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Professional paper

Drinking Water Safety in Rural Areas of Zagreb County in 2013

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Abstract: The paper analyzes the water supply in the rural part of Zagreb County, which is based mainly on individual water supply sources, i.e. dug or drilled wells and Norton pumps.

The aim of the paper is to investigate whether there is a difference in health quality of drinking water taken from the wells and taken from the Norton pumps. The wells are supplied from an aquifer that lies at a depth of 12 to 14 meters, while the Norton pumps reach a depth of 6 and 7 meters.

The analysis of water samples taken from the water supply sources revealed that the water does not basically comply with the Ordinance on the parameters of assessment and the methods for the analysis of water intended for human consumption, the Act on Water Intended for Human Consumption. Organoleptic indicators such as color and clarity do not satisfy, while the physical and chemical parameters such as pH and conductivity satisfy the criteria set for both water supply sources. Of all the chemical parameters only the chloride content was within the permitted limits, while the oxidativity, the content of ammonium, nitrite and nitrate were above the allowed limits in water samples taken from the wells and Norton pumps. Microbiological indicators in the analyzed samples, i.e. the number of colonies at 37 ° C and 22 ° C, as well as total coliforms also do not satisfy the requirements of the Ordinance. In order to use the water for drinking it is necessary to perform the conditioning and disinfection of wells, while with the Norton pumps these interventions are almost impossible to perform.

Keywords: Drinking water health safety, wells, Norton pumps, Zagreb County.

Introduction

Water is a common good of all living beings on the planet. The supply of safe drinking water is one of the fundamental preconditions of developed societies and one of the main principles such societies are based on. Many experts agree that human health is closely related to the quality and quantity of water one consumes. Furthermore, it is a well-known fact that the quantity of water consumed depends on water availability, healthy habits, climate, development level, degree of urbanization of an area, industry, agriculture, etc.

Croatia is a country rich in high quality water and when it comes to estimated water quantities per inhabitant, it ranks fifth in Europe and 42nd in the world. Only 80% of Croatia's population is connected to the grid, whilst only a small part of wastewater is collected of which an even smaller percentage is treated in wastewater facilities and later reused. It is believed that by 2015, 94% of the population will be using water supplied by the public water facility, bringing Croatia closer to EU standards.

According to the legislation in Croatia, water is a common good and thus enjoys special protection. Water management criteria and priorities are defined nationally and range from comprehensive environmental protection to general economic and sustainable development. In other words, this means that the privatization of the country's water resources would be impossible (The Waters Act, OG 152/2009, 130/2011) and that no form of natural water storage in Croatia can be privately owned. Lika is the most water-rich region in Croatia, followed by alluvial deposit areas between the Sava and Drava depression and the wider Gorski Kotar area.

Many suburban settlements close to major towns have an inadequate water supply system and therefore use dug or drilled wells, Norton pumps or water tanks (Mayer, 1993). Depending on soil configuration and its hydro-pedological relations, groundwater lying in the first aquifer, from which water is most often extracted, is often contaminated with faecal material from septic tanks or manure. This allows for the potential entry of pathogenic microorganisms, such as *Salmonella typhi, Shigella sp., Proteus, Yersinia enterocolitica*, or viruses, such as Hepatitis A virus, Poliovirus, Enterovirus, Adenovirus and Reovirus. Parasites include *Giardia lamblia* and *Cryptosporidium* and pose a particular threat.

Other forms of ground water pollution are also significant, such as e.g. the increased use of pesticides and fertilizers in agriculture, and pollution caused by numerous landfills (legal or illegal) of hazardous waste, that pose an even greater burden on ground water quality. However, wastewaters are an extremely important problem that still lacks systematic regulation in many areas.

Materials and Methods

Surveys have been conducted in rural areas of Zagreb County, more specifically in the small towns of Brdovec and Dubravica. There, the soil quality index is medium. Alluvial and marshy gleic soils are predominant alongside rivers and wet meadows, while drained plains are mostly characterized by pseudogleic soils and hilly areas by acid brown soils (dystric cambisols) and luvisoils. The wide Sava River valley predominantly occupying the territory of the City of Zagreb is composed of older and younger alluvial plains made of layers of gravel-sand, mild clay and clay. The climate is moderate continental, with warm summer periods and moderately cold winters with occasional snowfalls. Most precipitation is recorded in late spring, early summer and fall, while the lowest levels of precipitation are recorded during the winter and early spring. There are no extremely dry or humid periods, and the annual quantity of precipitation decreases from the western towards the easternmost part of the country (Riđanović, 1999).

Sample No 1. Family farm that grows vegetables, which is sold at a local market. The farm also has two to five fattening pigs and some 30 poultry. Water is extracted from a dug well, some 15 meters deep.

Sample No 2. A small cottage occasionally used by the owner family. There is an orchard around the house. Water is extracted from a dug well, some 17 meters deep.

Sample No 3. A family farm that produces fruit for their own needs. They also have around a dozen chickens and three pets. Water is extracted from a dug well, some 20 meters deep.

Sample No 4. An estate that is inhabited only at weekends and on holidays. They have a garden and a flowerbed. Water is extracted by a Norton pump, whose pipe goes some 7 meters deep.

Sample No 5. An older family farm, where vegetables for the family needs are grown in the garden. They own around 10 chickens, a dog and a cat. Water is extracted by a Norton pump, whose pipe reaches some 6 meters deep.

Sample no 6. Family farm with a garden but no domestic animals, except for the two pets. The house is surrounded by a lawn and a small flowerbed. Water is extracted by a Norton pump, whose pipe reaches some 6 meters deep.

The samples of water used for determining the organoleptic, chemical and bacteriological indicators were taken once in the months of February, April, June, August and October of 2013.

The samples for physical and chemical analysis were taken from chemically clean, transparent 1-liter glass bottle. Prior to sample taking, all bottles were washed in warm water with detergent, thoroughly rinsed and washed out thrice with destilled water, and then dried in a sterilizer. They were closed with a cork top covered in aluminum foil. The bottles were labelled, with information on the type of sample, as well as the time and place of sample-taking. Samples for the bacteriological analysis of water were placed in clean, sterile 0.5 liter bottles. The bottles were tapped with cork or silicone rubber bottle stoppers, which were then covered with aluminum foil. Water samples were taken after water was allowed to flow for several minutes and the pipe was previously burned with a flame, by immersing the bottle into a well or in the same way the consumer would take the water. Water samples for bacteriological analysis were taken to a cooling device and delivered to the laboratory within 6 hours maximum.

In the laboratory, drinking water was tested for organoleptic indicators.

Colour was defined by spectrophotometry, where sample spectrum was measured in the 400-500 nm wavelength on an HACH DR/2400 device. A turbidity meter was used to determine water turbidity and a pH meter with a scale of 0-14 WTV pH 720 (Germany) was used for pH value determination. Conductivity was determined by means of a conductivity meter type WTV Cond. 720 (Germany).

Among the chemical indicators measured were the potassium permanganate demand – water oxidation by cooking in an acid medium and titration using the Kübel-Tiemann method, which is based on the principle that an oxidating organic matter reduces $KMnO_{4.}$ Chloride levels were determined using the analytical-chemical titration method according to Mohr-Winkler, with a combined silver nitrate and potassium cromate indicator. Ammonium, nitrite and nitrate levels were determined on a portable spectrophotometer type HACH DR/2400. Bacteria counts at 20 ºC/mL and at 37 ºC/mL were determined in two Petri dishes where they were grown and taken as bacteriological indicators. Colony count was taken after 48-hour-incubation at 37 ºC and 72-hour-incubation at 22 ºC. The result is expressed as the number of colonies per 1 mL (CFU/mL). Total coliform count per 100 mL was determined after multiple platings of sample water into test tubes with liquid agar (lactose peptone water) using Durham tubes. The first 5 tubes, in the line of 7 test tubes with lactose pepton water, were plated with 10 mL of sample water, while the next tube in the line was impacted with 1 mL and the last one with 0.1 mL. Results were read after 48-hour-incubation at 37 ºC. A positive result is recorded as the number of tubes where the agar turned blurry, changed colour and when gas occurred in the Durham tube. The results are read from the table, depending on the combination of positive results.

Results

Chart 1. Colour indicators in well and Norton pump water samples, by months

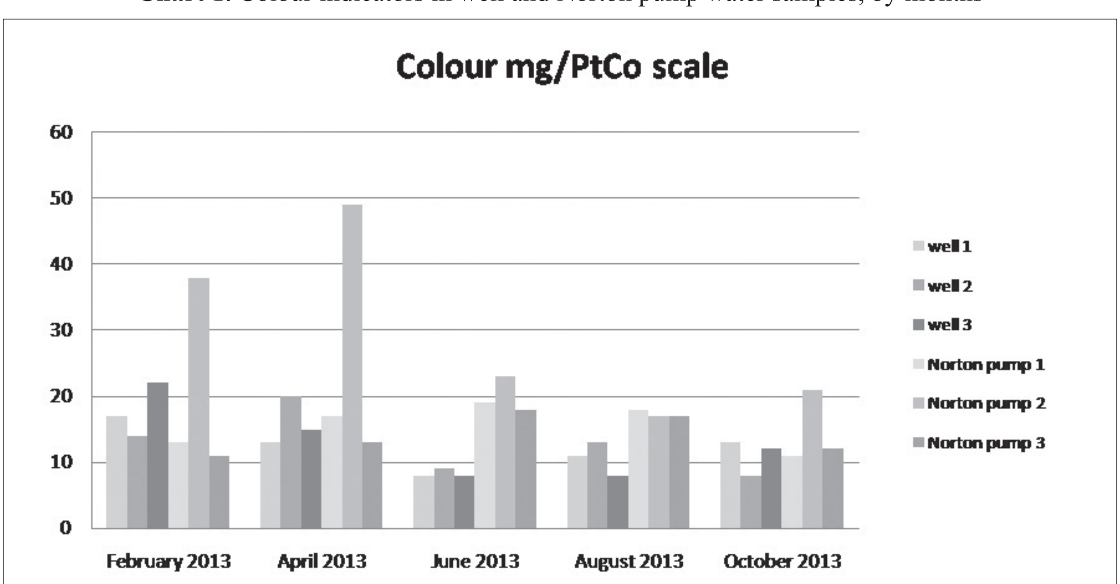


Chart 2. Turbidity indicators in well and Norton pump water samples, by months

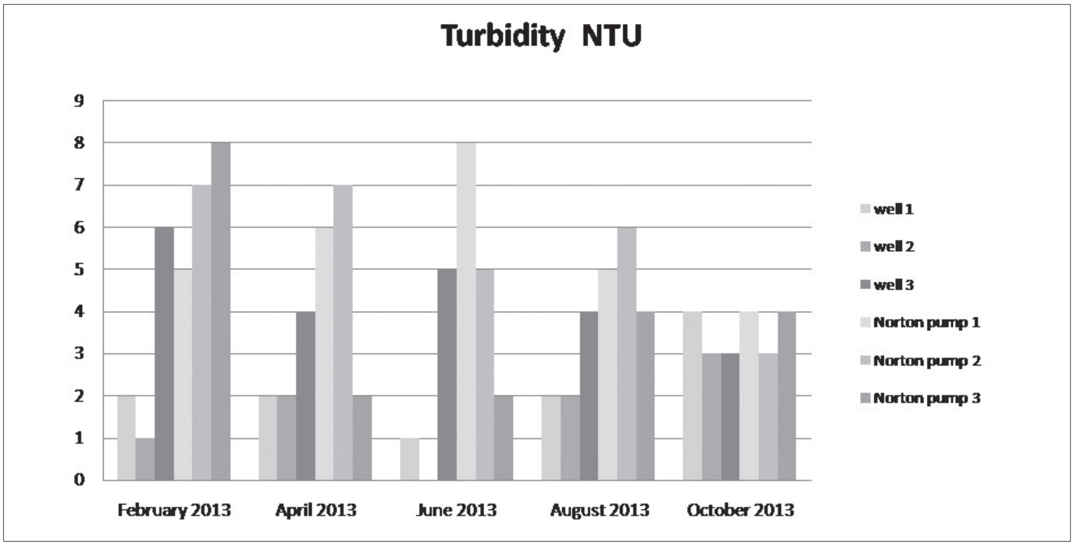


Chart 3. pH concentration indicators in well and Norton pump water samples, by months

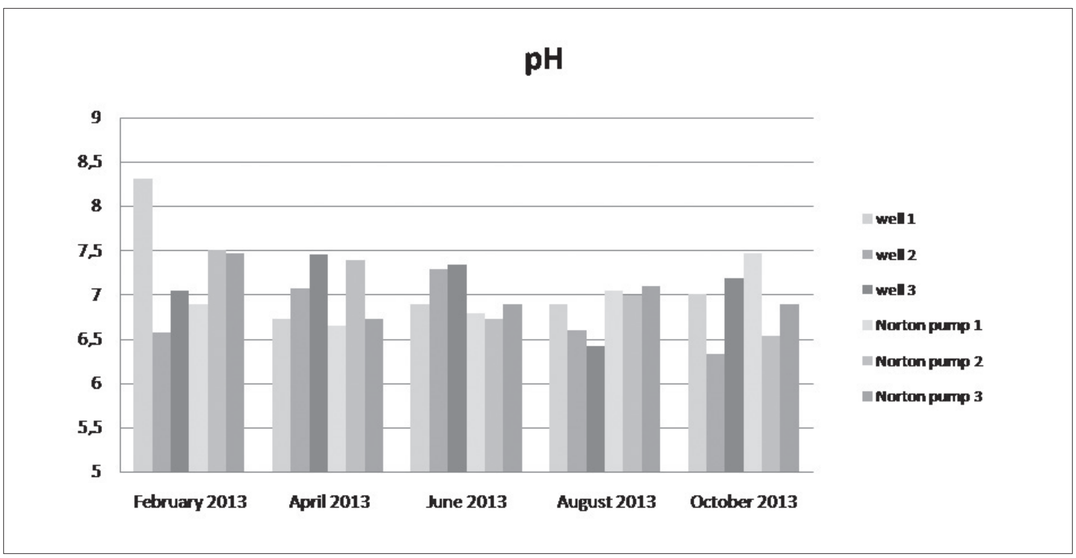


Chart 4. Conductivity indicators in well and Norton pump water samples, by months

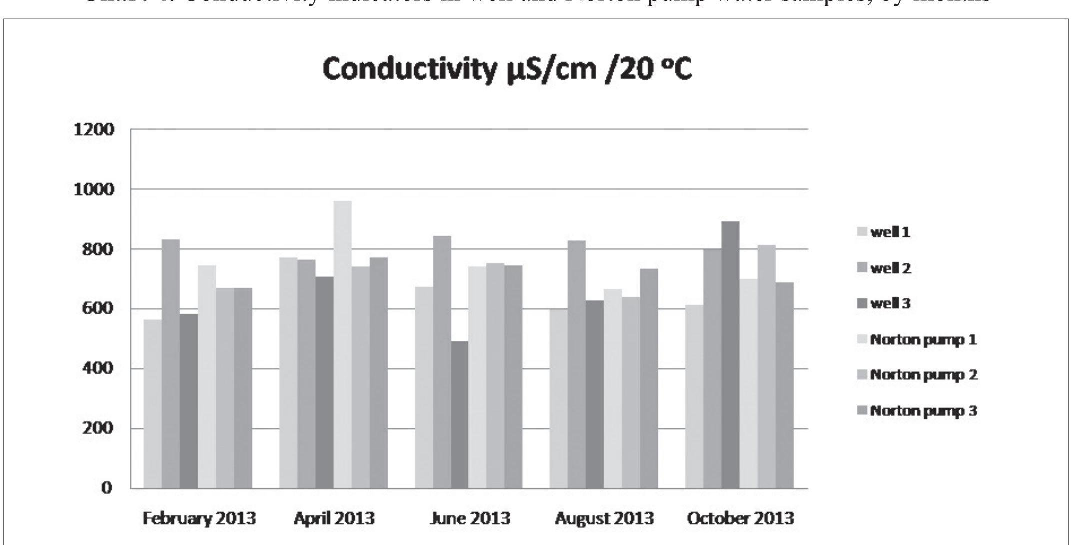


Chart 5. Potassium permanganate demand in well and Norton pump water samples, by months

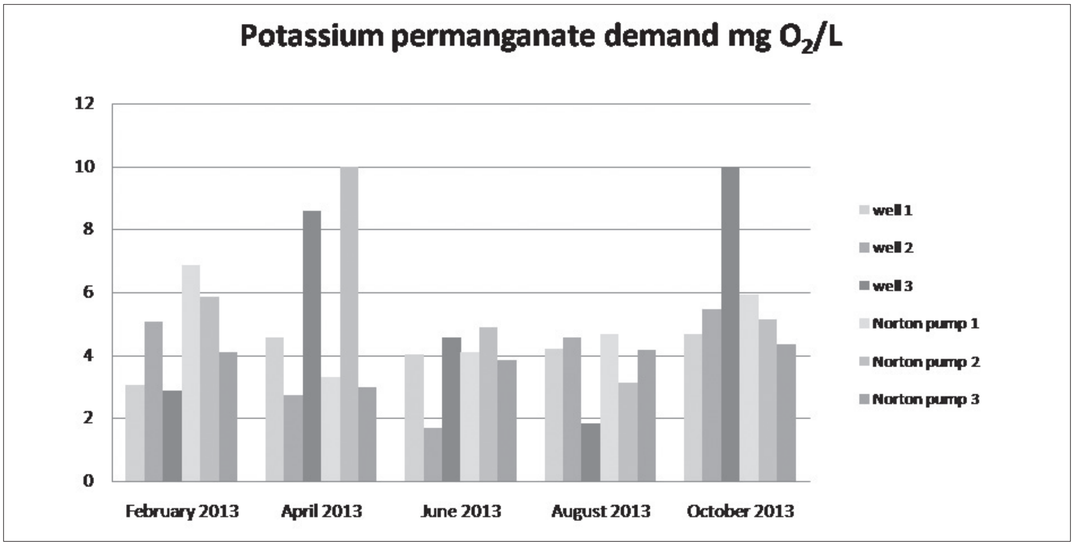


Chart 6. Cloride indicators in well and Norton pump water samples, by months

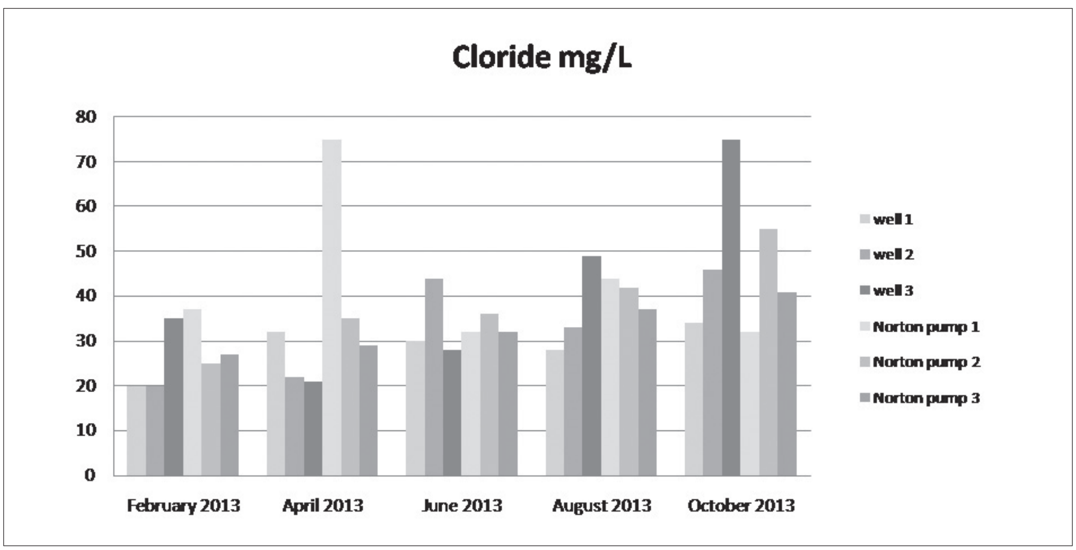


Chart 7. Ammonium indicators in well and Norton pump water samples, by months

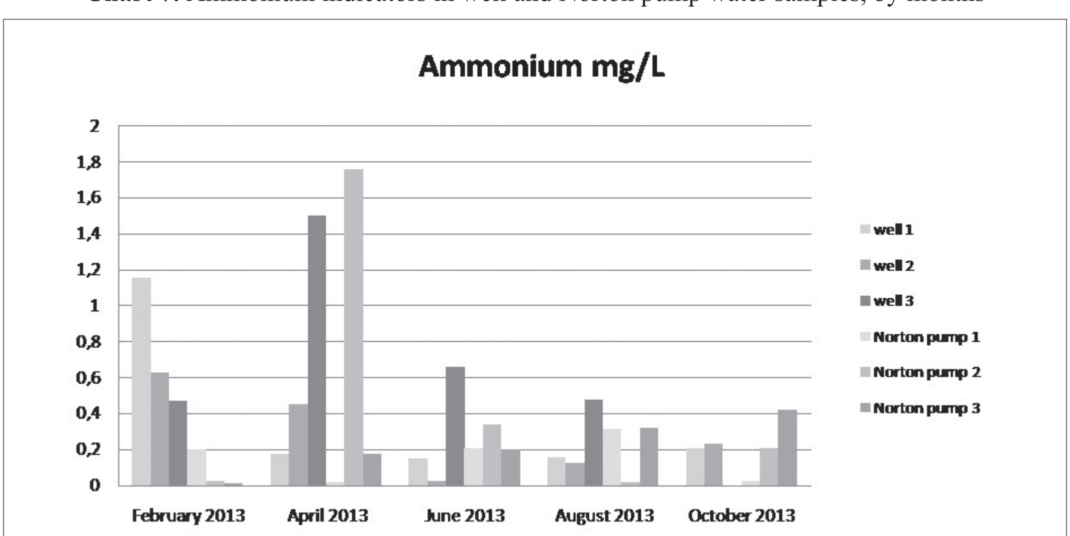


Chart 8. Nitrite indicators in well and Norton pump water samples, by months

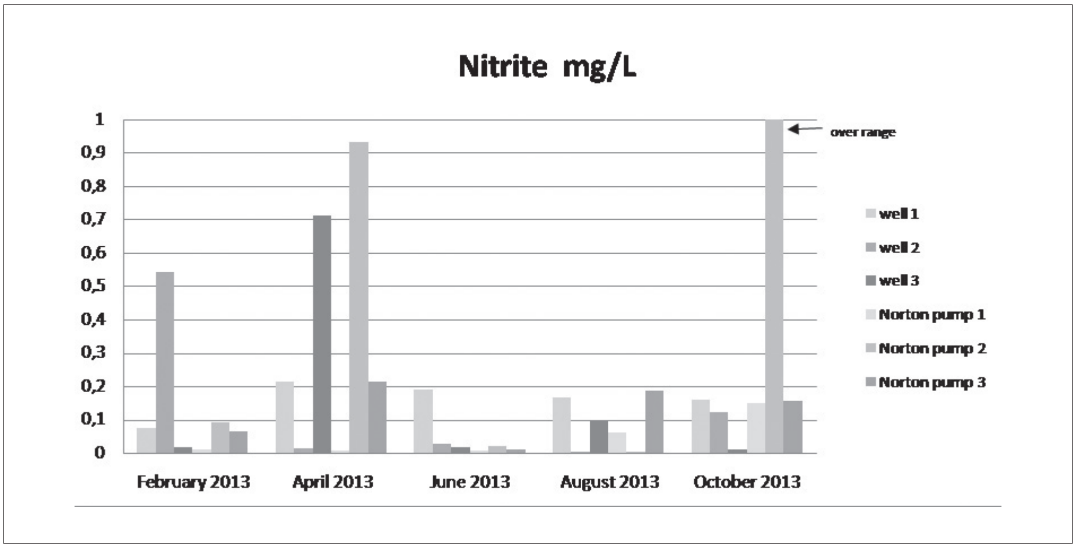


Chart 9. Nitrate indicators in well and Norton pump water samples, by months

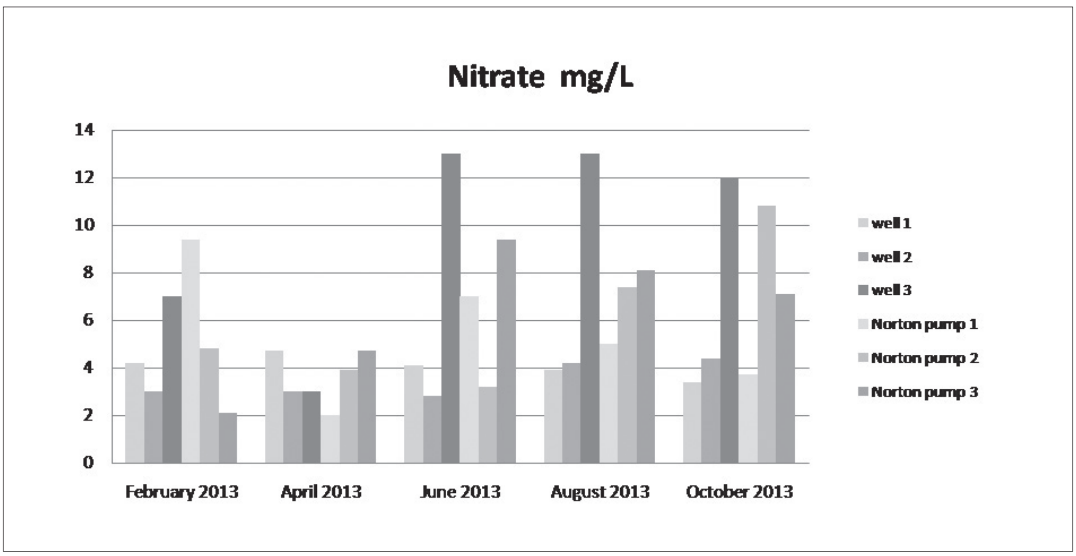


Chart 10. Colony count at 37 °C in well and Norton pump water samples, by months

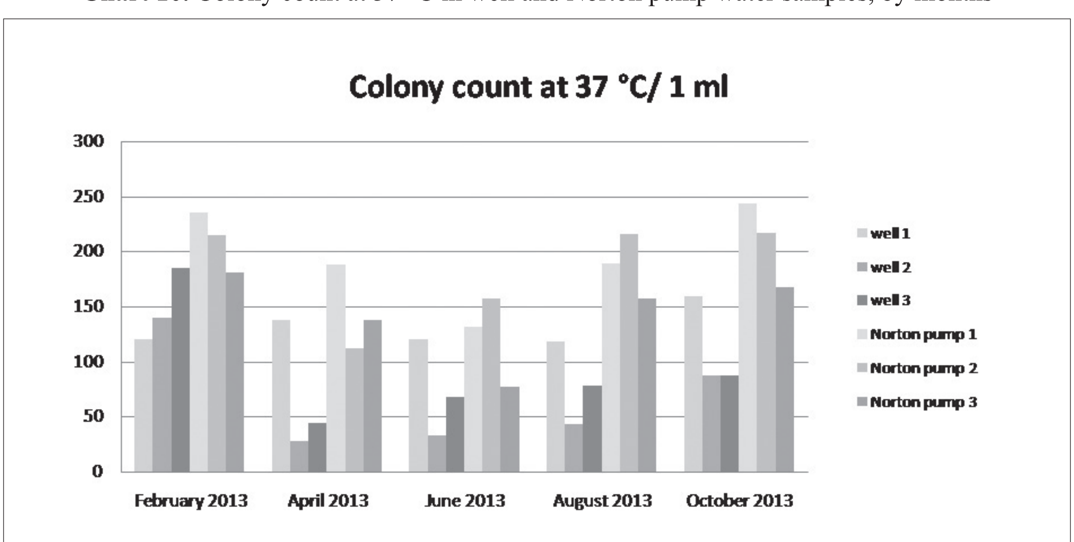


Chart 11. Total colony count at 22 °C in well and Norton pump water samples, by months

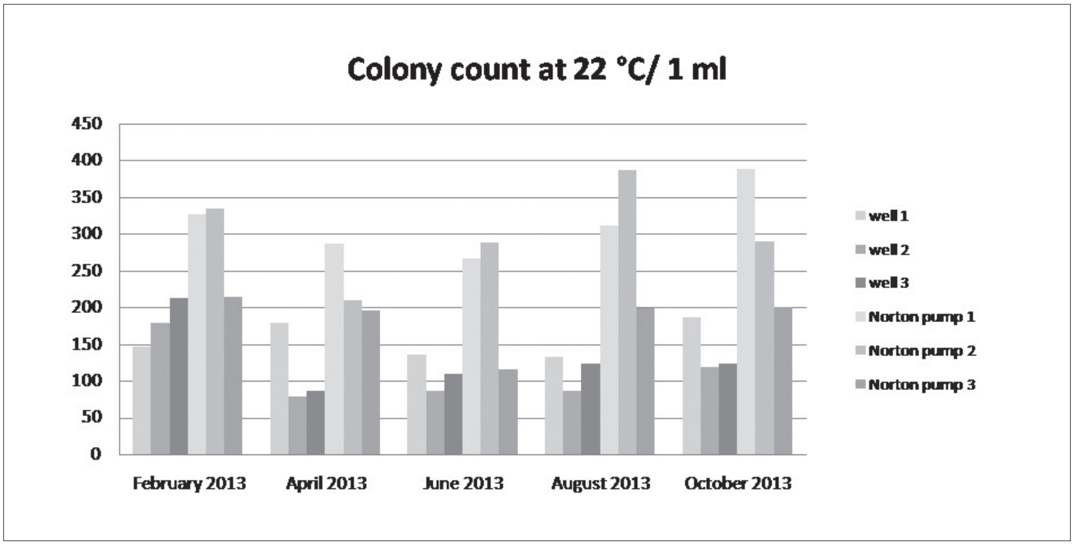
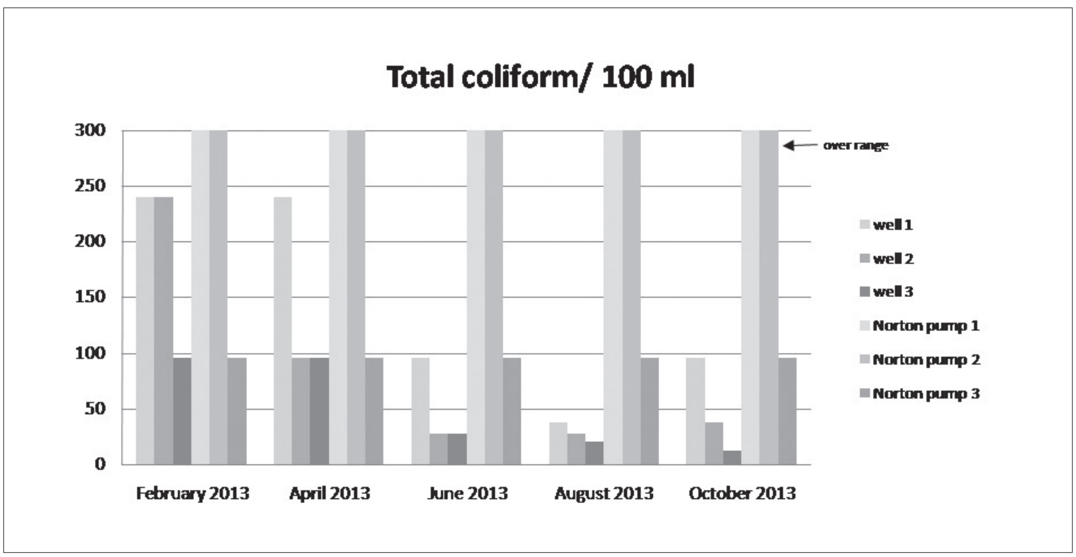


Chart 12. Total coliform count in well and Norton pump water samples, by months



Discussion

Safe drinking water means life, and the quality of life of future generations highly depends on how much we protect our water resources. Drinking water safety and protection have become global issues, since water is increasingly threatened by various types of pollution. It is estimated that over 2.5 billion people worldwide do not have adequate waste water drainage/sewage systems.

Changes in the environment caused by natural phenomena and human actions affect water supplies and threaten its quality. Fertilization of agricultural areas with organic or chemical fertilizers has an impact on the quality of groundwater in wells. Only a week after field fertilization, a drastic oxygen decrease is recorded in water samples from a nearby brook, while the levels of ammonium, nitrate, chloride, BPK_5, and the total number of bacteria and chloroform bacteria increase significantly (Hadžiosmanovi et al., 1994). Water quality does not improve until two months later. Nitrites and nitrates are often detected in water wells that are close to fertilized plough-land or pastures. Such waters are not adequate from a general hygienic and health point of view (Vučemilo et al., 1994). It is a well-known fact that agriculture is globally the largest individual user of surface waters and one of the main agents of degradation of surface water and groundwater due to erosion and chemical soil penetration. The main polluters that reach the waters as results of agricultural activities are phosphorus and nitrogen (which cause the harmful eutrophication phenomenon), metals, pathogenic microorganisms, pesticides, salts, traces of elements such as selenium, sediment, etc.

As already mentioned in the Materials and Methods section, we analysed two types of water-supply in the rural areas of Zagreb County: three samples were taken from dug wells (Brdovec) and three from Norton pumps (Dubravica). The two points are some 30 km away in aerial distance.

The comparative analysis of colour in water samples from the wells and Norton pumps per months shows rather high values in the Norton pump 1, of 49 mg/PtCo scale and, in February, in the Norton pump 2: 38 mg/PtCo scale, which is considerably above the maximum allowed concentration of 20 mg/PtCo scale. Other values were mostly within tolerable limits. In addition to colour, one of the most commonly cited organoleptic indicators is turbidity. In almost all samples from the Norton pumps, turbidity was above legal limit and ranged from 5 to 8 NTU. Only in October it was 4 NTU. Turbidity in the wells was within tolerable limits, except for Well 3 when in Feruary and June it was above tolerable limit. In water wells, the pH value expressed as the concentration of hydrogen ions was in only two cases under 6.5, as prescribed by the Ordinance. The samples from Norton pumps were within tolerable limit. Furthermore, the process of soil acidification and degradation of natural organic matter has already been present in rural areas for several years, which was reflected in soil waters (Glavač, 2001). It is proportional to the concentration of ions in water, inorganic anions and inorganic cations. Pursuant to the Ordinance, it can amount up to 2500 µS/cm /20^{o}C. All analysed samples were within tolerable limit and ranged from the lowest value of 494µS/cm /20^{o}C, recorded in Well 3 in June, up to 963 µS/cm /20^{o}C, recorded in the Norton pump 1 in April.

Oxidative characteristics, i.e. potassium permanganate demand, indicate the quantity of organic matter in water. Water containing organic matter of human, plant, animal or industrial origin, demands a certain quantity of $KMnO_4$ for its oxidation. Although potassium permanganate demand was expected to increase in almost all analysed samples (Zebec, 1990), this was not the case. The highest content of 8.60 and 9.97 mgO_2/L was recorded in Well 3 in April and October, while a high content of organic matter was also recorded in Norton pump 2, with 9.98 mgO_2/L. Chlorides are present in all types of waters, and they can originate from soil, household waters or waste waters, especially those that are mixed with faeces and urine. Although the maximum legal concentration is 250 mg/L, this limit has been set due to taste and is not hazardous, but when talking about chloride content in the waters of a certain area, we need to take into consideration of the average chloride content in the waters of that area. This is extremely important, for if we detect a chloride content of 125 mg/L C1 in a sample, and the average for the area is 50 mg/L C1, that sample will be deemed unsatisfactory (Asaj, 1974). Chloride content in water wells ranged from 20 to 75 mg/L C1. Chloride content in water samples taken from Norton pumps ranged from 32 to 75 mg/L C1. As a rule of thumb, ammonium cannot be traced in clean water. Its presence in surface waters indicates fresh organic contamination, i.e. water pollution with fresh faeces or urine. In water wells, ammonium content was significantly above maximum allowed concentration of 0.5 mg/L, in two cases: in Well 1 it was 1.16 mg/L in February, and in Well 3 1.502 mg/L in April. Ammonium content in water samples from Norton pumps was within the tolerable limit, except in the Norton pump 2 in April, when it was 1.758 mg/L. Nitrites usually reach ground waters with the rinsing of soil. They cannot be found in clean water, or only in traces. Their presence indicates the presence of partially disintegrated organic waste matter. Otherwise, they can be found in drinking water taken from freshly cemented wells or in waters coming from galvanized pipes where nitrite concentration can be high (Vučemilo and Tofant, 2009). In February, 0.543 mg/L was the content determined in Well 1 and in April, 0.712 mg/L were determined in Well 3, which is significantly above the permitted concentration of 0.5 mg/L. Nitrite content in water samples from Norton pumps was the highest in April, in Norton pump 2 and it amounted to 0.932 mg/L, while in October the sample could not be measured by an instrument and was marked as over range. High nitrite content indicates the presence of biological waste matter in the last stage of stabilisation, or rinsing from fertilized agricultural areas, which were not determined in our research. All analysed water samples from both sources of water-supply were well under the maximum allowed concentration of 50 mg/L.

As was stated in the Materials section, the first aquifer layer in the Zagreb Country is quite shallow, at the depth of around 6 to 8 meters. This water is not safe for drinking, since it can be contaminated by surface impurities. Bacterial contamination travels at shorter distances than virus or chemical contamination. In our area, microbiological contamination prevails in shallow ground waters (Zebec, 1990). Norton pumps are supplied from this layer. The second aquifer layer is at a depth of 12 to 14 meters and it supplies the wells. Although it is deeper than the first layer, its waters are also not protected from contamination. In order to determine microbiological indicators, the number of colonies was measured at 37˚C in 1 mL of water sample. In all analysed drinking water samples, the number of colonies at 37˚C increased significantly and ranged from 28 to 244/1 mL. The number of colonies at 22˚C was also determined, which also significantly increased and ranged above maximum allowed concentration, except in Wells 2 and 3 in April, and in Well 2 in June and August. The total number of coliforms is a criterion for determining water contamination with faecal waste. Coliforms, as a group, are defined as gram negative bacteria which ferment lactose, they are aerobic, do not create spores and they grow optimally at 35-37^{o}C within 48 hours. A high level of coliform contamination was determined in water samples from the Norton pumps, in pumps 1 and 2, where the number of total coliforms was above 240/100 mL, while the number of total coliforms in the Norton pump 1 was 96/100 mL, which also does not comply with the provisions of the Ordinance.

Although the microbiological indicators in the analysed water samples from the wells and Norton pumps are devastating, almost no diseases that could be associated with bad microbiological water quality have been detected. This could partly be ascribed to the fact that weekend visitors usually bring drinking and cooking water, and the local population has gotten used to and become immune to such water with years of consumption.

If we compare previous research with today's, it is obvious that the quality of ground and surface waters has not changed significantly in the last ten years (Kolarek, 1994, Režek, 1995).

It needs to be pointed out once again that agriculture is globally the largest individual user of surface waters and one of the main agents of degradation of surface and ground waters due to erosion and the rinsing of chemicals through soil. The main polluters which come into water as a result of agricultural activities are phosphorus and nitrogen (which cause the damaging eutrophication phenomenon), metals, pathogens of microorganisms, pesticides, salts, traces of elements such as selenium, sediment and others. Many matters that contaminate waters have long-term negative effects on water quality, and the consequence is a serious decrease of safe drinking water quantities, which is a serious threat to human health.

Conclusion

The following conclusions can be reached based on the analyses of water samples from dug wells and Norton pumps, so-called Norton pumps, in Zagreb County:

Overall, the water taken for analysis in the sites here analysed does not meet the conditions prescribed in the Ordinance on the Parameters of Assessment and the Methods for Analyzing Water for Human Consumption or the Act on Water for Human Consumption. Colour as an organoleptic indicator is not satisfactory in either one of the samples taken from wells and in three of the samples from the Norton pump. Physical-chemical indicators, such as pH values and conductivity do meet the standard. In terms of chemical indicators, the analyzed samples from wells and Norton pumps are fully in line with the standard in terms of their chloride and nitrate content. Other analyzed indicators – ammonium and nitrite levels, potassium permanganate demand (oxidation) – are well above the maximum concentration allowed by the law. Microbiological indicators in the samples here analyzed i.e. colony count at 37 ºC and 22 ºC and total coliform count are also not in line with the provisions of the Ordinance. If the water is to be used for drinking, water conditioning and disinfection must be done in wells, procedures which would be practically impossible in Norton pumps.

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