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# Impact analysis of Brijesnica landfill site on the water system in the Majevica canal

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**Abstract:** The work presents the results of an investigation on an interaction between Brijesnica landfill site and ground and surface waters in the landfill site zone. Landfill site Brijesnica is located between the 44 °N Latitude and 19 °E Longitude touching the flat Semberija region and a slightly hilly area under Mt. Majevica. The seepage of the leachate water from the landfill into the ground and surface waters and their characterization was examined on a range of samples of ground and surface waters in the landfill zone. The dominating type of ground and surface water during the examination was Ca-$HCO_3$, Mg-$HCO_3$ and Ca-Mg-$HCO_3$ with Ca-$HCO_3$-$NH_3$ being recorded at the periphery of the landfill site. A somewhat larger amount of ammonium has been recorded at the periphery of the landfill site and in the ground and surface waters in comparison with other samples. Microbiological contamination was noted alongside the landfill site and in the ground and surface waters.

## INTRODUCTION

The examined area is located between the 44 °N Latitude and 19 °E Longitude touching the flat Semberija region and a slightly hilly area under Mt. Majevica. It is situated at the southwest brims of Semberija where this flat land begins to turn into a slightly undulated hilly area starting from the hill Obriješ (Šerifović, Goletić and Avdić, 2015). The location of the landfill site Brijesnica borders with the perimeter canal on the north-east side and the perimeter drainage canal from the south-west for draining the atmospheric water. The location stretching out at 950 x 250 m extends in the northwest – southeast direction while the surrounding area is scarcely populated. The landfill site "Brijesnica" is situated at the northwest side of the location in subject (Šerifović, 2014). The total area of the location with the projected construction site for a waste management centre (sanitary landfill site) amounts to approximately 250.000 $m^2$. As for the topography, the location can be characterized as a plain with elevations between 90.00 to 97.00 m. The terrain slightly drops from the south and southeast towards the north and northeast in the direction of the Majevica perimeter canal. The anticipated area for the sanitary landfill site is to be located on the north and north-eastern part of the location. In terms of geomorphology, the area is located in the border zone of the fluvial terraces of Drina and Sava.

River Brijesnica is located one kilometre northwest of the location while the Majevica canal makes up the northeast border of the location. Watercourse Dašnica is 2 km away from the subject location. In hydrological terms, the terrain generally represents a double-layer medium where the upper, immediate roof (silty-clay

sediments) presents a relative hydrogeological barrier while the lower gravelly layer represents a relative hydrogeological accumulator – ground water reservoir. The natural construction of the terrain holds a unique aquifer with a free layer of water (Šerifović,, 2014).
This aquifer is in a direct hydraulic connection with rivers Sava and Drina and we can say that that it represents an integral part of a unique aquifer formed at an alluvial plane of the mentioned rivers. Therefore, the oscillations in water levels of these rivers are reflected on the levels of ground waters. The oscillations of ground water levels in the study zone are largely influenced by the water level of rivers Drina and Sava. Furthermore, as we can see on the geotechnical cross-section of the terrain, with the digging of the Majevica canal in the zone downstream from the geotechnical cross-section 5-5’ (Figure 1), a connection between the ground and surface waters was made and thus the aquifer recharge is also performed through the Majevica canal. At the time of high ground water levels, the water level of the Majevica canal practically represents the level of ground waters.
Based on the analysis and results of ground water level measurements, it was established that the measured levels are mostly found in the formations of clay sediments. In view of the fact that the terrain construction implies that the main aquifer is a series of gravel that lies in the clay slope, we can note that the aquifer is mostly under certain pressure, up to several meters of the water column (Nakić, Prce and Posavec, 2007).
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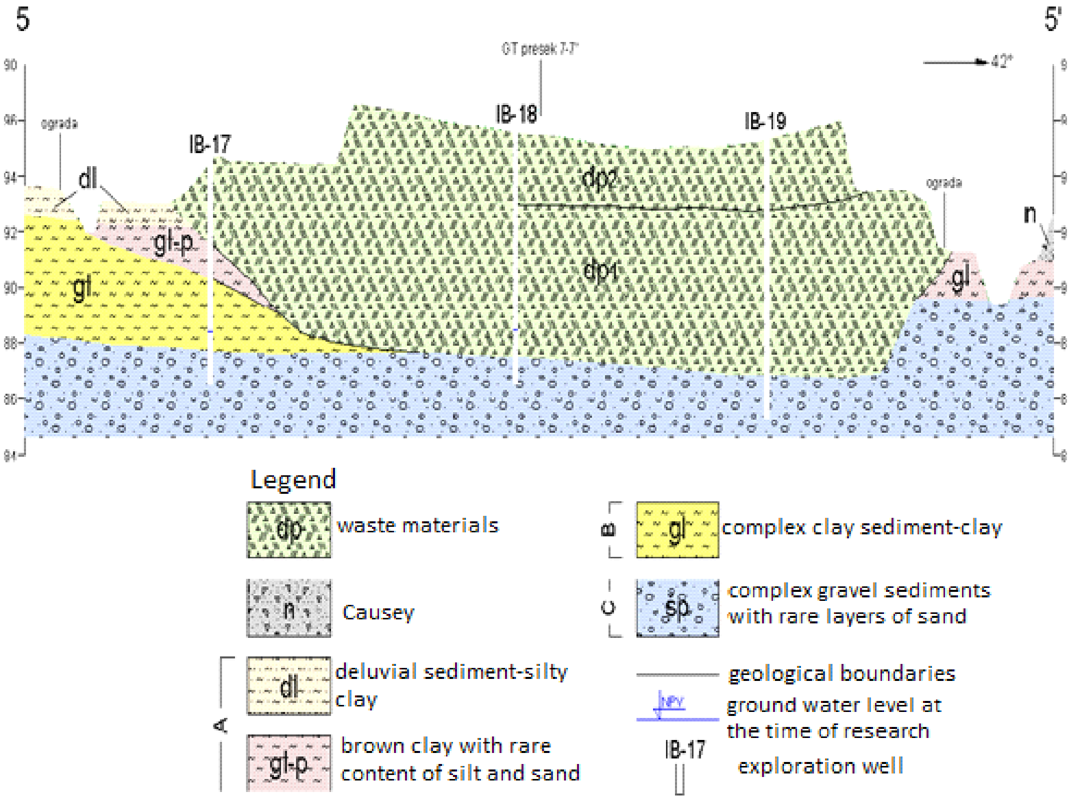


**Figure 1.** Geotechnical section terrain landfills (Hidrozavod, 2007)

## EXPERIMENTAL

### Ground water sampling

Research drilling was conducted with the general aim of establishing the lithological composition and soil structure and the level of ground waters at the research area and to take representative samples of soil for laboratory and geomechanical analysis as well as samples of ground and surface waters for establishing the chemical composition and the level of contamination.
For the purpose of periodical monitoring, data collection, composition and flow of ground waters, physical and chemical composition of the water systems during a longer period of time which would be used for project development of “Brijesnica” landfill site, 16 piezometric constructions were installed. The piezometers were made of PVC pipes, 50 mm in diameter with a 2.0 m metal part at the end.
The sampling and analysis of ground and surface waters in the subject zone was conducted in accordance with the standard regulations and norms which included: BAS ISO 5667-11; BAS ISO 5667-14; BAS ISO 5667-3.
After the installation of piezometric constructions into the drills, monitoring of ground water levels in these constructions was conducted. The piezometers were marked as engineering piezometric drills IpB-1 to IpB-16. Recording of the water levels was carried out with the help of electric gauges constructed on a principle of electrical circuit being generated after the electrode is immerged into water. All the observations of ground

water levels in a piezometer were conducted during rainy periods (October-December 2007). The engineering-geological map, Figure 2, presents the ground and surface water flow at the "Brijesnica" landfill site and the location of all piezometric drills in the whole study area (Šerifović, Goletić and Avdić, 2015). The samples were also taken from the perimeter canal upstream Mku and downstream Mkn in relation to the landfill.

The ground water course (Figure 2) is generally from the southeast towards the northwest towards the lowest recipient – river Sava as shown on Figure 2. The most prominent level of bacteriological contamination was registered at the current landfill site "Brijesnica." A high level of microbial contamination was also present in the ground and surface water samples (Figure 2). The microbial contamination was most noticeable in the Majevica zone canal because of its direct connection with the contaminated leachate water.

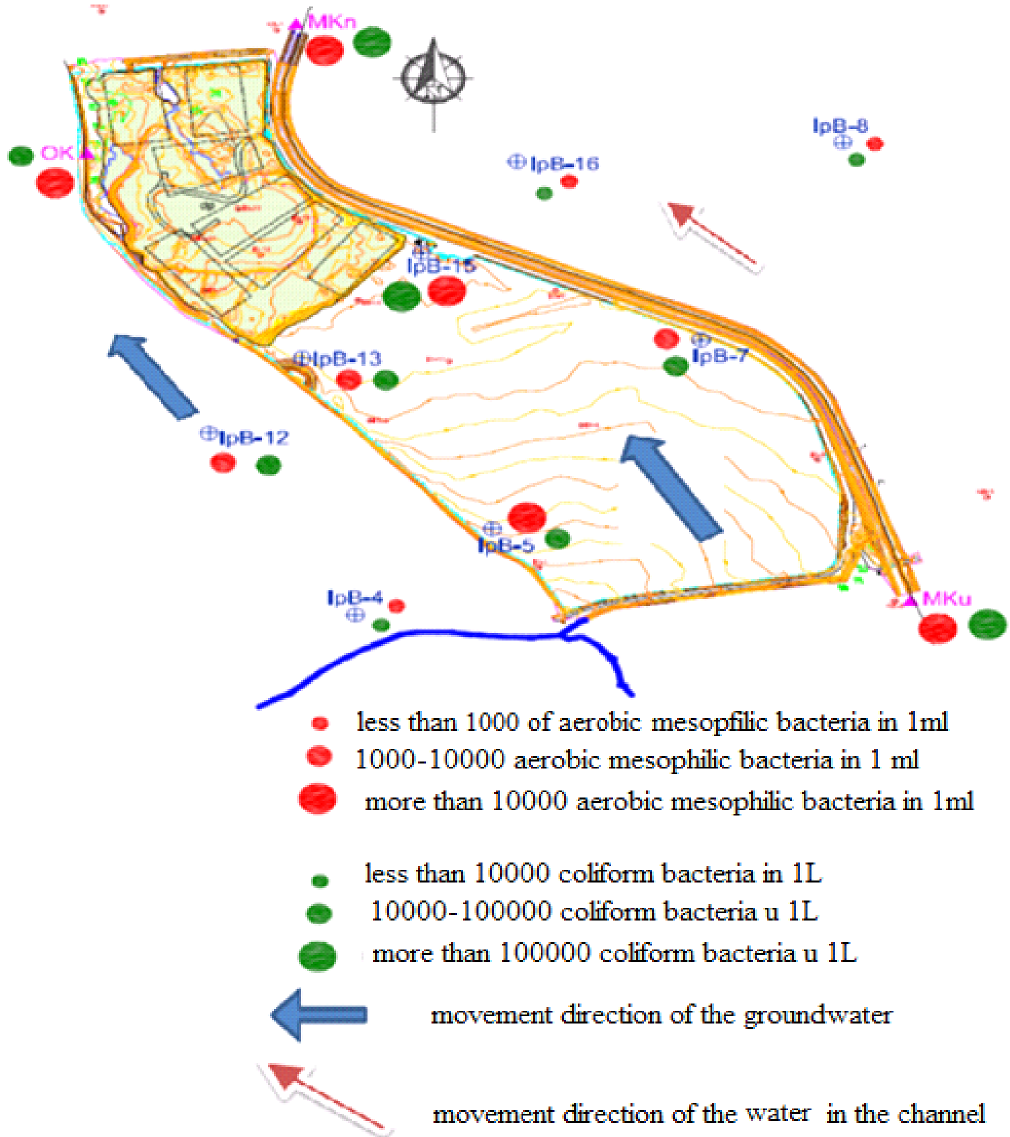


**Figure 2.** Groundwater flow and microbial contamination (Hidrozavod, 2007)

## RESULTS AND DISCUSSION

The chemical composition of the ground water is the result of the interaction between the ground water and solid materials and gases during the hydrological cycle. The type and concentration of ions in the ground waters varies in relation to the physical and chemical processes which the water was exposed to (Nakić, Prce and Posavec, 2007). The changes in the quality of ground waters usually occur due to natural or anthropogenic influence with the latter undermining the water system balance. Every measurable chemical indicator in the ground water that can be linked to a certain process may be deemed as a hydro-chemical tracer for the process in matter (Nakić, Prce and Posavec, 2007).

**Table 1.** Chemical analysis of water outside the landfill zone measured in piezometers IpB-4 IpB-5 IpB-7 IpB-8, IpB-12, IpB-16

| Average | Total dry residue | EC µS/cm | pH | Anions meq/L | | | | Cations meq/L | | | | | KPK mg $O_2$/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $Na^+$ | $K^+$ | $Mg^{2+}$ | $Ca^{2+}$ | $HCO_3^-$ | $NH_4^*$ | $SO_4^{2-}$ | $Cl^-$ | $NO_3^-$ | |
| Average | 471 | 653.5 | 7.42 | 0.55 | 0.07 | 2.12 | 4.62 | 6.63 | 0.10 | 0.49 | 0.50 | 0.21 | 3.63 |
| Min. | 433 | 591.8 | 7.05 | 0.44 | 0.04 | 1.65 | 2.60 | 6.30 | 0 | 0.33 | 0.45 | 0 | 1.30 |
| Max. | 555 | 686.1 | 7.69 | 0.73 | 0.15 | 3.56 | 6.35 | 7.40 | 0.27 | 0.84 | 0.52 | 0.30 | 12.47 |

**Table 2.** Physical and chemical analysis of water around Brijesnica landfill site, MkN; Mku – water samples from the Majevica canal taken downstream and upstream from the Brijesnica landfill respectively, IpB-13; IpB-15 water samples from piezometers before the Brijesnica landfill site

| Parameter | | Mkn | | | Mku | | | Piezometers | |
|---|---|---|---|---|---|---|---|---|---|
| | | Average | Min. | Max. | Average | Min. | Max. | IpB-13 | IpB-15 |
| Total dry residue mg/L | | 296 | 204 | 363 | 275 | 225 | 316 | 493 | 406 |
| EC µS/cm | | 600 | 290 | 861 | 475 | 271 | 791 | 649.4 | 600.1 |
| pH | | 8.09 | 7.14 | 8.70 | 7.78 | 6.80 | 8.70 | 7.22 | 7.67 |
| Anions meq/L | $Na^+$ | 1.08 | 0.29 | 1.53 | 1.08 | 0.33 | 1.56 | 0.56 | 0.30 |
| | $K^+$ | 0.45 | 0.18 | 0.64 | 0.40 | 0.44 | 0.78 | 0.05 | 0.05 |
| | $Mg^{2+}$ | 0.89 | 0.71 | 1.15 | 1.07 | 0.63 | 1.90 | 2.99 | 3.04 |
| | $Ca^{2+}$ | 2.41 | 1.28 | 3.32 | 2.20 | 1.44 | 2.81 | 4.14 | 3.37 |
| Cations meq/L | $HCO_3^-$ | 3.20 | 1.05 | 4.67 | 2.78 | 1.10 | 3.85 | 7.40 | 6.50 |
| | $NH_4^+$ | 0.12 | 0.06 | 0.18 | 0.14 | 0.07 | 0.18 | 0 | 0 |
| | $SO_4^-$ | 0.84 | 0.48 | 1.10 | 0.76 | 0.20 | 1.12 | 0.33 | 0.41 |
| | $Cl^-$ | 0.88 | 0.41 | 1.23 | 0.80 | 0.38 | 1.17 | 0.49 | 0.48 |
| | $NO_3^-$ | 0.67 | 0.51 | 1.07 | 0.76 | 0.54 | 0.79 | 0.25 | 0.20 |
| KPK mg $O_2$/L | | 38.91 | 19.93 | 57.80 | 37.80 | 19.32 | 55.10 | 1.25 | 1.62 |

## Electrical conductivity and pH

The electrical conductivity (EC) of samples outside the landfill zone (Table 1) ranges between 653.5 µS/cm to 686.1 µs/cm with an average value of 591.8 µS/cm. The other samples were closer to the mean rather than the minimum or maximum values. This information indicates that part of the watercourse has not been subjected to changes regarding the salinity. Table 2 presents electrical conductivity values of the perimeter canal before Mku and after Mkn landfill as well as the electrical conductivity values of samples from piezometers IpB-13 and IpB-15 that are located in the immediate vicinity of the landfill zone. The average electrical conductivity value of the samples from Mkn landfill amounted to 600 µs/cm while the maximum and minimum values were noted at 861 µs/cm and 290 µs/cm respectively. The average, maximum and minimum EC values of samples from the Mku were 475 µs/cm, 791 µs/cm, 271 µs/cm respectively and were somewhat lower after the landfill, which clearly indicates to the presence of landfill leachate water in the perimeter canal. The EC values in the samples from piezometers IpB-13 and IpB-15 were close to the mean values of other samples. In view of the fact that the impact of ground waters of the Sava and Drina river basin is great and that there is a large number of agricultural holdings without adequate treatment of waste waters which are usually disposed in septic tanks and end up in the ground watercourses in the densely populated area around the landfill, it is clear that they have an important influence on their quality. However, the results indicate to the fact that the aquifer has been subjected to either a natural or anthropogenic process of salinity.

All pH values in the samples are above neutral and are slightly alkaline which reflects the basic nature of ground water. The surface waters in the perimeter canal before and after the landfill site do not have prominent differences in the pH values and are somewhat higher than the pH values of ground waters which indicates that in addition to possible effects of leachate water from the landfill there is also the environmental impact of the area through which the water flows. Moreover, we cannot say that any change to the above parameter correlates with the content of sodium and potassium in the samples.

## Classification of water at the research area

The chemical composition of ground water primarily depends on geology and geochemical processes undergoing in the ground water system (Kazemi and Azam, 2012).

By analysing the physical and chemical data, we established that piezometer IpB-12 located behind the outskirts of the landfill site has registered a type of ground water containing a larger amount of ammoinium ion ($NH_4^+$) in comparison with other measuring sites. The significant presence of ammonium ions in the ground water in the immediate vicinity of the landfill site outskirts indicates to the development of a geochemical zone with methane ($CH_4$) (Nakić, Prce and Posavec, 2007; Appelo and Postma, 1994) and an ammoinium ion ($NH_4^+$) under the landfill site. The piezometers located directly at the outskirts of the landfill site registered ground waters of the following composition Ca-HCO3-NH4 i Ca-HCO3-Cl-NH4. Other nitrogen compounds nitrates and nitrites are present in lower concentrations with a higher concentration of nitrates being only registered at a perimeter canal downstream.

The chemical consumption of oxygen in all samples is very low and ranges between 1.30 to 2.84 $mgO_2$/L with the exception of piezometer IpB-12 where the value was 12.47 $mgO_2$/L which indicates to a low content of organic material in the ground waters. On the contrary, the water from the perimeter canal both upstream and downstream from the landfill has a significantly larger content of organic material which is indicated by the consumption of oxygen that ranges between 19.32 to 57.80 $mgO_2$/L.

The results of the chemical analysis and characterization of ground waters from the research area can easily be illustrated on a Piper diagram (Kumar, 2013). Figures 3 and 4 show such diagrams including the zones that present the chemical composition of waters characteristic for ground waters and penetration of leachate water into the water system.

From the Piper diagram shown in Figure 4 and Table 1 we can note that the ground water at the landfill site at the time of low water levels was mostly of the Ca-Mg-$HCO_3$ type. The predominant cation is $Ca^{2+}$ with an approximate share of 70% and $Mg^{2+}$ with a share of 30%. The predominant anion is $HCO_3^-$ with a presence of more than 80% while $SO_4^{2-}$ and $Cl^-$ together participate with less than 20% in the overall composition of ground water. At the time of high waters, the dominating type of ground waters is Ca-Mg-$HCO_3$. This only differs at piezometers IpB-7 and IpB-6 where the ground water type is Ca-Na-Mg-$HCO_3$ and a somewhat higher content of Mg in comparison with other samples.

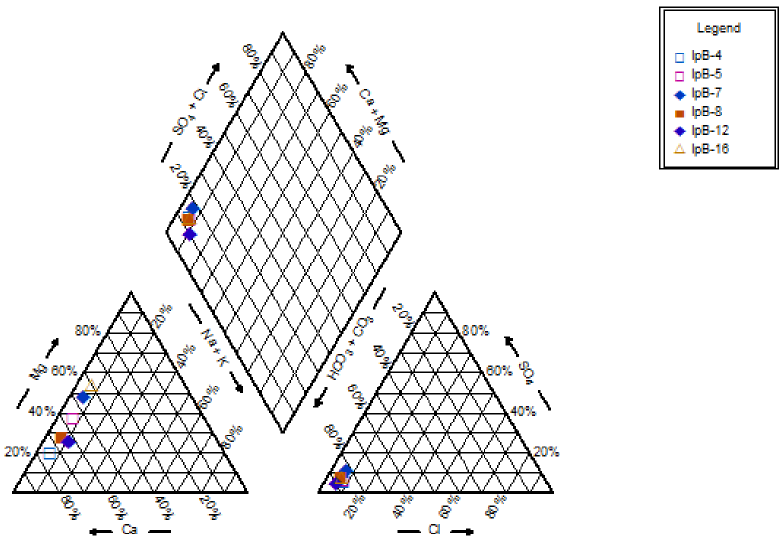


**Figure 3**. Piper diagram of analysed ground water samples in piezometers IpB-4, IpB-5, IpB-7, IpB-12, IpB-16

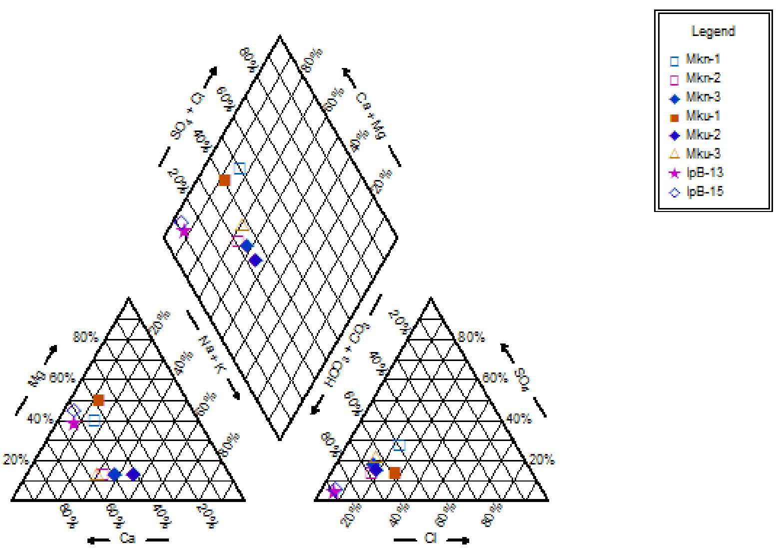


**Figure 4.** Piper diagram of the ionic composition of ground and surface waters around the "Brijesnica" landfill site as indicated in Table 2

Furthermore, the microbial contamination is highest around the landfill zone itself which conditioned by the direct contact with leachate waters being produced in the body of the landfill site "Brijesnica." The microbial pollution in the surface waters and analysed piezometric samples found downstream and in the vicinity of the landfill site indicate to the penetration of leachate waters into the watercourse and the effect of the landfill onto the water system (Figure 4).

From table 2 and Piper diagram in Figure 4 we can note the effect of the landfill onto the water system, the increased content of $Na^+$, $K^+$ , $Cl^-$ and $NH_4^+$ ions with concurrent decrease in the content of $Ca^{2+}$ and $Mg^{2+}$ in comparison with other samples. This variation has been recorded on the Piper diagram (Figure 4) where the water type was shifted towards the Ca-Mg-Na-$HCO_3$ plot. A slight rise in the pH value of the analysed samples is also clearly evident.

**CONCLUSION**

The results of the physical and chemical analysis indicate that all water samples are naturally slightly alkaline. The influence of water systems of rivers Sava and Drina onto the quality of the ground water in the landfill zone is very prominent notably at the time of high water levels.

The types of ground and surface waters are defined on the grounds of physical and chemical analysis and the Piper diagram. Most of the water samples are of the Ca-$HCO_3$ type followed by $MgHCO_3$ and Ca-$MgHCO_3$ types. The effect of the landfill site has been noted downstream in the watercourse and in the water system in the landfill zone through an increased presence of $Na^+$, $Cl^-$ i $NH_4^+$ ions in comparison with the upstream samples

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## Summary/Sažetak


U radu su prikazani rezultatai istraživanja interakcijskih djelovanja između odlagališta Brijesnica te podzemnih i površinskih voda u zoni odlagališta. Odlagalište Brijesnica locirano je između Lantitude 44 °N i Longitude 19 °E, a na dodiru ravne Semberije i blagog podbrđa Majevice. Prodor procjedne vode odlagališta u podzemne i površinske vode i njihova karakterizacija ispitana je na nizu uzoraka podzemnih i površinskih voda u zoni odlagališta. Dominantan tip podzemne i površinske vode tokom trajanja ispitivanja bio je Ca-$HCO_3$, Mg-$HCO_3$ i Ca-Mg-$HCO_3$ te uz rub odlagališta Ca-$HCO_3$-$NH_3$. Uz rub odlagališta i u podzemnim i površinskim vodama pojavljuje se nešto veći sadržaj amonijaka nego u ostalim uzorcima. Mikrobiološko onečišćenje uočeno je uz deponiju i u podzemnim i u površinskim vodama.