Ending the 100 Years Salt Water Industrial Exploitation in Mineral Salt Site in Tuzla

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Resume

The rocks of the salt sites are widespread in north-east part of Bosnia and Herzegovina in Tuzla basin area the. Dissolution of mentioned takes place with the presence of water what is shown at the terrain surface by appearance of salt wells of various mineralizations. In regard with the fact that salt was of interest for human civilization through the centuries, the first settlements were in the nearness. In these areas there were mostly smaller rural settlements using the wells for needs of interior population.

More significant for salt water use appears in the end of XV century with arrival of Turks in these areas, when more organized way of its exploitation takes plase. Progresively, they dig wells on which there is not enough data. Therewith, the Turks realized that there are significant salt quantity in these areas that can satisfy their needs. The reason enough to form settlement step by step, in nearby the site edge and named it Tuzla (tuz- salt in Tirkish).

This kind of exploitation stayed until the end of XIX century, when Austria-Hungarian Monarhy comes to these areas. With its arrival begins new era of salt exploiatation , with deep wells from the terrain surface, what is considered as begining of salt water industrial exploitation. Salines were built in Simin Han (1885) and Kreka (1887), as well as soda factory in Lukavac (1893). In the future 100 years exploitation was taking place with various intensity but same methodology, known as the method of incontrolled saltbox exploitation.

Saltbox exploitation hastened regional industrial development and town Tuzla became one of the most important industrial centers of the former Yugoslavia. However, saltbox exploitation left enormous consequences in the town. Due to salt water exploitation performance without any control, the natural condition of rocks nearby the site and around area has been disturbed. The consequences are almost total distruction of the town center area due to terrain sinking, which is around 13,0 m.

To keep the industrial development and, at the same time stop salt water exploitation and prevent further town destruction, the salt sites researches were hastened, which manifested as discovery of new site in the 80's north of the town, around 15,0 km far. After about twenty years of preparation, the exploitation at new site took place, what ended a hunderd year saltbox exploitation in the town area.

Introduction

Salt water exploitation in the site of stone salt in Tuzla, marked the 20th century in Tuzla town area. Thanks to its exploitation, the town and the whole region went through huge economic development, bu, at the same time, the town core deseppeared that was more than 100 years old. At one side we have modern town that can be put in the group of developped European towns of population to 100 000 citizens, an on the other hand all recognition things of Tuzla town were destroyed.

Industrial town and regions development is established with salt water exploitation, which is the basic raw material for production of salt, soda and chlorine. In that way, it is complete processe from mineral raw material exploitation to the final product, what puts this region in one of rare regions in the world that completes the whole cycle in the area of 20 km.

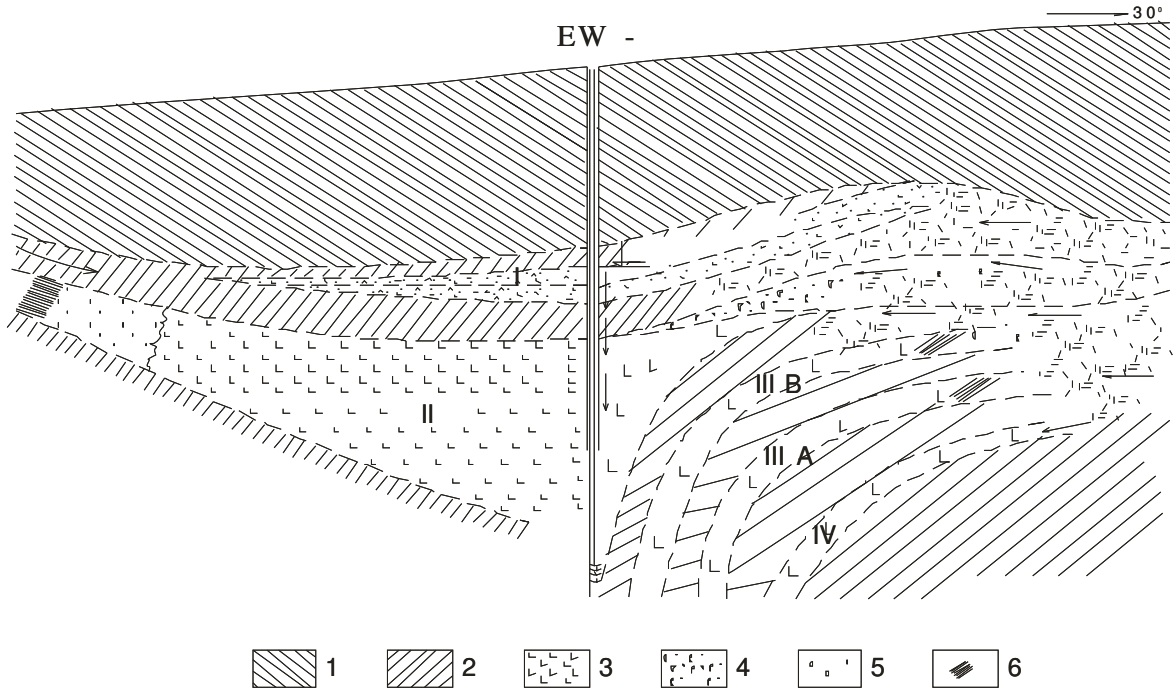
The end of 19th and begining of 20th cenury insinuated industrial development, with the pririty of mineral raw materials. The first to understand that were Austrians, who started with development of chemical industry. First salt and soda factories were built, for that period very modern factories. With the desire for good profit, and development of region to take that profit from, no one thought about the consequences that can result that kind of eploitation.

Soon, Austrian-Hungarian Monarchy is falling apart and a new state is taking place, which continues with exploitation of salt and production in allready built factories. By the time being it is developing more and more, but as previous no one thinks about the consequences at the terrain surface. When the first damages tookplace in the central town area, it was too late to do anything about it. Exploiatation

of salt could not be stopped, because there was no other way to provide mineral raw materials in existing factories which were allready meaningfull economy capacities. The only thing that could be done is determination of present situation and monitoring the consequences that were more significant in the town every year.
By the time the town core totally desappeared and town was developing towards east and west, leaving the factor time to do its own and wait for the moment of finding replacing capacities for the existing site. At the end of 20th century new site was found nearby Tuzla town, what created conditions to stop the salt exploitation at the existing site.
By receiving its moment, the old town core again „lived“ in some other form, but enough to become the center of all events. By the time, earlier degradated areas will consolidate, what will make conditions to renew the part of the past in this area and fit in the new values of the twenty first century.

Geographic – geological terrain characteristics
Tuzla town is settled in the north-east part of Bosnia and Herzegovina. It has good traffic connections in north, over the highway in east towards Belfrade and in the west towards Zagreb. In the south it is connected to Sarajevo and further towards Mostar, from where it has connection with Adriatic main road, and further to the south towards Dubrovnik, and in north-west over the recently built highway towards Split and Zagreb.
Salt site is settled in a smaller basin between two peaks in north and south, with maximum altitude sea-level 450 – 500 m. The lowest basin part is about 220 m, where the river Jala flows with the inflow of a number of smaller streams in both sides of its flow.
Significant contribution to the researches of salt sites provided as follows: F. Katzer, I. Soklić, P. Jovanović, M. Vujović, J. Stojković, Z. Brajković, N. Đurić, E. Oruč. Besides mentioned, many more of explorers made its contribution, considering the significance of the consequences found due to exploitation of salt sites by method of uncontrolled salt exploitation.
Salt rocks site has sedimentary origination, made in the processe of chemical sedimentation due to sea water vaporation in lagune type basin. There is presence in sedimentation cycle, where five salt series are divided, randomly from youngest to the oldest named I, II, IIIB, IIIA and IV, picture 1. Origination is in the myocen period.

Figure 1 *Movement directions of groundwaters towards exspoitation wel 1. Way out yones; 2. Banding marls; 3. Salt (salt series I, II, IIIB, IIA i IV),4. Cement rock`s sets, 5. Anhydrates, 6. Assumed limit of salt way outs*



North-east side part of the site includes groundwaters, which were dissolving salt series during time and which were dissolving salt series during time and in the form of salt sources they appeared in lower parts of rivers Jala and Solina. That is the way of groundwater origination, named crack-sedimentary rocks groundwater. By the time water was dissolving salt rocks, and caused the processe of sedimentary rocks origination and appereances of salt sedimentary rocks origination. Dissolving processe was very slow, so at the same time of salt rocks dissolving, consolidation of sedimentary rocks zones took place. That period is called old processe of sedimentary rocks origination.
More intenzive activity of sedimentary rocks origination processe begins in the period of Turkes exploitation. By the period of uncontrolled exploitation had more significant meaning and represents conteporary salt product origined by the processe of sedimentary rocks origination. In accordance with the examination made by N. Đurić (1987), the indicator of modern activity of salt sedimentary rocks origination processe from natural exploitation to uncontrolled exploitation, is average of 78%. The mentioned amount is related to total dissolving of salt rocks in salt sites.

History of site exploitation

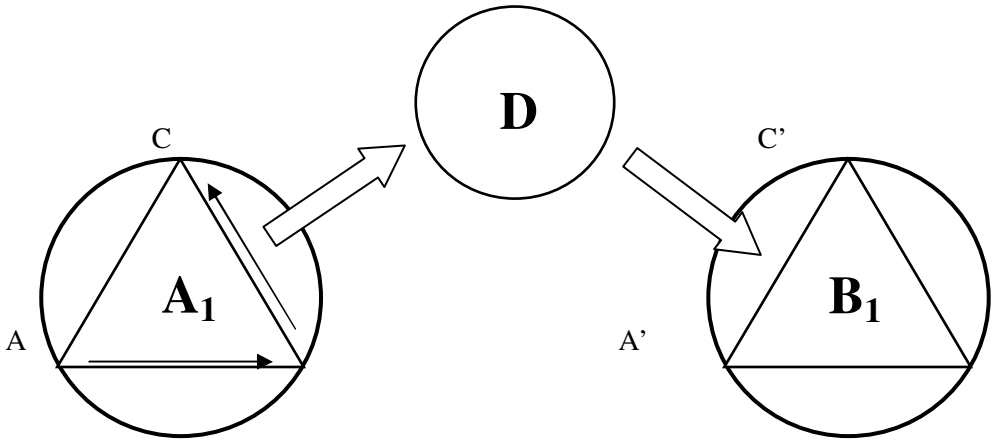
Salt exploitation from digged wells that begun by Turkes arrivel and its maintanance for about 400 years, brought changes in balance of groundwater and natural regime of renewal the crack-sedimentary rocks groundwater. Gradually, the appereance of salt sources at the terrain surface stopped, so at the end of this exploitation period, piesometric level lowered cca 20,0 m.
By aplication of uncontrolled exploitation method, more amounts of salt were exploited , than it naturally flows into the site. Since than, there is a gradual fall of piesometric level, during which the limits of site amounts increase, and drainage decreases. After 100 years of exploitation the level is lowered to about 200 meters, in the first 70 years to about 50 meters and in future 30 years to about 150 meters.
In the 80s the salt exploitation reached the critical limit , so it was decreaesd to about 50%, and as that it was kept in the future twenty years. The further fall of piesometric level is stopped, and it was gradually rising, e.i. returning to its naturla regime.
Together with salt exploitation in south-east part of the site, there was classical mining salt exploitation going on in its north-west part. The mine is oppened in vertical pits, and exploitation was going on in the depth of 450 – 520 m bellow the terrain surface.
Uncontrolled exploitation jeopardized stabiluty of mining pits, what made dependence of one exploitation from the other. The constant control of groundwaters level was taking place, and that level could not be too low because the salt exploitation would be jeopardized, and it could not be to high because the pits stability would be jeopardized. The parallel „control“ processe lasted more than 30 years.
At the end of 20th century, the end of uncontrolled exploitation of salt was the cause of mining exploitation ending. During that the mine was gradually sank by salt water, so the piesometric level would not come to the sudden fall, what would make catastrofic consequences at the terrain surface.

Deficit of rocks mass during salt exploitation

Salt water exploitation dissolves salt rocks what causes rocks mass deficit. In the starting faze of exploitation, fresh water were dissolving salt series in its side parts. Dissolving processe was very slow, sothe consequences ai the terrain surface could not be noticed. By more intensive exploitation the dissolving processe was faster and salt concentration was reaching from several tenth gr/l to concentration over 300 gr/l.
Rocks mass deficit is not lineary related to the amount of dissolved salt during the salt exploitation. Salt series contains certain percent of marl lamination, what increases the volume of degradated spaces. During mentioned teh space position increases depending on salt series included in dissolving processe. Made spaces, as the result of rocks mass deficit are not empty spaces, but they are fulfilled by marl lamination from dissolved salt series and convulsion of sedimentary roof-covering.
The convulsion processe of sedimentary roof-covering above dissolved salt series is transfered to the terrain surface that manifests by sinking. Sinking magnitude at terrain surface is significantly smaller comparing to the processes right in dissolving faze. The measure of transfering processe to the terrain surface depends on lithologic composition, structural-tectonic terrain characteristics, power of

sedimentary roof-covering, salt rocks dissolving speed, consolidation level of zones included in salt dissolving and magnitude of the area where the salt rocks dissolving takes place.
The convulsion processe of sedimentary roof-covering causes slight by continious external changes of single points, e.i. terrain surface parts, when they sink, and rarely rise. Time after time, the suden brake of the terrain surface occured, making craters of a funnel form, to 30 meters radius and 20 meters of depth. It is considered that there was more appereances of this kind, but not every manifested at the terrain surface, because the density distribution was regurarly to the terrain surface, and only increased sing manifested.
Longterm researches of terrain sinking processe due to uncontrolled salt exploitation indicate various values between mathematic calculations and real situation in the field that can be determined by continious geodetic measurements. In the eightees of twenteeth centiry the processe of uncontrolled exploitation was partially directed by expanding to the wider area, so the salt rocks were dissolved in bigger surface, and, in that way, decreasing dissolving according to power. Consolidation processe of degradated zones became faster, what manifested by smaller sinking in terrain surface.
Graphic of the processe and appereances that occured in the period of uncontrolled salt water exploitation are shown in the picture 2. Factors from triangle A_1 (A, B, C) are presented by circle and they all operate in terrain sinking processe (D). This processe causes all of the appereances that are shown in triangle B_1 (A', B', C') and they are all presented by a circle in the triangle. Those appereances are jeopardizing mining, infrastructural and construction objects, as well as the environment.

Figure 2 *The graphic of appereances and processes during uncontrolled salt exploitation A. The fall of piesometers level, B. Dissolving (making empty spaces), C.Convulsion of sedimentary roof-covering, D. Terrain sinking. A'. Deformation in the terrain surface (construction objectsi), B'. Deformation in subsurface part (infrastructural objectsi), C'. Deformation in the depth (mining objects).*



Environment jeopardizing during uncontrolled salt exploitation
Application method of catching the groundwater by deep wells from the terrain surface, fastened the jeopardizing processe of natural balance, which gradually started to be noticed in macroscopic way in a form of terrain surface sinking. In the zone of exploitation the older construction objects started to brake down, after which geodetic measurements took place. The measuremnts were not conducted regularly, although it was determined that intensive exploitation increases terrain surface sinking. In the 50th of the 20th century the damages at the terrain surface were more significant, so irganized measurements of terrain surface were conducted every year. The measurement task was to determine the terrain movements, its intensity and extensity, and terrain deformation character in conditions of constanc and intensive salt water exploitation
For the period of about 100 years the terrain sinking conditioned meaningfull changes in the look of the town, where terrain surface included in sinking was more than 500 ha, and maximum sinking about 13 m. Of the total surface included in urban plan, about 20% is in the sinking zone. The north part of the town totally desappeared, and the central part of the town is mostly destroyed and the town

is divided in two parts, east and west. In the sinking zone number of objects are damaged in the terrain surface, and in terrain subsurface, and all along till the depth where the processe of salt rocks dissolving takes place.
Jeopardizing of the mining objects is related to exploitation wells and mining pits. More often deformations in exploitation wells are related to salt series dissolving zones, although they often appear in higher terrain parts. In period of about 100 years uncontrolled salt water exploitation there were about 200 wells. Duration of one exploitation well was changing during time of salt water exploitation. In the begining it was about 30 – 40 years, and in the period of the most intensive exploitation of salt water, during 80s, it was about 2 years. By decreasing uncontrolled salt water exploitation to about 50%, the duration of one well was prolonged to 5 – 6 years. Mining pits were constructed after the Second World War in a heavy circumstances, considering the presence of groudwaters. They are found in the zone of direct influence of uncontrolled salt exploitation, what jeopardizes their stability. During the last years of exploitation, the balanced level was kept that does not jeopardize the pits stability, and secures needed amount of the salt water.
Jeopardizing the infrastructural objects is directly related to terrain surface sinking processe. The most jeopardized is water-supply and canalization network, while te traffic roads are surface indicators of terrain deformation in the function of time which can be observed in macroscopic way.
The begining of uncontrolled salt exploitation was the indicator that by the time the damages of construction objects at the terrain surface will take place. In the starting exploitation period, badlly built single constructions were ruined. By decreased intensity of terrain sinking the stabile construction objects were cracking, as well. Later on, very solid construction objects constructed in XVI, XVII i XVIII century were damaged and later demolished, and those were the objects that were representing cultural-historic constructions and monuments of various architectonic style. Different architectonic styles, Bavarian, oriental, barock, mixed, than tipical Bosnian to most modern styles, deseppeared from the town. In the past period of uncontrolled salt exploitation from the surface that was included in terrain sinking, about 2000 objects of different sizes were demolished, and during that about 20 000 people were moved out.

End of uncontrolled salt exploitation

Intensive sinking of town area due to uncontrolled salt exploitation, at the end of 60s and begining of 70s, fastened new salt water sites researches. In 1978 new salt site was found, far from the town about 15 km. The begining of its exploitation took place in 1992, by method of controlled salt water exploitation. Together with the begining of this exploitation, the exploitation of salt site in tuzla took place. Besides that, the new site has been prepared for the full capacity and the old site was ending its exploitation century.
The war in these areas stopped exploitation at new site and continued at salt site in Tuzla. And, again, the processe of uncontrolled salt water exploitation was fastened, what manifested with more intensive terrain sinking. In the aim of keeping the stability of mine pits, the piesemetric level was continiouslly kept at the certain hight, what demanded the salt water exploitation, more than industrial production needed.
At the begining of 21st century the salt water exploitation in new site was renewed. Also, the mining exploitation in salt site in Tuzla is ending. Uncontrolled salt exploitation prolonges its duration for few years, in function of control of planned sinking the existing mine pit. After complete mine pit sinking and establishing the balance state in groundwaters regime over the whole site, the further salt water exploitation ended.
The return of groundwater to the state, approximate to that before begining of uncontrolled sakt water exploitation, will be going on in the future several years. By which intensity it will be, it depends on site feed and the level of degradated zones consolidation.
The estimations of groundwaters return regime were done in the end of 80s, when expecting end of uncontrolled salt water exploitation and in the begining of 20th century whan the mentioned exploitation ended. The first estimations for groundwaters movements regime in function of time, are made by M. Avdić and N. Đurić (1988), applying mathematical model on the base of existing data. The return period of groundwaters into the natural state is 533 days.
Salt water exploitation did not end during the planned period, but continues till the begining of 21st century. With its ending, new analyses of return regime the groundwaters into the natural state was

conducted. E. Oruč (2003) for the estimation of groundwaters movements level applies statistical regression analising method. Linear reggression provides the estimation for the return of groundwaters level in approximate natural state within 569 days.

By the end of uncontrolled salt water exploitation, the sinking terrain surface processe was lowered, what provides conditions for taking damaged areas into some certain purpose. Nowadays, it is only sports-recreational objects, considering that not very soon will terrain consolidate for the construction of object for some other purposes. In the begining of 21st century, in the area of most intensive terrain surface sinking part, the artifficial salty lake was made, named „Panonsko jezero“, like “Panonsko more” from earlier geological history.

In the area of salt water exploitation, some single wells have “museum” value, and the area included in sinking is “museum under the opened sky”. In that terrain part there is a lot objects that “survived” salt water exploitation period, as well as new built objects, that went through the exploitation period. They are pretty damaged, but have historical value and are slightly repeared, adopting certain purposes

The return of groundwaters level into the approximate state before the beginning uncontrolled salt water exploitation, will make some certain changes that will differ from the erlier state. Nowadays, the terrain surface is conditioned by sinking, lower than about 13 m, and massive rocks roof-covering degradated, what makes possible the groundwaters movement. Still, there are questiones whether the salt sources will appear in the valley of rivers Solina and Jala, as before uncontrolled salt water exploitation, or in the old town part where the sinking is the greatest.

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