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# Impact of Water Table Fluctuations in Dug Wells on the Content of Nitrates in Water

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**ABSTRACT**

The present study indicates the quick response of a shallow aquifer to precipitation. The nitrate content in water from 20 wells was determined. The study showed a significant 1-m decrease in the water table in the studied wells at low precipitation levels (10 mm) in April (wells 13 and 16). In turn, the water table in the wells after the maximum rainfall in September (130 mm) increased by 0.5 m in well 19. The results of the chemical analysis of the water indicate that the permissible nitrate content was highly exceeded in wells 3, 17, and 18. The nitrate content in wells 1 and 2 was almost 50 mg/l, which is the permissible value for drinking water. The precipitation level did not influence the content of nitrates in the well water.

**Keywords:** dug wells, nitrates, groundwater table fluctuations.

## INTRODUCTION

Good quality drinking water is essential for life. Human activity interferes with the natural water cycle and affects the quality and quantity of water. The constantly growing human population and its expectations for standards of living are associated with higher requirements for exploitation of existing resources, including water (Chowdhury, 2013).

Water is one of the most important determinants of the socio-economic development of regions, countries, and continents. The availability of water for the needs of populations and the economy is connected with natural resources and water cycle in nature. The amount of water resources is determined by hydrometeorological and geological factors, i.e. precipitation, catchment retention capacity, infiltration conditions, thickness of aeration the zone, and groundwater table depth as well as anthropogenic factors, i.e. land melioration, regulation of water courses, changes in the land use structure, etc. In dry periods, groundwater is the only source of water recharging rivers and lakes. Deep-lying aquifers have to be reached increasingly often to meet the population and economy requirements for clean potable water. Aquifers are natural and widely available retention reservoirs of water with stable physicochemical properties; hence, these groundwater reservoirs are an attractive source of water (Skrzypczyk, 2003). The physical and chemical properties of groundwater depend on natural factors, which are modified by anthropopressure (Chełmicki, 2001). Changes in the quality of groundwater are most often induced by anthropogenic contaminants and their migration with surface waters infiltrating the ground (Pawęska et al. 2012; Sasakova, 2018). The impact of anthropogenic factors on changes in the chemical composition of groundwater is not always discerned or is sometimes ignored, especially in cases where the increase in the concentration of substances dissolved in water does not exceed accepted quality standards. Then, it is very often assumed that the groundwater is not subject to adverse effects and no measures for prevention of future water degradation are taken (Mianowski, 1982).

In agricultural areas, wells used to be the only source of drinking water and, despite the considerable progress in the development of water supply networks in rural areas, large numbers of rural inhabitants still use water from dug wells (Pawęska et al. 2012). Dug wells have been and still are the simplest and cheapest sources of groundwater worldwide. The only problem is their depth, which is related to the water table level, i.e. local hydrogeological conditions. Shallow aquifers are exposed to large fluctuations in the water table and anthropogenic pollution. Changes in the quality of groundwater are usually caused by anthropogenic pollutants and their migration with surface waters infiltrating the ground (Łomotowski and Szpindor, 1999).

Groundwater is still the main source of drinking water, especially in small villages where there are no supplies from water mains. There are relatively many such villages in the Podkarpacie region. The aim of the study was to detect changes in the water level in Sarzyna wells and to determine the impact of these fluctuations on the content of nitrates in water. Despite the importance of the problem of the quality of water in individual wells, there is insufficient research in this field, and the water quality in dug wells is not controlled by their users.

## MATERIALS AND METHODS

### Sample collection

The investigations were carried out from January to December 2020 in Sarzyna (50° 21′ 5″ N, 22° 20′ 40″ E), located in the north-eastern part of Podkarpackie Province in the Leżajsk County, Nowa Sarzyna Commune. The village has approx. 4 000 inhabitants. The research covered 20 dug wells located on farms (Figure 1). The investigations consisted in a single measurement of the well depth and monthly measurements of the water level in the wells using a hydrogeological whistle. The height of the well head was subtracted from the measured value. The presented values indicate the distance from the ground surface to the water table in the well. Concurrently, 240 water samples were collected in 100-ml sterile bottles for determination of the nitrate content. The chemical analysis was carried out with the use of a Thermo scientific DIONEX ICS-5000 + DC ion chromatograph in the laboratory at the Department of Soil Science, Environmental Chemistry and Hydrology. Figure 1 shows the location of the analyzed wells in Sarzyna.

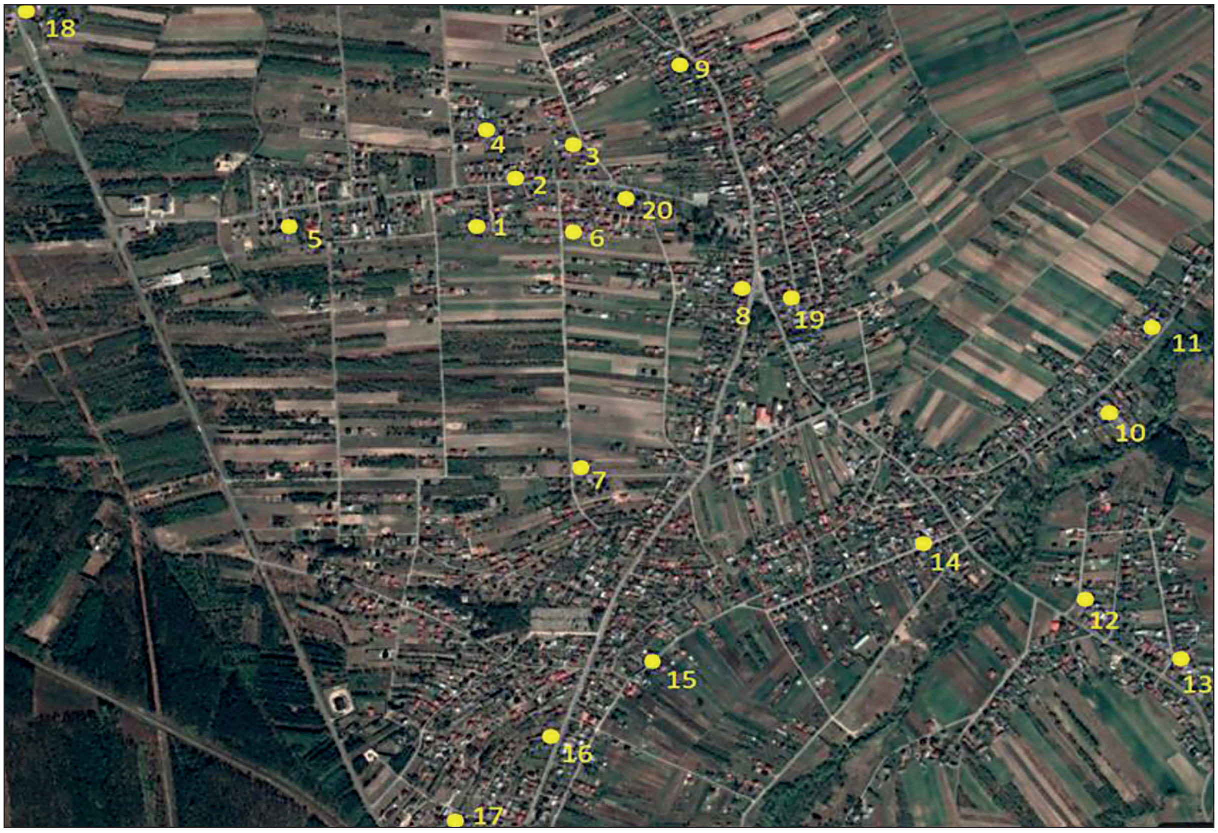


**Figure 1**. Location of the wells in Sarzyna (https://www.google.com/maps/place/Sarzyna/zmieniona)

## RESULTS AND DISCUSSION

Groundwater resources are replenished by rain and snowfall. In recent years, the annual sums of rainfall have been lower not only in Podkarpacie but also in Poland. In 2020, the annual rainfall sum in Sarzyna was 733 mm versus the average annual sum for Poland of 600 mm (tps://www.meteoblue.com/pl/pogoda/historyclimate/weatherarchive/sarzyna_polska).

The wells where the water level was measured are located on private property. Water from 14 of the 20 analyzed wells is used for watering gardens and livestock, whereas water from wells 9 and 16 is intended for human consumption. The other wells are unused and serve as a decorative element. Table 1 shows a description and depth of each well.

The present study showed high water table fluctuations in relation to the amount of atmospheric precipitation (Figure 2). The depth of the wells ranged from 9 to 5 m (Table 1), which indicates a shallow location of the groundwater table, given the average depth of wells of 10 m. All the dug wells exhibited a correlation between the water level and the amount of precipitation.

The relationships shown above are associated with the reaction of groundwater to the amount of supply and soil permeability. The soil in the studied area is classified as silty sands. Higher soil permeability contributes to a higher water infiltration rate and more efficient aquifer recharge. Shallow groundwaters react much faster to rainfall or snowmelt water recharge. In their study, Jędruszkiewicz et al. (2016) reported a similar relationship. Deeper

**Table 1.** Depth and description of surroundings of the wells in Sarzyna

| Number of well | Depth (m) | Surroundings of wells |
|---|---|---|
| 1 | 9 | The well is still used; it is located at a distance of 0.5 m from the residential building and 3.0 m from the home vegetable garden. The well was dug in the 1980s. |
| 2 | 6 | The well is still used; the water is drawn by a pump. It is located at a distance of 15-20 m from the house and outbuildings. The well was dug in the 1980s. |
| 3 | 6 | The unused well was dug in 1980-1985; it is located at a distance of 15 m from the buildings. |
| 4 | 6 | The well is still used; the water is drawn by a pump. It was dug in 1979 at a distance of 10 m from the buildings. |
| 5 | 6 | The well is not used; it is located at a distance of 2 m from the building; it was dug in the 1990s. |
| 6 | 6 | The well is not used; it was dug in the 1970s. It is located at a distance of 4 m from the farm buildings and 1 m from agricultural land. |
| 7 | 7 | The well is not used; it was dug in 1990. It is surrounded by a home garden. |
| 8 | 8 | The well is still used; the water is drawn by a pump. It was dug at a distance of 3 m from a residential building and wild-growing trees in 1982. |
| 9 | 6 | The well is still used; the water is drawn by a pump in the summer months for consumption purposes. It was dug at a distance of 10 m for residential buildings in 1970. |
| 10 | 6 | The well is still used; it was dug in the 1970s. It is located 12 m from the residential building. |
| 11 | 6 | The well is still used; it was dug in the 1970s. It is located on the border of the plot at a distance of 12 m from residential buildings. |
| 12 | 6 | The well is still used; it was dug in the 1990s. It is located in the garden at a distance of 9 m from the outbuildings. The water is used for watering plants. |
| 13 | 6 | The unused well was dug in the 1990s. It is located at a distance of 2 m from the residential building and is surrounded by a home garden. |
| 14 | 7 | The well is still used; it was dug in the 1980s. It is located at a distance of 2 m from a trunk road and 10 m from the residential and farm buildings. The water is intended for watering the garden. |
| 15 | 8 | The well is still used; it was dug in the 1970s. It is located at a distance of 2 m from a trunk road and 5 m from the buildings. The water is used for watering the garden and livestock. |
| 16 | 7 | The well is still used; it was dug in the 1980s. It is located at a distance of 3 m from residential buildings. The water is intended for human consumption and watering livestock. |
| 17 | 6 | The well is still used; it was dug in the 1990s. It is located on the border of plots at a distance of 10 m from the buildings and a pasture. The water is used to water the garden in summer. |
| 18 | 5 | The unused well was dug in the 1980s. It is located at a distance of 10 m from the buildings. |
| 19 | 7 | The well was dug in the 1960s but has been unused since 2005. At present, it serves as a decorative element. |
| 20 | 5 | The well is still used; it was dug in the 1990s. It is situated near agricultural land. The water is used for watering the garden and livestock. |

aquifers have a longer reaction time. In the analyzed wells (Figure 2), a significant 1-m decrease in the water table was noted at the low rainfall rates of 10 mm in April (wells 13 and 16). In turn, after the maximum rainfall (130 mm) in September, the water table in the wells increased even by 0.5 m, as in the case of well 19. The height of the groundwater table depends not only on morphological and hydrogeological factors but also on the type, size, and intensity of precipitation (Dynowska,


**Figure 2.** Presents the fluctuations of the groundwater table in relation to the precipitation in selected 20 in the town of Sarzyna

Pietrygowa 1978; Chełmicki, 1991). The infiltration rate depends on the moisture level of the aeration zone located above the water table. In addition to the permeability of surface formations, an important role is played by the atmospheric determinants of the infiltration process. The type of wells depends on local conditions, mainly on the aquifer depth, topography, and soil type (Wojciechowski, 2010). In the study area, the depth of the wells did not exceed 9 m. The wells are supplied by the first

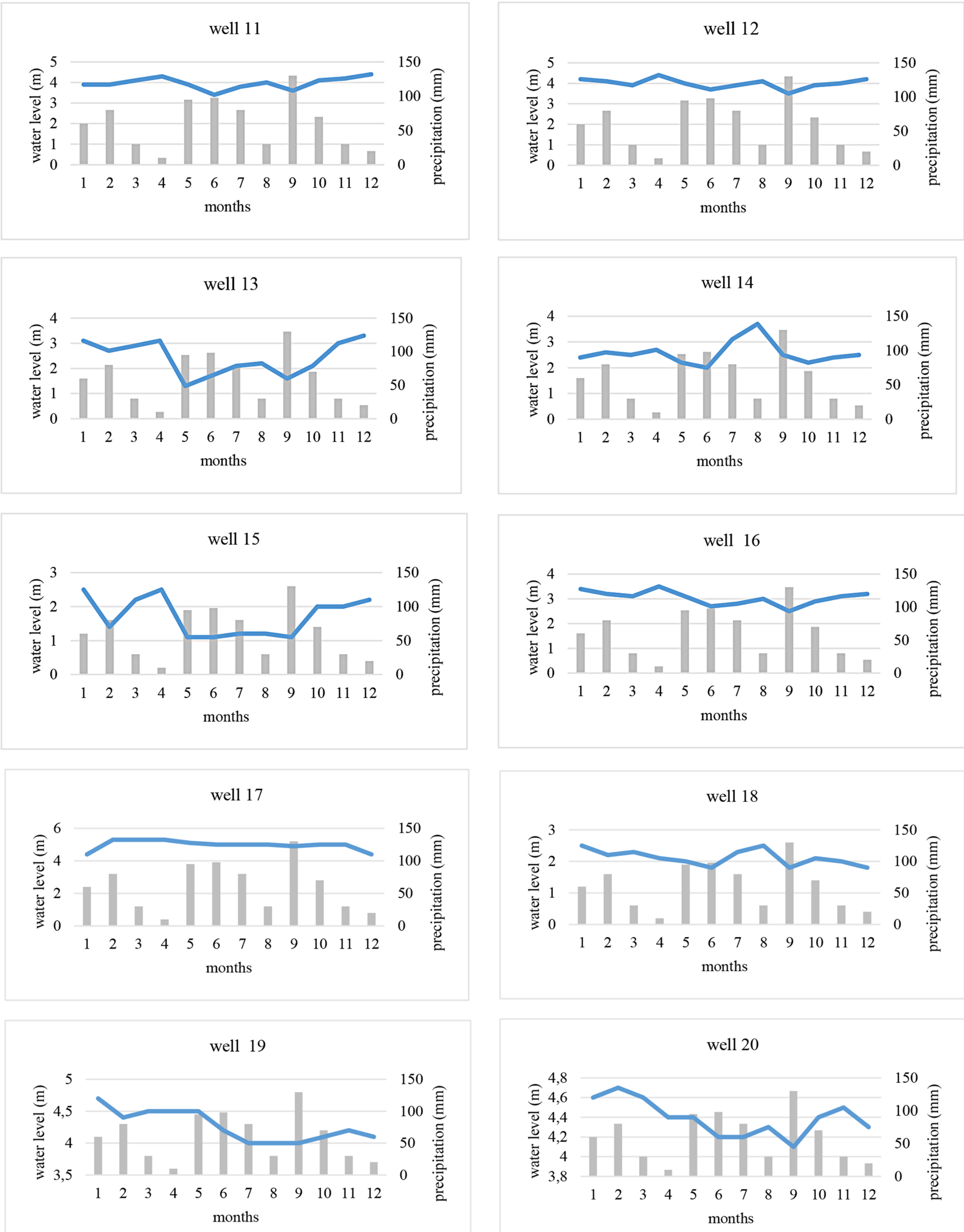


**Figure 2. Cont.** Presents the fluctuations of the groundwater table in relation to the precipitation in selected 20 in the town of Sarzyna

shallow aquifer, which may and often is subject to anthropogenic contamination. The present results show the fast rate of changes in the water table depth in the wells after rainfalls.

The properties of waters in the natural environment are determined by natural, artificial, and anthropogenic factors. The study was focused on the analysis of the content of nitrates in water due to the harmful effects exerted by these compounds. Figure 3 is a summary of the results of the nitrate content (mg/l) in the waters sampled from the wells in Sarzyna every month in 2020 (Table 2).

**Table 2.** Content of nitrates (mg/l) in water from Sarzyna wells in 2020 (the red color indicates values exceeding the permissible level of 50 mg/l)

| Months | I | II | II | IV | V | VI | VII | VIII | IX | X | XI | XII |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of well | | | | | | | | | | | | |
| 1 | 39.4 | 35.4 | 51.2 | 47.7 | 39.9 | 49.1 | 36.1 | 43.1 | 15.8 | 42.5 | 22.9 | 23.1 |
| 2 | 41.2 | 39.8 | 38.6 | 47 | 45.2 | 19.1 | 45.2 | 48.9 | 37.7 | 16.7 | 34.8 | 34.2 |
| 3 | 45.9 | 51.3 | 62.4 | 53.8 | 57.4 | 70 | 67.7 | 69.7 | 78.8 | 52.3 | 72.3 | 69.7 |
| 4 | 20.1 | 19.2 | 17.5 | 20.9 | 23.7 | 19.6 | 19.3 | 18.9 | 16.1 | 21.4 | 14.3 | 15.1 |
| 5 | 17.3 | 21.2 | 22.1 | 23.4 | 22.3 | 21.4 | 20 | 20.1 | 17.2 | 11.2 | 36 | 28.4 |
| 6 | 18.6 | 15.3 | 16.2 | 16.3 | 19.7 | 14.5 | 18.5 | 19 | 18.6 | 17.4 | 14.4 | 15.3 |
| 7 | 15.9 | 16.4 | 14.6 | 16.2 | 13.9 | 14.6 | 25.5 | 18.8 | 10.9 | 17.1 | 14.7 | 15.1 |
| 8 | 10.6 | 9.8 | 14.3 | 7.5 | 8.2 | 9.7 | 9.1 | 20.9 | 36.7 | 10.9 | 26.5 | 19.2 |
| 9 | 13.2 | 14.2 | 15.8 | 17.9 | 16.3 | 11.2 | 19.2 | 15.5 | 12.2 | 10.8 | 19.5 | 16.3 |
| 10 | 29.4 | 18.9 | 28.7 | 16.2 | 38.1 | 18.5 | 31.2 | 35.1 | 17.9 | 18.2 | 18 | 19.6 |
| 11 | 12.5 | 14.3 | 15.2 | 16.6 | 10.8 | 12 | 12.7 | 15.2 | 12.4 | 19.5 | 15.1 | 16.2 |
| 12 | 16.2 | 13.5 | 14.1 | 15.5 | 19.5 | 11.1 | 10.2 | 14.6 | 16.3 | 16.3 | 12.7 | 13.4 |
| 13 | 4.9 | 5.1 | 5.4 | 5.9 | 3.1 | 2.2 | 2.4 | 3.6 | 2.1 | 2.3 | 3.3 | 2.9 |
| 14 | 22.5 | 21.3 | 25.4 | 26.5 | 24 | 29.2 | 23.4 | 34.5 | 16.3 | 17.8 | 28.4 | 19.5 |
| 15 | 5.5 | 5.1 | 4.3 | 6.4 | 5.1 | 1.6 | 2.2 | 2.7 | 4.1 | 7.4 | 8.5 | 7.9 |
| 16 | 1.6 | 0.8 | 1.5 | 1.2 | 2 | 1.2 | 0.8 | 0.4 | 1 | 1.4 | 1.9 | 1.5 |
| 17 | 45.2 | 56.1 | 52.3 | 46.3 | 77.9 | 88.3 | 96 | 88.4 | 70.5 | 44.5 | 71.3 | 72.6 |
| 18 | 51.2 | 65.4 | 64.8 | 75.9 | 89.4 | 62.5 | 97.1 | 68.4 | 36.9 | 37.4 | 89 | 74.9 |
| 19 | 42.1 | 43.1 | 44.2 | 44.4 | 33 | 33.8 | 46.4 | 19.3 | 37 | 21.2 | 26.6 | 23.1 |
| 20 | 19.6 | 20.2 | 18.5 | 20.8 | 22.5 | 22.3 | 25.6 | 21.1 | 22.9 | 13.8 | 22.6 | 21.1 |

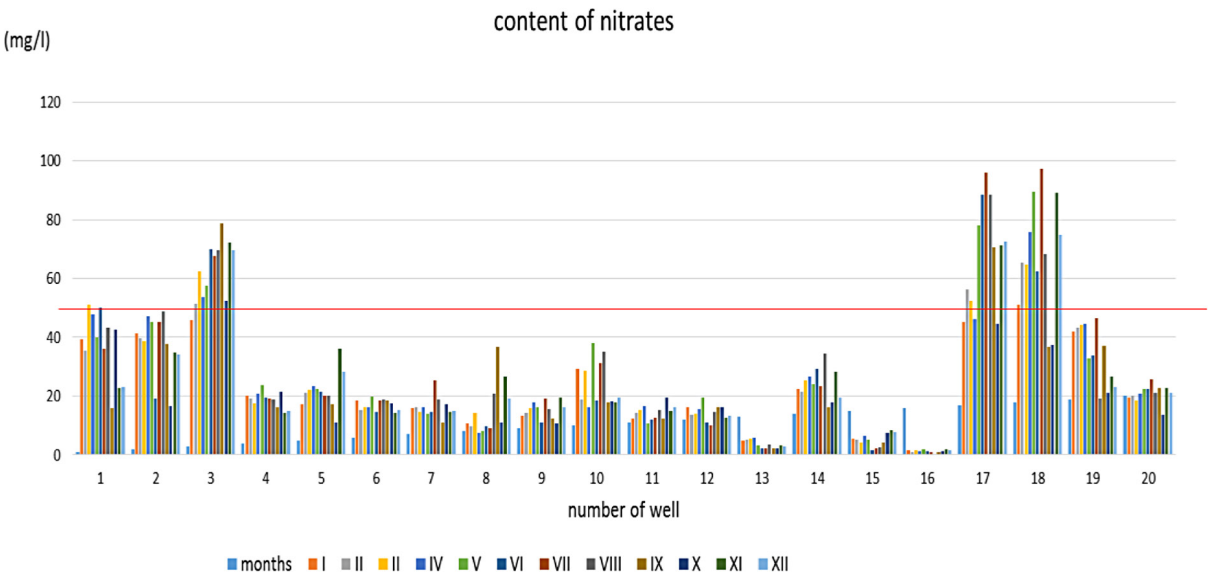


**Figure 3**. Content of nitrates (mg/l) in the well water between January and December 2020. The red line denotes the permissible value of 50 mg/l

Due to the specific technology of construction, dug wells are shallow, i.e. they reach up to 10 m below the ground surface (Hackett, 1988; Przewłocki et al. 1970). Hence, there is a serious threat of potentially inappropriate quality of water supplied by dug wells, which may be exposed to soil surface contaminants, especially nitrogen compounds. There are various sources of nitrates in well water. The most common source of nitrates in drinking water is presence of slurry in fields or leaky septic tanks. As reported by Pawęska et al. (2012), nitrate nitrogen (III) is the most unfavorable form of nitrate compounds in groundwater with high toxicity to living organisms. As specified by the Polish standards (Regulation of the Minister of Health of December 11, 2017), the allowable concentration of nitrates in drinking water is 50 mg/l, and this content can be fatal for infants. The present study showed higher levels of nitrates than the permissible value in wells 3, 17, and 18 and values close to 50 mg/l in wells 1 and 2 (Figure 2). As reported by Balcerzak and Bąk (2008), the concentration of nitrates in groundwater in Poland ranges from trace amounts to 100 mg $NO^{3-}/dm^3$. Even higher levels have been recorded in some regions, e.g. in Żagań 132.7 mg $NO^{3-}/dm^3$ (data from 1992). In Poland, 37% of water in rural wells has excessive content of nitrates (Balcerzak and Bąk 2008). The present results revealed elevated nitrate content in the water from the Sarzyna wells. Nevertheless, the precipitation amount did not influence the nitrate content in the water. The main cause of the high content is the infiltration of nitrates from farm buildings and fields fertilized with manure and slurry and the shallow location of the groundwater. The quick changes in the water table after rainfall indicate uncontrolled migration of contaminants through the highly permeable soil.

The negative impact of nitrates contained in water from dug wells on human health was reported by Raczuk et al. (2009, 2013). Investigations conducted in Podkarpacie by Bilek et al. (2014, 2015) also showed that the permissible amounts of nitrates were exceeded in some wells with water used for human consumption. This problem was extensively described by Sasakov et al. (2018). In Sarzyna, the water from the wells where the acceptable levels of nitrates were exceeded was used for watering the gardens. It should be noted that water with increased levels of nitrates is equally detrimental to livestock health.

The quality of water, especially groundwater, is important for the present and future supply of water for domestic and farming purposes to the general population.

## CONCLUSIONS

Shallow aquifers are mainly recharged by atmospheric precipitation, and the infiltrating water carries large amounts of anthropogenic pollutants. Therefore, research is necessary to monitor groundwater table fluctuations and the chemical composition of water, especially in areas where the population has no access to water supplied by water mains. The problem of the quality of water in wells in many regions, not only in Podkarpacie, is highly significant. It is essential that water from dug wells should be tested by users at least once a year.

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