01.01.2012 is reduced each 12 months for 20% in order to reach 0% on 01.01.2016 | 1 μg/m$^3$ | 01.01.2016 |
| Benzene | Calendar year | 5 μg/m$^3$ | 3 μg/m$^3$ (60 % of limit value as of 01.01. 2010 is reduced each 12 months for 0,5 μg/m$^3$ in order to reach 0% on 01.01.2016 | 8 μg/m$^3$ | 01.01.2016 |

| | Averaging period | Limit value | Tolerance limit | Tolerance value | |
|---|---|---|---|---|---|
| Carbon monoxide | Maximum daily 8 hour value. | 10 mg/m3 | 60 % of limit value as of 1. January 2010, is reduced on 1. January 2012, and then each 12 months for 12 % per year in order to reach 0% on 1. January 2016 | 16 mg/m3 | 01.01.2016 |
| | One day | 5 mg/m3 | 100 % of limit value as of 01. January 2010, is reduced on 1. January 2012, and then each 12 months for 20 % per year in order to reach 0 %on 1. January 2016 | 10 mg/m3 | 01.01.2016 |
| | Calendar year | 3 mg/m3 | | 3 mg/m3 | 01.01.2016 |
| Soot | One day | 50 μg/m3 | 25 μg/m3 (50 % of limit value) | 75 μg/m3 | 01.01.2012 |
| | Calendar year | 50 μg/m3 | 25 μg/m3 (50 % of limit value) | 75 μg/m3 | 01.01.2012 |

### 6.2.2. Basic methodology approach for analysis and assessment

The propagation of noxious materials depends on the type of pollution source, i.e. whether it is point source pollution (at ground or at altitude), area source or line source pollution. The Gaussian models are most frequently used for determination of noxious materials spreading in methodological investigations and practical analyses. The primary reasons for the most frequent applications of Gaussian models is, first of all, simple application as well as a relatively good concordance with physical experiments. The Gaussian models start from the presumption that passive concentrations distribution in a plume has a certain mathematical form, i.e. contain the diffusion equation by Gaussian, which, in fact, represents the solution for Fick's diffusion equation with constant coefficient. In the basis of Gaussian model for a plume of smoke lays the following equation:

$$\bar{\chi} = \frac{q_s}{2\pi U \sigma_2 \sigma_3} \exp\left[-\frac{1}{2}\left(\frac{x_1}{\sigma_1}\right)^2\right]\left\{\exp\left[-\frac{1}{2}\left(\frac{x_3-h}{\sigma_3}\right)^2\right]+\exp\left[-\frac{1}{2}\left(\frac{x_3+h}{\sigma_3}\right)^2\right]\right\}, \quad (6.1)$$

Where:

- $\chi$ - mean concentration,
- $q_s$ - emission velocity,
- U - mean wind velocity (constant),
- H - plume altitude,
- $\sigma_i$ - the standard deviation of the passive substances concentration distribution in Gaussian cloud in the direction (i).

The use of index (i) implies that i=1corresonds to the wind direction (x), i=2 to side wind to the wind direction (y) and i=3 to the vertical direction (z).

The Gaussian models can be divided into two basic equation forms depending on the passage of time from pollutant emissions and emission duration. If the duration of emission and sampling is longer than the transport time is used the previous equation, for so-called continual emission. In case that the transport time is longer than the emission duration or sampling the diffusion equation for transient emissions is applied, which has the following form:

$$\bar{\chi} = \frac{Q}{(2\pi)^{\frac{3}{2}}\sigma_x\sigma_y\sigma_z} \exp\left\{\left[-\frac{1}{2}\left(\frac{x-ut}{\sigma_x}\right)^2+\left(\frac{y}{\sigma_y}\right)^2+\left(\frac{z}{\sigma_z}\right)^2\right]\right\}, \quad (6.2)$$

Where: Q – total liberated quantity of passive substances.

In the Study on the environmental impacts of the project of development of the phosphogypsum storage in the industrial complex of the company ELIXIR PRAHOVO INDUSTRY OF CHEMICAL PRODUCTS LTD. PRAHOVO, for analysis and estimate of impacts of the technology of development of the new storage on air pollution was used the standard EPA model (US Environmental Protection Agency) AERMOD.

The AERMOD modeling system (EPA, 1988a) include a wide range of possibilities for modeling of pollutants impact on air pollution. The quoted modeling system include modeling of a larger number of pollution sources including the following: point source, line source, area source, and volume source pollution. The modelling system contains algorithms for the modelling of aerodynamic current in proximity and around the building. The pollutant emission rates from source can be treated as constant during the period for which analysis is performed, or can be varied during month, the observed period, hour or some optional time of changes.

The AERMOD modeling system is characterized with a significant flexibility in the specification of receptor's location. The user has on his disposal the option which provide capability of specifying multiple receptor networks in the analysis and may mix Cartesian and polar receptor networks. The AERMOD modeling system has capability of taking into account terrain relief as well as receptor's altitude in relation to the existing terrain.
The meteorological data for this model are entered through the data on the parameters for surface boundary layer and the data on the profile of changeable meteorological parameters which includes wind velocity, wind direction and turbulence parameters. The two quoted parameters for the AERMOD modeling system are generated with a meteorological data preprocessor AERMAT (EPA 1998b).

### 6.2.3. Assessment of potential threats and expected impacts on air quality

A potential danger from air pollution depends, to the greatest extent, on dispersion of fine dust fractions from dry surfaces and distribution, under the impact of wind, outside the industrial complex.

The active benches and plateau at the storages (area emitters) and roads used for truck transport (line emitters) under certain natural conditions (moisture deficit, high temperature, and increased wind velocity) become important emitters of dust. Construction machinery and technological equipment used for operations at disposal, to lesser extent, contribute to additional emissions.

The quantification of PM10 particulate matter emissions, i.e. of the factors of dust emissions for various activities in the process of stockpiling phosphogypsum in the industrial complex of ELIXIR PRAHOVO INDUSTRY OF CHEMICAL PRODUCTS LTD. PRAHOVO was conducted in accordance with the EPA documents (US EPA AP-42, Compilation of Air Pollution Emission Factors) and National Pollutant Inventory (Emission Estimation Technique Manual for Mining and Processing of Metallic Minerals, 2011). In Table 6.4 are presented dust emission factors depending on the type of activity and equipment. Those dust emission factors correspond to natural and technological conditions at the industrial complex of the company Elixir Prahovo Ltd. Prahovo.

Table 6.3: Dust emission factors depending on the type of activity and equipment, according to the National Pollution Inventory (2011) (US EPA AP-42)

| Activity/equipment | Unit | Dust emission factor | |
|---|---|---|---|
| | | TSP | $PM_{10}$ |
| Loading from the pile | kg/t | 0.004 | 0.0017 |
| Vehicle movement | kg/km | 4.08 | 1.24 |
| Unloading from a truck | kg/t | 0.012 | 0.0043 |
| Bulldozer | kg/h | 17.0 | 4.1 |
| Wind erosion | kg/ha/h | 0.4 | 0.2 |

The air pollution intensity depends on the following factors: natural properties of disposed material, climate and meteorological conditions, disposal and stockpiling technique, the efficiency of applied procedure for prevention of dust emissions. In the emission fund dominates the secondary dust emission from active areas under the impact of wind. The distribution of suspended particles is limited to relatively small distances because of ground and low altitude emission sources.

The AERMOD model (US Environmental Protection Agency) was used for estimation of the air quality for the purpose of distribution of concentration of particles PM10. The obtained results represent average daily values of concentration of particles PM10 (µg/m$^3$) for defined sources of separation, defined period and receptors. It ought to be emphasized that in the reviewed models has been taken into consideration the terrain elevation. Data from the period 2010-2013 were used for meteorological conditions.

Figure 6.1 shows the distribution of daily average concentration of suspended particles PM10 (µg/m$^3$) around the industrial complex of the stage 1 of the development of the phosphogypsum storage in the complex of Elixir Prahovo Ltd. Prahovo for analyzed meteorological conditions. The analysis was conducted for conditions in which exist 5 dust sources: the two surface sources (the phosphogypsum storage, the ash dump) and the three volume sources (loader, hydraulic excavator and unloading from a truck) under conditions in which are not applied dedusting measures.

The contour lines of dust particles PM10 concentrations presented in Figure 6.1 clearly indicate that can be expected impact of dust in the area around implementation of works on storage of phosphogypsum, because of the overall activities. In the broader area around industrial complex dust particles PM10 concentrations substantially decrease from 267 µg/m$^3$ (the phosphogypsum storage) to 50 µg/m$^3$ in the industrial border area zone.

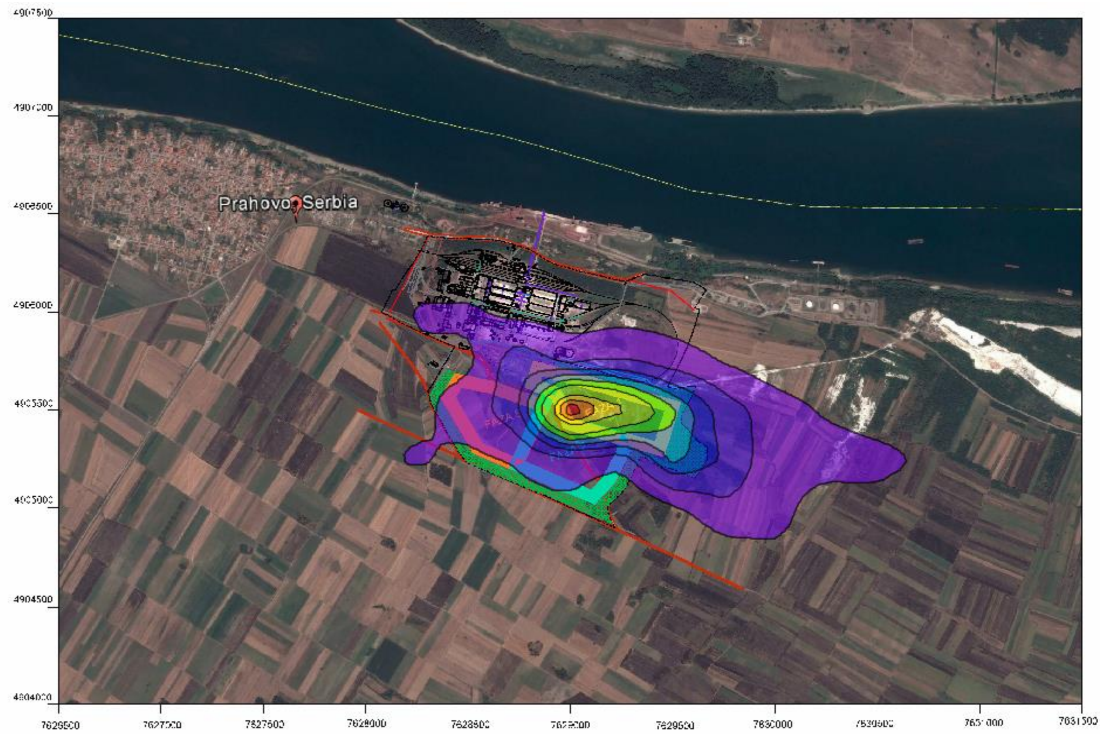



Fig.6.1 The distribution of mean daily concentration of particles PM10 (µg/m$^3$) around the phosphogypsum storage in the development stage 1 without application of methods and procedures for dust protection

Fig.6.2 shows The distribution of daily average concentration of suspended particles PM10 (µg/m$^3$) around the industrial complex of the stage 2 of the development of the phosphogypsum storage in the complex of Elixir Prahovo Ltd. Prahovo for analyzed meteorological conditions. The analysis was conducted for conditions in which 6 dust sources exist: the three surface sources (the phosphogypsum storage of stage 1 and 2, the ash dump) and the three volume sources (loader, hydraulic excavator and unloading from a truck) under conditions in which are not applied dedusting measures.

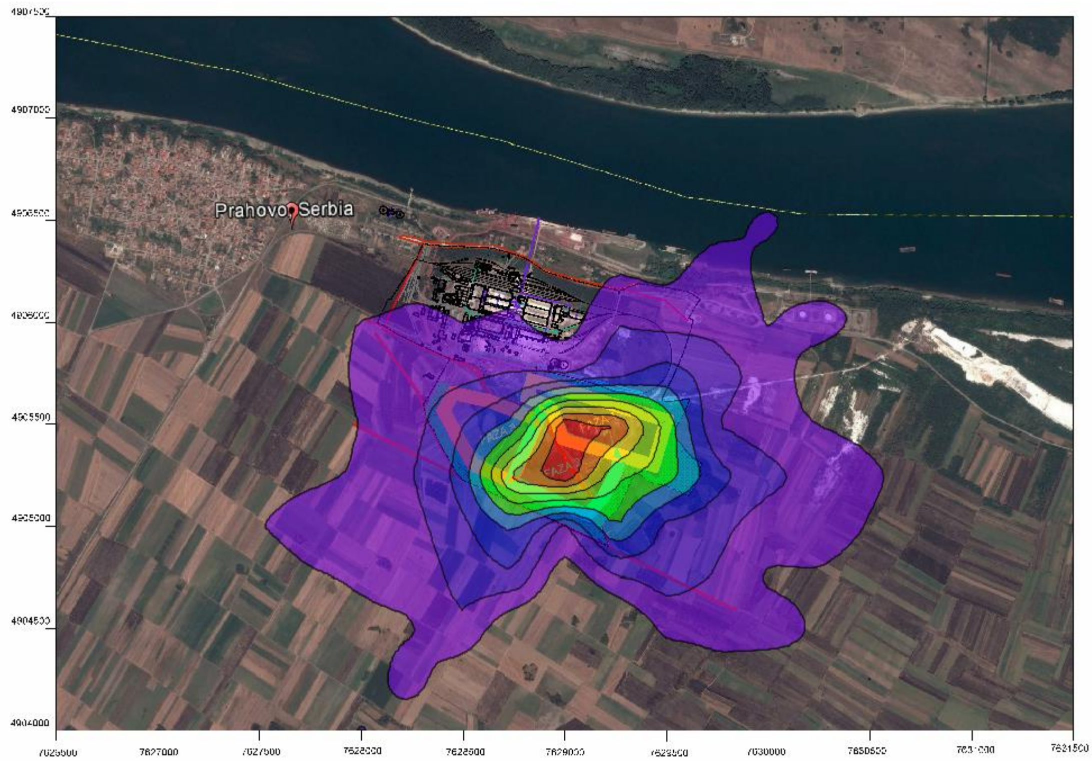



Fig.6.2 The distribution of mean daily concentration of particles PM10 (μg/m$^3$) around the phosphogypsum storage in the development stage 2 without application of methods and procedures for dust protection

The contour lines of dust particles PM10 concentrations presented in Figure 6.2 clearly indicate that can be expected impact of dust in the area around implementation of works on storage of phosphogypsum, because of the overall activities. In the broader area around industrial complex dust particles PM10 concentrations substantially decrease from 277 μg/m$^3$ (the phosphogypsum storage) to 50 μg/m$^3$ in the industrial border area zone.

The evaluation of the stage 3 was conducted in order to better estimate air quality for the purpose of distribution of concentration of particles PM10 for various activities in the process of phosphogypsum disposal in the industrial complex of the company Elixir Prahovo Ltd. Prahovo was conducted the analysis of the development stage 3 of the phosphogypsum storage. Figure 6.3 shows the distribution of daily average concentration of suspended particles PM10 (μg/m$^3$) around the industrial complex of the stage 3 of the development of the phosphogypsum storage in the complex of Elixir Prahovo Ltd. Prahovo for analyzed meteorological conditions is presented in Figure 7. The analysis was conducted for conditions in which 7 dust sources exist: the three surface sources (the phosphogypsum storage of stage 1, 2 and 3, the ash dump) and the three volume sources (loader, hydraulic excavator and unloading from a truck) under conditions in which are not applied protection dedusting measures.

The contour lines of dust particles PM10 concentrations presented in Figure 7 clearly indicate that can be expected impact of dust in the area around implementation of works on storage of phosphogypsum, because of the overall activities. In the broader area around industrial complex dust particles PM10 concentrations substantially decrease from 347 μg/m$^3$ (the phosphogypsum storage) to 50 μg/m$^3$ in the industrial border area zone.

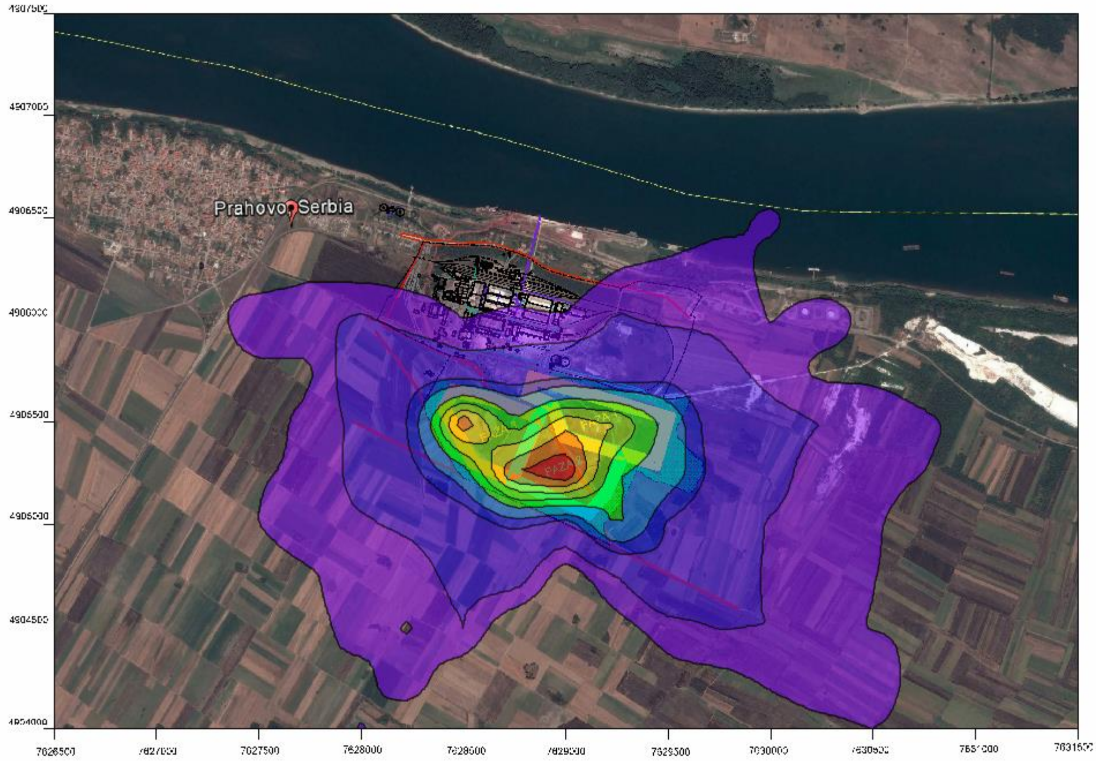



Fig.6.3 The distribution of mean daily concentration of particles PM10 (μg/m$^3$) around the phosphogypsum storage in the development stage 3 without application of methods and procedures for dust protection

On the basis of the analysis of distribution of suspended particles PM10 emitted from the technological process of phosphogypsum storage in the complex of Elixir Prahovo Ltd. Prahovo can be concluded that is a reliable estimate that in the area of the nearest receptors (residential buildings in the village Prahovo) emissions of suspended particles will not exceed prescribed limits of 50 μg/m$^3$.

According to the data from US EPA (AP-42, 1992) and the National Pollutant Inventory (2011) dust particles emission from the various sources present during disposal and stockpiling of mineral raw materials and various other materials can be reduced for 50% and more with the application of moisturizing techniques for raw mineral materials or dedusting (sprinkling with water). Having in mind the estimated dust concentrations in the operation zone at the phosphogypsum storage for protection from dust in work environment, in technical documentation will be anticipated measures for removal of floating dust from the atmosphere in work environment within the industrial complex. In this ways will be reduced suspended particles emissions in the atmosphere of the wider area, and it will have more favorable impact on the air quality in this region.

During operation of motor with internal combustion will be emitted the following pollutants: carbon monoxide (CO), carbon dioxide ($CO_2$), nitrogen oxides ($NO_x$), sulphur dioxide ($SO_2$), volatile organic compounds (VOCs), aldehydes, soot, etc. Having in mind that it is about a relatively small pollution emission, determination of gas concentration fields does not have practical importance. The impact zones are of local character, i.e. they are related to a small area immediately around the pollution source and, most frequently, are spread within the working environment.

## 6.3. Analysis of noise and vibrations

Possible occurrences of unfavorable impacts of excessive noise in working environments exist in the all phases of operation on the disposal and storage of mineral raw materials and other materials. The sources of noise are construction machines for excavation, transport and ancillary works: drilling machines with compressors, loaders, bulldozers, trucks, tanker trucks, as well as crushers, mills, classifying screens, etc.

The danger from noxious impacts of vibration only exist in some phases during operation of construction machines and it is only connected with the working environment.

### 6.3.1. Standardized values

The regulations on the protection of residents from noise and vibration include the system of measures, technical and organizational, for protection of noise and vibration with the facilities construction planning, that is utilization of machines and equipment as noise sources, as well as the protection from vibrations caused by blasting at open-pit. The prescribed conditions and measures have as an objective that noise does not exceed the allowable level according to the Regulations on the noise indicators, limit values, methods for evaluation of the noise indicators, alarming and damaging effects of noise in environment (Official Gazette RS, No. 75/2010). This regulation prescribes the noise indicators in environment, limit values, evaluation methods for noise indicators and damaging effects of noise to human health.

Table 6.4: Limit values of noise indicators in an open space

| Zone | Utilization of area | Noise level dB (A) | |
|---|---|---|---|
| | | for day and night | for night |
| 1 | Recreational zones, hospital zones, cultural and historical localities, large parks | 50 | 40 |
| 2 | Tourist areas, small town and villages and areas around schools | 50 | 45 |
| 3 | Strictly residential area | 55 | 45 |
| 4 | Business - residential zones, residential zones, trading – residential zones, children playgrounds | 60 | 50 |
| 5 | Downtown area, areas with craftsman, trading facilities and administrative and residential buildings, areas along highways and magistral roads | 65 | 55 |
| 6 | Areas with industrial, warehouse and service facilities and transport terminals without residential buildings | At boundaries of nose zone, noise is not allowed to exceed levels in the zone with which is bordered | |

### 6.3.2. Basic methodology procedures for analysis and assessment

A certain number of methods has been developed for prediction of noise which occurs at large, open sites. The British standard Noise Control on Construction and Open Sites Part 1 (1997) contains the method for estimation of an equivalent continual level of noise in decibels (Leq – A-ponderation). The mapping noise system SiteNoise 2000 provides a precise method for implementation of computation procedure, quoted in British standard BS5228 with a certain number of optional methods for estimate:

- correction due to sound propagation over soft terrain;
- noise reduction due to barrier presence;
- corrections depending on observation angle;
- the source – receptor distances.

It has to be underlined that meteorological effects, such as wind velocity and atmospheric conditions which influence sound propagation are not implicitly included in this procedure. The approach adopted in SiteNoise 2000 system treat those effects in the list favorable form or, more specifically, it is supposed that wind blows toward noise receptor and because of that the measured noise level will be inclined toward a higher value than those real one measured in practice.

SiteNoise calculates noise intensity generated with activities performed at some work site or locations. Noise spreads from a source to a receptor. As noise spreads it is also spread the impact zone, but intensity is reduced. This effect is known as geometrical spreading or noise reduction due to noise attenuation by distance. If noise spreads along “soft” terrains (ground) then will occur additional reduction of emitted noise, depending on how near to ground passes the propagation direction. This effect is known as reduction due to terrain characteristics.

During propagation sound has to pass certain barriers in order to get to a receptor. Those barriers can cause certain noise reduction. This is known as sound attenuation by barriers. If there is any reflecting surface in the receptor zone, it can occur increase of sound intensity due to reflection. However, reflection surface has to be rather large in order to have a significant impact.

The sound level at measurement location is also under influence of the wind direction. As it has already been mentioned SiteNoise assumes that wind blows toward noise receptor, what corresponds to the least favorable measurement conditions, i.e. the highest noise levels. This is quite a stable condition which provides reliable data.

For utilization of SiteNoise 2000 is necessary to define the work site model (location model) on the basis of corresponding map or plan. The open work sites are frequently complex, first of all, because of their changeable makeup and a substantial number of activities which are carried out at such work site, and terrain characteristics (this is particularly pronounced with open-pits).

The user firstly enters a site plan and then the system SiteNoise automatically determines effects of distances, noise reduction due to barriers, resounding, etc. and after that it is calculated noise level which originates from the defined activities. Hence, the user does not need 3D visualization, which implies drawing of cross-section, distance measurements, and likewise, what is frequently a daunting task, and also requires data from various sketches, drawings, etc.

For creation of the work site model, a site map is required, of sufficient scale in order to detect adequate details, including information on local terrain elevations. Besides, in order to achieve the higher accuracy, it is required to conduct observation in order to record information on building heights, fences and other barriers of importance for sound propagation, as well as data on plant, equipment, machines, the traffic flow for trucks and their speeds at a defined site. After the model is created, it is possible to review details in various colors, according to the detail’s character, what provides a prompt visual control of precision for entered data.

### 6.3.3. Assessment of potential threat and expected noise impact on environment

The estimation of noise level which originates from activities on phosphogypsum storage was implemented with the application of NoiseMap-SiteNoise model. The model is based on the British standard 5228, Part 1, 1984, Noise Control on Construction and Open Sites. The model includes the following sources of noise:

1. Floating pump – 65 dB(A), situated in the middle of the cassette, on a pontoon, it transfers water from the cassette into the peripheral canal;
2. Hydraulic excavator 75 dB(A), it operates on formation of the embankment in the stage of cassette immuring;
3. Pumping station 60 dB(A) - it returns collected water in the peripheral canal to the factory –the water cycle.

It has been modelled the development stage 3 of the phosphogypsum storage (Fig. 6.4), when the works on phosphogypsum storage are at elevation +64 m. According to topography, elevations of the village Prahovo ranges from 60 to 62 masl. Stages 1 and 3 have not been modelled since in those cases works are further from the residential buildings. Considering that the sources of noise in those stages are the same as in the stage 3, it is realistic to expect the same noise levels in their surroundings, and the obtained outlines of noise would be moved toward the east for the moved operations. A excavator is situated in the side which faces the settlement, i.e. the all sources are in the modelled moment nearest to the residential buildings in the immediate surroundings of the industrial complex.

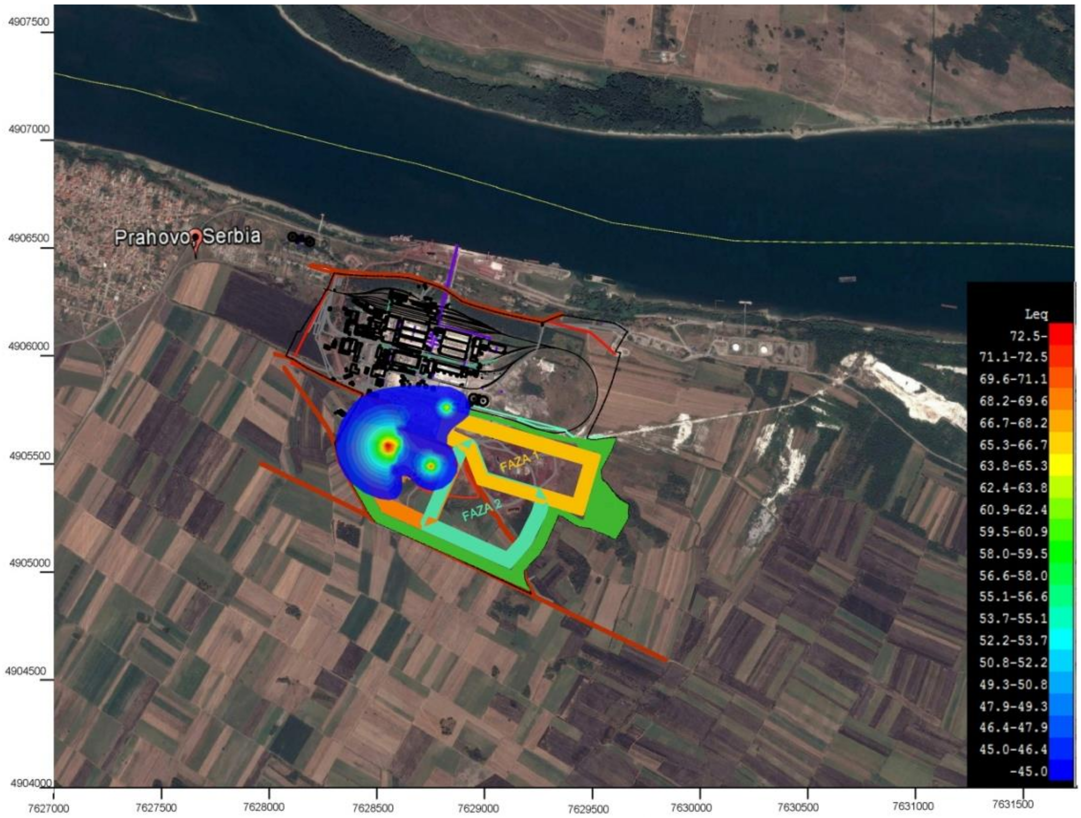



Fig.6.4 The estimate of noise levels around the phosphogypsum storage

Since the phosphogypsum storage is situated within the industrial zone, the allowable noise level at the border of this zone is not allowed to exceed the limit value of the zone with which is bordered. In the concrete case, the industrial zone borders with the zone 3, the residential settlement, so that the adopted limits for day and evening are 55 dB, i.e. 45 dB during night. As it can be seen in Figure 6.4, a reliable estimate is that the noise connected with activities on phosphogypsum storage will not have impact on the nearest residential buildings in the village Prahovo.

The estimate of noise level, presented in Figure 6.4, indicates that in the area of phosphogypsum storage the noise levels above 70 dB(A) can be expected. The fact is that noise in this part of the industrial complex will have first of all, impact on the workers at the location of implementation of works – workers and operators. Because of that, corresponding protection measures have to be undertaken (construction or personal protection measures) in order to prevent unfavorable impact of noise on the employees.

The danger of noxious impacts of vibration exists only in some phases of construction machines operations and is only connected with the working environment. In that sense, it is required to regularly conduct measurements of vibration level during operation of equipment and implement required protection measures for operators as required.

## 6.4. Analysis of impacts on the quality of surface waters and groundwaters

### 6.4.1. Standardized values

The legislation related to waters is harmonized with the EU documents. It includes the following documents:

1. Law on waters (Official Gazette RS, No. 33/10);
2. Regulation on systematic soil quality monitoring program**,** indicators for assessment of risk of soil degradation, and methodology for development of remediation programs (Official Gazette of RS, No. 88/2010);
3. Regulation on limit values for priority and hazardous substances which pollute surface waters and deadlines for their reaching (Official Gazette of RS, No. 35/2011);
4. Rulebook on referential conditions for the surface waters types (Official Gazette of RS, No 67/2011);
5. Regulation on emission limit values in waters and deadlines for their reaching (Official Gazette of RS, No. 67/11 and 48/2012);
6. Rulebook on parameters of ecological and chemical status of surface waters and parameters of ecological and chemical status of groundwaters (Official Gazette of RS, No. 74/2011);
7. Regulation on the pollutant limit values in surface waters and groundwater and sediments and deadlines for their reaching (Official Gazette, No. 50/2012);

Considering a substantial number of documents and quantitative parameter values which define the surface waters and groundwaters quality, and the fact that there is some inconsistency between them, herein, for orientation purposes is included the part from the Regulation of water classification (Official Gazette SRS, No. 5/88 and 33/75) in order to gain an insight in the term water stream class. In this regulation are defined four classes, while the waters which had required parameters values over maximum allowable concentrations (MOC) for the IV class were graded as uncategorized condition (UC). The five classes are defined in the new documents, while in fact class V is for its quality with MAC values correspond to the uncategorized condition, according to the old classification. The limit values (LV), and previously MAC for individual parameters, according to which are classified in a certain class, are systematized and presented in tabular form in the above-quoted documents (Table 6.5).

In the Regulation on water classification (Official Gazette SRS, No. 5/68 and 33/75) is written that:

- class 1 – the waters which in natural condition or after disinfection can be utilized or used for potable water supply, in food processing industry and for breeding fish such as the salmonids;
- class 2 – the waters which are suitable for bathing, recreation and water sports, for breeding fishes such as fishes from the carp family, as well as water which can be used after regular treatment methods (coagulation, filtration, disinfection) for potable water supply, for bathing and in food processing industry:

  Class 2 waters, outside border streams and streams intersected with the borders of the Republic of Serbia, are divided in subclasses:

- subclass 2a includes waters which can be used after regular treatment methods (coagulation, filtration, disinfection) as potable water supply, for bathing and in food processing industry; and
- subclass 2b includes waters which can be used for water sports, recreation, for breeding fishes such as fishes from the carp family and for livestock water consumption.

- class 3 – the waters which can be utilized or used for irrigation in industry, except in the food processing industry;
- class 4 – the waters which can be utilized or used only after the special treatment.

Table 6.5: Water stream classes (Official Gazette of SRS, No. 5/68 and 33/75)

| Indicator | Class 1 | Class 2 | Subclass 2a | Subclass 2b | Class 3 | Class 4 |
|---|---|---|---|---|---|---|
| Suspended materials for dry weather in mg/l, up to | 10 | 30 | 30 | 40 | 80 | - |
| Total dry residue during dry weather in mg/l up too:<br>- for surface waters and natural lakes<br>- for groundwaters | 350<br><br>800 | 1000<br><br>1000 | 1000<br><br>1000 | 1000<br><br>1000 | 1500<br><br>1500 | - |
| pH | 6.8 -8.5 | 6.8 -8.5 | 6.8 -8.5 | 6.5 -8.5 | 6.0 -9.0 | - |
| $BPK_5$ u $mgO_2$ /l up to | 2 | 4 | 4 | 6 | 7 | - |
| Most likely number of coliform germs in 100 ml of water, up to | 200 | 6000 | 6000 | 10000 | - | - |
| Visible waste materials | without | without | without | without | without | without |
| Noticeable color | without | without | without | without | - | - |
| Noticeable odour | without | without | without | without | - | - |
| Cyanide | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Iron (mg/l) | 0.3 | 0.3 | 0.3 | 0.3 | 1.0 | 1.0 |
| Copper (mg/l) | 0.1 (0.01) | 0.1 (0.01) | 0.1 (0.01) | 0.1 (0.01) | 0.1 | 0.1 |
| Nickel (mg/i) | 0.05 | 0.05 | 0.05 | 0.05 | 0.1 | 0.1 |
| Cadmium (mg/l) | 0.005 | 0.005 | 0.005 | 0.005 | 0.01 | 0.01 |
| Zinc (mg/l) | 0.2 | 0.2 | 0.2 | 0.2 | 1 | 1 |
| Arsenic | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |

### 6.4.2. Methodology procedures for analysis and assessment

As for wastewaters, in the world practice the two water quality management methods are applied. The first method is based on the quality of waters in a water receptor – surface waters, i.e. stream standards, and the second one on the quality of discharged wastewater (effluent standards) [50].

In the first case, stream standards in water receptor can be discharged wastewater without limit as for quality and quantity as long as are not exceeded prescribed limit values, LV (maximum allowable concentration – MOC, or annual average concentration – AAC) for the receptor water quality. However, this method does not define sampling location for receptor's water after mixing of wastewater and receptor's water. Also, in case of several dischargers in the one water receptor, it is not defined which discharging site and in which scope has the right on utilization of receptor's free capacity, i.e. loading capacity per individual parameters, taking into account receptor's self-cleaning properties.

In the second case, for effluent standards is determined discharged water quality (limit emission value – LEV). The limit emission values can be determined in the two ways. According to the first method, the limit emission values are defined on the basis of the best available cleaning technology (BAT). The advantages provided with defined limit values in this way is simplicity, they can be easily controlled and on their basis can be easily defined water quality improvement measures. With the second method are defined individual limit values, separately for each discharger, taking into account: prescribed limit values for the water quality in receptor; pollution loading in receptor's water; receptor's loading capacity; dilution conditions; receptor's self-cleaning capacity. The determination of limit emission values (LEV) is rather complex and require knowledge and utilization of mathematical models for quality estimate and water quality management. Nowadays, in the world is applied the combined approach for water quality management, which is within the Framework Directive 2000/60/EC), and which implies emission control and establishment of the environment quality standard, applying the both mentioned methods, i.e. the both type of limit concentrations [53].

For the issues of groundwaters quality, the following documents serves as guide:

1. Regulation on systematic soil quality monitoring program**,** indicators for assessment of risk of soil degradation, and methodology for development of remediation programs (Official Gazette of RS, No. 88/2010);
2. Regulation on the pollutant limit values in surface waters and groundwater and sediments and deadlines for their reaching (Official Gazette, No. 50/2012).

### 6.4.3. Assessment of the phosphogypsum storage's impact on groundwaters and surface waters

The estimation of wastewaters impact from the complex Elixir Prahovo Ltd. Prahovo, on the quality of surface waters and groundwaters, the Danube River, which is classified according to the Rulebook on benchmark conditions for types of surface waters (OJ of RoS, No. 67/2011) in the large lowland rivers, domination of a fine deposit (Type 1), and according to the Rulebook on the parameters of chemical and quantitative status of groundwaters (OJ of RoS, No. 74/2011) in the class II for limit values (limit value and maximal allowable value) of pollutants defined by the Regulation on the pollutant limits in surface waters and groundwater and sediments and deadlines for their reaching (OJ of the RoS, No. 50/2012), is based on the results of physical and chemical analyses of water presented in Section 5.4 of this Study, with a combined approach of stream and effluent standards

The results from 2008 demonstrated that according to the New Dutch List (target, limit and intervention remediation values for pollutants in the New Dutch List are identical as in the Regulation on the pollutant limit values in surface waters and groundwater and sediments and deadlines for their reaching (Official Gazette, No. 50/2012). The following results were obtained: of 12 tested wastewater samples 10 samples had pH below 6.5, increased content of sulphates was recorded with 6 samples and heavy metals with As (5 samples), Cu (6), Ni (4), Cd (6), Cr (7) (Tables 5.7-5.9). The wastewater from the factory's collector had pH=2.3, while for phosphates was recorded value 560 mg/l). However, it did not have significant impact on the quality of the Danube's water downstream from the discharge site (pH=7.5, phosphates 3.2 mg/l). Also, the results obtained in 2012 indicated that wastewater from the collector was not of class 2 for parameters: suspended materials, BPK5, HPK values, ammonium ion, detergent concentrations. However, the quality of the Danube's water upstream and downstream from the wastewater discharging site was, according to presented result, of class 2 except for suspended materials. Therefore, it can be said that wastewater did not have impact on the quality of recipient water.

With comparison of the wastewater samples from the collector analyzed during the period 2008-2012 it is noticed that the values of some parameters are substantially different (for example, pH). It can be explained with the fact that the all production facilities in the complex were not in operation in certain periods. Consequently, it had impact on the quality of wastewater discharged into the recipient, i.e. the Danube. It has already been mentioned that the wastewater from the collector can influence the quality of the Danube's water. However, the Danube's water upstream from the discharge site for collector's wastewater, most frequently, was not of the required class 2, and the quantity of the Danube's water had impact on a great dilution of wastewater. As a result, the quality of the Danube's water downstream is not substantially changed in relation the water quality upstream from the inflow location.

The 16 groundwater samples analyzed in 2008 and remediation intervention values or limit values were exceeded with some samples for a certain number of parameters (Table 5.4). The three samples had pH below limit value pH=6.5. In some samples was ascertained an increased concentration of fluorides (7 samples) and nickel (3 samples), while concentration of total phosphorous ranged from 1-500 mg/l (for comparison, for surface water limit value for water stream class 2, type 1 is 0.1 mg/l, class 3 0.2 mg/l, class 4 0.5 mg/l, and for class 5>0.5 mg/l there is not limit value). The results of physical and chemical analyses of groundwaters from three piezometers from 2012 indicated that concentrations of the investigated parameters did not exceed limit or remediation intervention values of pollutants in groundwaters in any samples according to the Regulation on the pollutant limit values in surface waters and groundwater and sediments and deadlines for their reaching (Official Gazette of RS, No. 50/2012).

On the basis of the obtained results it can be said that in the period 2008-2012 were not registered indicators which would point out to a substantial impact of groundwaters on the quality of the Danube's water.

In the following text the estimate of impact of the present phosphogypsum storage on groundwater and the Danube's water is singled out, with the objective to estimate impact of the new phosphogypsum storage, first of all, on groundwater, taking into account its future location.

As it has already been mentioned phosphogypsum is a by-product from phosphoric acid production, the wet process with dehydration, obtained with action sulphuric acid on phosphate rock. As a by-product phosphogypsum is transported via pipeline to the storage.
Depending on qualities and composition of input materials, phosphogypsum can contain traces of certain pollutants which does not contain gypsum produced from other sources (natural gypsum or gypsum generated with desulphurization of waste gases, etc.). The important elements and compounds which are part of phosphogypsum composition include: fluorine, heavy metals, metalloids, rare earth elements, sulphuric acid, hydrofluoric acid and radioactive nucleoids.

The three types of impurities are present in phosphogypsum:

- free phosphoric and free sulphuric acid;
- monocalcium phosphate, dicalcium phosphate and fluorosilicates;
- sodium and potassium salts.

The undissolved impurities can be divided in two groups:

- the impurities already present in raw phosphates (rocks, silicates and organic materials);
- the impurities formed in the second reaction cycle during raw phosphate processing.

Radionuclides present in phosphogypsum are an important impurity which does not particularly influence the phosphogypsum quality, but has a significant environmental impact. Radionuclides of special importance are $^{238}U$ and products of its radioactive decay $^{226}$ Ra, $^{222}RN$ and $^{210}PO$, originate from natural uranium compounds present in raw phosphates, while their concentration depend on type and origin, whether they are of primary or secondary origin. During phosphate processing the largest share of uranium passes into the products based on phosphates, while in some products such as artificial fertilizers passes radioactive uranium decay products such as $^{226}Ra$, $^{210}Po$. The distribution of uranium between phosphoric acid and phosphogypsum depends on uranium oxidation state.

Phosphogypsum in contact with water produce acid solution because of phosphoric, sulphuric and fluorosilicic acid. It is easily dissolved in precipitation, in the same way as natural gypsum, but phosphogypsum dissolution does not depend on pH value. If phosphogypsum is continually exposed to precipitation or high groundwater levels, in the phosphogypsum storage can be developed canals and cavities.

The phosphogypsum properties depend on size of its particles, and it differentiates from natural gypsum for this characteristic. Phosphogypsum contains numerous fine particles. Because of this the specific surface of phosphogypsum particles is exceptionally large and, consequently, phosphogypsum dissolves much faster than the same quantity of natural gypsum.

During disposal and stockpiling of phosphogypsum problems might arise due to seepage below the storage in case the storage is not properly insulated. For example hydrofluoric acid which is present is phosphogypsum can dissolve silica minerals according to the following reactions:

$$14nHF + 2M^{n+}(AlSiO_4)_n \rightarrow 2M^{n+} + 2nAlF_3 + 2nSiF_4 + 7nH_2O$$

where: $M^{n+}(AlSiO_4)_n$ alumosilicate mineral,
M cation Ca, Mg, Na, K or Fe.

$SiF_4$ is capable of forming $H_2SiF_6$ (fluorosilicic acid) via hydrolysis reaction in the drainage waters from phosphogypsum storage. The presence of fluorosilicic acid can cause dissolution of clayey soil at the bottom of the phosphogypsum storage. This can lead to rapid groundwater pollution if phosphogypsum is not properly stockpiled.

The water erosion of phosphogypsum storage can create cavities and instability within the constructed dike and cause occurrence of surface wastewaters from the phosphogypsum storage, as well as the erosion around the pipeline system. The slopes at the phosphogypsum storage can be endangered due to erosion cause by heavy precipitations.

The present phosphogypsum storage does not have hydro insulation and, secondly, overflow as an effluent is directly comes down in the Danube through the storage's overflow dam. As for the results from 2008 the water from the spillway of the present phosphogypsum storage was, according to certain parameters, of class 1 and 2 (Table 5.10). pH value of spillway water at the phosphogypsum storage was 6.2 and is somewhat lower than the emission limit value, or limit value of 6.5, and for parameter it would be classified in class 5. However, the analysis of water from the Danube, downstream from the effluent discharge location indicated that pH value of the Danube's water is 7.4. Only in relation to nitrite water was of class 3 (6 mg/l), and to phosphate ($PO_4$ 0.35 mg/l), electro conductivity was of class IV. By comparing the values of those parameters in wastewater samples from the collector in 2008 ($PO_4$ 560 mg/l, $NO_3$ 140 mg/l), and the Danube's water downstream from the inflow site for storage's overflow ($PO_4$ 0.45 mg/l, $NO_3$ 7 mg/l), according to the stream standard method, it can be said water from the present phosphogypsum storage did not have impact on the quality of recipient's water, in this case the Danube, for those parameters.

From the Study prepared in 2008 the results of physical and chemical analyses were singled out for three groundwater samples (Table 5.5), sampled at sites which are according to the sampling sites nearest to the present phosphogypsum storage (Table 5.3). According to the obtained results those groundwater samples do not exceed remediation intervention values standardized by the Regulation on the pollutant limit values in surface waters and groundwater and sediments and deadlines for their reaching (Official Gazette of RS, No. 50/2012). If it is commented on the quality of those waters on the basis of the stream standards method (the method based on the quality of recipient's water), for values of maximum allowable concentrations or limit values for class 2 which is required class for the Danube as a possible recipient, at Prahovo's profile for a good ecological status, of a large plain river, with domination of a fine deposit – Type $1^{1-3}$, then those two groundwaters are, according to electro conductivity parameters, of class 4, concentrations of phosphate and sulphates of class 5 (for class 5: $MAV_{phosphates}$ >0.5 mg/l; $MAV_{sulphates}$ >300 mg/l), arsenic - class 3, manganese - class 4 (MAV=1 mg/l) or class 5 (MAV >1 mg/l).

The groundwater from piezometer 3, which was set up at the present phosphogypsum storage (Table 5.6), was analyzed in 2012. It was concluded that those parameters for which remediation intervention concentration values exist they did not exceed standardized values (Cu, Zn, As, Pb, V). If the quality of water from the piezometer 3 would be commented as the quality of surface water, type 1, then it is noticeable that some parameters are of class 5 ($NH_3$, $NO_2^-$, what would point out to the pollution with nitrogen compounds, sulphates and total phosphates) and that water could not be discharged into that recipient as an effluent in relation to the quality of class 2 stream according to the stream standard method.

In order to estimate the impact of the future phosphogypsum storage, first of all, on groundwaters (and soil), herein is underlined that the solutions anticipated in the conceptual design provide protection of soil and groundwater. The new storage will have hydro insulation on the bottom and internal sides, while water will be used in the production process as return water. On the basis of the data from terms of reference and the data from the Report on investigation of technical and geotechnical characteristics of phosphogypsum (Faculty of Mining and Geology, University of Belgrade, July 2013), it has been adopted that in the process of continual operation, 70 t of deposited gypsum will bond 50 t ($m^3$) of water and, according to the mass balance from around 210 $m^3$ of water from the storage around 160 $m^3$ will be return water. It virtually averages that on the new storage will not be any surplus of water.

Table 6.6: Mass balance

| | Hydromixture from factory | Deposited mass | Return water |
|---|---|---|---|
| Quantity of solids, % | 100.0 | 100.0 | - |
| Quantity of solids, t/h | 70.0 | 70.0 | - |
| Quantity of solids, $t/m^3$ | 2.36 | 2.36 | - |
| Solids mass concentration, % | 25.0 | - | - |
| Quantity of water, $m^3/h$ | 210.3 | 50.0 | 160.3 |
| Quantity of hydromixture, $m^3/h$ | 240.0 | - | - |
| Density of hydromixture, $t/m^3$ | 1.168 | - | - |
| Moisture content, % | - | 41.7 | - |

On the basis of the presented it can be estimated that the future phosphogypsum storage will not have any impact on the groundwater of the complex Elixir Prahovo Ltd. Prahovo. Only in cases of some industrial accidents, bursting of the pipeline or damage of the liner used for hydro insulation of the future phosphogypsum storage, it is possible that the quality of groundwaters would correspond to the quality of groundwater from the piezometer 3 (2012) or to those qualities detected during 2008 around the present phosphogypsum storage, if there is free water in the new storage. For those groundwaters it is ascertained that there were not exceeded remedial values standardized with the Regulation on the pollutant limit values in surface waters and groundwater and sediments and deadlines for their reaching (OJ of the RoS, No. 50/2012). As for the water from the pipeline, it could correspond to the quality of water from the spillway of the present phosphogypsum storage, for which it can be said according to the stream standards methodology that does not influence the quality of water in the recipient, i.e. the Danube River nor groundwaters.

The design does not anticipate discharge of waste water into the recipient nor in groundwater.

## 6.5. Analysis of impacts on the soil quality

Considering that it belongs to limited natural resources which are hardly renewable, occupation and disturbance of soil represents the most important conflict of the industry with the surrounding. The stage development of the new phosphogypsum storage has been planned at the location of the industrial complex. Thus, the stage 1 includes the degraded area around the existing pyrite slag disposal, the area which is the company's property while the stages 2 and 3 imply utilization of the area which Elixir Prahovo Ltd. Prahovo will purchase from the present owners.

AERMOD model (US Environmental Protection Agency) was used for evaluation of dust deposition in function of distribution of deposition matter at area the phosphogypsum storage. Obtained results are average daily deposition values (mg/m$^2$ day) for defined emission sources and receptors. It should be mentioned that these models included terrain elevation. Data from the period 2010-2013 are used for meteorological conditions.

Figure 6.5 shows the distribution of deposition particles (mg/m$^2$ dan) around the industrial complex of the development stage 1 of the phosphogypsum storage in the complex of Elixir Prahovo, Industry of Chemical Products Ltd. for analyzed conditions.

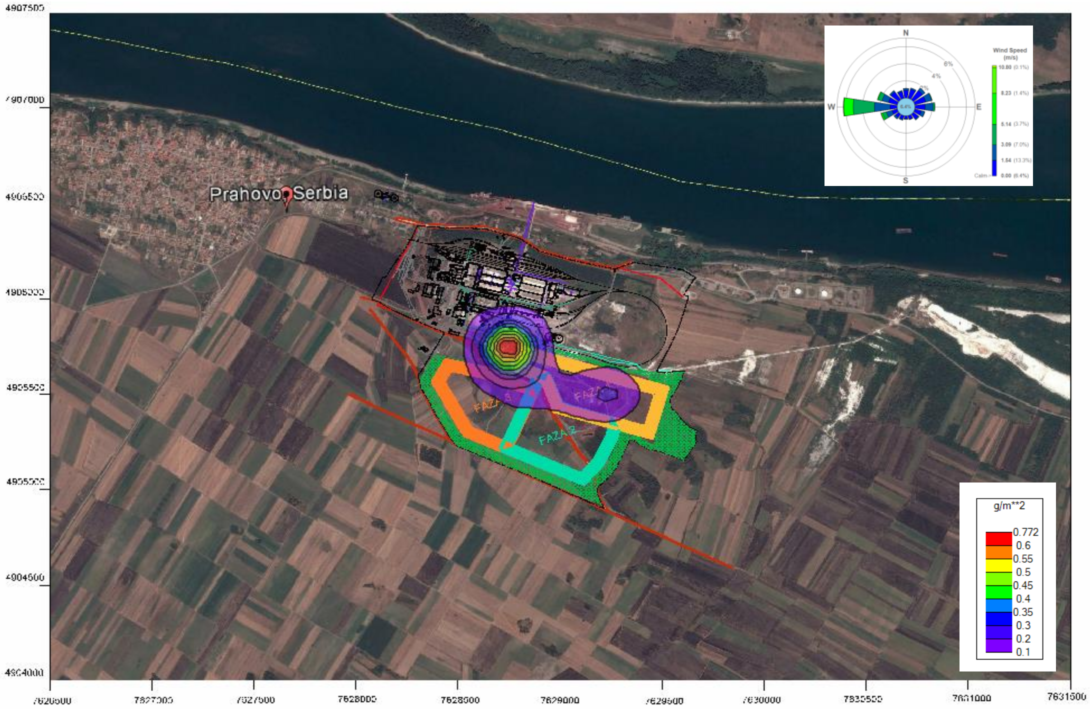



Fig.6.5 The distribution of concentrations of deposited particles mg/m$^2$ per day) around the industrial complex of the stage 1 phosphogypsum storage without application of methods and procedures for dust protection

The deposition particles at the level of maximal allowable value of 450 mg/m$^2$ per day are located in the area of the phosphogypsum storage, i.e. within the boundaries of the industrial complex, so that it can be concluded that the deposition particles due to activities on the phosphogypsum storage will not exceed limit values in the area of residential buildings in the village Prahovo.

The distributions of deposition particles (mg/m$^2$ per day) around the industrial complex of the developmental stages 2 and 3 of the phosphogypsum storage in the complex of Elixir Prahovo Ltd. Prahovo for analyzed meteorological conditions are presented in Figures 6.6 and 6.7.

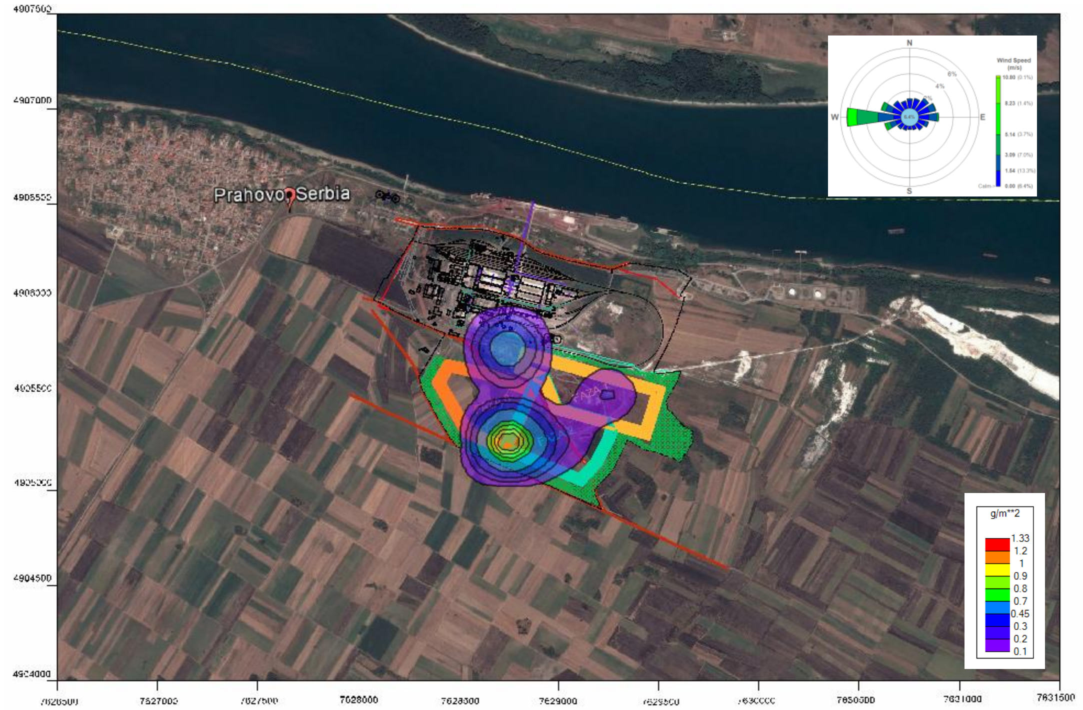



Fig.6.6 The distribution of concentrations of deposited particles mg/m$^2$ per day) around the industrial complex of the stage 2 phosphogypsum storage without application of methods and procedures for dust protection

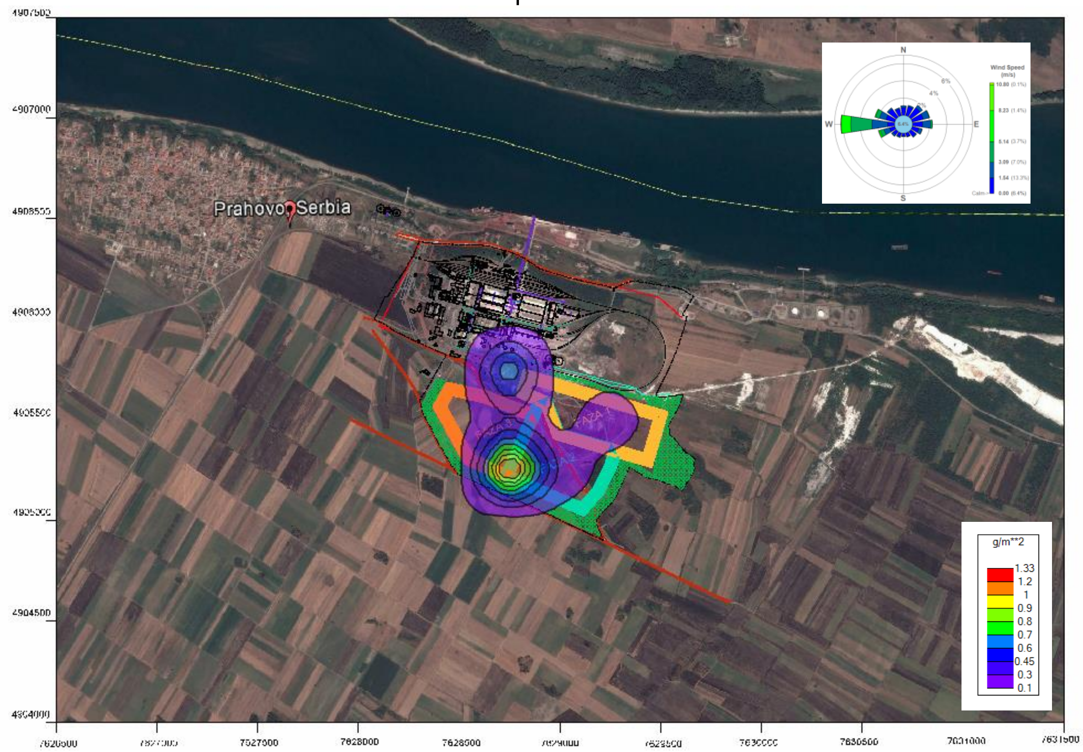



Fig.6.7 The distribution of concentrations of deposited particles mg/m$^2$ per day) around the industrial complex of the stage 3 phosphogypsum storage without application of methods and procedures for dust protection

The deposition particles at the level of maximal allowable value of 450mg/m$^2$ per day are located in the area of the phosphogypsum storage, i.e. within the boundaries of the industrial complex, in case of the stages 2 and 3 of the storage development, so that it can be concluded that the deposition particles due to activities on the phosphogypsum storage will not exceed limit values in the area of residential buildings in the village Prahovo.

The soil quality in the area of the industrial complex of Elixir Prahovo Ltd. Prahovo presented in Section 6 herein, to great extent support the conducted estimate of impact of deposition particles and the statement that impact can be expected in the area of the phosphogypsum storage, i.e. within the boundaries of the industrial complex. It is required to perform detailed soil investigations outside the industrial complex for more comprehensive analysis and realization of impacts.

The problematics related to the occupation of surfaces required for construction of the phosphogypsum storage as well as all accessory facilities required for the process of disposal operation represents one of important parameters which is authoritative for the definition of relation between the storage and environment. The total area occupied with cassettes is 46.5 ha.

The problematics of visual pollution as a criterion for the relation of industrial facilities and environment assumes that landscape characteristics represent a qualitative factor which appears as an element of degradation of the existing and regulated relations. In order to upgrade descriptive estimates of impact in this domain to quantitative methods, which include a complex space valorization, it is necessary to implement the entire series of evaluation procedures which require high technological level of graphical and visual information.

The problematics of visual pollution has been taken into consideration through the basic level which includes the relation of phosphogypsum storage and space in order to define its impact on landscape. It was performed division on certain individual categories such as morphology, vegetation, surface waters, facilities and overall appearance in order to estimate the impact of the phosphogypsum storage on landscape.

The impact of process, i.e. phosphogypsum storage on change of the landscape characteristics, in a sense of morphological changes of the terrain, implies formation of the storage of certain size. During implementation of works on the phosphogypsum storage at the observed location will be unavoidably occupied the present surfaces, what will condition change and disturbance of morphological and esthetical characteristics of the existing natural ambient. Considering that the character and scope of the designed works is such that it is not possible to restore the original morphological appearance It is planner's obligation that with the technological process of storage, i.e. the activities on disposal of phosphogypsum and technical recultivation develop the storage's final geometrical outline in the way that newly formed space is adjusted in a functional and esthetical sense as much as possible to the existing natural ambient.

With the estimate of impact of the phosphogypsum storage on landscape characteristics in the domain of vegetation it is valued the vegetation's visual and biological quality, having in mind changes of appearance. For the disposal technology and formation of the phosphogypsum storage change of the landscape occurs due to unavoidable changes of vegetation in the surrounding area

It is necessary to define overall appearance of landscape as a special parameter in order to estimate impact of the phosphogypsum storage on landscape. For the estimate procedures, considering a substantial impact of subjective estimates, it is required to conduct, first of all, definition of interesting landscape entireties, and then if possible to perform valorization. The disposal of material and storage formation do not change, to great extent, basic landscape characteristics due to a relatively small occupied area. Nevertheless, the included terrains are characterized with certain negative visual impression.

## 6.6. Analysis of impacts of expected seismic activities on storage's stability

The terrain on which the phosphogypsum storage will be established is virtually leveled with mean elevation +47-51 masl. The ground has been explored several times, the last time at the site of the future storage at the end of 2013. The terrain foundation is formed from Pliocene sediment, and below a relatively thin humus layer, which will be removed, is the dusty clay layer. The starter dike at the storage will be constructed from broken stone and gravel.

Groundwater is hydraulically connected with the Danube and at the time of hydrological maximum will be at elevation +41 masl.

The view of the future storage with location of characteristic cross-section is provided in Fig.6.8. The geotechnical model of storage's slope made along the characteristic profile is provided in Fig.6.9.

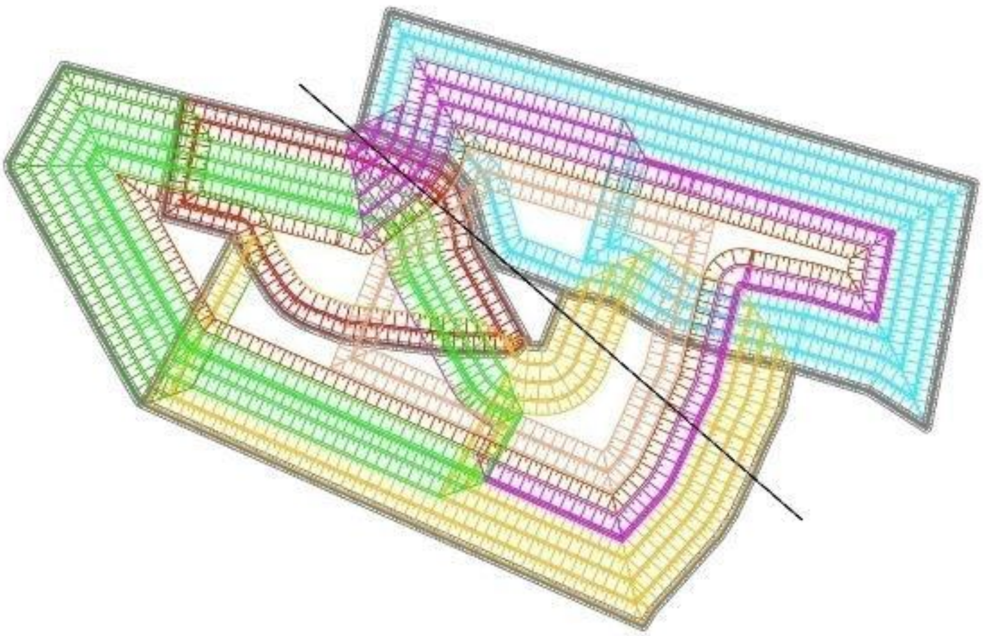


Figure 6.8: View of the storage with the location of characteristic profile

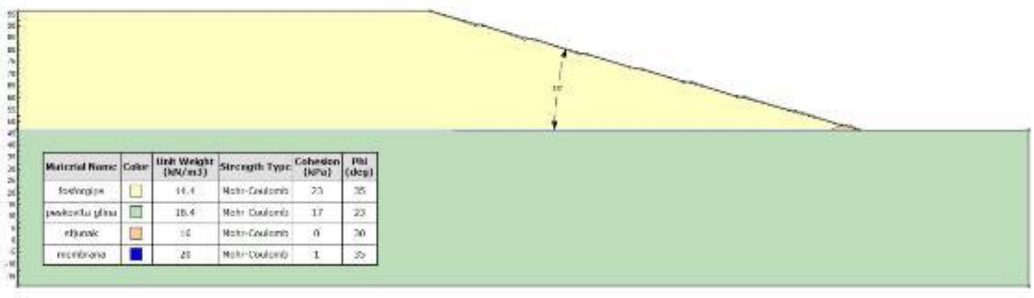



Figure 6.9: Geotechnical model for characteristic profile

According to the submitted (partial) seismic map of Serbia, Fig.2.8 for the return period of 100 years, in the area of Prahovo can be expected the maximum earthquake of 8 degrees of Mercalli intensity scale. The limit equilibrium concept is used to estimate pseudo-static load from earthquake of expected intensity. Earthquake intensity is described with seismic coefficient for vertical and horizontal directions. This coefficient has, most frequently, values from 0.1 to 0.3, i.e. and its value can also be calculated according to the formula:

$$C_s = \frac{\log^{-1}\left[0.267 + (MM - 1)0.308\right]}{980}$$

where: MM – Earthquake intensity according to the modified Mercalli intensity scale.

Firstly, on the basis of presented geotechnical model was created the finite element method model on which is determined distribution of pore pressure and position of filtration line, Fig.6.10. The calculated distribution of pore pressure with the position of filtration line in the storage and in the ground is provided in Fig.6.11.

The estimate of slope stability was firstly determined for cylindrical sliding plane (Fig.6.12. It has been calculated satisfactory safety coefficient of 1.814. Then, the same estimate was repeated for case of maximum expected magnitude of $8^0$MMS. It has been calculated satisfactory safety coefficient of 1.052 > 1 (Fig.6.13).

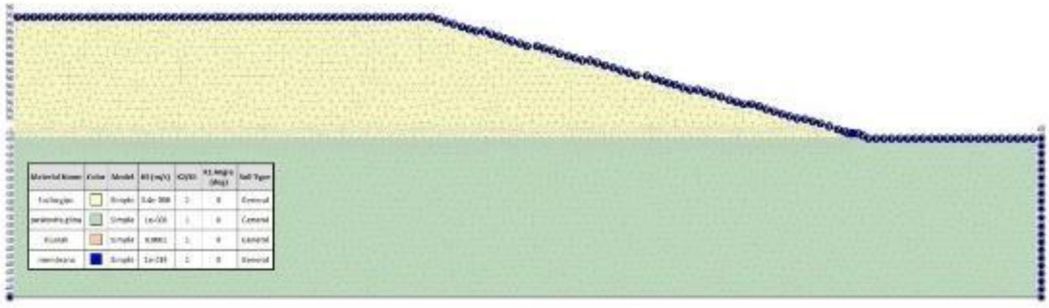


Figure 6.10: Finite elements method model with contour conditions

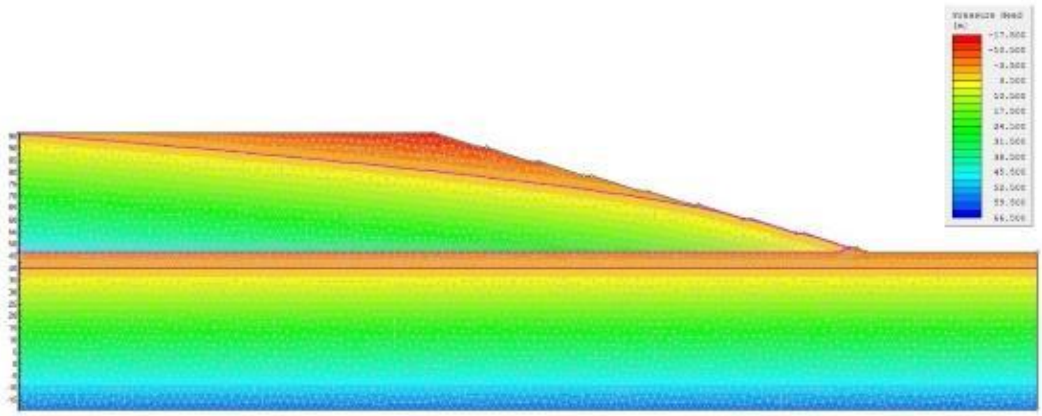


Figure 6.11: Distribution of pore pressure with position of filtration line

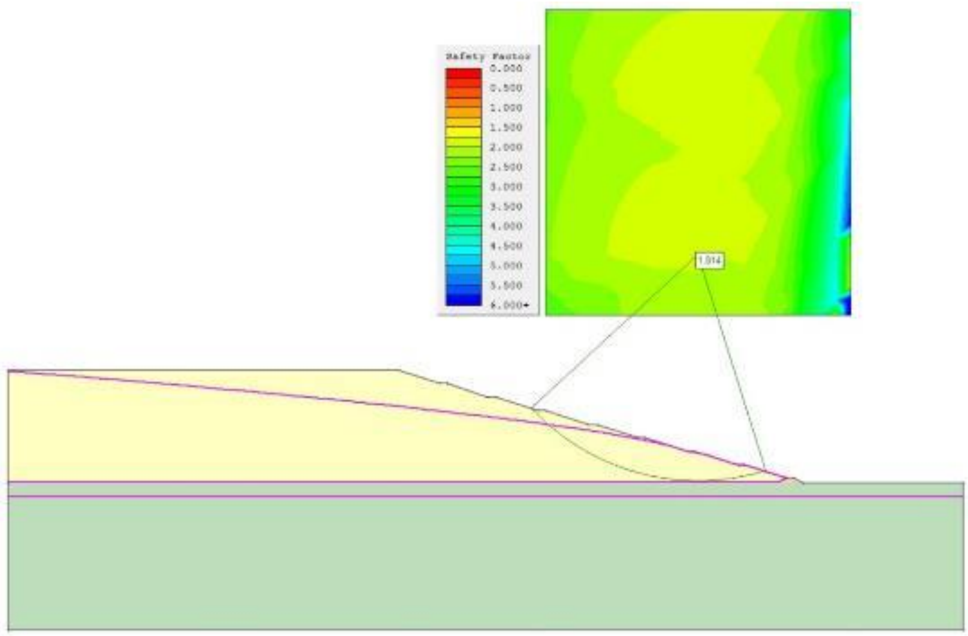



Figure 6.12: Graphic presentation of stability estimate based on the limit equilibrium concept for a cylindrical sliding plane

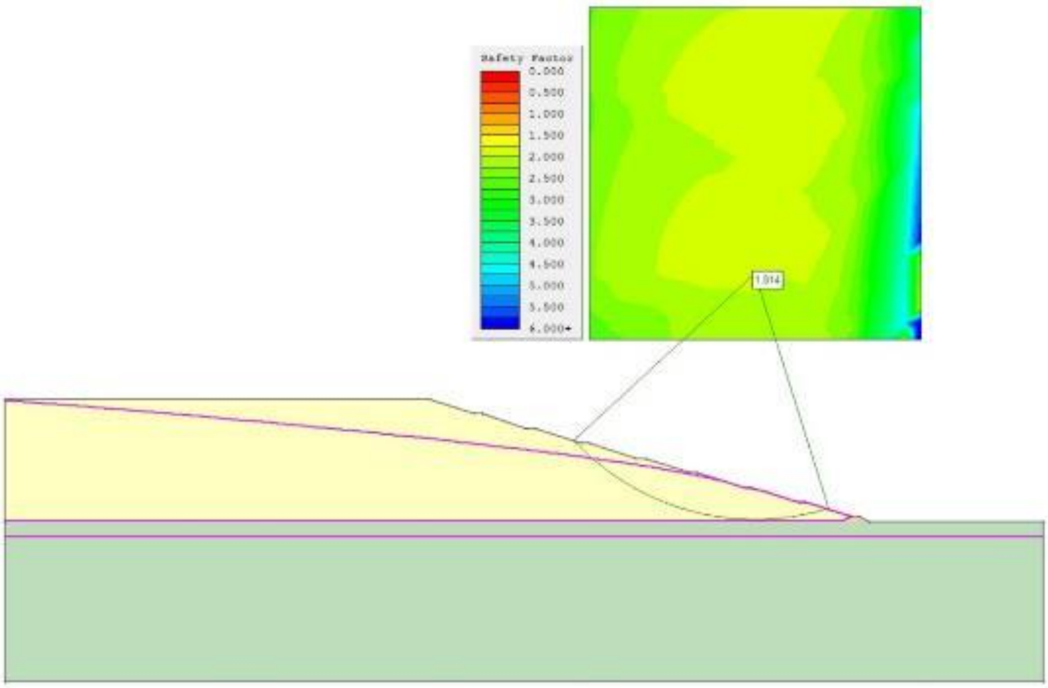



Figure 6.13: Graphic presentation of stability estimate based on the limit equilibrium concept for a cylindrical sliding plane, in case of maximum expected magnitude

After checking was performed for stress and deformation analysis with the Finite element method, with calculation of safety coefficient with the method for reducing dilatation (tangent), Fig. 6.14. It has been calculated satisfactory safety coefficient of 1.69, but with a different form of sliding body. Namely, the position of the zone of maximum tangent dilatation points out that break will occur, mainly due to sliding of deposited material on the foundation.

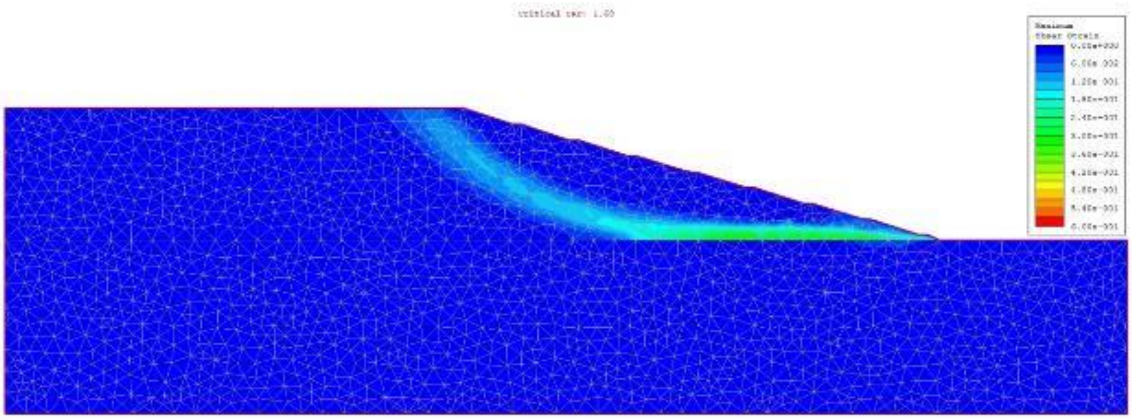


Figure 6.8: Graphic presentation of stability estimate with the Finite elements method

Because of that the estimate based on the limit equilibrium concept was repeated for the predisposed sliding plane, Fig.6.15. It has also been calculated satisfactory safety coefficient of 1.773.

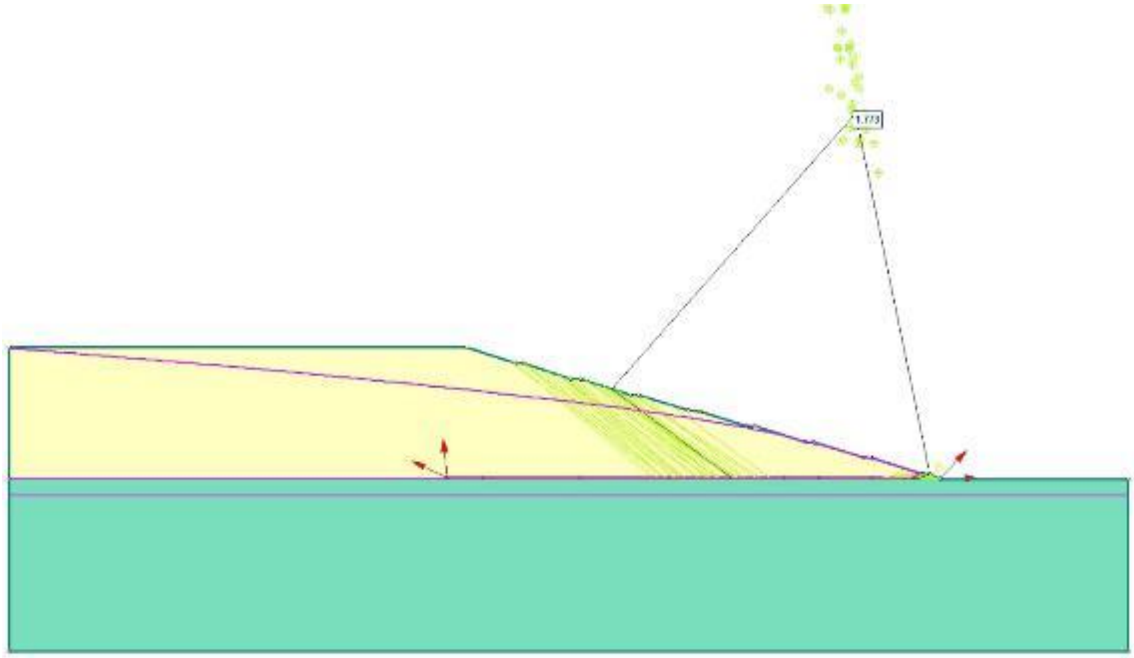


Figure 6.15: Graphic presentation of stability estimate based on the limit equilibrium concept for a predisposed sliding plane

Then, the same estimate was repeated for case of maximum expected magnitude of $8^0$MMS. It has been calculated satisfactory safety coefficient of 1.061 > 1 (Fig.6.16).

The stability estimate was done for balanced conditions at the storage and with parameters which are obtained in a very short period after discharge of suspension in the storage. It is expected that a real situation will be somewhat changed since with the passage of time will occur solidification of stored phosphogypsum. With that it will be altered values of the elements of internal friction (cohesion and angle of internal friction) and filtration coefficient. It is expected that the results of estimate will be more favorable than it is presented herein. In order to maintain stability condition under control it has been recommended to perform drilling on the established cassettes in the stage of development of final designs and ascertain real values of the quoted parameters, and to perform estimate with taking into account impacts caused with the time of stockpiling.

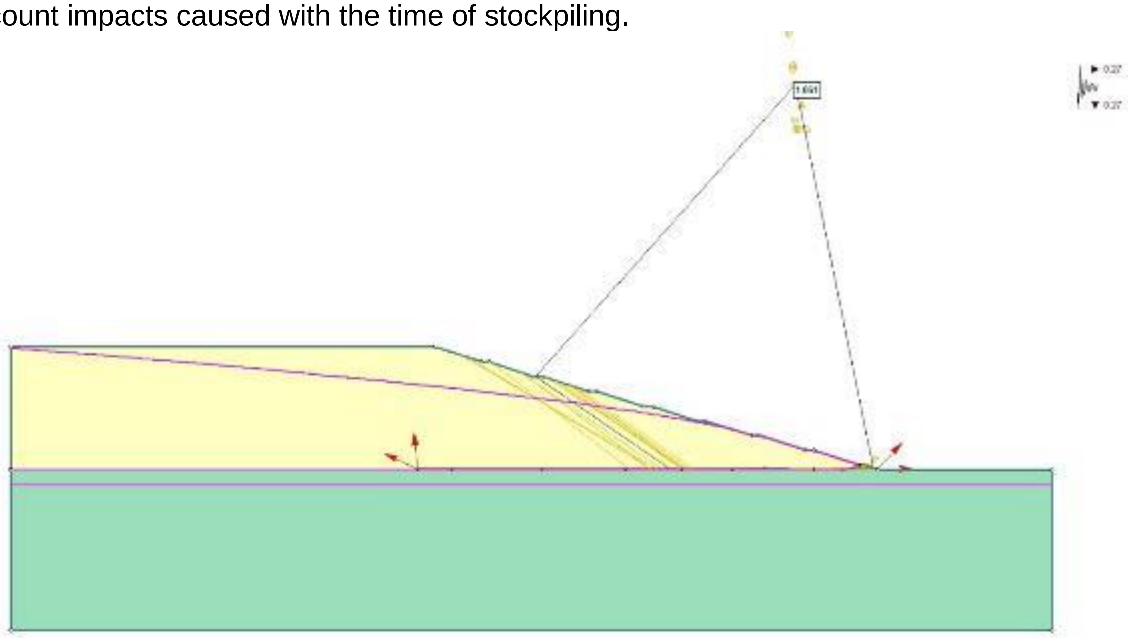


Figure 6.16: Graphic presentation of stability estimate based on the limit equilibrium concept for a predisposed sliding plane, in case of maximum expected seismic activities.

## 6.7. Impact evaluation of utilization of contaminated pyrite slag as a geological barrier below geomembrane in stage 2 of the phosphogypsum storage development

For removal of pyrite slag from the unregulated disposal area (it belongs to so-called historical pollution) and its sale Elixir Prahovo Ltd. Prahovo has obtained, on the basis of the project Rehabilitation and Remediation of the Pyrite Slag Disposal at the complex of IHP Elixir Prahovo Ltd. in Prahovo (Expert Engineering, Šabac, 2013), the agreement from Ministry of Energy, Development and Environmental Protection, the Decision No. 350-02-86/2013-05 as of 16.08.2013. The project anticipates excavation and sale/export of the entire quantity of pyrite slag to China. According to the calculations obtained by the team which controls the sale, around 100,000 m3 (around 190,000 t), to +46 masl, occupies contaminated pyrite slag which cannot be exported.

It will remain around 190,000 t of contaminated pyrite slag, what in relation to the estimated total quantity 2.46 million tons is around 7.7%. As for composition it is very heterogenic waste which besides burns with smaller share of iron than the contractual and also include unprocessed pyrite concentrate, phosphogypsum, “common” earth, sand and gravel, concrete fragments, textile, plastic and paper wrapping material and other components of unknown origin. Such a heterogenic material cannot be usefully used, but concrete fragments, wrapping material and other components of unknown origin are not present in the larger part and, therefore its utilization is possible. It is possible to perform visual selection among waste heaps, layer by layer. It has been estimated that the larger part or, more specifically, 100-150,000 t of contaminated waste consists of burns of inferior quality, phosphogypsum, pyrite, gravel, and earth waste. Hence, the idea to use that material as a “geological barrier” of unsatisfactory water permeability characteristics, on which is placed geomembrane (liner) which will provide required water permeability for regulated foundation, in accordance with the Regulation on waste disposal.

The utilization of pyrite slag as a “geological barrier” below geomembrane is essentially connected with the three conditions:

- technical condition: availability and technical applicability of material as the foundation for the future storage;
- ecological condition: applicability of that material in relation to realistically possible endangerment of environment in a longer period; and
- administrative (legal) condition: fitting of the option for utilization of that material in positive legislation of the Republic of Serbia.

### 6.7.1. Technical aspect of utilization of waste pyrite slag

There are several technical limitations:

- availability of sufficient quantities of material;
- it has to be possible to form levelled foundation for placement of liner without special protection;
- it has to be possible to obtain water permeability coefficient in accordance with legal framework;
- it has to be provided possibility to select the most suitable materials;
- it has to be provided consistency of that material in concrete conditions prevailing at the storage, etc.

**Availability of sufficient quantities of material for foundation.** The present estimate forecast that for around 150,000 t of pyrite slag is not provided placement on the market. If it is expressed as volume it provides around 78,000 m3 of available material. Since the minimum thickness of a “geological barrier” is 0.5 m it means that this material can be deposited on around 156,000 $m^2$ of the stage 2 area. The approximate dimensions of stage 1 cassettes are 700 x 280m what makes the area of around 196,000 $m^2$, or 19.6 ha. In other words, the estimated available quantities cover around 80% of future requirements. Considering that we deal with the estimate it can be concluded that exist required quantities of material at the site of the present pyrite slag disposal. It is useful to be mentioned that in the extension of pyrite slag disposal, toward the easts, are deposited soil heaps prepared for dump's rehabilitation and remediation. The all soil would be incorporated in a "geological barrier". The quantities of this soil are not known for the time being.

**Possibility of formation of levelled foundation.** In order to secure formation of levelled foundation, without additional protections, it is required to provide that there are no larger fragments which are rolled in. According to the grain-size distribution table provided in the document: the Project of utilization of iron pyrite slag in accordance with criteria for application of the concept end-waste (City Institute for Public Health, Beograd and Jugoinspekt, Beograd, 2011), it is fine-grained material (99.28% -0.4 m).

Besides the analyzed burns in the terrain are also noticed sand and gravel grains which were placed to facilitate mechanization movements during clearing stage. In principle, sand and gravel do not pose any threat since their spherical form will not violate liner's mechanical structure. Anyway, since there is possibility to come across pieces of broken, crushed concrete besides gravel, the visual check and removal of all larger fragments will have to be implemented.

**Capacity to reach a suitable water permeability coefficient.** According to the Serbian Regulation on waste disposal and EU Directive on the landfill of waste, on the bottom of the future storage it is required to provide water permeability coefficient lower than 10-9 m/s. At present, it is not available data on natural water permeability coefficient of the disposed burns, without special processing, but with visual inspection can be detected existence of water on almost entre terrain (Fig.6.17) and its very slow loss, connected with filtration and evaporation. However, it is not realistic to expect that required water permeability coefficient will be achieved with sprinkling and rolling, although on the basis of known geotechnical characteristics can be estimated that filtration coefficient of the consolidated profile will be very near to the required value. Hence, it will be necessary to install geomembrane which will provide quoted water permeability, in accordance with the quoted laws. It is therefore not anticipated to avoid installation of liner with cultivating foundation.

Figure 6.17: Pyrite slag disposal under water from precipitation

**Possibility to select suitable material.** Considering that heaps are open it will not be difficult to separate inferior parts in order to prepare foundation only from suitable materials (burns, phosphogypsum, soil, sand and gravel).

**Stability of material on which will be placed liner.** Pyrite slag, phosphogypsum, soil, sand and gravel are made of stable minerals which do not significantly change its characteristics when exposed to various weather conditions or pressure. The basic components with burns include iron minerals (51-59%), $SiO_2$ (7-11%) and with phosphogypsum CaO (26%) and $SiO_2$ (14%). $SiO_2$

prevails with sand and gravel, while soil is of changeable composition. Depending on share of clay it will occur gradual and unequal settling of material, but this cannot have an adverse impact on storage's technical stability since minimum stretching of liner (to bursting point) is 70%, and in the drainage system will be installed plastic tubes which will compensate changes which eventually originate due to unequal foundation settling.

### 6.7.2. Ecological aspect of pyrite slag applicability

It is possible to evaluate ecological aspect of selected waste pyrite slag applicability in a longer term in relation to air, water and soil pollution, and, consequently, in relation to possible impact on residents' health. It is, of course, important to take into consideration from the ecological aspect which consequences on the quoted factors can originate due to various accidental situations.

**Impact on air quality in the surroundings.** Due to very fine grain size freely deposited burns are susceptible to be wind-blown during dry and windy periods. At the site has been planned rolling of pyrite slag and duly covering with HDPE liner and, therefore, it is prevented its drying and distribution around the surrounding.

**Impact on water quality.** It is required to take into consideration two cases in relation to the impact of pyrite slag on surface waters and groundwaters. The phosphogypsum storage design anticipates that entire area (storages, ditch, road, canal and interspace) is covered with watertight geomembrane. Phosphogypsum will be stockpiled on a geomembrane, ditch will be made of concrete, the road will be covered with gravel and rolled, the canal will be under water, and interspaces will be filled with soil layer in order to protect liner from mechanical damage as well as from exposure to ultraviolet (UV) light. In that way, it is constructed a sufficiently reliable barrier to prevent contact of rolled pyrite slag with surface waters in the surrounding.

The impact of rolled foundation on other surface waters located at some distance is possible only through groundwaters. Hence, it is required to prevent any contact of groundwater with the foundation material.

Table 3.4 shows the relation between maximum groundwater level and the geological barrier location from the aspect of elevation. It is seen that the maximum groundwater level is for 5.5 m below the level at which are rolled pyrite slag. That tampon zone prevents contact between groundwater and rolled pyrite slag.

By reviewing possible scenarios for seepage of water from the storage into groundwater it can be concluded that the only way is that water seep through the damaged liner ends up into "geological barrier" and then seeped through the soil into groundwater. It might turn out that even in this accidental situation the pollution of groundwater is almost impossible.

According to the results of geotechnical investigations of phosphogypsum, it has compressibility modulus which range from 2,300 to around 16,000 kN/$m^2$ and consolidation coefficient of around 100$m^2$/year. This means that phosphogypsum filtration coefficient drops from maximum $2.5 \cdot 10^{-6}$ m/s to 3.6·10-7, after is reached the full storage's height and consolidations. It virtually means that seepage water will not reach the storage's bottom but it will happen, the same what is observed as occurrence with the existing phosphogypsum storages, that very small quantities of percolating comes down along storage's sides and ends into perimeter canals.

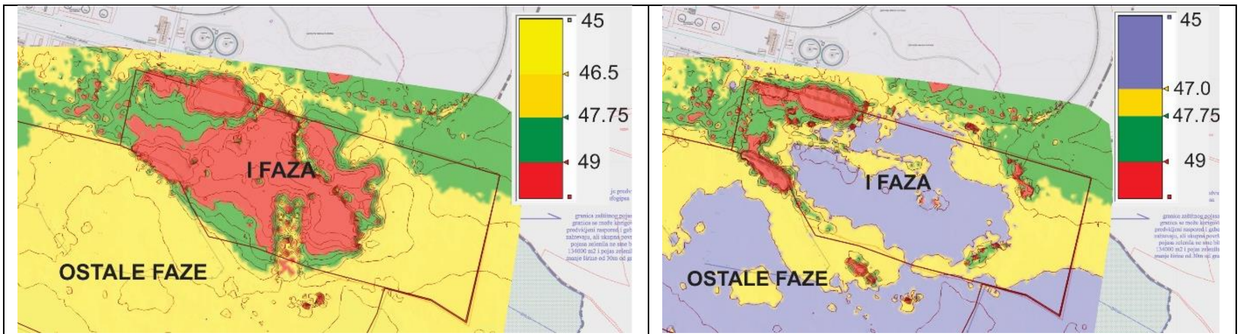
If percolating reach mineral barrier then it is raised a question whether those small quantities of water could reach to groundwater. It is almost impossible for two reasons.

Firstly, after storage reaches its full height the consolidation of geological barrier will occur, as well as of the ground below the storage which thickness is to the maximum groundwater level around 5.5 m. On the basis of data from the Geotechnical report for requirements for rehabilitation of the facilities 1-7, reservoir and phosphoric acid facility as well as for construction requirements for the new packing facility in the complex Elixir Prahovo Ltd. Prahovo (GT Engineering 2012), it can be concluded that the ground below the storage is dusty clay, which will consolidate after loading to the maximum settling of around 20 cm. Simultaneously, it can be estimated that the filtration coefficient will decrease from the value $10^{-7}$ m/s provided in the geotechnical report, to the value which is proportional to the change of porosity coefficient ($k \sim e^3/(1+e^2)$), and range from $2 \cdot 10^{-8}$ to $4 \cdot 10^{-8}$ m/s. It is obvious that the filtration coefficient is very small, which also related to a saturated ground and permeability coefficient (k) in Darcy's filtration law.

The second reason on which basis can be claimed that is almost impossible to occur seepage into groundwater is the fact that is possible to be talked only about very small quantities of water which can enter into the sub-ground level, but they cannot cause full water saturation of the ground below the storage. Hence, it cannot be achieved filtration coefficient (k). With reduced saturation of sub-ground with water (S) it is also reduced filtration coefficient proportionally to saturation degree: $k(S) = k S^{3.5}$. For example, for saturation degree 0.6 (60% of pores is filled with water), filtration coefficient is 6 lower than permeability coefficient (k) in Darcy's filtration law, which relates to the saturated ground. It is obvious that the realistic filtration coefficient for sub-ground will be around $3 \cdot 10^{-9}$ m/s, and it is the filtration coefficient of the same order of magnitude requirements which are set up for conditions when there is no liner. Accordingly, it can be concluded that it does not exist a realistic possibility that percolating water from the future storage (situated at the present site of pyrite slag disposal) reach the groundwater.

**Impact on soil.** The soil will be covered with selected waste pyrite slag rolled on the soil. The waste pyrite slag was loaded with all possible pollutions since at the dump was deposited pyrite concentrate, pyrite slag and other various wastes during last decades. Since protection measures were not applied it is realistic to expect that soil has reached a certain pollution level which will not be increased with the proposed solution. At the same time, with the utilization of the same soil for the stockpiling of the phosphogypsum is prevented occupation of the new land of better quality. It can be concluded that burns in the foundation will not further undermine soil quality.

In Fig.6.18 is provided the comparative scheme of the area which encompasses pyrite slag prior the commencement of its utilization in July 2014 and at the end of utilization.




| At the beginning of utilization of pyrite slag | At the end of utilization of pyrite slag |
|---|---|

Figure 6.18: Geodetic survey: the pyrite slag disposal

It can be seen in Fig.6.18 that the largest part of area occupied which was occupied with burns is between elevations +45 and +47 masl. It means that the existing burns layer will not be exceeded but it will be only rolled in order to install liner. This is an additional positive circumstance since it is avoided additional activation of deposited burns.

**Impact on resident's health.** Considering that the "geological barrier" is below the geomembrane there is no impact on water, air and soil and, consequently there is no any impact on residents' health. It is also favorable circumstance that there are no any settlements in the immediate surroundings.

**Accidental situations.** As for the negative impact of pyrite slag from the foundation on the surrounding it is required to take into consideration two situation. The first is connected with damage of HDPE liner, and the second for lifting of groundwater.

**Damaging of HDPE liner.** The damage of HDPE liner is realistically possible in the stage of storage establishment. At that time in the work site will be present a large number of workers in various parts of the storages, performing various tasks. The liner can be mechanically damaged by mistake and it can lead to the contact of precipitation and surface water from the storage's outlines with the rolled foundation. The solution for this is a strict control of all works what will prevent any damage and, if it occurs will be duly noticed and rehabilitated (technically possible, it is performed fast and does not incur a substantial cost).

When outsourced workers leave the work site and starts stockpiling, the number of workers will be reduced to the required human resources, and they will be assigned to the zone in which dike is upgraded or is performed discharging, the mechanization movement will be strictly controlled and scheduled, the storage main part will be filled with phosphogypsum, in the rigol and canal will be water, the road will be protected with rolled gravel, the interspaces will be below the soil layer and, therefore, it is very unlikely that liner can be damaged. If mechanization damaged the liner at some place around the main part it will be visible. It sets up conditions to prevent any contact of water from the storage with foundation, with prompt rehabilitation.

If by any chance the liner is damaged, under unexplained circumstances, and occur the longer contact of the water from the storage or precipitation with the foundation under the liner it is important to know which consequences that might have on the waters in the surrounding. The heavy metal leaching from contaminated pyrite slag testing was performed in order to forecast a possible condition.

It was used the most frequently applied TCLP (Toxic Characteristic Leaching Procedure), SW-846 Method 1311 developed by EPA and which our state accepted. For leaching is used one or two solutions depending on material's pH value. In case when pH value is below 5 (it was case here) it is used solution 1 which has pH value 4.93±0.05. According to the procedure the relation between solution and material which leaching is measured is 20:1, and samples are continuously mixed in a magnetic mixer during 18 hours. The solution is separated with vacuum filtration through a glass fiber filter with pore size 0.5 micrometer.

The selection of heaps on which are deposited contaminated burns and sampling was performed by SGS staff from Prahovo, while testing was performed in the SGS Laboratory in Ontario, Canada. The samples of visible contaminated burns were marked C1 to C4. The sample C1 was characterized as a contaminated mixture; sample C2 as contaminated, yellow colored material; sample C3 as black colored mixture; and sample C4 as course-grained burns mixed with phosphogypsum. In Fig.6.19 is presented sampling.

| Sample C1 | Sample C2 | Sample C3 | Sample C4 |
|---|---|---|---|

Figure 6.19: Sampling C1-C4

The results obtained by the leaching testing and legally allowable limit values in the USA (EPA regulations) and in the Republic of Serbia are provided in Table 6.7.

Table 6.7: Results obtained by the leaching test

| **Sample ID** | | **C1** | **C2** | **C3** | **C4** | **TCLP limit. USA** | **TCLP, LV Serbia** |
|---|---|---|---|---|---|---|---|
| Sample weight | g | 100 | 100 | 100 | 100 | | |
| Ext. Fluid | #1 or #2 | 1.0 | 1.0 | 1.0 | 1.0 | | |
| Ext Volume | mL | 2000 | 2000 | 2000 | 2000 | | |
| Initial Ph | | 5.02 | 5.06 | 5.09 | 4.98 | | |
| Final Ph | | 4.66 | 4.72 | 5.21 | 4.87 | | |
| pH | no unit | 4.69 | 4.75 | 5.19 | 4.89 | | |
| **Hg** | **mg/L** | < 0.00001 | 0.00005 | 0.02222 | < 0.00001 | **0.2** | **0.2** |
| Al | mg/L | 22.3 | 10.3 | 6.34 | 2.41 | | |
| **As** | **mg/L** | 0.697 | 0.062 | 0.009 | 0.128 | **5.0** | **5** |
| **Ag** | **mg/L** | 0.000236 | 0.000238 | 0.001534 | 0.000075 | **5.0** | **5** |
| **Ba** | **mg/L** | 0.0796 | 0.0872 | 0.105 | 0.09999 | **100** | **100** |
| Be | mg/L | 0.00127 | 0.00157 | 0.00152 | 0.00061 | | |
| B | mg/L | 0.360 | 0.303 | 0.547 | 0.307 | | |
| Bi | mg/L | 0.00030 | 0.00067 | 0.00011 | < 0.00007 | | |
| Ca | mg/L | 749 | 686 | 789 | 834 | | |
| **Cd** | **mg/L** | 0.142 | 0.213 | **2.44** | 0.006 | **1.0** | **1** |
| Co | mg/L | 0.370 | 0.133 | 0.200 | 0.0249 | | |
| **Cr** | **mg/L** | 0.222 | 0.672 | 0.0158 | 0.0129 | **5.0** | **5** |
| Cu | mg/L | 17.7 | 12.2 | 8.19 | 2.67 | | **25** |
| Fe | mg/L | 71.1 | 30.2 | 0.297 | 0.126 | | |
| K | mg/L | 0.846 | 1.27 | 4.27 | 0.956 | | |
| Li | mg/L | 0.0205 | 0.00932 | 0.0659 | 0.00375 | | |
| Mg | mg/L | 14.6 | 5.21 | 11.8 | 0.836 | | |
| Mn | mg/L | 3.62 | 3.54 | 20.3 | 0.0538 | | |
| Mo | mg/L | 0.0108 | 0.0013 | 0.0003 | 0.0032 | | **350** |
| Na | mg/L | 1440 | 1350 | 1370 | 1370 | | |
| Ni | mg/L | 1.12 | 5.15 | 0.238 | 0.026 | | **20** |
| **Pb** | **mg/L** | 0.026 | 0.192 | **8.05** | 0.013 | **5.0** | **5** |
| Sb | mg/L | < 0.002 | < 0.002 | < 0.002 | < 0.002 | | **15** |
| **Se** | **mg/L** | 0.02 | 0.01 | 0.05 | < 0.01 | **1.0** | **1** |
| Si | mg/L | 2.69 | 2.67 | 47.9 | 0.56 | | |
| Sn | mg/L | 0.0021 | 0.0035 | 0.0003 | 0.0003 | | |
| Sr | mg/L | 0.526 | 0.986 | 0.821 | 2.28 | | |
| Ti | mg/L | 0.0394 | 0.0360 | 0.0024 | 0.0032 | | |
| Tl | mg/L | 0.00032 | 0.00269 | 0.04826 | 0.00105 | | |
| U | mg/L | 0.02090 | 0.02526 | 0.01327 | 0.00246 | | |
| V | mg/L | 0.0243 | 0.0074 | 0.0036 | 0.0048 | | **24** |
| Zn | mg/L | 76.0 | 133 | **941** | 0.686 | | **250** |

**Note:** The limit values for Serbia are excerpted from the Rulebook on categories, investigations and waste classification (Official Gazette of RS, No. 6/2010, Appendix 10, the List of parameters for investigation of the waste for disposal.

From the presented results it is seen that only sample C3, characterized as black colored mixture, does not meet requirements according to the TCLP limit values for cadmium, lead and zinc concentrations. With other samples the all parameters were far below limit values.

In Elixir's archive, in the Project of Rehabilitation and Remediation of the Pyrite slag Disposal at the complex of IHP Elixir Prahovo Ltd. in Prahovo (Expert Engineering, Šabac, 2013) are presented the results of leaching of samples from the burns dump, processed according to EU standards SRPS EN 12457-4 (for ration liquid/solid – L/S=10, water, mixing 24 hours, grain-size <10mm) and according to the TSLP procedure. In Table 6.8 are presented leaching results, while only elements which value is limited with EPA standard and the Serbian Rulebook are singled out.

By comparison of the obtained results with the limit values prescribed for TCLP test it is clear that the all parameters are far below the "allowable" limit. The closest to the limit value is arsenic share, but its concentration is more than 3 times lower than the limit value. According to the EU standard copper and zinc concentrations are exceeded, especially if the initial leaching is observed, after 24 h.

Table 6.8: Results obtained for pyrite slag leaching tests, excerpted from the Elixir's archive

| | **SRPS EN 12457-4, leaching time** | | | | **TCLP** | |
|---|---|---|---|---|---|---|
| | **24 h, mg/kg** | **72 h, mg/kg** | **168 h, mg/kg** | **Criteria , mg/kg dry** | **Results mg/L** | **Parameters mg/L** |
| **Hg** | <0.01 | <0.01 | <0.01 | 2 | <0.002 | **0.2** |
| **As** | 0.55 | <0.20 | <0.20 | 25 | 1.49 | **5.0** |
| **Ba** | 0.12 | 0.21 | 0.46 | 300 | 0.010 | **100** |
| **Cd** | 1.50 | 0.11 | 0.02 | 5 | 0.063 | **1.0** |
| **Cr** | 0.32 | 0.02 | <0.02 | 70 | 0.019 | **5.0** |
| **Pb** | <0.09 | <0.09 | <0.09 | 50 | <0.009 | **5.0** |
| **Se** | 0.45 | <0.88 | <0.88 | 7 | <0.038 | **1.0** |
| **Cu** | **1700** | **126** | **230** | 100 | 69,2 | **100** |
| **Ni** | 7.3 | 0.5 | 0.07 | 40 | 0,297 | **20** |
| **Sb** | <0.06 | <0.06 | <0.06 | 5 | <0,022 | **15** |
| **Zn** | **3280** | **226** | 3.7 | 200 | 14,1 | **250** |
| **Mo** | <0.03 | <0.03 | <0.03 | 30 | <0,003 | **350** |

Criteria for the EU test are downloaded from the website http://www.intersol.fr/pdf2012/Jaap_Willem_Hutter_Alconto_Laboratory_Intersol_2012.pdf.In the study prepared by the Greek company Intergeo from 2008, are provided the leaching test results prepared according to the EU standards, and obtained results are presented in Table 6.9.

Table 6.9: Results obtained for pyrite slag leaching tests

| | **SS12. Pyrite dust red, mg/kg** | **Waste categories, mg/kg dry** | | |
|---|---|---|---|---|
| | | **inert** | **non-hazardous** | **hazardous** |
| **As** | 4.5 | 0.5 | 2 | 25 |
| **Ba** | 0.100 | 20 | 100 | 300 |
| **Cd** | 0.063 | 0.04 | 1 | 5 |
| **Cr** | <0.05 | 0.5 | 10 | 70 |
| **Cu** | 13 | 2 | 50 | 100 |
| **Hg** | 0.003 | 0.01 | 0.2 | 2 |
| **Mo** | <0.05 | 0.5 | 10 | 30 |
| **Ni** | 0.130 | 0.4 | 10 | 40 |
| **Pb** | <0.05 | 0.5 | 10 | 50 |
| **Sb** | <0.05 | 0.06 | 0.7 | 5 |
| **Se** | 0.003 | 0.1 | 0.5 | 7 |
| **Zn** | 4.800 | 4 | 50 | 200 |

By comparing with the limit values for inert and non-hazardous waste they concluded that the arsenic content is higher than the limit value, 0.5 and 2 mg/kg, respectively.

Considering that test results are taken from the Elixir's archive, performed on the composite samples from the pyrite slag disposal, and the assigned analysis on contaminated pyrite slag dump as the more trustworthy results we have adopted the results obtained in the SGS Laboratory, and they lead to the conclusion that for leaching criteria the rolled burns are suitable for placement below the geomembrane. The impact on groundwater and surrounding will be negligible even in cases when water breach below the liner.

**Raising of groundwater levels.** This is undoubtedly more a theoretical than practical issue. If occurs uncommon raising of groundwater level it will mean that water below the storage is under pressure and that it can jeopardize the storage, especially in the initial development stage, when the foundation loading is low. In real circumstances this will condition occurrence of free water around, or in some part, of the storage, the occurrence known as "soaking". It happens on the sandy-gravel terrain, where the groundwater level is high, as the reaction of groundwater on pressure to which is exposed from the storage. Since that upward pressure cannot uplift the storage then unburdening occur in the surrounding terrain in which there is no pressure downwards so the upwards pressure is higher. In this case, from the ecological aspect it will occur flooding of the lowest parts of the terrain around the dump. If this occurs, and it can be visually easily detected, there is no fear that it will come into the contact with the foundation below the liner and jeopardized surrounding in that way, but will be jeopardized crops where water occur. The threat is resolved with construction of a separate canal, now without the liner cover, which will represent the "unburdening line" toward the lowest point, which will temporary accept that water, prior to being transferred by pumps into the defended part of the storage. This measure has not yet been taken into consideration because of a huge impact of the Danube on groundwater formation in the hinterland, the probability of occurrence is low and, therefore, it is not initially required to spend funds on solving low-probability situations.

### 6.7.3. Administrative (legal) aspect of pyrite slag applicability

From the administrative aspect it is of great importance to comply with the all prescribed decisions. This is of particular importance in conditions when employees/engineers authorized to make decisions and estimate situation act as a typical administrators without aspiration to reduce unnecessary costs with realistic estimates, and to contribute to more efficient industrial operation.

The basic act which ought to be recontrolled is connected with the Regulation on dump waste disposal, which the Government of the Republic of Serbia adopted in 2010 (Official Gazette of RS, No. 92/2010), and which is based, to greatest extent, on the EU Landfill Waste Directive. The basic provision of this Regulation are connected with the disposal of communal waste, but its jurisdiction, administratively, is related to the disposal of industrial waste. In the Appendix 2 of this Regulation are provided Technical and Technological Conditions for Designing, Construction and Dump Commissioning.

**Conditions for dump's main part**

At the dump it is regulated the dump bottom and slopes, in the way which provide the dump's stability, sealing, i.e. water impermeability which with the system for reception and removal of seepage water prevent its breach into the dump's sub-ground.
Technical and technological conditions for provision of impermeability of the dump's bottom, controlled and managed with seepage water, the all waters which gravitate to the dump or are generated in it, dump gas, measure for reduction of spreading of unpleasant odors and external adverse impacts and measure for provision of dump's stability are:
1. Conditions connected with the dump's bottom: The dump's bottom and sides has to include a natural geological barrier which satisfy requirements in connection with permeability and thickness with a combined action for the protection of ground, groundwaters and surface waters, at least equal to the action which is the result of the following requirements:
- the hazardous waste dump: K≤ 1.0 x $10^{-9}$ m/s; layer thickness ≥ 5 m;

- the non-hazardous waste dump: $K \leq 1.0 \times 10^{-9}$ m/s; layer thickness ≥1 m;
- the inert waste dump: $K \leq 1.0 \times 10^{-7}$ m/s; layer thickness ≥1 m.

2. Conditions regarding seepage waters – When a natural geological barrier does not satisfy prescribed values, then it is secured with coating of the dump's bottom with synthetic materials or a natural mineral tampon zone which has to be consolidated in the way that it is obtained the equivalent value for the bottom for its water permeability properties.
The natural mineral tampon is not allowed to be smaller than 0.5 meter.
It is also required to provide additional protection for the bottom in order to prevent migration of the seepage water into the dump's sub-ground, in the following way:

| Dump category: | For non-hazardous waste | For hazardous waste |
|---|---|---|
| Liner (artificial sealing coating) | it is required | it is required |
| Drainage layer ≥ 0.5 m | it is required | it is required |

For the sealing of the dump's bottom and side can be used other methods and technique which provide conditions from the table.

Hence, the Regulation requires that water permeability is reduced to $10^{-9}$ m/s with a joint action of a natural geological barrier and artificial sealing coating, i.e. liner, but the thickness of mineral tampon zone is not allowed to be lesser than 0.5 m. It does not exist special requirements connected with the geological barrier's composition, particularly when it is not capable on its own to provide required water permeability but has to include also liner. It is obvious that the proposed solution is in agreement with the provisions from the quoted regulations.

No other regulations which has been adopted by the Republic of Serbia until now takes into consideration the composition of geological barrier and its special characteristics.
The Law on waste management (Official Gazette of RS, No. 36/2009 and 88/2010) in principle regulates the administrative part of waste management, but in the part in which deals with some waste types it does not treat the industrial waste of this type. General principle, Article 3 anticipates:

Waste management is performed in the way in which is provided the least possible risk for people's lives and health, with control and reduction measures for:
1. water, air and soil pollution;
2. endangerment of flora and fauna;
3. danger from origination of accident, explosion and fires;
4. negative impacts on landscape and unique natural resources;
5. noise levels and unpleasant odors.

It is clear that utilization of contaminated pyrite slag, as a foundation for geomembrane, meets the all criteria. If it is directly observed it can be raised doubt in the condition connected with soil pollution, but since it is historic pollution with further utilization of the same land it is prevented occupation of the new surfaces and, therefore, even for this criteria is not violated relevant legislation. If contaminated pyrite slag were separately deposited at a new and regulated site, it is obvious that the occupation of the new, non-polluted soil would be inevitable, and an adverse impact is impossible to be avoided.

### 6.7.4. Environmental impact monitoring

From the aspect of definition of eventual negative impact of the pyrite slag foundation on groundwaters, within the regular environmental monitoring in the industrial grounds and at the phosphogypsum storage, especially will be controlled level and water quality in piezometers set up around the storage and the piezometers set up in the period 23.07 to 31.07.2012 by Geo Engineering BGP Ltd. from Beograd.

In Fig.6.20 is presented the piezometers arrangement.

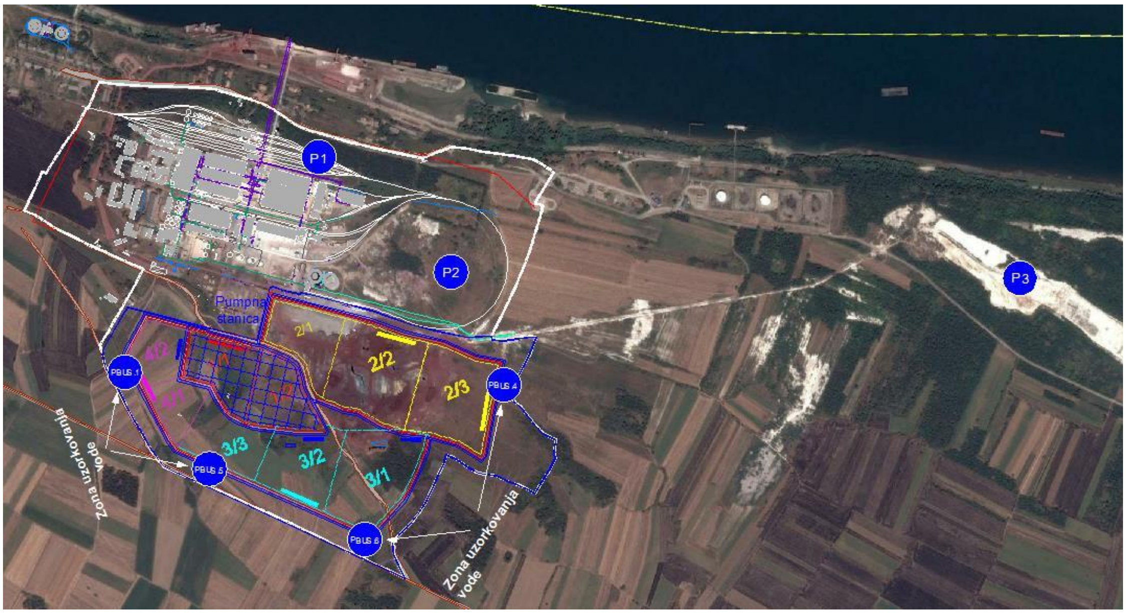



Figure 6.20: Piezometers around the storage, in the industrial ground and at the old phosphogypsum dump

From the previous analysis it is clear that utilization of contaminated pyrite slag, which is cannot be sold because of contamination and reduced iron content, can be managed in a rational way. Instead of formation of a new, separate and technically regulated and more expensive dump, the selected material (without large fragments with sharp edges and packing materials of various composition) will be rolled in at the site on which is situated for the time being in order to form the foundation, i.e. the geological barrier – geomembrane. The geomembrane will have a sealing role as hydraulic insulation for the future phosphogypsum storage, in accordance with relevant legal provisions.

It does not exist technical reasons why contaminated remains of pyrite slag cannot be used for the quoted purpose since the burns for its quantity and quality satisfy technical conditions.

Furthermore, it does not exist ecological obstacles, even in possible accidental situations, that rolled pyrite slag below the geomembrane can jeopardize the surrounding. The difference between the maximum recorded and expected groundwater level and the level on which pyrite slag are rolled is more than 5.5 m. This difference prevents any contact of those water with pyrite slag. It is not possible contact between pyrite slag and surface water since the entire occupied area of the future phosphogypsum storage will be insulated with geomembrane. The conducted leaching tests indicated that the pollutant concentration in solution is far below limit values even in accidental situations in which occurred contact of pyrite slag and water.

It does not exist administrative (legal reasons) no to approve this rational treatment and utilization of the contaminated pyrite slag.

## 6.8. Analysis of impacts on human's health

The estimate of impacts on residents' health can be performed with the implementation of the model compatible with the WHO procedures, which consists of the following steps:

- identification of issue;
- identification of danger;
- identification of dose and effects of negative impacts;
- estimate of exposition for the relevant population;
- characterization of the risk.

The fundamental dangers for residents' health as a consequence of activities on the phosphogypsum storage are mineral dust, noise and wastewaters. The causes of possible adverse impacts and occurrence of related health problems are, first of all, inadequate monitoring and control of air pollution and noise levels, absence or inadequate equipment and instrument maintenance as well as luck of awareness about possible dangers for people's health.

The dust particles are emitted in the air during the stockpiling of phosphogypsum. The impact of those particles on the respiratory system depend on their mineral and chemical composition, dust particle size, the exposure period, concentrations, etc. The individual's health condition and conditions at work place can increase the impact of dust particles on the respiratory system.

The significant impact has dust particle size, which determine the penetration degree and stay in the respiratory system. Of a particular importance for the occupation pathology is dust which contains particles sized up to 5 μm since they reach alveoli in the respiratory system. The inhalation of dust particles can cause pulmonary diseases – pneumoconiosis. The particles of larger dimensions than 5 μm stay in the upper parts of respiratory systems mainly causing chronic bronchitis.

In the case of prolong exposure to higher dust concentrations frequently occur the occupational respiratory diseases. Because of the quoted reasons it is necessary to organize continual control of dust concentrations in work environment in order to provide of duly and adequate application of dust protection measures.

It has been established that inhalation of particles from air is connected with undesirable short-term consequences for human health: the increased rate of cardiopulmonary mortality with elderly people and exacerbation of asthma in the all age groups. Those observations on asthma sufferers are supported by numerous laboratory studies, which indicate that certain particle types cause inflammation, as well as an increased number of allergic reaction caused with the inhalation of particles from exhaust gases from motors with internal combustion. As for the long-term consequences for human health, and particularly regarding development of allergy and asthma, the evidence for undesirable consequences because of exposition to particles is not so substantial, but certain epidemiological studies reported the results which confirm lung function and pollution caused with particle pollution. In the laboratory studies conducted on animals and people it has been proved that fossil fuel particle, but also other suspended particle, increase development of allergic immune responses. The differences in body's response can be related to additional activity of those particles, on allergens which are bonded to particles or to inflammatory consequences caused by particles.

Apart from allergens, the three groups of exogenous factors have been determined as hidden, causative and regulatory factors for generation and aggravation of respiratory asthma cases. That are diet factors, exposition to microbes in early childhood and other air polluters.

On the basis of knowledge of mechanisms with which particles cause lung damage, the clinical relevant connection between the air pollution with micro particles and mortality is linked with the aggravation of existing cardiologic and respiratory diseases. It includes patients with diagnosed asthma, chronic obstructive lung diseases, acute respiratory infections and ischemic heart diseases.

The three action mechanisms have been established which with those patients cause mortality, with the cause of cardiac and respiratory disease during the interval with increased pollution PM10 and PM25:

1. Acute bronchitis and bronchiolitis can be wrongly diagnosed as pulmonary edema;

2. The present micro particles and pollutants can increase permeability of pulmonary parenchyma and condition pulmonary edema with individual who suffer myocarditis and increased arterial pressure in the left ventricle;
3. Bronchiolitis and pneumonia originated due to increased air pollution, in case of existence of heart disease can cause congestion and cardia arrest.

Seaton et al (1995) established hypothesis that ultrafine particles cause alveoli inflammation, what aggravate (cause) pulmonary diseases and increase the mortality rate from cardiovascular diseases due to increased blood coagulability.

The industrial complex of Industry of Chemical Products Elixir Prahovo Ltd. Prahovo is situated on the left bank of the Danube, near the Port of Prahovo, within the Prahovo Cadastral Municipality. The nearest populated settlement is the village Prahovo (northwest from the site at distance of around 1000 m to the nearest residential buildings, 1197 residents).

Within the study, for estimate of the risks of the project for health of local residents, will be singled out and analyzed possible impacts of dust, noise and discharge of wastewater. The identification of dangers and estimate of impact intensity is presented under items 6.2.3 and 6.3.3 herein. It is required to be underlined that the residents in the village Prahovo, northwest from the industrial complex of Elixir Prahovo Ltd. Prahovo (the total number of residents is 1,197) can be exposed to such impacts during implementation of mining works at the excavation site in case of the southeast wind.

The estimate of impacts of suspended particles and noise on local residents' health is performed with the application of the methodological concept developed within Pollution Prevention by Design in Pacific Northwest National Laboratory (2003, by US Department of Energy). According to the quoted methodological concept, the level risk (R) of individual impact criterion is defined as the product of impact scope of the applied technology (I) and probability category of impact occurrence (P), i.e. R = I x P.

Within the quoted methodological concept, the categories of impact occurrence (P) are valued through three categories: no impact (0), small impact (1) and great impact (2). The level of individual risk from certain activity from the analyzed technological process is determined through the following differentiated categories: negligible risk (0), small risk (2), moderate risk (2) and great risk (4).

In case of the emission of suspended particle during implementation of works on the phosphogypsum storage, the level of risk for local residents is R = 1 x 1 = 1. That estimate points out to the small risk. In case of noise level during operation of used equipment on the phosphogypsum storage, the level of risk for local residents is R = 1 x 1 = 1. The estimate also points out to the small risk from the increased noise level in the surrounding of the site. In case of the uncontrolled discharge of wastewater from the phosphogypsum storage's area the level of risk for local residents is R = 2 x 1 = 2. The estimate points out to a moderate risk.

In other words, the populated area in the vicinity of the site and pollution emission, both in work environment and in the surrounding, represent precondition for a direct impact of the project on human health from the aspects of air, water quality and potential immissions of excessive noise.

The situation is the same when it is taken into account direct impact of the said project on human health via other products for human consumption, and which can come into contact with eventual pollutants that originates from the storage, indirectly and to certain extent, lead to a direct impact on human health in its surrounding.

## 6.9. Analysis of impacts on flora, fauna and ecosystems

On the basis of the present evaluations of defined impacts it is possible to reliably perceive relevant factors for the estimate of phosphogypsum storage's impact on flora and fauna in the region. The most serious impact within the area of the industrial complex, which is taken into consideration, is expressed through the already analyzed effect of the area occupation. The several other impacts are also present but to lesser extent. However, it has to be underlined that in no case it has impact on floristic elements classified as unique natural resources.

The existing natural habitat within the industrial complex of Elixir Prahovo Ltd. Prahovo will be destroyed as well as the vegetation on the planned area for the construction of the phosphogypsum storage due to the stockpiling of phosphogypsum.

After completion of operation as well as possible phosphogypsum marketing, on the eventually remained quantities of phosphogypsum at the storage will be performed recultivation, with the objective to restore the entire previous ecological balance.

As for the time period for soil recultivation and remediation it will depend on the project realization and stockpiling dynamics and product marketing with the additional period for the reestablishment of planted and seeded vegetation.

During the implementation of works on the stockpiling of phosphogypsum the majority of animal species will leave the area of the industrial complex and its adjoining area, with a possible exception of bird species and small rodents which can adjust to the changed habitat. It has to be taken into account that the chemical industry was present at this place in a long period.

The noise generated from the operations on the phosphogypsum storage will mainly have an adverse impact on the fauna in the immediate surroundings of the industrial complex.

At the site of phosphogypsum storage in the industrial complex of Elixir Prahovo Ltd. Prahovo there are no recorded rare plant communities, nor rare animal species and also, some susceptible ecosystems are not identified. In that sense, it does not occur any significant impacts on flora and fauna, except the ones already quoted in that section of the Study

## 6.10. Social and economic impact

Approximately, 15 workers will be required for implementation of works on the phosphogypsum storage. The company Elixir Prahovo Ltd. Prahovo requires operators of heavy mechanizations, mechanics, process operators, administrators and others. The certain number of workers, for the quoted jobs, is recruited from the local community, while for the specific technological operations will be hired more experienced workers from the other areas. In this way, the requirements for workers will have impact on the infrastructure of local community.

The prevention and mitigation measures for the adverse impacts of the project related to the stockpiling of phosphogypsum has to be based on the social policy which is harmonized with the preliminary socioeconomic analysis and defined economic program for community development:

- appreciation of culture, tradition and individual and group values connected with the project;
- the sustainable development concept applied in social, economic and cultural field, ecology and institutional components of the community under the project impact;
- synergy with the local plans and community objectives;

- participation and communication with the local community and stakeholders through dialogue mechanisms and mediation in solving possible conflicts;
- transparency, and provision of information for the local community in the region in which is located the industrial complex;
- as for health and safety requirements, it is the obligation of the company Elixir Prahovo Ltd. Prahovo to implement the all necessary measures and activities to provide the required health and safety requirements at work place and for the residents in the area under the project impact.

## 6.11. Analysis of the impact on the natural assets of special value and immovable cultural assets

The primary objective of protection (conservation, restauration and revitalization) of heritage monuments is its preservation as historical testimony of the settlement's identity and civilization achievement of peoples which left their imprints of their way of living and work during ages. Without the protected heritage there is no lasting contribution to civilization, neither required historical memory which directs ways of living and region urbanity.

The heritage protection in the area of industrial complexes represents a delicate task, particularly in case of disturbed morphological constitution of the terrain. According to the available data in the observed locality are not recorded any archeological sites or cultural and historic monuments which can be jeopardized.

At the locality of the industrial complex Elixir Prahovo Ltd. Prahovo are not recorded any protected natural assets.

## 6.12. Analysis of impact on infrastructure and traffic

The aspects of operations impact on the infrastructure in the region, connected with the proposed project of the phosphogypsum storage within the industrial complex of Elixir Prahovo Ltd. Prahovo are related to the following:

- **Solid waste management**. In the technological production process in Elixir Prahovo Ltd. Prahovo, with the Waste Management Plan is anticipated suitable storage of the all waste types (iron and other scrap metal waste, paper, wrapping material, plastic, electronic waste, etc.). The all waste in the industrial complex is deposited at the anticipated repository for non-hazardous and hazardous waste, regularly marked and protected from atmospheric waters. Waste will be classified and will be separated municipal waste from the industrial non-hazardous and hazardous waste and waste wrapping material. The municipal waste will be handled by PE Badnjevo from Negotin. In the same way will be disposed the inert waste with index number 07 02 99. The project holder will sign the contract with PE Badnjevo for evacuation and disposal of the aforementioned waste from the complex. The waste will be deposited in an adequately sealed metal container emptied by competent PE Badnjevo.
- **Telecommunications and power distribution grid**. It is not required replacement of the existing telecommunication and power distribution grid in the analyzed industrial complex for requirements of operations on the stockpiling of phosphogypsum. The all power infrastructural facilities are constructed in the way so that will not be under affected with the phosphogypsum storage formation.
- **Road traffic**. The Detailed Regulation Plan defines the traffic infrastructure in the way that the industrial complex with the newly planned storage is isolated as a separate unit and that present traffic infrastructure, which intersects the complex, is reorganized with in some parts, according to the defined entireties and zones, technological and organizational requirements of the company Elixir Prahovo Ltd. Prahovo and conditions from public enterprises.

- **Rail traffic**. The industrial railway is owned by the company Industry of Chemical Products Prahovo and is used for local transport requirements. Within the chemical industrial complex are situated 18 industrial railways and can be singled out two separate entireties. The one group consist of railways for reception and dispatch and the second of railways for loading and unloading, which serve for delivery to the certain plants and production facilities. The plan anticipates utilization of industrial railways, as well as to be undertaken measures for their maintenance and eventual revitalization or capacity increase. On the basis of the developmental plans of Serbian Railways – the joint stock company, it has been planned revitalization, modernization and electrification of the existing single-track railway Niš – Crveni Krst – Zaječar -Port of Prahovo.
- **Water pipeline and sewerage system**. It has been planned the potable water supply for the industrial complex from the Baroš water source of capacity 43 l/s. It has been anticipated reconstruction of the potable water pipeline system in accordance with the future requirements of Elixir Prahovo Ltd. Prahovo. The all additional extension will be subsequently analyzed in the designs defined pursuant to the Law. The supply of technical water, which will be used in the production process, as well as in the hydrant network, for street washing, will be performed from the water intake at the Danube. The existing installations in this pipeline system, due to poor condition will be reconstructed and replaced with new installations made of suitable materials resistant to environmental impacts. The hydrant network will be extended, if required, so that the entire complex will be covered. The anticipated consumption of technical water in the production process is around 2700 $m^3/h$. It has been also planned connection of the technical water pipeline system with the existing water tower (with adequate rehabilitation of the water tower). In that way, it will be provided the reserve of 200 $m^3$ for fire protection requirements and cooling of ammonium spheres during the summer period. It has been planned the technical solution for the sewerage system based on the separation system, with the construction of a new sanitary sewer. The sanitary waste water from the internal sewerage system will be further treated in the bio-filtration facility of optimal capacity, after which will be with conditionally cleaned atmospheric waters transferred to the recipient, the Danube. It should be mentioned that two projects have been prepared: Conceptual Hydrotechnical Design for the Complex Elixir Prahovo and the Main Design of Reconstruction and Rehabilitation of the Industrial Water Pipeline System within the Industrial Complex Elixir Prahovo.

# 7. ENVIRONMENTAL IMPACT ASSESSMENT IN THE CASE OF ACCIDENT

The EIA Study contains the presentation of dangerous materials, their quantities in the relation to the project for which is prepared the Environmental Impact Assessment Study. The first step for definition of potential accident situations is identification of dangerous materials and their quantities in connection with the design for which the EIA study is prepared. The subject of this Study is the storage, i.e. the process of phosphogypsum storage. In that sense, the question is raised whether phosphogypsum is a dangerous material, i.e. whether it ought to be observed as such in the process of definition of potential accidents.

The Law on Amendments of the Law on Environmental Protection, adopted in the National Assembly of the Republic of Serbia in May 2009, in accordance with recommendations of the Sevaso Directive (II), defined the Sevaso plant. It is the plant in which are performed activities in which is present or can be present a dangerous material in the equal or higher quantities of the prescribed ones. In accordance with it, Ministry of Environment and Spatial Planning of the Republic of Serbia identified the plants which are under obligations of the Sevaso Directive (II) and published the preliminary list of those plants (14 May 2009). In that list, under No.46 is IHP Prahovo – Fertilizers Ltd. However, it should not be neglected the fact that in the production of artificial fertilizers are used several compounds which are dangerous materials according to the definition from the Law on Environmental Protection (Official Gazette of RS, No. 135/2004, 36/2009, 36/2009 – state law, 72/2009 – state law): “Dangerous materials are chemical and other materials characterized with noxious and dangerous properties” and which belong to this category.

The fact that phosphogypsum ought not to be regarded as a dangerous material is supported with the content of the Rulebook on the list of dangerous materials and their quantities and criteria for definition of the document types which compile the operator of the Sevaso plant, i.e. the complex (OJ of RoS, No. 41/2010). With this Rulebook the list of dangerous material and their quantities and the list of danger classes and limit quantities of dangerous materials is prescribed, which are printed with this Rulebook and are its integral part. Phosphogypsum is not mentioned as a dangerous material in them.

Accordingly, the all measures undertaken during designing of the phosphogypsum storage have as an objective the prevention of environmental pollution, i.e. prevention of soil, water, air pollution etc. At the same time, it does not prevent the investor to sell or place phosphogypsum as by-product on market.

## 7.1. Quantity and phosphogypsum properties

From the aspect of space and volume, the storage needs to provide the storage space of 12,568,063$m^3$ during the 29 year period. Furthermore, from the aspect of the occupied surface, the utilization will unfold in 3 stages, and in relation to the occupied volume in 8 stages. The first three stages implies occupation of the entire planned surface and overbuilding to elevation +18 m, while the following three stages include overbuilding to height of 36 m. The seventh and eighth stage include overbuilding to the final height of 50 m. The estimate is provided for the annual production of phosphogypsum of 460,000 t and the required storage space of 485.000 $m^3$.

The phosphogypsum properties are quoted from the Report on Investigation of Technological and Geotechnical Properties of Phosphogypsum prepared by Faculty of Mining and Geology, the University of Belgrade for Elixir Group Ltd in July 2013.

The wet sample for testing was taken on 03.06.2013 from the pan filter in the plant for phosphoric acid production. At the time of sampling it was processed Syrian low-grade ore. The pH value of dissolved phosphogypsum sample, which had been delivered, was 6.6.

The total moisture was determined with drying of three samples until they reach constant mass. The moisture of individual samples ranges between 34.12 and 38.01%, i.e. the mean was 36.45%.

The moisture content was higher than expected (around 30%), but it is noticeable that there is no separation of free water from the collected phosphogypsum mass. From the aspect of stockpiling and environmental impact this is of utmost importance since it points out to the conclusion that free water will not be separated from the deposited mass.

In order to provide additional support for aforementioned observations it was performed the test of separation of free moisture depending on air temperatures. The conditions of high temperatures ($40^0$C, in the oven, the 16 hour period), of medium temperatures ($20^0$C, in the room, the 16 hour period) and of low temperatures ($8^0$C, in the refrigerator, the 16 hour period) were simulated. The values obtained during testing are presented in Table 7.1.

Table 7.1: Test results for separation of free moisture

| Temperature, $^o$ C | Mass, g | | Difference | |
|---|---|---|---|---|
| | at the beginning | in the end | g | % |
| 40 | 812 | 707 | 105 | 12,93 |
| 20 | 825 | 810 | 15 | 1,82 |
| 8 | 964 | 954 | 10 | 1,04 |

As it can be seen from Table 7.1 it is obvious that moisture loss depends on air temperature, but it is more significant only at extremely high temperatures. Moisture loss is negligible on average and low temperatures.

The another characteristic important with stockpiling of this type of raw material, connected with moisture, is the ability of material under loading to release or keep moisture as bound. The results of this test indicated that it is chemically bound water. This bound water remain bound even under static load and is not separated.

The grain-size distribution is common for ground mineral raw materials. The upper-size limit is $d_{95}$=1.65 mm. The share of grains larger than 1 mm is around 7%, and of grains smaller than 0.074 is around 37%. The mean diameter of grains is 0.085 mm. It can be therefore concluded that grain-size distribution is characteristic for finely downsized materials.

It is important for hydraulic disposal to gain insight into the steadiness or unsteadiness degree. When the unsteadiness degree is lesser than 5 it is considered that material has a steady composition, when this values is higher than 15 the composition is unsteady. A high degree of unsteadiness is characteristic of coherent (bound) material. In case when such material is used of construction of perimeter dikes it is desirable that the unsteadiness degree is higher, in an ideal case around 9. The investigation demonstrated that the unsteadiness degree is 5.

Hence, it is the material of steady composition, which is unsuitable for the construction of perimeter dikes (this parameter does not take into account bounding phosphogypsum properties) and as such is predisposed to liquefaction. Liquefaction is phenomenon which happens in loose, water saturated material, when occur a sudden increase of pore water pressure due to earthquake action, so that it becomes equal to the value of intergranular tension. The ground/deposited materials then behaves as liquid and are not able to resist to higher shearing tensions, what results in the failure of dike and sudden discharge of deposited mass and water.

The chemical composition is defined in accordance with the prescribed methodology, and obtained results are provided in Table 3.4 (Section 3 Project Description).

It is obvious that basic components are $SO_3$ group and Ca), which form $CaSO_4$ (gypsum). In relation to other components it is increased share of $SiO_2$, which originates from admixtures in ore, and which is a desirable composition of deposited material.

In the analyzed sample the dominant minerals are the ones from the gypsum group (gypsum anhydrate and basanite). Quartz is significantly less present. From the accessory minerals have been determined salts (most likely halite (NaCl) and/or silvine (KCl) which only occur as euhedral crystal of octahedron shape and opaque minerals.

On the basis of delivered samples tested for density, it has been obtained the mean 2.36 t/$m^3$.

The bulk density was determined on the dry and wet sample. On the dry phosphogypsum sample the bulk density was 800 kg/$m^3$. The bulk density or mass was determined in the same way but on the samples which had moisture at delivery 741 kg/$m^3$, what points out to the conclusion that present moisture conditions formation of more pores than it is a case with dry phosphogypsum and bulk density is lesser. It virtually means that in case of filling with filtrated phosphogypsum without compacting for deposition, a significant space will be occupied since for 1 t will be required to provide the retention space of 1,350 $m^3$.

Volume density was determined as in the previous case, on the dry and wet phosphogypsum sample. The volume density was 950 kg/$m^3$ for the dry sample and for the sample with moisture at delivery it was 1,440 kg/ $m^3$. On the occasion of compacting occurred separation of free water on the vessel's surface in which the testing was performed. This points out to the fact that in case of compacting of a deposited mass there will separate free water. The additional testing, in this direction, demonstrated that it will be relatively small quantities of water, which will evaporate or be bound by gypsum deposited afterwards or, what is the least likely, be scooped and removed from the storage via the drainage system.

The testing demonstrated that hydraulic compactness is lower than volume density, and, therefore, the all recalculations for the required space for deposition of unit mass were conducted on the basis of hydraulic compactness.

Since the hydraulic compactness test is performed with a solid raw material in dry condition, for requirements of the future phosphogypsum storage and water balance definition would be useful to determine how much added water remain bound, and how much separate. The test demonstrated that it will separate around 68.5% of added water, while the remainder will remain bound in the storage. Namely, when free water is used as return water it will be required to add around 30% of fresh water in order to close the water balance.

The results of direct shearing test performed to determine existence of cohesion (C, kPa) and angle of internal friction (φ, degrees) show absence of cohesion, while the angle of internal friction was $45^0$, what represents a relatively high value.

The water permeability of phosphogypsum, expressed through the filtration coefficient is very important since it points out to the capability of deposited mass to pass through water and with it acquiring favorable geotechnical characteristics, what is of great importance for stockpiling of this type of raw material and in the designed way. With the measurement of filtration coefficient was obtained the value $3.4x^{10-6}$ m/s.

The obtained value for the filtration coefficient indicated that the tested phosphogypsum belongs to the group of medium permeability materials (on the level of dust and loess). Generally, the obtained water permeability can be regarded as acceptable.

The consolidation of deposited phosphogypsum as a function of loading and loading time was carried out under certain loading and in the period from 1 to 28 days. The obtained data point out that deformation occurs fast and that lasts long. The compacting was not ceased after 28 days. Considering chemical and mineralogical structure of gypsum it is more likely that “typical” consolidation was ended during first 24 (or 48) hours, and that further volume decrease is consequence of chemical reactions.

The additional tests indicated that compression (loading) will condition volume decrease for around 4%. This points out that it is not case of a “typical” material but the material with which its properties significantly influence chemical bonding. The change of volume after compacting (loading) is minimal and deformations are permanent.

Compressibility index ($C_c$) 0.121 is obtained from the compression test’s results. The lesser compressibility index the more suitable material is for construction of perimeter dikes, in this case at the phosphogypsum storage. The compressibility index is high in comparison with “typical” incoherent materials. However, it comparison needs to be treated with some reserve since phosphogypsum behaves as material which chemical process continues in the deposition stage. Generally, testes indicated that it is a case of compressible material.

## 7.2. Hazards identification

The identification of hazards includes identification of critical points, i.e. locations in the process or the plant which represent the weakest points or possible sources of hazard from the aspect of possible accidents.

With identification of critical points are checked the all procedures for unfolding of the technological process and the all parts of facility, devices, transport vehicles and equipment, detect and defined critical points at plants, devices and equipment, as well as causes which might cause disturbances or failures which lead to the chemical accident. Among other things in the process of phosphogypsum disposal it implies the analysis of:

- technical and technological specifics and deficiencies in the process of phosphogypsum stockpiling;
- specifics of physical and chemical properties of a deposited material;
- possible failures of components and materials due to deteriorated equipment and supply interruption, in this case power electric energy required for operation of return water pumps;
- external sources of danger (extreme temperatures, wind, precipitation, floods, fires, earthquakes and land sliding); and
- the analysis of previous accidents.

As a potential accident is imposed an eventual destruction of peripheral embankments which enables formation of the phosphogypsum storage. There are several possible reasons for unfolding of such scenario:

- Mistakes in the formation of peripheral embankments, as a consequence of non-compliance with the design solutions for formation of the storage;
- Failure of the pumps for return water, what would cause the occurrence of excessive water on the surface of some stages of the phosphogypsum storage and eventual decay and breach of peripheral embankments; and
- External sources of accidents, as potential dangerous ones can be singled out abundant precipitations, eventual flooding of the Danube River or earthquake.

## 7.3. The assessment of possible accident level and risk estimate

The possible level of accident is defined on the basis of the width of affected area and the analysis of vulnerability, and it is expressed as I, II, III, IV and V level of accident (the Rulebook on the content of policy of accident prevention and content and methodology for the compiling of reports on safety and the plan for accident prevention, (OJ of RoS, No. 41/2010):

- I level of accident: at the level of dangerous plants where consequences of an accident limited on that part of the plant (installation) or on the entire plant, but there are no any consequences for the entire complex;
- II level of accident: at the level of industrial complex where consequences of an accident limited on the part or on the whole industrial complex, but there are no any consequences outside the complex;
- III level of accident: at the level of municipality where consequences of an accident are spread outside the complex, to the municipal territory;
- IV level of accident: at the regional level, where consequences of an accident are spread to territories of several municipalities or towns, to the region;
- V level of accident: at the international level where consequences of an accident spread to outside borders of the Republic of Serbia.

The analysis of vulnerability implies identification of vulnerable facilities in the surrounding, within the vulnerable areas, and it is taken into account:

- workers employed in the production and which can come under the impact of accident,
- people outside the industrial complex on which accident might leave consequences; but also
- buildings, natural and cultural assets which might suffer consequences of direct accident or its follow-up effects, in form of fires, destruction or contamination (production, ancillary facilities in the complex and outside it; residential buildings, infrastructural and other facilities; agricultural facilities; flora and fauna; protected cultural assets; surface waters and groundwater; facilities of significance for the domino effect (warehouse, production facilities of dangerous materials within and outside the industrial complex), etc.

From the aspect of phosphogypsum storage, and on the basis of the estimate of the width of the vulnerability zone and the analysis of vulnerability, it can be concluded that is only realistic, in case of the quoted potential accident, to expect I and II level of accident.

The consequences of accident would be, first of all, limited on the part of facility in which is performed storage, what consequently leads to the conclusion that it would not have any direct consequences for the entire complex. However, indirectly, the inability to stockpile phosphogypsum as a by-product in the phosphoric acid production as a final product, could lead to reduction or cessation of production, until rehabilitation of consequences of a supposed accident. In this case, we may speak about the II level of accident, i.e. the accident with consequences for the entire industrial complex, although physical integrity of the complex will not be jeopardized.

It is well known that the risk estimate is based on the estimate of probability for origination of the accident and possible consequences. According to the Rulebook on the policy content for prevention of accident and the methodology for preparation of safety reports and the plan for protection from accidents (Official Gazette of RS, No. 41/2010), probability is expressed as small, medium and big, and consequences as insignificant ones (of small importance), significant, serious, huge and catastrophic consequences.

By applying the table with criteria for estimate of probability for occurrence of accident from the aforementioned rulebook, it can be said that in given case we deal with a small probability of occurrence.
At the same time, by using the table with criteria for the estimate of possible consequences, and which is based, among other things, on the data obtained with the vulnerability analysis, it can be said that we deal with consequences of small importance.

On the basis of the low probability of an accident with consequences of little importance or without importance, can be concluded, from the aspect of assumed accidental situation, i.e. the failure of the peripheral embankments of the phosphogypsum storage, the risk is negligible.
There are several factors which support this assertion but it will be singled out only the two:

1. The stability of perimeter dikes represents one of basic technological process parameters, i.e. phosphogypsum stockpiling and as such this process parameter crucially impacts the entire process;
2. Because of such importance, in the designing process particular attention is directed toward the estimate of adequate slope angels and the safety factor which is always for this parameter increased for safety reasons in relation to the estimated value. Furthermore, its value is calculated with several different methods in order to exclude each unpredictability.

On the basis of the aforementioned the authors are of opinion that in case of this phosphogypsum storage the potential danger of eventual perimeter dike failure does not pose any significant danger, i.e. a realistic source of accident.

## 7.4. Prevention measures and procedures in case of accident estimate

The prevention of accident is the set of measures and procedures at the level of facility, the complex and the broader community which have for the objective prevention of the accident, reduction of probability of accident occurrence and minimization of consequences the Rulebook on the content of policy of accident prevention and content and methodology for the compiling of reports on safety and the plan for accident prevention, (OJ of RoS, No. 41/2010). On the basis of this, it is not difficult to conclude that prevention measures are those which in case of this project reduce a potential risk of accidental situation to the least possible measure.

Generally, the measure which can be undertaken for the accident prevention can be classified in the several groups:

- measures applied during designing and construction;
- technical and technological measures;
- fire protection measures;
- organizational measures.

To those measures also need to be added several other measures which are available for the operator, and which are not classified in any of the listed groups.

In connection with this project, prevention of possible accidents as well as prevention and reduction of eventual consequences are boiled down to the following:

- The measures which are anticipated and realized with the designing and construction of the facility – In the designing process, as it has already been mentioned, and described in the previous sections herein, the main attention was directed toward the stability of perimeter dikes and the process of their formation since they are in the foundation and make possible the storage formation. Hence, each further activity would be impossible without this stage;
- The measures which are anticipated and realized with the selection of technological equipment, the equipment for process management and other technical equipment – The all equipment which will be used in the process of stalk formation, both in the primary stage and later on and all the way to the formation of its final outline, has to be harmonized with the designed solution, that is from the technical and technological aspect has to correspond, all the time, to set design requirements;
- The measures which are anticipated in the security system;– Supervision, safety and protection system management as well as detection and identification of danger,

warning and response to danger are only some of measures anticipated to contribute to safety at work for operators but also wider ;

- The measures which are anticipated with the objective of staff training for management and responds to the accident, what presuppose educating people about potential accidental situations and measures for their prevention as well as for rehabilitation;
- Forces and technical averages planned and provided for preventive action and response to the accident – It represents concretization of staff training in connection with potential accidents and responses to them as well as technical resources and available equipment for fast response and rehabilitation of eventual accidents. The crews are set up and technical resources are provided with the objective to minimize or complete eliminate conditions and consequences caused by eventual accidents, first of all for human resources but also for ecological aspects.

The prevention measures are primary means to confront eventual accident and as such those measures form the foundation for all activities directed toward elimination of eventual accidents. However, in case of accident the measures to be put into action to limit consequences are of crucial importance. From the aspect of this project and eventual accidental failure of perimeter dikes those measures can be classified into several groups:

- Definition of the method for raising alarm and involvement of personal which participate in the response (sound alarm, by phone etc.) as well as designation of people which are competent and responsible for raising alarm and to take into service other staff and individuals;
- Preparation of management scheme and coordination among the staff which respond to the accident – the all staff and individuals planned to participate in the response to the accident from plant operators and, if required, from the local self-government. It is also provided information on organizations trained for emergency response and the ones authorized for provision of medical help, detection and monitoring (specialized laboratories for air, water and soil control).
- The emergency response crew organization and procedure for emergency response:
  - suspension of stockpiling operations and if required of the entire production process;
  - extinguishing of initial fires and limiting initial accidents;
  - notification and alarming;
  - transport and provision of medical help for the injured;
  - detection and pollution control;
  - public information.

It has to be underlined that at the operator site because of the presence of ammonium and TNG at the surrounding site we speak about the Sevaso plant of a higher order. Because of that the Report on safety and the Plan for protection from accident have been prepared and submitted to the ministry competent for environmental protection affair for the provision of agreement.

# 8. DESCRIPTION OF MEASURES FOR PREVENTION, REDUCTION AND REMEDIATION OF ENVIRONMENTAL IMPACTS

A numerous measures for environmental protection have been undertaken for prevention of pollutions with the pollutants which originate from the phosphogypsum storage.

- **The storage location.** The selection of the storage location along the holding of IHP Prahovo, on partially degraded and agricultural land of inferior worthiness, without surface currents and water supply sources, at a sufficient distance from the Danube, far away from the zones with sanitary protection, and also from the residential areas, the terrain is plain and mildly sloped, virtually there is no catchment area from which water gravitates toward the storage.
- **Technical regulation.** The undertaken technical measures for provision of geotechnical and ecological stability implies a complete geotechnical and hydrotechnical regulation for the storage (starter dike, drainage system, hydro insulation of the storage internal area, the completion of the industrial water cycle with its collection and return to the phosphoric acid factory, perimeter canals for temporary reception of all excessive water and insulation of the storage from the influx of water from the outside, etc.)
- **Monitoring and control**. The anticipated complex and encompassing measures of technical monitoring of conditions at the storage, facilities at the storage, utilization dynamics and storage development with which is established geotechnical and technological control of conditions at the storage and in the surrounding. Those measures are accompanied with the environmental monitoring program in order to dully detect disturbances or conditions which might impact the environment.

The individual effects of anticipated measures for water, air and soil protection from the negative effects of pollutants are specifically analyzed.

## 8.1. Measures for prevention, reduction and elimination of damaging environmental impacts envisioned with the law, conditions and agreements from competent institutions

During preparation of the Environmental Impact Assessment Study (EIA Study), one of the investor and project developers' tasks is to submit the all necessary conditions and agreements from state institutions in which field of activity is a certain environmental aspect for which are requested aforementioned conditions and agreements. The all conditions and agreements are based on specific legislation, and in that sense represent measures envisioned with the law. For the type of facility for which is prepared the said study, and on the basis of estimated potential environmental impacts it needs to be singled out the following conditions and agreements:

- The opinion in the process of issuing water conditions, issued by the Public Enterprise "Srbija Vode" the Water Management Center "Sava-Dunav" Novi Beograd, the operational unit "Negotin" from Negotin, within which are underlined certain conditions which are required to be met in the process of acquiring of water management conditions; and
- The decision on nature protection conditions, issued by Institute of Nature Conservation of Serbia, in which besides general conditions are provided specific conditions which are required to be implemented with the objective of an adequate protection of the surrounding environment.

The both documents are necessary steps provided in the process of the Detailed Regulation Plan for the industrial chemical complex in Prahovo, for the defined area in the Cadastral Municipality Prahovo. Since the future phosphogypsum storage is one of the central facilities of the chemical industry complex in Prahovo, the all measures in the aforementioned opinion and decision are also mandatory for the said facility for which this study is prepared, to the extent in which are related to the said facility, i.e. the phosphogypsum storage.

Since the protection measures, within the opinion and decision, cover not only requirements in connection with environmental protection but also more extensive requirements, in the following text are presented measures, first of all, of significance for environmental protection.

The opinion in the process for issuing water conditions, among other things, anticipate the following protection measures:

- For the protection of the Danube's stream, which for this project has transboundary character has been quoted: "The Danube is according to the Regulation on categorization of water streams and the Regulation on the classification of water streams (Official Gazette SRS, No 5/68) classified in the II water stream category. The maximum quantities of dangerous materials for the given class, which are not allowed to be exceeded are defined with:
    - Regulation on emission limit values in waters and deadlines for their reaching (Official Gazette of RS, No. 67/11);
    - Regulation on limit values for priority and hazardous substances which pollute surface waters and deadlines for their reaching (Official Gazette of RS, No. 35/11);
    - Regulation on limit values for pollutants in surface waters and ground waters and sediments and deadline for their reaching (Official Gazette of RS, 35/11).
- Anticipate evacuation of sanitary wastewater and other wastewaters. Wastewater cannot be discharged into the existing regulated and unregulated water streams, without prior treatment (cleaning system) to the quality level in water stream, in which they are discharged, that is if they are discharged in the town sewage collection system, i.e. collector they have to correspond to a municipal decision for discharge of waste water into the public sewage system;
- For all works which are implemented in the zone and beside water facilities it is required to provide a detailed review of required protection measures for stability of water facilities and detailed dynamics for realization of the anticipated works;
- Watery soil can be used in the way so that does not generate a damaging impact on water and the coastal ecosystem and does not limit rights of the others in accordance with Article 10 of the Law on Waters;
- On the occasion of adoption of the decision for facility evacuation, i.e. waste water treatment, it is necessary to adhere to the following regulations:
    - Regulation on water classification (Official Gazette SRS, No 5/68);
    - Regulation on the classification of water stream (Official Gazette, 5/68);
    - Rulebook on the method and number of investigations of wastewater quality (Official Gazette SRS, No. 47?83 and 13/84);
    - Rulebook on dangerous materials in water (Official Gazette SRS, No.1/82);
    - Rulebook on pollutants emission limit values in waters and deadlines for their reaching (Official Gazette of RS, No. 67/11)
    - Rulebook on referential conditions of surface water types (Official Gazette of RS, No. 67/11);
    - Rulebook on groundwater parameters (Official Gazette of RS, No74/11).

The decision on conditions for nature conservation anticipate two types of conditions, general and specific:

- General conditions
  - All planned activities can be implemented only at the site quoted in the submitted application, on the basis of which is issued the decision on conditions;
  - The noise level during implementation of work is not allowed to exceed limit values, first of all for work environment, with which is protected surrounding to certain extent;
  - As for issue of environmental protection from sanitary wastewater and other wastewaters, the conditions overlap with the protection measures provided in the text above, related to the opinion in the process of acquiring water management conditions.
  - During implementation of works, it is required to undertake the all measures in order to prevent spillage of fuel, fuel oil, or other noxious and dangerous materials in soil or water recipient. If for any reason occur accidental spillage of fuel, fuel oil or other noxious or dangerous materials, the contractor shall be obligated to remove the spilled material in the shortest possible time and perform rehabilitation of the contaminated soil or natural water stream.
  - In order to protect natural assets it is said: "If it is come across during implementation of works on geological-paleontological documents or mineralogical-petrological structure, for which is supposed to have attribute of a natural asset, in accordance with Article 99 of the Law on Nature Protection (Official Gazette of RS, No36/2009), the contractor shall be obligated to inform a competent Ministry, as well as to undertakes the all measures for protection from destruction, damaging or theft until the authorized person arrives.
- Specific conditions
  - Infrastructural facilities (electrical, PTT) need to be underground (cables) and laid down mainly through roads and pats, while the overground facilities (belt conveyor and likewise) designed in the way so that do not spread pollutants in environment (soil and air);
  - A new space for disposal of waste material shall be defined and provided at the site which is most suitable for that purpose and to undertake the all measures to prevent pollutant to reach soil and recipient, i.e. the Danube;
  - For powdery materials shall be anticipated continual irrigation with water in order to prevent their floating in air and distribution to the surrounding agricultural land or toward the Danube;
  - Provide required conditions and equipment for collection, classification and temporary safeguarding of various waste materials (communal waste, packaging waste, organic or process waste, recyclable materials, waste generated from cleaning fuel oil and oil separator, etc.). waste shall be passed on to authorized operators for that category of waste;
  - Anticipate suitable equipment, technical and technological solutions, which provide that quality of ambient air satisfies prescribed limit values;
  - The new phosphogypsum storage is to be defined and secured at the site which is for that purpose defined with Detailed Regulation Plan with application of all environmental protection measures;
  - For requirements of protection of surrounding agricultural land as well as water, from the activities anticipated with the Detailed Regulation Plan, including the phosphogypsum storage, around the whole complex shall be anticipated the protection greenbelt, i.e. a wind break from autochthonous species, particularly from those species resistant to characteristic local polluters, and which have dense and well-developed tree tops. The greenbelt needs to be in a thicker layer, of several rows (combined tall vegetation with bushes in the front). It can be used a certain percentage of conifer species (around 30%) in order to secure greenbelt action during winter period. Species need to be selected carefully, since conifers are mainly susceptible to pollution (for example, in any way avoid to plant

spruce since is very susceptible to pollution, and it is also prone to be lifted out soil by wind and snow loading).

## 8.2. Measures for prevention, reduction and elimination of damaging environmental impacts anticipated with the said project

### 8.2.1. Air protection

The project provides air protection in several steps:

- It has been selected the site for storage in which is such wind rose that each eventual air pollution does not affect the populated settlements;
- Around the storage is anticipated formation of a powerful wind protection belt, of 25 m width up to over 50 m, in which will be planted suitable trees;
- The initial peripheral embankment will be made from coarse-grained and properly rolled material from the borrowing source so that elevation of dust is not expected regardless of the intensity and wind direction;
- A small size of retention area of the storage conditions that the discharge locations ought to be frequently changed in order to provide balanced filling of the space, and that activity virtually means that the beach formed within the storage's retention area is continually maintained in a wet condition, in order to prevent floating of the finest particle and environment pollution.

### 8.2.2. Water protection

For water protection the following measures are undertaken:

- It has been selected the site near the factory, i.e. there are no surface water courses in the area, and the maximum expected groundwater level is at least 1 m below the foundation of the future storage, while average levels are significantly lower;
- The bottom and internal slopes of the storage are hydro insulated with installation of a geomembrane (liner) made of high-density polyethylene (HDPE) (Fig.8.1);

- Fig.8.1 Liner spreading along the storage cassette's bottom

- It is closed a cycle of industrial water in the way that the entire water from the storage, drainage water as well as water from the settling pond is collected in the specially designed pumping station and from there is delivered to the phosphoric acid factory for reuse;
- Considering that there is virtually no catchment area from which water would be collected into the tack it is relatively easy to close the water balance between the storage and the factory, since there is always basic technological water those water which return from the storage as return water, and the quantity of that water is always lesser than the quantity of the required water;

- Around the storage are constructed the peripheral protection canals which ought to prevent entrance of water from the surrounding into the storage and its mixture with waters from the storage.

### 8.2.3. Soil protection

The soil protection is specific since the development of storage has to permanently change the purpose of the existing land. The fact is that it is difficult to find a favorable location in the wider location of the factory, without impact on the soil.

The investor was desirous to avoid jeopardizing agricultural land with grown crops and, therefore, opted out for the development of the new storage at already degraded soil used for storage of pyrite, pyrite slag and other waste, but in one part will be included agricultural land immediately along the factory which quality is significantly reduced, due to activities in the chemical complex in the previous period.

At the same time, the storage height was elevated to the maximum possible 50 m in order to increase in that way volume and reduce surface required to be occupied for the industrial storage.

The protection of soil is performed also indirectly, with protection of soil and air from pollution. Namely, water and air are main pollution transporters around the surrounding, and precipitation and other meteorological events condition that air pollutions are deposited onto the soil, there are scooped with water and further distribute around the surrounding

### 8.2.4. Noise protection

An adverse impact of excessive noise in the working environments exists in the all stages of formation and utilization of the phosphogypsum storage. This fact becomes even more important when it is taken into account that noise can easily spread from work environment to the surrounding, especially if exist favorable spatial relation between the surrounding and work environment. However, it is also the fact that noise spreading modelling in the stage of phosphogypsum storage formation, for anticipated scope of works, indicated that this impact is reduced to limited work environment. Justification for this assertion is possible to be confirmed after concrete measurement, at the moment of formation, but also later in the utilization stage. Accordingly, it is required to anticipate temporary measurements of noise levels at the phosphogypsum storage, first of all because of workers protection from excessive noise.

In that sense, preventive measures from the aspect of environmental protection include:

- the control of noise level within the chemical complex, i.e. the phosphogypsum storage and eventual surrounding residential buildings;
- the reduction of noise at individual plants and machines;
- application of the acoustic protection with installation of a greenbelt for protection, physical barriers and fences, if required; Formation of a greenbelt for requirements of protection of surrounding air and soil will greatly influence the quality of environment from the aspect of noise.

The employee education is very important in the context of awareness of workers about the need for reduction of noise levels to the values defined by the regulations and about noxious effects for people’s health due to exposure to an excessive noise. It is also important staff training in the field of equipment maintenance, i.e. in proper operating condition, as well as requirements and methods of use of personal protection equipment (PPE) for protection from noise.

### 8.2.5. Fire protection

The planning and designing of fire protection measures is performed on the basis of realization of fire class and estimate of fire load, which depend on the heat value of flammable material and on equipment and facilities types.

A potential danger from fire is manifested through possibility of origination: exogenous fires of class A, B and D (Standard SRPS ISO 3941:1994). In this concrete case a potential danger from fire is connected with origination of smaller fires, and as such can be estimated as objectively small.

The quoted fire classes can cause some machine elements or machines themselves. That dangers are of a short duration and with application of fire protection equipment, such as fire extinguishers, they are promptly localized.

With a due detection and fire control, virtually the danger from larger scale fires is reduced to the least possible measure, and accordingly the eventual impact of originated fire on environment.

In the function of protection from exogenous fires of smaller proportions in the area of the phosphogypsum storage, it is required to place on machines fire extinguishers, types S-6, S-9 and $CO_2$ which are allocated depending on fire load and fire types. If those apparatuses already exist it is required to perform adequate maintenance in accordance with legislation which regulates the fire protection field.

### 8.2.6. Phosphogypsum storage closure

After completion of disposal of phosphogypsum, will be performed sealing of the stored mass which cannot be sold on the market in the foreseeable future. The sealing is successive since it can be only sealed those parts which are not physically connected with the activities from the following stages. The closure implies a complete hydro insulation of the deposited mass, i.e. cover liners are joined with the line installed on the storage's bottom and internal slope of the peripheral embankment and protection of the cover liner from damage with application of the drainage layer from the gravel and coarse-grained inert material layers.

After completion of each stage will be performed closure of that part of the storage which overbuilding is not planned, in the way as designed on the drawing in the design's graphic section. Firstly, it is performed covering of that storage surface with the 1.5 mm HDPE liner, Fig. 13. This liner on its lower part will be connected with the bottom' liner and internal slope liner on the starter dike, in the way which firstly anticipates partial excavation of this liner from the trench for its anchoring and welding with the liner used for storage covering. With this step it is provided that the entire storage external surface is covered with a watertight liner and protected from the contact with atmospheric waters which reach on the storage surface.

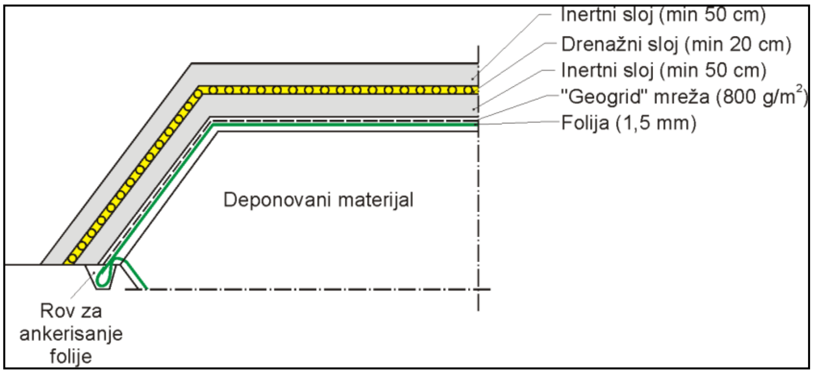



Fig.8.2 Layers arrangement with phosphate storage closure
(inter layer – minimum 50 cm; drainage layer – minimum 20 cm; inert layer – minimum 50 cm; geogrid net – 800 g/m2; liner – 1,5 mm; deposited material; trench for liner anchoring)

For the covering of storage slopes will be used the liner with coarse surfaces on the both sides, while horizontal safety zones will be covered with a fine liner.

The design anticipates installation of the protective geogrid net, minimum weigh 800 g/m$^2$ over HDPE water tight liner. Geogrid net receives loads from a cover layer and protect the liner from tearing or damage.

It is further anticipated to apply the 50 cm inert material layer as a minimum, and then the 20 cm gravel layer. The used gravel will have the same grain-size as a protection layer. As the final layer is anticipated a 50 cm coarse-grained inert material as a minimum.

## 8.3. Measures to be undertaken in case of industrial accident

The potential industrial accident implies possibility of:

- origination of fires and explosions;
- discharge of dangerous materials in water and soil, due to damage on perimeter dikes;
- release of uncontrolled emissions in atmosphere;
- occurrence of natural disasters (lightening, earthquakes, floods, landfalls, etc.)

As for the entire process of phosphogypsum storage development and utilization, from the quoted accident categories it is possible to occur: fires, of a local character (mechanization and facilities in the storage area), discharge of dangerous materials, which originates from the phosphogypsum storage, (in waters or soil) due to damage and natural disasters (lightening and earthquakes).

A potential danger from fire is manifested through the possibility of origination: exogenous fires of class A, B and D (Standard SRPS ISO 3941:1994). In this concrete case a potential danger from fire is connected with the origination of smaller fires, and as such can be estimated as objectively small.

The fire which eventually originates at the storage due to ignition under action of external factors (open flame, sparks, electric arch, etc.) for its proportions would be oriented to the location where originated, with a relatively small possibility of further spreading outside the complex, and that only in case of spreading of fire to the surrounding plant vegetation, when it is formed protection greenbelt.

It exists the possibility of spreading of fire gases at larger distances and outside the complex, under the impact of air currents, but their emission is of such a scope that environment would not be endangered. The experiences with fires from larger complexes point out to that. However, the size of a potential fire and the scope of damage caused on such an occasion condition application of corresponding technical and organization measures which are used to prevent the possibility of their origination.

Generally, a potential danger from fire is connected with the facilities' fire loading values and equipment at the storage and with origination of an exogenous fire of limited proportions. On the basis of the aforementioned, it can be concluded that a potential danger from exogenous fire at the phosphogypsum storage can be categorized as a low degree danger.

The quoted potential danger conditions applications of corresponding technical and organization measures which will prevent the occurrence of fire as well as provide facilities protection, first of all, with a definition of locations equipped with fire extinguishers and their number. In the function of protection from exogenous fires of smaller proportions in the area of the phosphogypsum storage, it is required to place on machines fire extinguishers, types S-6, S-9 and $CO_2$ which are allocated depending on fire load and fire types.

On the basis of the previously stated it can be concluded that the likelihood of an industrial accident due to fire in the storage formation process is small and, accordingly, the possible consequences for the lives and health of people and environment are estimated and negligible, on the basis of data obtained with the analysis.

Since the risk of an accident is estimated on the basis of accident origination as well as on the scope of possible consequences, it can be concluded that the risk from accident due to possible fire occurrence is low, in case of the phosphogypsum storage.

As one of possible accidental situations is mentioned at the beginning of this section discharge of phosphogypsum into surrounding land or eventually into water streams due to damage, i.e. accident. The cause of manifestation of such accidental situation would be damaged or complete failure of perimeter dikes.

Because of this, within the said design a great attention is directed toward the estimate of phosphogypsum storage stability. For that purpose it is formed phosphogypsum storage model and with assistance of software programs were conducted the all necessary testing of the formed storage model and, first of all, the estimate of stability of storage slopes, i.e. perimeter dikes.

The estimate of slope stability is first determined for the cylindrical slip plane. It has been calculated a satisfactory safety coefficient (1.814). Then, the same estimate is repeated for case of maximum expected seismic activity of $8^0$MMS. It has also been calculated a satisfactory safety coefficient 1.052>1.

Afterwards, it was performed control in the process of tension and deformation analysis, with the finite element method (FEM), with calculation of safety coefficients with the method of reduction of tangential dilations. It has been calculated a satisfactory safety coefficient 1.69, but with a different shape of sliding body. Namely, the location of the zone of maximum tangential dilations, points out that failure will occur, dominantly due to sliding of the deposited material along the foundation.

Because of that the estimate was repeated with the method of **limit** equilibrium for the **predisposed** sliding plane. It has been also calculated a satisfactory safety coefficient 1.773. Then, the same estimate is repeated from the maximum expected seismic activities of $8^0$MMS. It has been calculated a satisfactory safety coefficient 1.61>1.

The stability estimate has been performed for balanced conditions in the storage and with parameters which are obtained in a very short period after suspension discharge at the storage. It is expected a real situation will be somewhat changed since with the time will occur solidification of the phosphogypsum storage. With it will also change of values of elements of internal resistance (cohesion, angle of internal friction) and filtration coefficient. It is expected that the estimate results will be more favorable than the presented herein.

In order to preserve stability under control it is recommended to perform drilling on the established cassettes during stage of preparation of main designs and define values for the quoted parameters in order to perform the estimate with taking into account impacts generated with the storage time.

## 8.4. Other measures which might influence prevention or reduction of damaging environmental impacts

The separate group of protection measures in this Study consist of the designed and anticipated program of geotechnical and ecological monitoring.

Considering that storage overbuilding and utilization are performed concurrently for the control of all conditions: geotechnical, hydrotechnical, technological and ecological it is of importance to set up a dual monitoring and control system:

- The first one is the system of technical monitoring as well as monitoring of the conditions at the storage in order to prevent disturbances of the storage stability, breach of water from the storage, spillage of suspension prior to stockpiling or from the storage, unbalanced filling of the retention area, inobservance for storage's development dynamics, etc. The all technical staff employed at the storage or in IHP Prahovo need to be included in this job, while a periodical condition need to be controlled and confirmed by the hired independent company, which employs professional staff that can estimate the existing condition and anticipate conditions in the near future.

- The second control system is based the environmental monitoring which is to lesser extent based on the technical details of storage's conditions, but the main attention is directed toward environmental conditions, results of eventual pollution, estimate of pollution sources, definition of pollution trends or improvements and impact on the residents in the surrounding areas.

Finally, it needs to be said that with undertaken and aforementioned protection measures is completed the process which will provide a safe utilization of the storage and coexistence of the residents in neighborhood and vital facilities required for operation and survival of the chemical complex.

# 9. MONITORING PROGRAMME OF ENVIRONMENTAL IMPACT

For an early detection of adverse environmental impacts it is required to develop the monitoring system for the storage and the surrounding area. This monitoring system ought to enable estimate of the scope and intensity of pollution and possible damages in order to undertake measures in a due time to prevent pollution, i.e. prevention of a wider pollution or a successful rehabilitation of the observed and recorded pollution.

The control of large industrial storage in open space, as well as the facilities assigned for specific purposes is performed through the two groups of activities:

- monitoring of facilities for control of its geotechnical stability; and
- monitoring of occurrences on and around the facilities in order to define ecological stability.

Monitoring, as a technical control, is performed by means of:

- visual observation of occurrences and events at the storage and its surrounding;
- individual parameter measurements for the estimate of condition;
- periodical preparation of studies, statements, expertise and reports which study conditions, and in a professional way solve the problem detected by visual observation and individual measurements.

The all monitoring elements are defined in the JUS U.C5.020 standard “Designing of Earth Dam and Hydrotechnical Embankments, “Technical Conditions” (the Rulebook No. 31-7303/1 as of 1980-04-17, Official Gazette of SFRJ No. 25/80). The details connected with storage monitoring are worked out in the Conceptual Design of the Phosphogypsum Storage, while herein has provided details important for monitoring organization for the control of ecological stability of the facility and its surrounding.

Monitoring tasks are:

- Definition of short-term and long-term trends;
- Recognition of environmental changes and analysis of causes;
- Measurement of impacts and comparison of results with forecasts;
- Monitoring system upgrading;
- Upgrading practice and environmental protection procedures.

Specific monitoring requests developed through the monitoring program are:

- What is measured?
- Where is measured?
- When is measured?
- How is measured?
- Estimate of used method;
- Required additional information.

## 9.1. Monitoring system configuration

A reliable environmental monitoring system in the area of the phosphogypsum storage consists of the following steps:

- the identification of pollution sources and parameters (type and dimensions);
- the selection of environmental parameters for which are conducted measurements (in space and time);
- determination of critical areas;
- collection of data, analysis and estimate.

With the proposed environmental monitoring system will be monitored pollutant emissions from the area where will be stored phosphogypsum and immissions from the several locations in the surrounding in order to define the impacts of activities in the stalk with covering of the following environmental entities:

- the quality of surface waters and groundwaters and occurrence of potential toxic materials:
- air quality;
- soil quality.

The environmental monitoring system proposed by this Study will be capable of conducted analysis of pollution sources in accordance with its contribution to the total environmental pollution with the realization of efficiency of applied environmental protection measures. The monitoring process will take into account the valid legal and institutional framework in the Republic of Serbia. In cases of non-existence of legislation in the Republic of Serbia will be followed international regulations and recommendations (EU, the World Bank, EPA, WHO).

The proposed environmental monitoring system needs to provide establishment of the procedure for estimating of environmental impact caused by activities at the storage, as well as environmental protection status. It has been estimated that the establishment of such system is realistic and that system development will provide an efficient monitoring in the area of the phosphogypsum storage and its surrounding.

## 9.2. Monitoring of zero state before commencement of project operations

The zero state monitoring is not legally binding stage in the monitoring in the area of the future storage, but positive experiences in industry indicate that is very desirable and useful for future interpretation of facility's environmental impacts. The significance of zero state monitoring is particularly obvious in the situation when the facility is established in a polluted or partially endangered location. It is frequently realized in this stage, i.e. zero state monitoring. The previous monitoring of environmental conditions in the surrounding of the phosphoric acid factory was performed in the area presented in Fig.5.3.

The Greek company Intergeo Environmental Technology conducted during 2008 the detailed investigations of water, air (including radioactivity) and soil. The similar investigations were conducted during 2012 in order to define the existing environmental conditions at the industrial complex IHP Prahovo by City Institute for Public Health from Beograd. In the previous monitoring were included the industrial grounds of existing factories and their close surroundings toward the old phosphogypsum storage at the Danube.

During investigations of groundwater quality from 2008 was ascertained that remediation intervention values had been exceeded for the following investigation parameters:

- arsenic in one, nickel in three and cadmium in one sample;
- aliphatic hydrocarbons in two samples.

It was ascertained an increased concentration of fluorides, sulphates, nitrates and phosphates in some groundwater samples.

During 2012 it was investigated the groundwater quality from the 4 newly set-up piezometers and it was ascertained:

- the concentrations of the investigated parameters did not exceeded limit or remediation intervention values of pollutants in groundwaters in any samples according to the Serbian Regulations;
- the only recorded deviations is related to the exceeding of the ammonium concentrations at the 2 locations in relation to the values for the III and IV water class according to the Rulebook on dangerous materials in water.

The general conclusion is that the soil contamination at some locations within the industrial complex IHP Prahovo is not significantly impacted the groundwater quality.

As for the quality of surface waters, the investigations conducted during 2008 indicated that in the majority of the investigated surface water samples collected from drainage canal, pipelines, etc., are increased contents of sulphates and heavy metals (As, Cu, Ni, Cd and Cr), and in a smaller number of samples is recorded low pH value and an increased content of TPH.

According to the valid regulations the Danube at Prahovo has been classified in the II category water streams, i.e. the water quality should satisfy provisions for the II category of river waters. The flow regime is regulated with the operation of HPP Djerdap II, and it also has impact on the quality of river water downstream from the dam.

According to the report by Hydrometeorological Institute of Serbia, the quality of the Danube's water on the route from the dam to the border with the Republic of Bulgaria occasionally do not correspond to the prescribed quality from physical and chemical and microbiological aspect. From the physical and chemical parameters deviations are recorded with the percentage of oxygen saturation, iron content as well as the content of hydrocarbons of petrol origin. From the microbiological aspect, occasionally occur an increased titre of total coliform bacteria. The phosphate content is not standardized, but are occasionally detected high concentration of ortho-phosphates and total phosphorus. Saprobiological investigations of the Danube's water quality pointed out to the presence of moderate organic pollution. In the water stream dominates bioindicators and mesosaprobic zones. In the all investigation periods was characteristic domination of centric and silicate alga, while during summer periods it was detected a significant presence of green alga.

If we study water condition according to the algorithm, Fig.9.1, the Water Framework Directive 2000/60/EC (Source: Immission Limit Values for Waters, Promotion of a New Approach in Water Protection in the Republic of Serbia, Belgrade Chamber of Commerce, as of 05.06, 2013) can be concluded that water condition in the surrounding of the future phosphogypsum storage can be graded as one in "good condition".

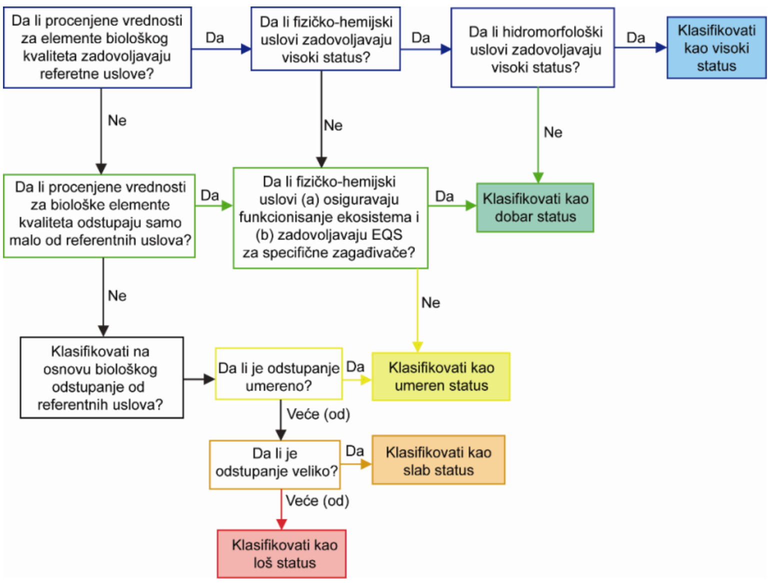



Fig.9.1 Algorithm for determination of water status according to the Water Framework Directive 2000/60/EC

For the said location it is of importance a potential emission of micro particles in air, since those particles, unlike deposited material, stay in atmosphere for long periods and can be transferred to larger distances. In the concrete case the deposited materials are of primary importance for the agricultural areas in the surrounding, and to lesser extent for surface waters and groundwaters, while suspended particles could be transferred to larger distances, i.e. to the surrounding settlements. The impact on the employed staff in the complex need not to be neglected.

The investigations of total deposited materials were conducted by Institute for Technology of Nuclear and Other Mineral Raw Materials (ITNMS) during 2010 (in the period May-September). The precipitators were located in the surrounding of the storage area at 14 locations at distances from 500m to 2500 m. During the period in which measurements were conducted total deposited materials only exceeded on two days limit values of 300 $mg/m^2/24h$.

The quantities of dissolved and undissolved part was changeable, depending on total deposited materials, while representation of a dissolved part was somewhat larger.

The radiological investigations were conducted on soil samples (more specifically, one sample from the surface layer and one sample from the drilled material), groundwater (one sample from each piezometer), NPK fertilizer samples and waste samples (20 samples). The testing was performed in the Laboratory for Protection from Radiation and Environmental Protection of Institute for Nuclear Sciences Vinča. On the basis of results it was ascertained the following:

- in the tested soil samples (from the surface layer and drilled material) it was not detected the presence of radionuclides above the prescribed limits for radioactive contamination;
- in the groundwater samples the measured values and activities are in accordance with the valid legislation;
- in one NPK fertilizer sample was recorded radioactivity; and
- in waste samples it was not recorded increase of radioactivity above prescribed limit.

The general conclusion could be boiled down to the following: the area of the industrial complex IHP Prahovo and its close surrounding are not substantially polluted and do not significantly disturb environmental condition.

This Study follows the Conceptual Design of the Phosphogypsum Storage, and as a starting foundation for monitoring adopts the existing real condition in accordance with the documents owned by the Investor, which were made available for study developers. The environmental condition in the surrounding of the industrial complex Elixir Prahovo, IHP Prahovo is presented in details in Section 5 herein.

## 9.3. Parameters for determination of harmful environmental impacts

The environmental impact needs to be monitored on the basis of measurements of air, water and soil. The pollutions which might occur will have mainly diffusive character. Hence, the monitoring program was done as a combination of emission monitoring, what is the legal obligation of each business entity, and immissions monitoring what is not an explicit obligation of a business entity, but in practice is applied when emission cannot be exactly measured and defined.

Because of possible jeopardy of water in accidental and pre-accidental situations in the wider location around the storage as a central issue is imposed the monitoring of groundwater quality, downstream and around the storage.

For soil it is anticipated monitoring of heavy metals spreading, while for air the impact of air pollution on residents which are located nearest to the storage and the industrial grounds.

Considering that storage will be formed by construction mechanization, and that the largest operations will be before the commencement of stage 1, it is of importance to monitor environmental conditions in the periods of the storage formation and utilization. Table 9.1 shows the parameters which are required to be monitored through these periods.

Table 9.1: Parameters for determination of damaging environmental impacts in the periods of storage formation and utilization

| | | | |
|---|---|---|---|
| **WATER EMISSIONS (POLLUTION) from the phosphogypsum storage** | | | |
| **IN THE STAGE OF STORAGE FORMATION AND FACILITIES CONSTRUCTION AT THE STORAGE** | | | |
| Noise | Monitoring of noise emissions in the period of storage formation (terrain levelling, excavation of perimeter canal, road construction, mineral barrier formation, liner installation, drainage system construction) needs to be performed within the factory grounds, immediately along the industrial facilities with a permanent crew, which are nearest to the storage | | |
| **IN THE STAGE OF STORAGE UTILIZATION** | | | |
| Emission in water | Considering that water is not discharged in the surrounding there is no locations at which can be measured emissions | | |
| Emission in air | Considering that is prevented dust formation during utilization with technical measures there is no location at which can be measured emission | | |
| Noise | Considering that technological process does not required particular involvement as a source of industrial noise, the measurement of noise emission does not make sense in the period of storage utilization | | |
| **IMMISSIONS (POLLUTIONS) in the phosphogypsum storage's surrounding** | | | |
| **IN THE STAGE OF STORAGE FORMATION AND FACILITIES CONSTRUCTION AT THE STORAGE** | | | |
| Air | Measurement locations within the industrial complex IHP, nearest to the storage | Quantity of pollutants in air | Soot, $PM_{10}$, $PM_{2,5}$ |
| | | Total deposited materials | Quantity of deposited material, heavy metals content (arsenic, cadmium, nickel, mercury, zinc, lead) and phosphorous content |
| Waters | Available piezometers in the industrial grounds and around the storage | Water quality | Parameters which are controlled and average (limit) annual concentrations prescribed by the Regulation on limit values for pollutants in surface waters and ground waters and sediments and deadline for their reaching (Official Gazette of RS, No. 50/12):<br>• nitrates; and<br>• active substances in pesticides, including their relevant metabolites, products of degradation and reactions<br>From the pollutant list are to be monitored content of:<br>• organophosphorus compounds<br>• inorganic phosphorous compound and elementary phosphorous,<br>• mineral oil and hydrocarbons<br>• metals, metalloids and their compounds: Zn, Cu, Ni, Cr, Pb, Se, As, Sb, Mo, Ti, Sn, Ba, Be, B, U, V, Co, Tl, Te and Ag |
| | | Water level | |
| Soil | Arable land in the surrounding | | pH, cadmium, lead, mercury, arsenic, chrome, nickel, fluorine, copper, zinc, boracium, cobalt, molybdenum, phosphor |
| **IN THE STAGE OF STORAGE UTILIZATION** | | | |
| Air | Measurement locations within industrial complex IHP, nearest to the storage | Quantity of pollutants in air | Soot, $PM_{10}$, $PM_{2,5}$ |
| | | Total deposited materials | Quantity of deposited material, heavy metals content (arsenic, cadmium, nickel, mercury, zinc, lead) and phosphorous content |
| | | Radionuclides content | |
| Waters | Available piezometers around the storage | Water quality | Parameters which are controlled and average (limit) annual concentrations prescribed by the Regulation on limit values for pollutants in surface waters and ground waters and sediments and deadline for their reaching (Official Gazette of RS, No. 50/12):<br>• nitrates; and<br>• active substances in pesticides, including their relevant metabolites, products of degradation and reactions<br>From the pollutant list are to be monitored content of:<br>• organophosphorus compounds<br>• inorganic phosphorous compound and elementary phosphorous<br>• metals, metalloids and their compounds: Zn, Cu, Ni, Cr, Pb, Se, As, Sb, Mo, Ti, Sn, Ba, Be, B, U, V, Co, Tl, Te and Ag |
| | | Level | |
| | | Radionuclides content | |
| Soil | Arable land in the surrounding | | pH, cadmium, lead, mercury, arsenic, chrome, nickel, fluorine, copper, zinc, boracium, cobalt, molybdenum, phosphor |
| | | | Radionuclides content |

## 9.4. Locations, means and frequency of parameters measurement

Locations, method and frequency of monitoring of the storage's impact on the surrounding need to be harmonized with the surveying locations, as well as with sampling locations and monitoring frequency in the industrial complex IHP Prahovo.

### 9.4.1. Monitoring of air quality

The proposed system for air monitoring will provide a recording of air quality in the phosphogypsum storage, in order to estimate risk for people's health which are potentially exposed to air pollutions. The all works on monitoring need to be conducted in accordance with the Regulation on monitoring conditions and requests for air quality (Official Gazette RS, No. 11/2010) and the Regulation on amendment of the Regulation on monitoring conditions and requests for air quality (Official Gazette RS, No. 75/2010 and 63/2013).

The zones for air quality measurements are selected at locations where the risk of exceeding the limit values is high. The zones proposed for the implementation of monitoring are the holding of IHP Prahovo and the nearest residential buildings outside the industrial grounds. Those measurement zones have been selected since they are locations in the in the wider surroundings in which in continuity stay people.

Fig.9.2 shows sampling zones at the location immediately along the storage.

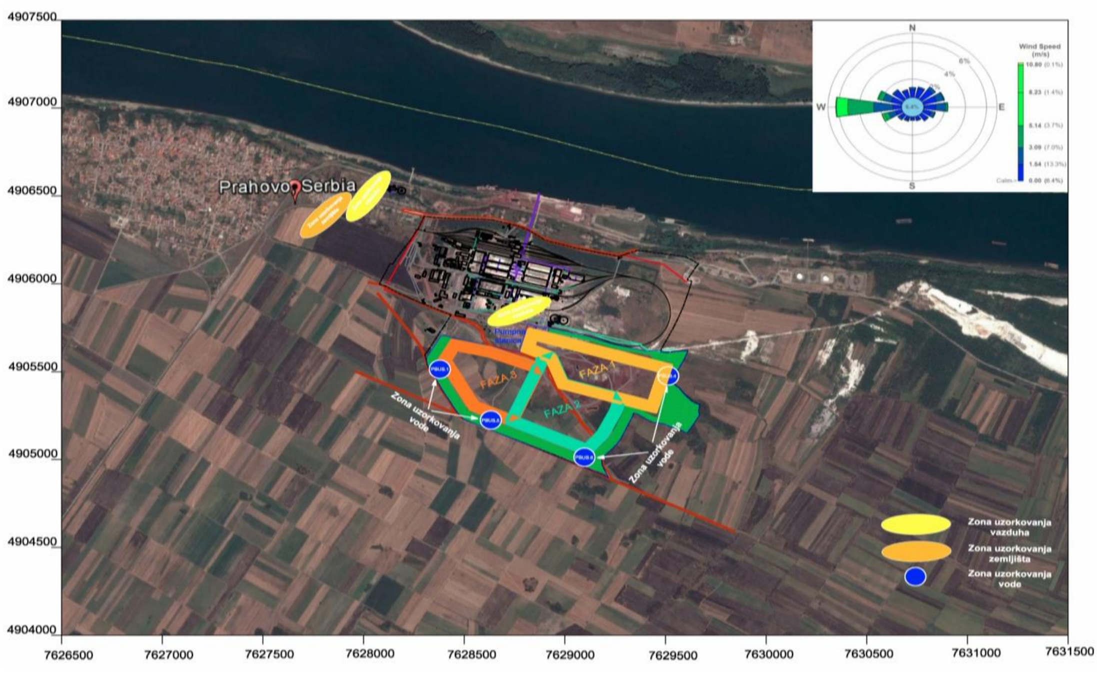



Fig.9.2 Sampling zones

The monitoring of air pollution will be conducted in the mobile laboratory, which can be dispatched to the target points in order to conduct measurements during temporary air pollutions. The data which are collected by the mobile laboratory are entered into the central database.

The measurement of undeposited particles will be conducted by the Bergerhoff dust gauge (for undeposited dust).

The dust sampling will be conducted occasionally, once a year in accordance with the Regulation on monitoring conditions and requests for air quality (Official Gazette RS, No. 11/2010) and the Regulation on amendment of the Regulation on monitoring conditions and requests for air quality (Official Gazette RS, No. 75/2010 and 63/2013) and the Rulebook on limit values, immissions measurements methods, criteria for establishment of measurement locations and data recording (Official Gazette RS, No 54/92, 30/99 and 19/2006), which regulate this type of monitoring. Depending on concrete circumstances and the auditor report's results, sampling frequency can be increased or decreased, all in accordance of the adaptive monitoring which implementation is proposed.

The measuring instrument and equipment have to be attested. The sampling and analyses need to be conducted according to the valid standards, while on the all occasions when monitoring, measurement or analysis are not covered by the Serbian standards, ISO and EU standards are applied.

Concurrently with the air monitoring it needs to be determined radionuclides content in the air. The measurements need to be conducted once a year, in accordance with the technical standards prescribed in the Rulebook on definition of program for systematic investigations of environmental radioactivity (Official Gazette RS No. 100/10).

### 9.4.2. Water monitoring

The primary recipient for waters from the site of industrial grounds and the new storage from where they are discharged, on surface or underground, is the Danube.

Water quality monitoring includes monitoring of levels and quality of water in piezometers which encircle the site of the future phosphogypsum storage, 4 piezometers were formed during March 2014, Fig. 15. It is requited that sampling, sample storage are harmonized with standards, and in the all cases when it is not covered with Serbian standard ought to be applied ISO and EU standards (sampling, sample storage, preservation of samples are covered by ISO Standards from Group 5667).

The quality of a surface water course, i.e. the Danube River, is monitored by Republic Hydrometeorological Service of Serbia and, therefore, it is not anticipated to monitor its quality as a part of the monitoring of the area around the storage.

The list of physical and chemical parameters, i.e. indicators which need to be monitored is provided in Table 9.1.

| Map with piezometers location | | | |
|---|---|---|---|
|  |  |  |  |
| PBUS.1<br>x: 7628378.91<br>y: 4905514.27<br>z: 47.82<br>water PPv 10.50 | PBUS.4<br>x: 7629513.65<br>y: 4905476.49<br>z: 47.69<br>water PPv 12.30 | PBUS.5<br>x: 7628632.57<br>y: 4905225.13<br>z: 46.50<br>water PPv 11.00 | PBUS.6<br>x: 7629097.43<br>y: 4905013.41<br>z: 46.70<br>water PPv 11.80 |

Fig.9.3 Piezometers around the phosphogypsum storage (P1-P4)

Concurrently with the water monitoring it needs to be determined radionuclides content in water. The measurements need to be conducted once a year, in accordance with the technical standards prescribed in the Rulebook on definition of program for systematic investigations of environmental radioactivity (Official Gazette RS No. 100/10).

### 9.4.3. Soil monitoring

The location of the storage is surrounded with the industrial complex from the north side and agricultural land from the other sides.

The sampling ought to be performed outside the grounds, up to 500 m from the site of the storage in direction toward a populated settlement. Samples ought to be taken from arable and cultivated land. Composite samples which consist of a greater number of subsamples ought to be taken.

The objective of investigation is monitoring of changes and eventual increase or reduction of concentrations of the analyzed elements in relation to the state before opening of the phosphogypsum storage. The all works need to be harmonized and obtained results are compared with provisions from the valid Regulation on systematic soil quality monitoring program, indicators for assessment of risk of soil degradation, and methodology for development of remediation programs (Official Gazette of RS, No. 88/2010).

The radionuclides content need to be determined on collected samples. The measurements are to be performed at least once a year, and in accordance with the technical standards prescribed in the Rulebook on definition of program for systematic investigations of environmental radioactivity (Official Gazette RS No. 100/10).

The list of physical and chemical parameters, i.e. indicators which need to be monitored is proved in Table 9.1.

### 9.4.4. Accidental situations

From the accidental situations which may have negative implications on environment the following are possible:

- the damage on the closed return water supply system, which supplies the plant with return water from the phosphogypsum storage;
- the damage on the transport system for phosphogypsum suspension, on the pipeline between the factory and the phosphogypsum storage;
- the damage on the storage.

If there is a damage on the return water supply system from the phosphogypsum storage it is possible to occur increased pollutants concentration in groundwaters. If this accident occurs it is required to immediately conduct unscheduled sampling from the all piezometers in order to realize a negative impact caused by the damage. Depending on the damage intensity it is required to conduct water sampling and determination of the relevant parameters (Table 1) several times during the first day, and at least once a day during several following days. The unscheduled sampling is stopped as soon as water quality becomes usual.

The similar effects and procedures are in case of the damage on the pipeline for the transport of suspension from the factory to the phosphogypsum storage.

If there is some damage at the storage (failure, sliding, overflow) it is possible pollution of the surrounding soil and groundwaters, in case of a larger damage the consequences can be detected on the Danube. In that case it is required to act in the same way with the water monitoring as with the damage on the system for return water supply. In the part of the terrain affected with phosphogypsum spillage it is required to collect at least 3 soil samples and investigate pollution.

## 9.5. Deliberation, control and adoption of obtained results

Auditing is an important part of the monitoring process since it is virtually used to verify recorded data and detected occurrences, define trends and perform continual correction of monitored parameters. In order to achieve this it is required to perform auditing for each previous years. The material for auditing need to prepare the monitoring service in cooperation with companies which performed other monitoring jobs. The same service needs to provide a proposal for adjusting of monitoring program on the basis of the achieved results and detected trends.

The introduction of monitoring is in accordance with the strategic plans in the Republic of Serbia for the establishment of plans for eco-management and review of environmental impact – EMASSS III (Eco-management and Audit Scheme).

It has been proposed the adaptive monitoring system in order to achieve an efficient environmental monitoring.

Monitoring ought to be established with trucking down at least those parameters provided in this Study. After monitoring is established and parameters are monitored for several years it is required, through the auditing process, to perform harmonization, i.e. adaptation of parameters which ought to be monitored in the next period. With that will be stopped monitoring of the parameters which are not characteristic for the technological process, but it will be put emphasis on importance and change of monitoring dynamics of the parameters selected like potentially dangerous. In conceptualization of proposals for adoption of corrected monitoring programme which would include monitoring of harmonized parameters it is important to conduct the auditing programme.

# 10. INFORMATION ON TECHNICAL INSUFFICIENCIES OR NON-EXISTENCE OF SOME PROFESSIONAL EXPERTISE OR SKILLS

It is necessary to emphasize that technical insufficiencies have not been identified in the stage of preparation of project documentation and preparation for realization of the phosphogypsum storage design with the insight in the available technical documents and visit to the company Elixir Prahovo Industry of Chemical Products Ltd Prahovo.

On the basis of review of staff's qualifications, which work on the realization of preparation for the establishment of the new phosphogypsum storage as well as the quality of professional cooperation on the Environmental Impact Assessment Study (EIA Study) it can be concluded that it has been provided a suitable level of professional expertise both with the management and other staff.

# 11. APPENDIX

## 11.1. Conditions and agreements from other competent authorities and organizations

The company Elixir Prahovo Industry of Chemical Products Ltd Prahovo has acquired the following documents, decisions and agreements connected with the obtainment of approvals for implementation of works, with the objective to obtain agreements from the authorities competent for affair of environmental protection, concerning harmonization of the Conceptual Design of the Phosphogypsum Storage with the Detailed Regulation Plan for the chemical industrial complex in Prahovo with conditions for environmental protection and improvement:

- The Decision in the process of issuing of water conditions by the public water management company Srbijavode – Beograd, No. 303/3-13 as of 13.08.2013;
- The conditions for preparation of the Detailed Regulation Plan for the chemical industrial complex in Prahovo, Serbian Railway, the joint-stock company, No. 13/13-1078 as of 29.08.2013;
- The condition for preparation of the Detailed Regulation Plan for the chemical industrial complex in Prahovo, PE Roads of Serbia, Beograd, No. 953-1083 as of 03.07.2013;
- The condition for power transmission grid in connection with technical conditions for preparation of the Detailed Regulation Plan for the chemical industrial complex in Prahovo, by the company “Jugoistok” Ltd. Niš, the Negotin facility, No. 349/13 as of 22.07.2013;
- The conditions for preparation of the Detailed Regulation Plan for the chemical industrial complex in Prahovo, PE for Urban Development Land of Negotin Municipality, No. 01/1430 as of 15.07.2013;
- The conditions for connection to the municipal infrastructure for preparation of the Detailed Regulation Plan for the chemical industrial complex in Prahovo, at cadastral parcel no. 2300 of C.M. Prahovo and in the area in the south and east part outside the factory grounds, PE Badnjevo Negotin, No. 17/8-02/2013 as of 28.06.2013;
- The construction conditions for preparation of the Detailed Regulation Plan for the industrial complex IHP Prahovo, Telecom Serbia, No. 234097/2-2013 as of 31.07.2013;
- The fire protection conditions preparation of the Detailed Regulation Plan for the chemical industrial complex in Prahovo, at cadastral parcel no. 2300 of C.M. Prahovo, No. 5354/13 as of 08.07.2013;
- The Decision on nature protection conditions for preparation of the Detailed Regulation Plan for the industrial complex IHP Prahovo, Institute for Nature Conservation of Serbia, No. 020-1514/13 as of 18.07.2013;
- The Act on preservation, maintenance and utilization of immovable assets as well as assets which are under previous protection and defined protection measures for the Detailed Regulation Plan for the industrial complex IHP Prahovo, Institute for Protection of Cultural Monuments Nis, No. 818/2 as of 19.08.2013;
- The notification in connection with preparation of the Detailed Regulation Plan for the industrial complex IHP Prahovo, Administration for Infrastructure, Department of Material Resources of Ministry of Defense, No. 2403-6 as of 04.09.2013;
- The Decision on agreement for the project Rehabilitation and Remediation of the Pyrite Slag Disposal at the industrial complex IHP Elixir Prahovo in Prahovo, Ministry of Energy, Development and Environmental Protection, No. 350-02-86/2013-05 as of 16.08.2013;
- The seismic conditions for preparation of the Spatial Plan of Negotin Municipality, Seismological Institute of Serbia, No. 021-721-1/10 as of 13.09.2010.

## 11.2. Graphic appendixes

In the Environmental Impact Assessment Study of the Phosphogypsum Storage are provided the following five graphic appendixes:

| | |
|---|---|
| **Appendix 1** | GENERAL LAYOUT PLAN OF THE PHOSPHOGYPSUM STORAGE WITH CADASTRAL PARCELS, SCALE 1:5000 |
| **Appendix 2** | FACILITIES LOCATION, SCALE 1:10000 |
| **Appendix 3** | CROSS-SECTIONS THROUGH THE STORAGE, SCALE 1:2000 |
| **Appendix 4** | PUMP STATION, SCALE 1:50 |

## 11.3. References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# APPENDIXES

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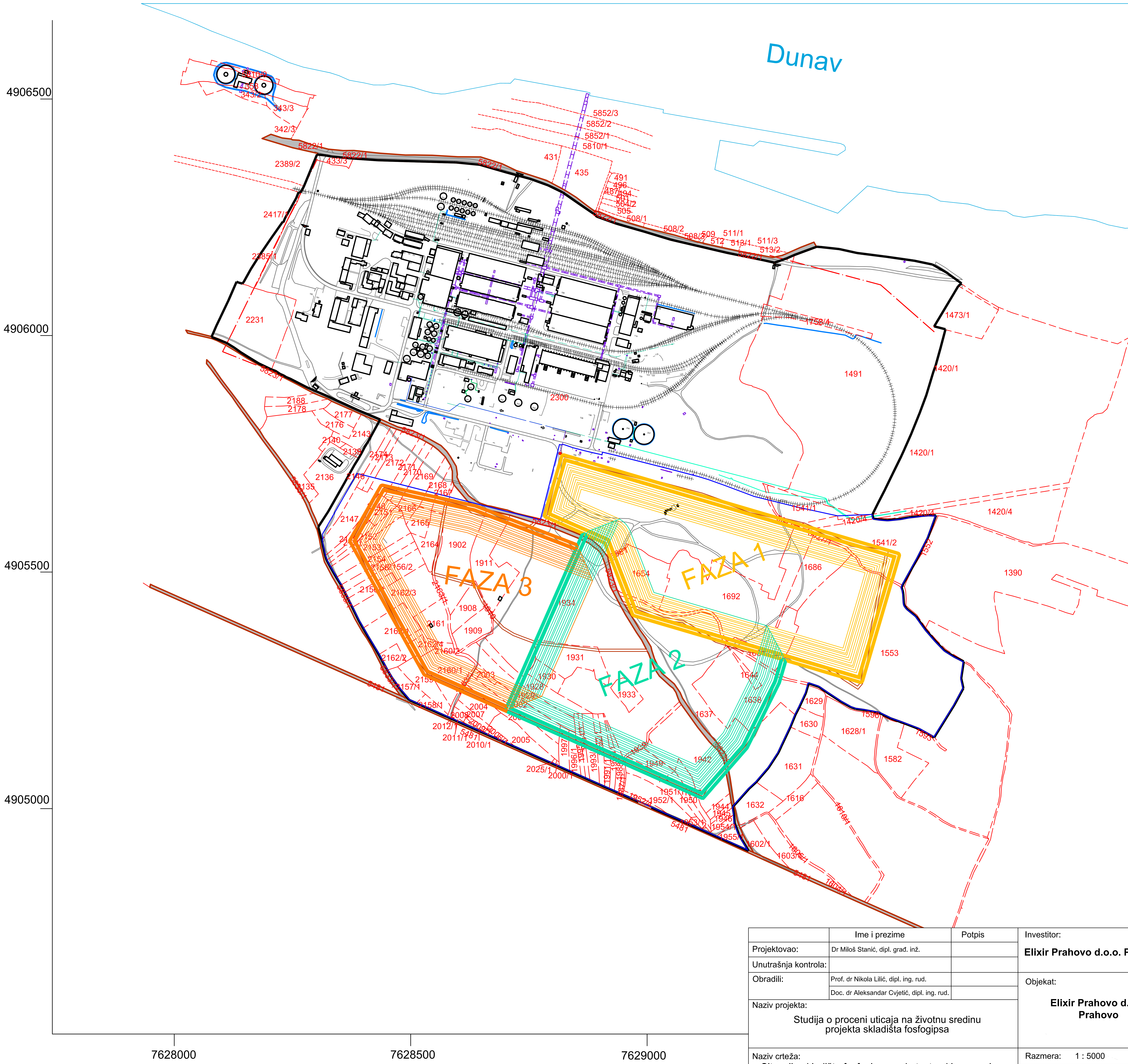
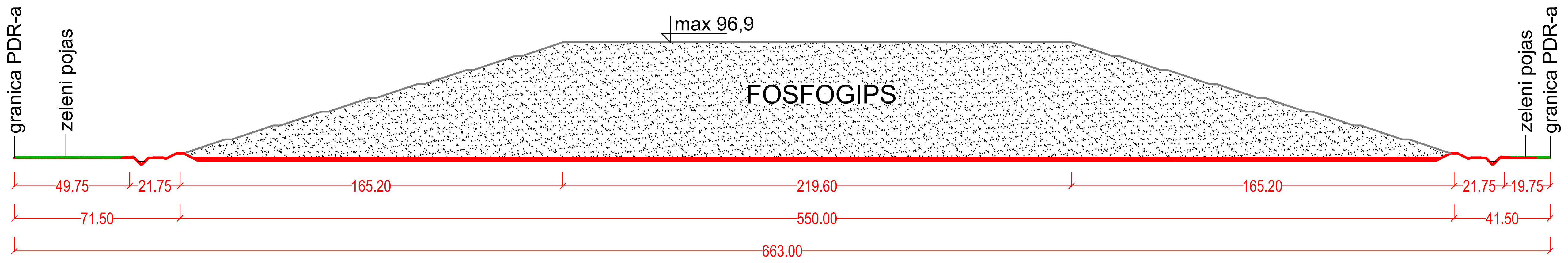
|---|---|
| **Appendix 1** | GENERAL LAYOUT PLAN OF THE PHOSPHOGYPSUM STORAGE WITH CADASTRAL PARCELS, SCALE 1:5000 |
| **Appendix 2** | FACILITIES LOCATION, SCALE 1:10000 |
| **Appendix 3** | CROSS-SECTIONS THROUGH THE STORAGE, SCALE 1:2000 |
| **Appendix 4** | PUMP STATION, SCALE 1:50 |




| | Ime i prezime | Potpis | Investitor: |
|---|---|---|---|
| Projektovao: | Dr Miloš Stanić, dipl. građ. inž. | | Elixir Prahovo d.o.o. Prahovo |
| Unutrašnja kontrola: | | | |
| Obradili: | Prof. dr Nikola Lilić, dipl. ing. rud. | | Objekat: |
| | Doc. dr Aleksandar Cvjetić, dipl. ing. rud. | | |
| Naziv projekta: Studija o proceni uticaja na životnu sredinu projekta skladišta fosfogipsa | | | Elixir Prahovo d.o.o. Prahovo |
| Naziv crteža: Situacija skladišta fosfogipsa sa katastarskim parcelama | | | Razmera: 1 : 5000 |
| | | | Broj priloga: 1 |


| | Ime i prezime | Potpis | Investitor: Elixir Prahovo d.o.o. Prahovo |
|---|---|---|---|
| Projektovao: | | | |
| Unutrašnja kontrola: | | | |
| Obradili: | Prof. dr Nikola Lilić, dipl. ing. rud. | | Objekat: Elixir Prahovo d.o.o. Prahovo |
| | Doc. dr Aleksandar Cvjetić, dipl. ing. rud. | | |
| Naziv projekta: Studija o proceni uticaja na životnu sredinu projekta skladišta fosfogipsa | | | |
| Naziv crteža: Lokacija objekta | | | Razmera: 1 : 10000 |
| | | | Broj priloga: 2 |

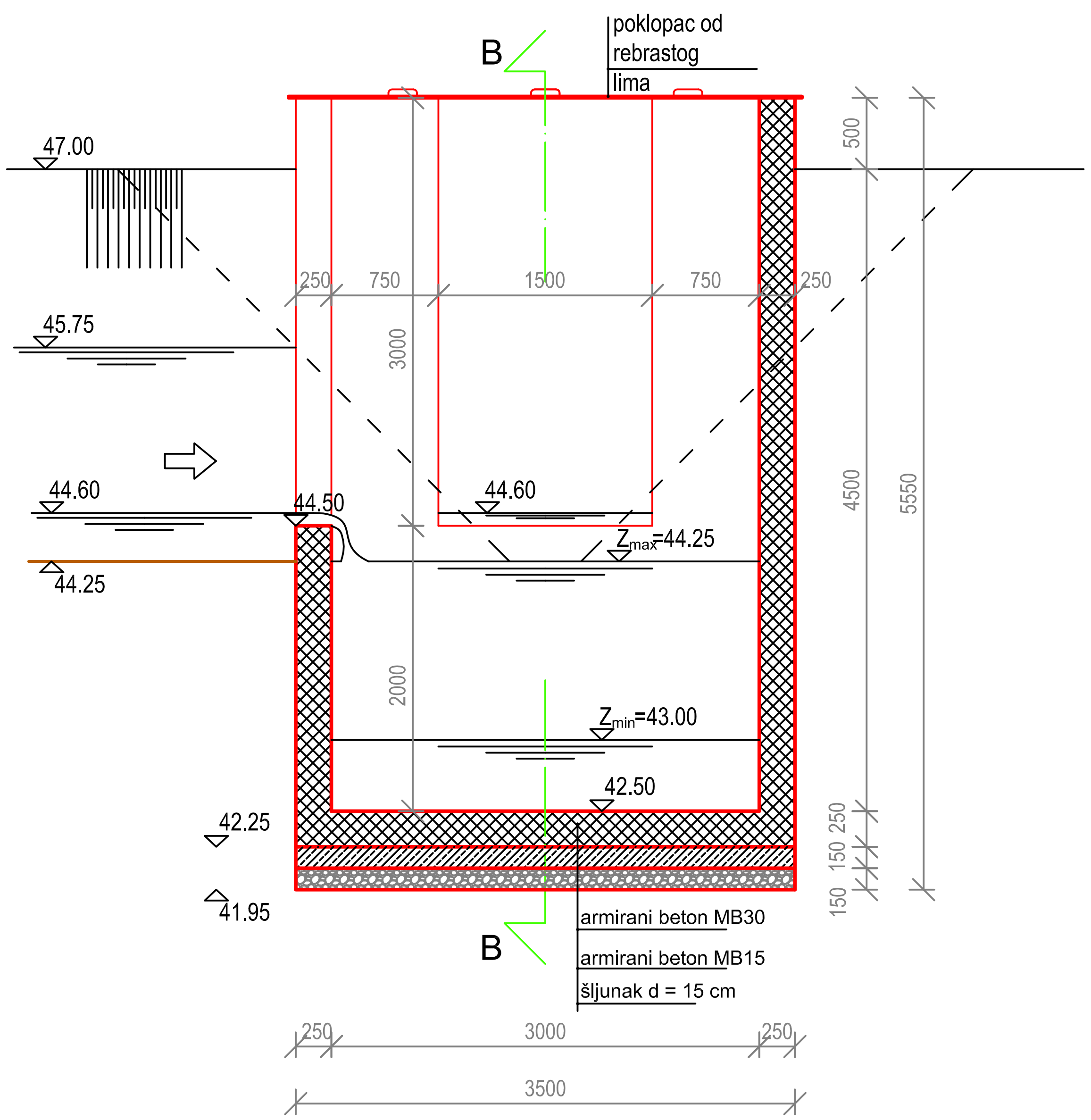
## PRESEK A-A



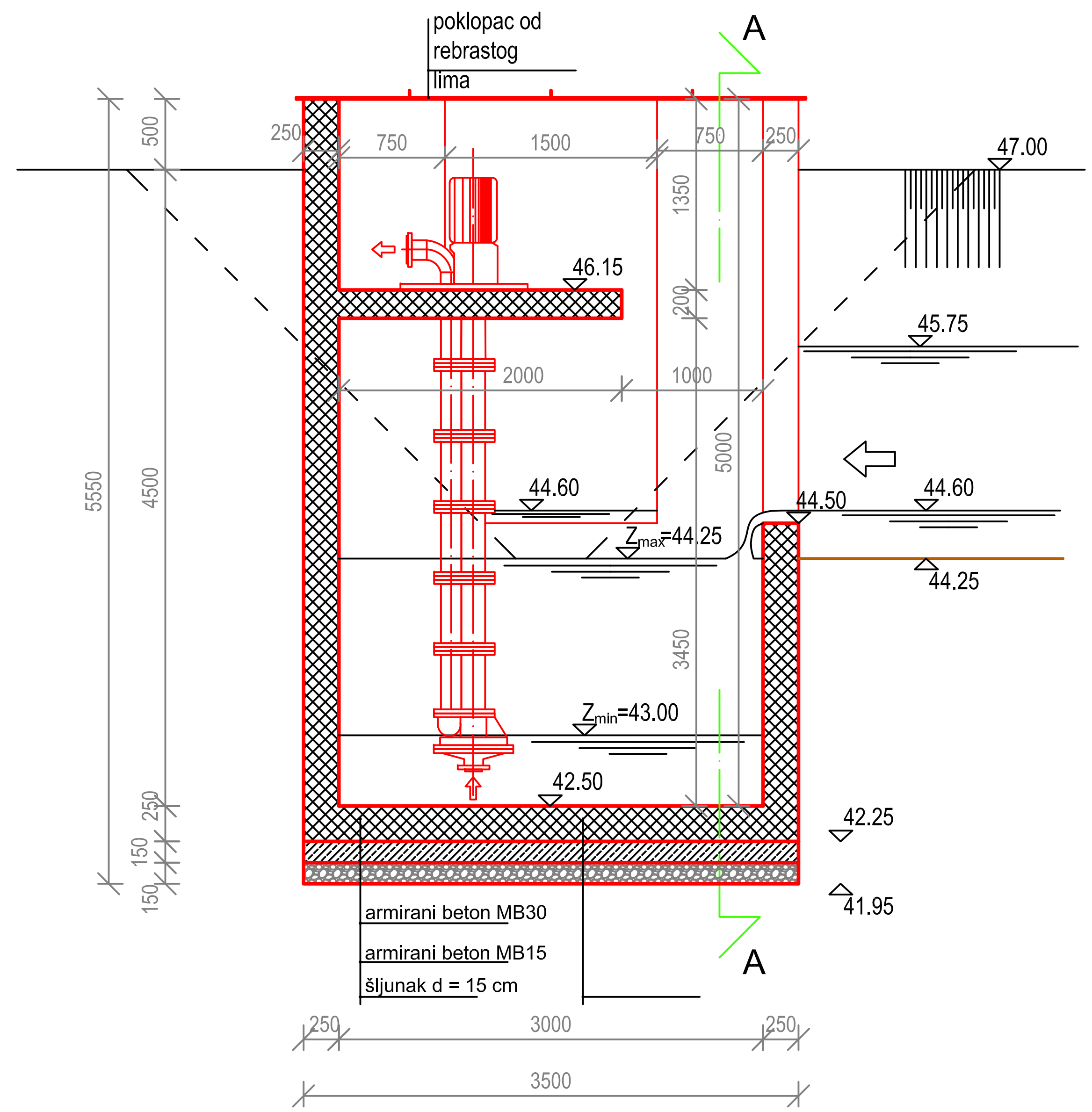

## PRESEK B-B


| | Ime i prezime | Potpis | Investitor: **Elixir Prahovo d.o.o. Prahovo** |
|---|---|---|---|
| Projektovao: | | | |
| Unutrašnja kontrola: | | | |
| Obradili: | Prof. dr Nikola Lilić, dipl. ing. rud. | | Objekat: **Elixir Prahovo d.o.o. Prahovo** |
| | Doc. dr Aleksandar Cvjetić, dipl. ing. rud. | | |
| Naziv projekta: Studija o proceni uticaja na životnu sredinu projekta skladišta fosfogipsa | | | |
| Naziv crteža: Poprečni preseci kroz skladište | | | Razmera: 1 : 2000 |
| | | | Broj priloga: 3 |

## PRESEK A-A




## PRESEK B-B




| | Ime i prezime | Potpis | Investitor: Elixir Prahovo d.o.o. Prahovo |
|---|---|---|---|
| Projektovao: | | | |
| Unutrašnja kontrola: | | | |
| Obradili: | Prof. dr Nikola Lilić, dipl. ing. rud. | | Objekat: Elixir Prahovo d.o.o. Prahovo |
| | Doc. dr Aleksandar Cvjetić, dipl. ing. rud. | | |
| Naziv projekta: Studija o proceni uticaja na životnu sredinu projekta skladišta fosfogipsa | | | |
| Naziv crteža: Pumpna stanica | | | Razmera: 1 : 50 |
| | | | Broj priloga: 4 |