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# GROUNDWATER IN THE TRESKA RIVER DRAINAGE BASIN AND RISKS FOR ITS POLLUTION

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## ABSTRACT

Groundwater has a great importance for the water supply of the population. In areas where the population density is high and the land use is intensive, groundwater is particularly vulnerable. The pollution is mostly caused by the infiltration of pollutants from the land surface. To the surface pollution, especially, are exposed the shallow aquifers. It should be emphasized that due to the relatively slow transfer of pollution inside the ground, pollutants can be detected even after several years. When groundwater is polluted, the process of purification is difficult and very expensive.

**Key words**: groundwater, pollutants, pollution, risks, protect.

## INTRODUCTION

Ground water has a great economic significance for the supply of population with quality drinking water, further for irrigation and in certain cases, for the industry. The aquifer usually represents a natural reservoir of water with high quality (Appelo & Postma, 2005). But despite being more protected than the surface water, groundwater is also a subject of pollution, a phenomenon that can be defined as follows: “Pollution is a modification of physical, chemical and biological properties of water, restricting or preventing its use in the various applications where it normally plays a part” (Fried, 1975). Pollution of groundwater almost always happens as a result of the human activity. In areas where the population density is high and the land use is intensive, groundwater is particularly vulnerable. Almost every action whereby the chemical substances or waste can be discharged into the environment, intentionally or accidentally, has the potential of groundwater pollution. When groundwater is polluted, the process of purification is difficult and very expensive (EPA, 1993).

## STUDY AREA

The Treska river drainage basin is located in the west-northwest of the central parts of the Republic of Macedonia. It lies between the mountains of Bistra (2163 m), Stogovo (2268 m) and Suva Gora (1857 m) in the west, Ilinska Planina (1909 m), Baba Sach (1695 m) and Busheva Planina (1788 m) in the south, Dautica (2178 m), Jakupica (2540 m), Karadzica (2472 m) and Suva Planina (2179 m) in the east, and mountain of Zeden (1259 m) in the north. The Treska river drainage basin, from its spring to the point where it exists the Kicevo Valley, stretches in the direction east-west, whereas from the Brodska Ravine it makes a sharp turn to the north. Within these boundaries, the river drainage basin covers an area of 2068 km$^2$.

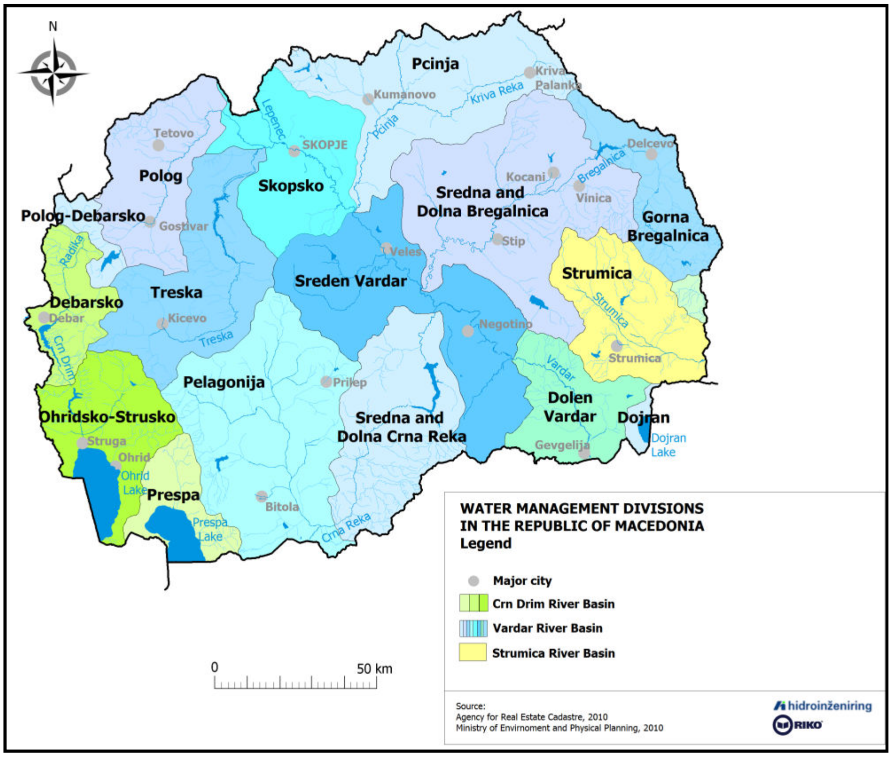


Figure 1: Geographical location of the Treska river drainage basin.

## GROUNDWATER IN THE DRAINAGE RIVER BASIN

In the Treska river drainage basin based on the presence of rocks of varying porosity and hydrogeological characteristics (Gjuzelkovski & Kotevski, 1977), four different types of aquifers can be found: isotropic, fractured, karst and karst-fractured aquifers.

***The isotropic types of aquifers*** appear along the bottom of the Kicevo valley, at the bottom of the River Treska basin, on its left side, from Makedonski Brod to the village Topolnitsa, as well as in the Treska river drainage basin tributaries as: Slanska River, River Krapa, River Ocha, River Suva and at the estuary of the river Treska into the river Vardar, i.e. in the Neogene and Quaternary sediments. In this kind of aquifers, we can define two different types: artesian and unconfined.

The unconfined aquifer in the Treska river drainage basin forms in alluvial, delluvial, fluvioglacial and other sediments that have intergranular porosity (Gjuzelkovski, 1999). In the central part of the Kicevo Basin, in all of the performed bore holes an unconfined underground aquifer at a depth of 0.5-15.0 m is registered. Unconfined aquifer has been registered in the alluvium of the river Treska just before its estuary into the river Vardar, where the groundwater level is located at a different depth: Saraj from 2.30 to 2.80 m, Gorce Petrov from 6.50 to 6.70 m.

The artesian aquifer in Kicevo basin appears in the Pliocene-lake sediments at different depths from 20.0 to 107.0 m, with the thickness of the aquifers from 3.0 to 5.0 m and profusion of the springs from 0.5 to 1.0 l/s, which are most common in the region of the village Oslomej. Artesian aquifer with low profusion is registered on the left side of River Treska in the investigation gallery of the profile "Matka II". The feeding of isotropic aquifer is mainly done by precipitation, surface water and partly by the participation of karst aquifer (Gjuzelkovski, 1999).

***The fractured type of aquifer*** appears in Kicevo valley, precisely on the mountains Bistra, Stogovo, Mountain Ilinska, Mountain Busheva, Dobra Voda, Cheloica, Pesjak, in Zajas region as well as in Suva Gora with Osoj. Rocks are mostly represented by the phyllite-slate-clay complex, but there also appear sandstones, conglomerates, quartzites and other similar ones, that are characterized by very low water permeability and cannot accumulate a significant supply of groundwater of fractured type. All of the rock masses are more or less cut through by fault lines and cracks, and in general cannot accumulate large supplies of ground water. Fractured aquifer is mainly fed by rainfall and much less from surface water. A favorable impact on feeding has the vegetation cover, which prevents rapid surface runoff of precipitation (Gjuzelkovski, 1999).

***The karst type of aquifer*** is the most common in the Treska river drainage basin that appears on mountains Bistra, Dautica, Jakupica, Karadzica and Suva Mountain. The greatest distribution has the karst type of aquifer developed in the carbonate rock masses along the river Treska, and the Bistra Mountain. The draining of this aquifer is done through numerous karst springs including: Studenchica that appears on the southeast side of the Bistra Mountain on the contact between limestone and limestone shales. This spring is tapped in order to supply potable water to Kicevo, Makedonski Brod, Krushevo, Prilep and other settlements and its profusion reach between 0.905-2.77 $m^3$/sec. Along the river Studenchica, smaller springs have appeared.

The greatest distribution and thickness, carbonate rocks have in the region of mountains Jakupica-Karadzica-Dautica (as a continuous mass), intensively and deeply karstified, with the appearance of different surface karst forms as sinkholes, vertical shafts, clints and grikes, karst valleys that allow intensive infiltration of precipitation and accumulation of large reserves of groundwater as separate socket. This represents the largest socket of groundwater within the carbonate karst fractured aquifers.

The feeding of karst aquifer is basically carried out by rainfall and water obtained from snow mass melting, as well as from the infiltration of surface water at the bottom of the riverbed. Karst aquifer is emptied through water springs with different profusion.

***Karst fractured type of aquifer*** is less represented in the basin and it can be found on the Bistra Mountain and Mount Osoj (right valley side of river Suva).

Karst-fractured type of aquifers does not represent a one and only aquifer and they appear same as the karst ones, as separated aquifers, distributed at different heights, with different profusion, that very much depends on the type of karst. The feeding of aquifer is similar to the karst type, by atmospheric precipitation, partly by surface waters, in that, the percentage participation of the atmosphere and surface water among other things depends on the infiltration power of rocks and their fractured porosity (Gjuzelkovski, 1999).

The drainage of the fractured karst aquifer is carried out in places where the constantly humid hydrogeological zone is cut by an allogeneic watercourse, further, by springs with an independent underground flow, and most often they are found on the contact between water impermeable rock masses that appear in the shelf and water penetrable carbonate rocks that appear in the capping layer. Karst water springs that appear in the contact zone are usually characterized by high profusion.

## SOURCES OF GROUNDWATER POLLUTION

Groundwater can become contaminated from natural sources or numerous types of human activities. Residential, municipal, commercial, industrial, and agricultural activities can all affect ground water quality (EPA, 1993).

**Natural sources.** Some substances represent a natural component of rocks and soils, such as iron, manganese, arsenic, chloride, fluoride or sulfate, and can be dissolved in groundwater. Organic compounds can be released into ground water as well. Such processes usually occur near the surface of the humus that the soil contains, but it can be found in the deeper ground strata where the peat, lignite or coal are present and are in contact with groundwater (Nonner, 2002). Some substances may pose a threat to the human health if is consumed in an excessive amounts; others can cause undesired smell, taste or color. Groundwater containing unacceptable concentrations of these substances is not used for drinking or other household necessities if not previously treated in order to remove these contaminants.

**Sewage systems.** Frequent are the cases when it comes to trickling of sewage waters from porous or damaged sewage pipes. Such cases are typical of the old parts of the cities where a sewage system built up by ceramic tubes still exists and become porous over time, and it often occurs the same to crack because of the load and vibration of vehicles. Sewage itself is a complex mixture and can contain many types of contaminants. The greatest threats posed to water resources arise from contamination bybacteria, nitrates, metals, trace quantities of toxic materials, and salts. Seepage overflow into drinking water sources can cause disease from the ingestion of microorganisms (Jain & Sharma, 2011).

**Septic systems.** One of the main reasons for pollution of groundwater is the leakage (outflow) from the septic systems. Many of the houses (especially in non-urban areas or in rural areas where the absence of the sewage system is present) rely on septic systems to divest their wastes. Septic systems (also known as on-site wastewater disposal systems) are used to treat and dispose of sanitary waste. When properly sited, designed, constructed, and operated, they pose a relatively minor threat to drinking water sources. On the other hand, improperly used or operated septic systems can be a significant source of ground water contamination that can lead to waterborne disease outbreaks and other adverse health effects (EPA, 2001). Although each individual system produces a relatively small amount of waste in the ground, the numerous and widespread use of these systems makes them a serious contaminating source. Septic systems that are improperly located, designed, constructed or maintained, can contaminate groundwater with bacteria, viruses, nitrates, detergents, oils and chemicals. Most regulations require a specific distance between septic systems and drinking water wells.

**Landfills.** Working and life activities of people are associated with the creation of large amounts of waste materials that are commonly disposed at the least suitable locations for that purpose. Various dangerous and harmful substances from these landfills can cause groundwater pollution. According to the type and the origin of waste that is delayed to landfills, they may be industrial and utilities. However, in current practice these types of waste are disposed simultaneously, regardless of their type and quality. A very important process that takes place in any landfill is the degradation of waste substances in the presence of water, which creates new organic and inorganic substances that very often are released from landfills in the form of filtrate which directly communicates with the surface and groundwater. The quantity of water sludge and the time of the year when it rains or snows are the major factor affecting the amount of liberated filtrate from the landfill (Markoviħ et al., 1996). The new landfills are required to have a built-in waterproof material on the bottom where the leachate will be collected in special systems in order to protect groundwater. Of course, there is no guarantee that the built clay, cemented soil or asphalt will permanently remain impenetrable. However, the majority of the older landfills, do not have these safety measures. Older landfills are often located in aquifers or near surface water also in porous soils with shallow water masses, which only increases the potential of groundwater pollution. Closed (abandoned) landfills can also continue to pose a threat of contamination to groundwater, if they are not covered with impermeable material (such as clay) before closing in order to prevent leaching of pollutants during rainfalls.

**Pesticide and Fertilizer Use.** The use of mineral fertilizers (nitrogen, phosphorus, potassium and mixed) and pesticides (herbicides, insecticides and fungicides) in agriculture, despite the positive impact of increasing yields, also has significant negative consequences (EPA, 1993). With their excessive application, these are not fully utilized by plants, so they can contaminate soil where under the influence of precipitation that can dissolve and later infiltrate into the interior of the ground and by that, contaminate the underground water.

**Livestock settlements.** Livestock settlements or sheepfolds present an important source of pollution of surface and groundwater, especially in karst terrain. They are located mostly in the area of highland pastures, among forest pathways and nearby villages. In the livestock settlements present is the physical pollution (plastic, nylon bags, rubber, cans, etc.), the chemical pollution (hygiene detergents of farmers, detergents used in the manufacturing process for the production of milk and dairy products, and chemical products used as medicines for livestock) and bacteriological contamination (remains of dead animals).

**Salts and chemicals used to deice roads.** One of the common causes of ground water pollution is the dissolution of the salt used for road salting in winter, or any other material which is stored in the open. The process of road salting, which involves the application of large quantities of salt for the roads to deice them, has negative effects on the environment, human health, and ground water systems. Salt from the highway is introduced into the groundwater through a number of ways:

1) When runoff occurs from highways, flows are sometimes carried to ditches and unlined channels through which the water infiltrates into the soil and eventually into the groundwater and

2) Also, when snow is plowed together with the salt, the pile that is accumulated on the roadside melts during the warmer weathers. The water that results contains dissolved salts which can also infiltrate (Seawell & Agbenowosi, 1998).

**Floods.** Occasional floods can also lead to contamination of groundwater. Flood waters often carry hazardous and toxic materials, including raw sewage, animal wastes, oil, gasoline, solvents, and chemicals such as pesticides and fertilizer. Flood water that enters a well can contaminate the groundwater and make the well water unsafe to drink or use. The effects may last long after the flood waters have receded.

**Mining and industrial activities.** Mining and industry are a potential risk for groundwater contamination. The improper handling and disposal of solid and liquid waste from mines and factories, accidents, and leaks may form sources for contamination. These sources could be located at the land surface, in the unsaturated zone, or even below the water table itself. Mainly, but not exclusively, they are point sources that may result in well-defined contaminant plumes in the groundwater system (Nonner, 2002).

## EFFECTS OF GROUNDWATER POLLUTION

The effects of groundwater pollution are numerous. One of the more serious adverse effects is the occurrence of health problems in humans as a result of consuming polluted water. In terms of water supply, in some cases, the contamination of groundwater is so hard that water supply must be abandoned as a source of potable water.In other cases, groundwater can be cleaned and reused, if the contamination is not too serious and if a sufficient of funds are provided.

A number of microorganisms and thousands of synthetic chemicals have the potential to contaminate ground water. Drinking water containing bacteria and viruses can result in illnesses such as hepatitis, cholera, or giardiasis. Methemoglobinemia or “blue baby syndrome,” an illness affecting infants, can be caused by drinking water high in nitrates. Benzene, a component of gasoline, is a known human carcinogen. The serious health effects of lead are well known: learning disabilities in children; nerve, kidney, and liver problems; and pregnancy risks. These and other substances are regulated by state laws. Hundreds of other chemicals, however, are not yet regulated, and many health effects are unknown or not well understood. Preventing contaminants from reaching the ground water is the best way to reduce the health risks associated with poor drinking water quality (EPA, 1993).

## RISKS OF GROUNDWATER POLLUTION IN THE TRESKA RIVER DRAINAGE BASIN

On the territory of the Treska river drainage basin, systematic - programming test and measurement of groundwater quality are not performed. For these reasons, taking into consideration the above mentioned sources of groundwater pollution (which are also present in the watershed) we are free to define areas where the pollutions of groundwaters is possible.

Among the isotropic and the fractured type of aquifer, the threat of contamination is lower for a reason that they are located at greater depth or the tapestry of cracks is such that can not accumulate large reserves of ground water.

Among karst and karst-fractured type of aquifer, the threat of a potential pollution is higher because in here, the polluted waters infiltrates inland where they interfere with aquifesrwater. For these reasons, in this type of aquifers that are emptied by springs and springs with a great profusion of water, it should be paid particular attention in not locating objects that pollute in their feeding area for reasons that some of them are used for water supply to residential areas.

In the river drainage basin the karst type of aquifers is quite present, especially in Poreche Basin, further on mountain Bistra and at the right side of the river drainage basin of the Suva River on the mountain Osoj where are located a larger number of villages. Often, at these areas, due to the lack of sewage systems, a septic system is present (usually built beyond standard), further problem is the landfills that are mostly wild and scattered all over the area, in the agriculture are use fertilizers and pesticides and in highland areas are located livestock settlements (sheepfolds).

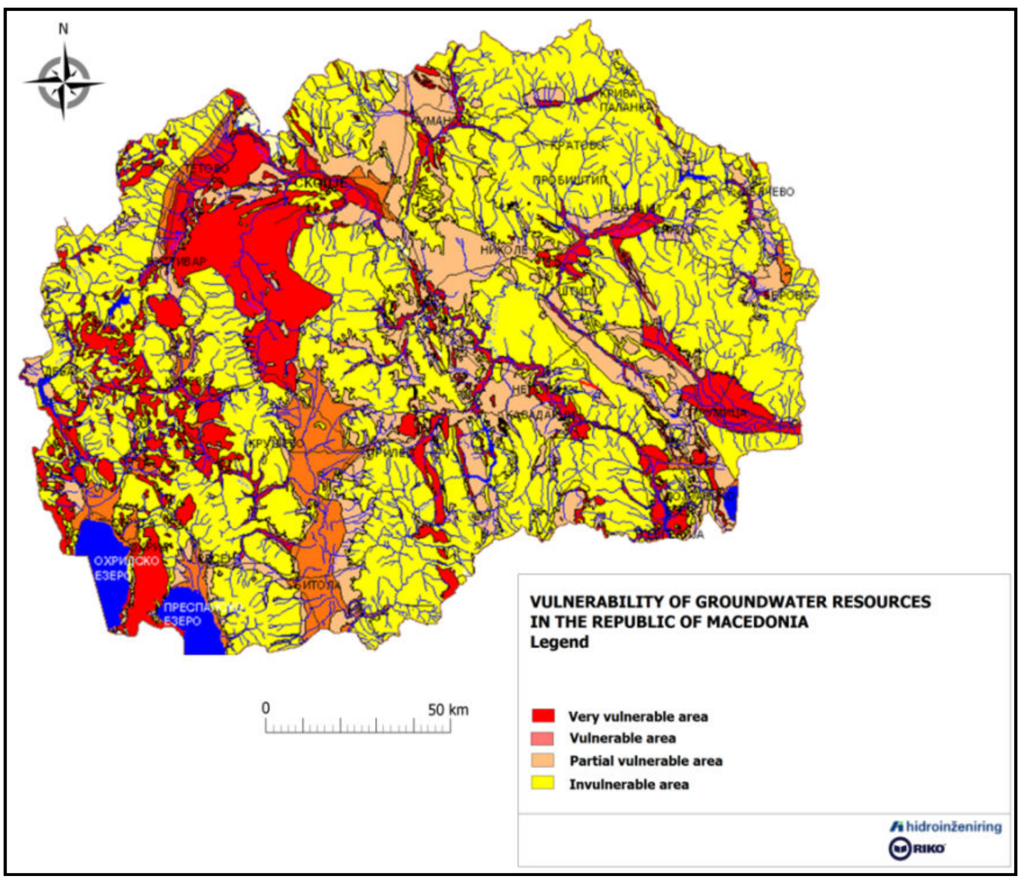


Figure 2: Vulnerability of groundwater resources in the Republic of Macedonia.

The map for the groundwater resource vulnerability of the Republic of Macedonia (MOEPP, 2012) is the "first approximation" on the studies of vulnerability of groundwater for pressures on existing or potential pollution from surface. The map does not show the state of the pollution, but it shows the hydrogeological aspects of danger. Based on the map it can be noticed that most of the Treska river drainage basin is marked as very sensitive.

## CONCLUSION

The main cause of pollution of groundwater lies in the possibility of direct contamination of the ground surface. The cause of pollution of groundwater may be different and given the origin of the contamination can be divided into: physical contamination (change of colour, smell, taste, turbidity and temperature), microbiological contamination (the presence of pathogenic microorganisms) and chemical pollution (presence of inorganic substances such as lead, hexavalent chromium, mercury, copper, cadmium, etc., An organic substance such as pesticides, nitrates, etc.). The form and extent of the pollution are causedby the shape of the entry of the pollutant into the interior as well as by the hydrogeology relationship and the parameters of the aquifers. Taking into account the consequences that occur as a result of contamination of groundwater protection is required. Often the protection measures are taken when the aquifers are or will be soon contaminated. Removing pollutants from aquifers usually require enormous material investments. Therefore, preventive protection of groundwater is more than necessary. In the Republic of Macedonia the protection of groundwater is regulated by several national laws, but the transport of Directive 2006/118 / EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration is of essential importance and is a framework for prevention and control of pollution of groundwater. It includes procedures for assessing the chemical status of groundwater and measures to reduce the level of pollutants.

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# ПОДЗЕМНИ ВОДИ ВО СЛИВОТ НА РЕКА ТРЕСКА И РИЗИЦИ ЗА НИВНО ЗАГАДУВАЊЕ

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## И З В О Д

Подземните води имаат големо стопанско значење за снабдувањето на населението со квалитетна вода за пиење, понатаму за наводнување а во одредени случаи и за потребите на индустријата. Во области каде што густината на населението е висока и користењето на земјиштето е интензивно, подземната вода е особено ранлива. Речиси секоја активност со која хемиските супстанции или отпад може да бидат испуштени во животната средина, намерно или случајно, има потенцијал да ги загади подземните води. Подземните води најчесто се загадуваат од природни извори и многубројни човекови активности (канализација, септички јами, депонии, употреба на пестициди и вештачки ѓубрива, сточарски населби, поплави, рударски и индустриски активности и сл.). Ефектите од загадувањето на подземните води се многубројни. Еден од посериозните негативни ефекти е појавата на здравствени проблеми кај човекот како резултат на конзумирање на загадена вода. На територијата на сливното подрачје на реката Треска не се вршат систематски - програмски мерења и испитувања на квалитетот на подземните води. Кај збиениот и пукнатинскиот тип на издани опасноста од загадување е помала од причини што се наоѓаат на поголема длабочина или сплетот на пукнатините е таков што неможе да се акумулираат поголеми резерви на подземна вода. Кај карстниот и карстно-пукнатинскиот тип на издани опасноста од потенцијално загадување е поголема бидејќи кај нив загадените води се инфилтрираат во внатрешноста каде се мешаат со изданските води. Во сливот карстниот тип на издани се мошне застапени особено во Поречкиот Басен, понатаму на планината Бистра и на десната долинска страна на Сува Река на планината Осој каде се сместени поголем број на селски населби. На овие простори најчесто поради отсуство на канализациони системи се присутни септичките јами (најчесто вон стандардно изградени), понатаму проблем се и депониите кои во најголем број се диви и расфрлани во просторот, во земјоделството се употребуваат минерални ѓубрива и пестициди а во високопланинските простори има лоцирано сточарски населби (бачила). Според изработената карта на ранливост на подземните водни ресурси во Република Македонија поголем дел од сливот на реката Треска е означен како мошне осетлив. Имајќи ги во предвид последиците кои се јавуваат како резултат на загадување на подземните води се наметнува потребата од нивна заштита. Најчесто мерките за заштита се превземаат кога водоносниот слој веќе е или наскоро ќе биде загаден. Отстранувањето на загадувачите од водоносниот слој обично бара енормни материјални вложувања. Поради тоа превентивната заштита на подземната вода е повеќе од неопходна.