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QUALITY AND QUANTITY ASSESSMENT OF GROUNDWATERS IN THE VICINITY OF KUTNO WITH RESPECT TO POTABILITY. PART II

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ABSTRACT

The study presents the characteristics of drinking water sources and subsequently performs an analysis of the deviations from the norm in terms of ions of iron, manganese, ammonia, sodium, chlorides as well as other factors affecting the quality of drinking water in the years 2015 - 2017 occurring in individual water intake points in the Kutno district.
Keywords: drinking water, properties, pollution, Kutno district.

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ANALYSIS OF EXCEEDENCES OF AMMONIUM, NITRITE, CHLORIDE, MANGANESE, IRON AND SODIUM IONS

THE CITY OF KUTNO

Since 2016, tests of water intakes in the city of Kutno, i.e. water points are treated as separate sources of water intake and the results are included in a collective tests protocol.

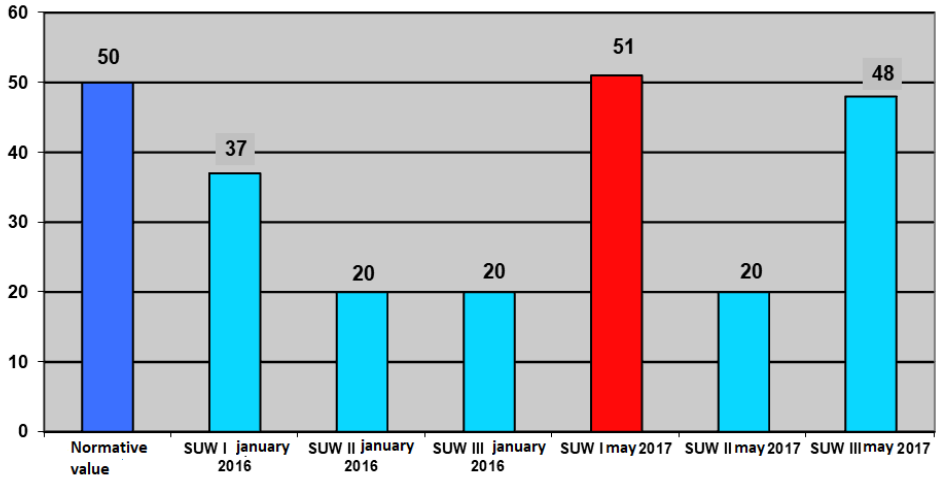

Fig. 1 Manganese concentration [mg/l] in the period 01.2016 - 05.2017. (Kutno city).

In May 2017, the concentration of manganese (51 µg/l) of the tested sample was slightly exceeded in relation to the normative value of 50 µg/l. The other parameters, the concentration of ammonium ion and iron were within the norm.

KUTNO – AZORY

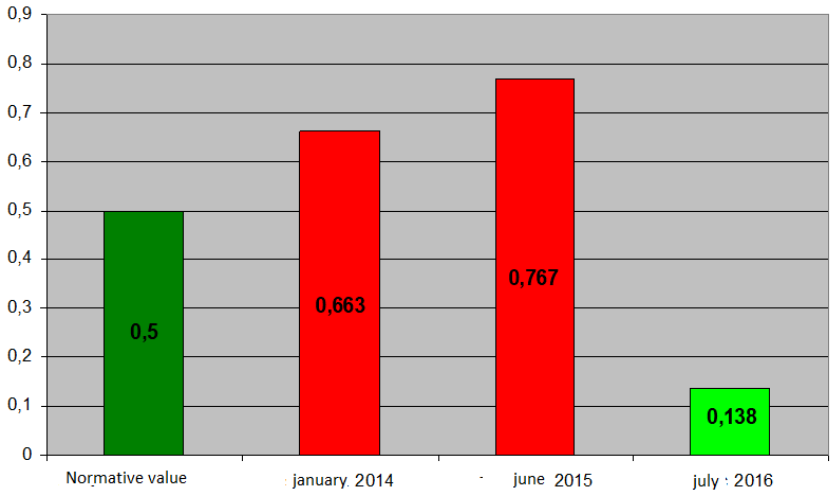

Fig. 2 Ammonium ion concentration [mg/l] in the period 01.2014 - 06.2016.

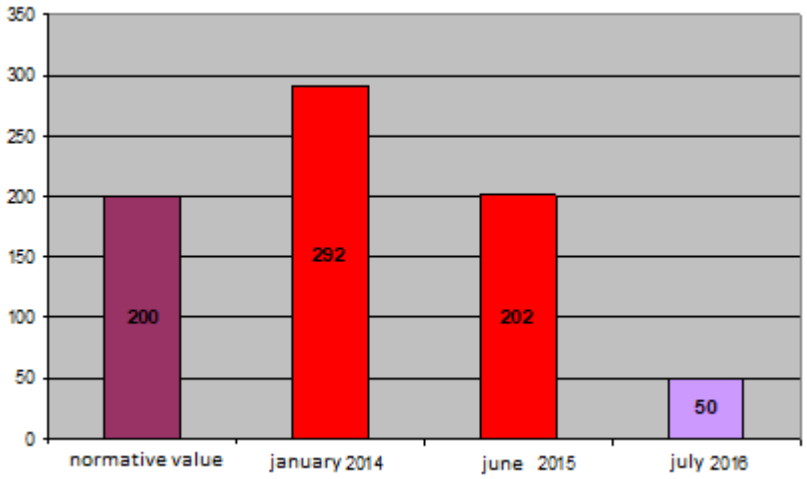

Fig. 3 Iron concentration [µg/l] in the period 01.2014. - 06.2016.

The parameters of concern in the intake were ammonium ion and iron content. Water testing from January 2014 to July 2016 showed exceedances of ammonium ion norms in January 2014 by 32.6%, and in June 2015 by 53.4%. During the same period the iron content was also exceeded by 92 units in 2014, but in 2015 the exceedance was only 2 units. In 2016, the water from the intake met all standards for water intended for consumption.

KUTNO — STRZEGOCIN

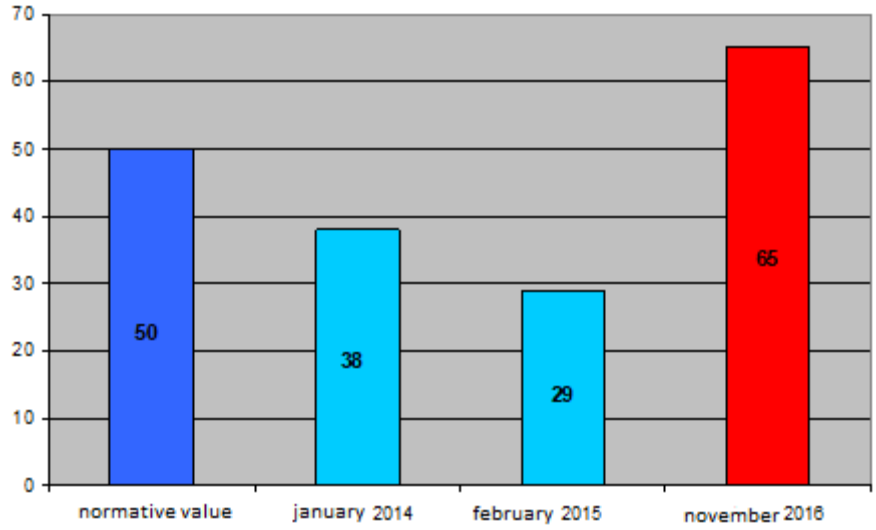

Fig. 4 Manganese concentration [µg/l] at the intake point in the period January 2014 – November 2016.

Testing of water parameters from January 2014 to November 2016 showed no exceedances in the normative values of ammonium ion concentration as well as iron content. The test from November 2016 showed that the norm of manganese content was exceeded by 30%. The iron content was not exceeded.

WATER INTAKE POINT — KROŚNIEWICE

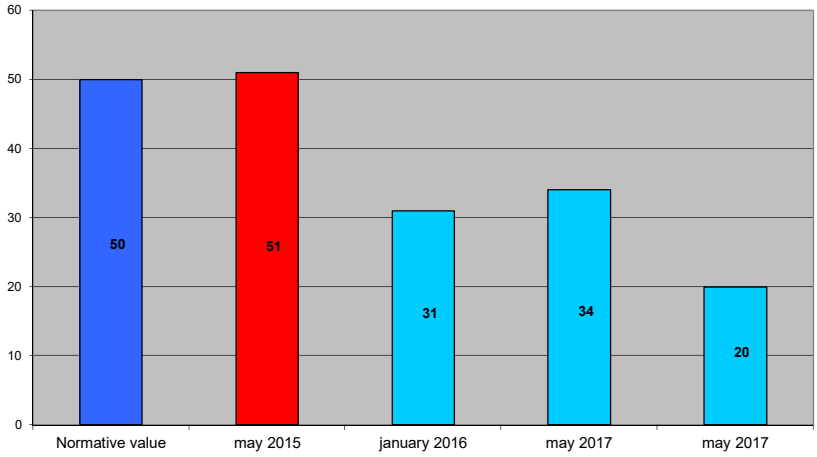

Fig. 5 Manganese concentration [µg/l] in the period 05.2015 – 05.2017.

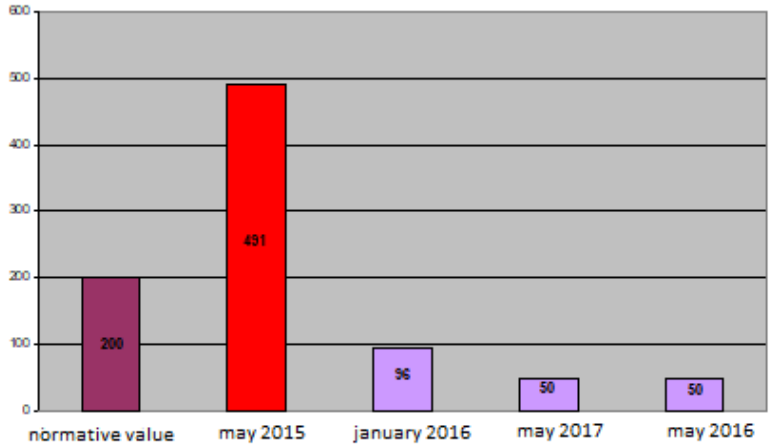

Fig. 6 Iron concentration [µg/l] for the period 05.2015 – 05.2017 r.

From May 2015 to May 2017, water colour and turbidity remained within normative values. Exceedances of manganese and iron parameters occurred in 2015. There was a slight exceedance of manganese concentration by 2% , while an exceedance of iron by 245.5%. Since 2016, all parameters are within the norms.

WATER INTAKE POINT - MUNICIPALITY OF KROŚNIEWICE - NOWE

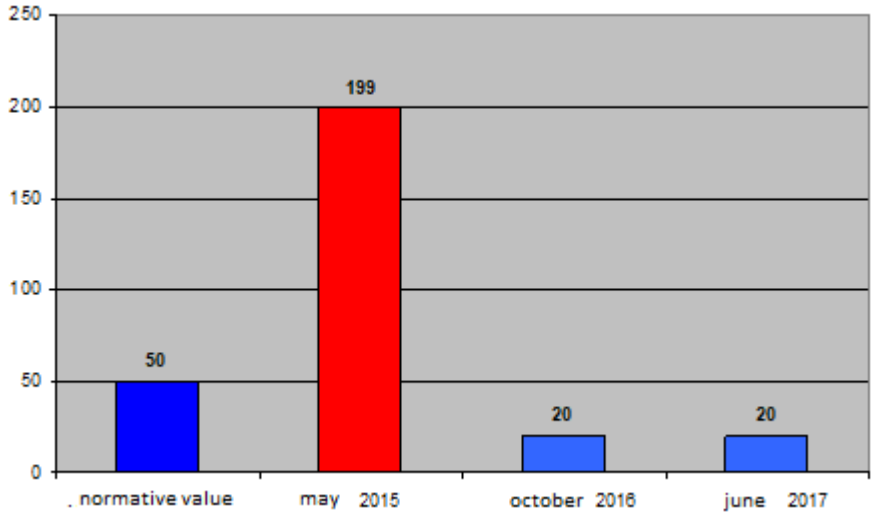

Fig. 7 Manganese concentration [µg/l] at the water intake from May 2015 to June 2017.

In the period from May 2015 to June 2017, no exceedances were recorded in the concentration of the questioned parameters included in the description of the water intake in Nowe, the municipality of Krośniewice, i.e. ammonium ions, iron. However, the study in May 2015 showed a four-fold exceedance of the permissible standard of manganese ions.

WATER INTAKE POINT - ŻYCHLIN

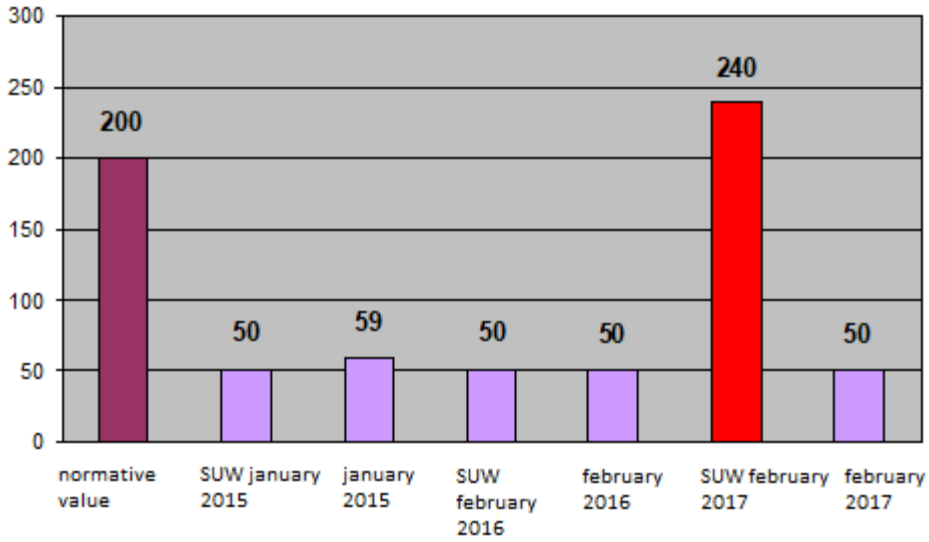

Fig. 8 Iron concentration [µg/l] at the water intake point during the period from April 2016 to July 2017.

The questioned parameters of the water intake were its colour, turbidity, content of ammonium and manganese ions. During the analysed period, from January 2015 to February 2017, no increase in the amount of the mentioned ions was observed. The ammonia level remained between 0.22 mg/l (2015) and 0.08 mg/l (2017) with a normative value of 0.5 µg/l. The iron content during the past period was at 20 µg/l with a limit value of 50 µg/l.

The anomaly was a large increase in the concentration of iron ion in the February 2017 water sample taken at the Żychlin Water Treatment Station to a value of 240 µg/l with a limit value of 200 µg/l. Re-testing at a later date showed a return to 50 µm/l. Figure 28 shows the changes in the concentration of iron ion in the period 2015÷2017.

WATER INTAKE POINT - DĄBROWICE

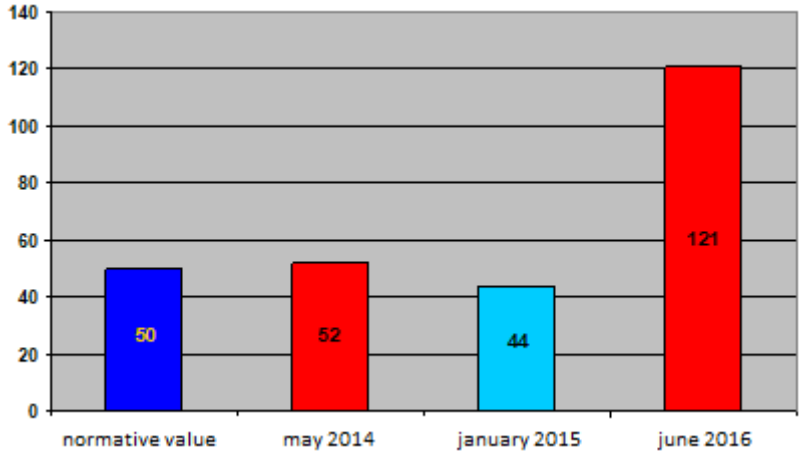

Fig. 9 Manganese content [µg/l] in samples taken between May 2014 and June 2016 at the water intake point.

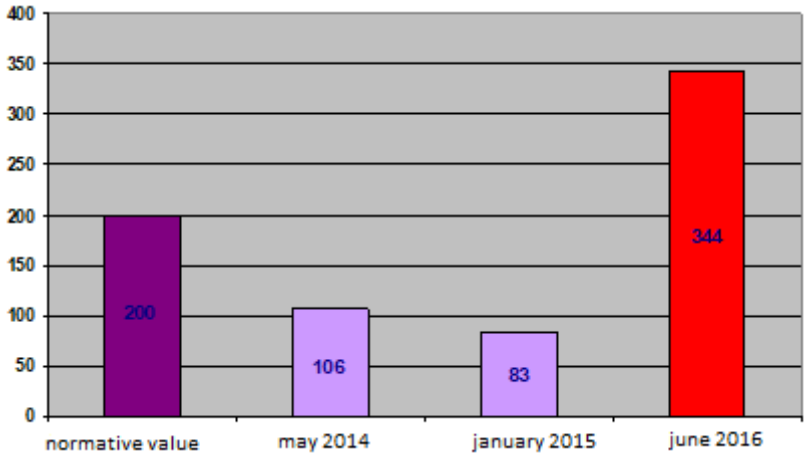

Fig. 10 Iron content [µg/l] in samples taken between May 2014 and June 2016 at the water intake point.

The questioned parameter of the water intake in Dąbrowice, was the high amount of manganese contained in the Jurassic spring. In May 2014 a slight exceedance of this standard of 52 µg/l was detected, but in June 2016 the manganese content increased to 121 µg/l. An exceedance of the allowable iron content was also detected in the 2016 sample. Other parameters were within the acceptable range.

WATER INTAKE POINT - BEDLNO - ORŁÓW

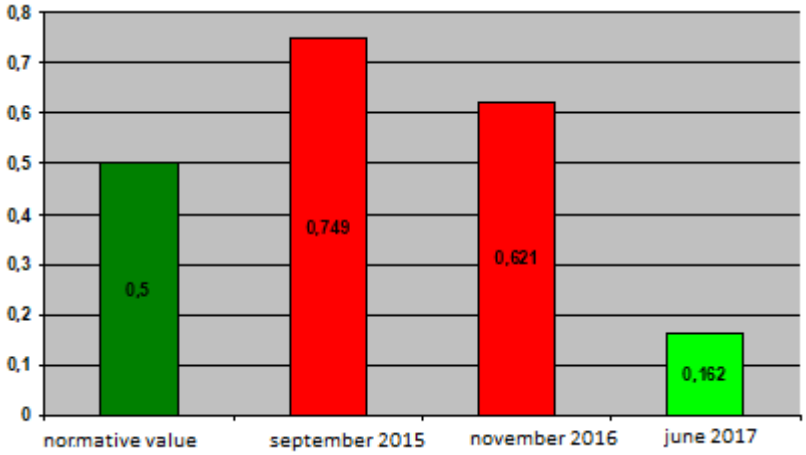

Fig. 11 Ammonium ion (ammonia) concentration [mg/l] at the water intake point, September 2015, June 2017.

In 2015 and 2016, the ammonium ion content exceeded the limit values, by 0.249 mg/l in September 2015 and by 121 mg/l in November 2016. The most recent test showed a reduction in the ammonia content to a value of 0.162 mg/l.

The manganese content in the sample increased sharply in the September 2015 sample and was 84 µg/l exceeding the permissible limit of 50 µg/l set by the drinking water standards.

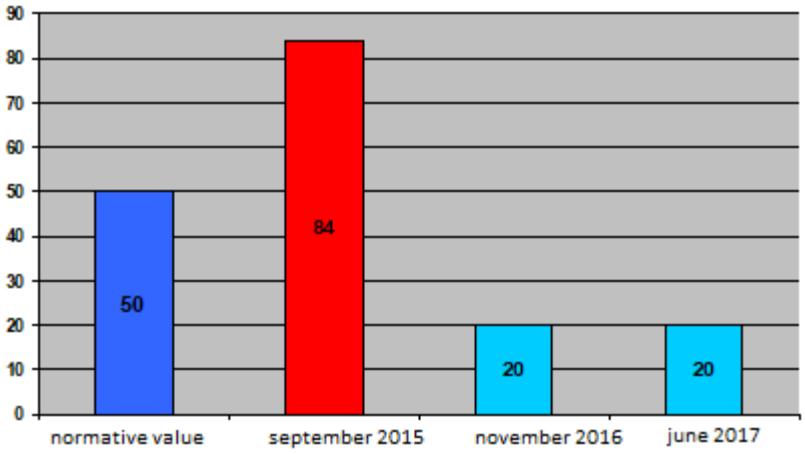

Fig. 12 Manganese content [µg/l] at the water intake point in September 2015, June 2017.

WATER INTAKE POINT - BEDLNO - PNIEWO

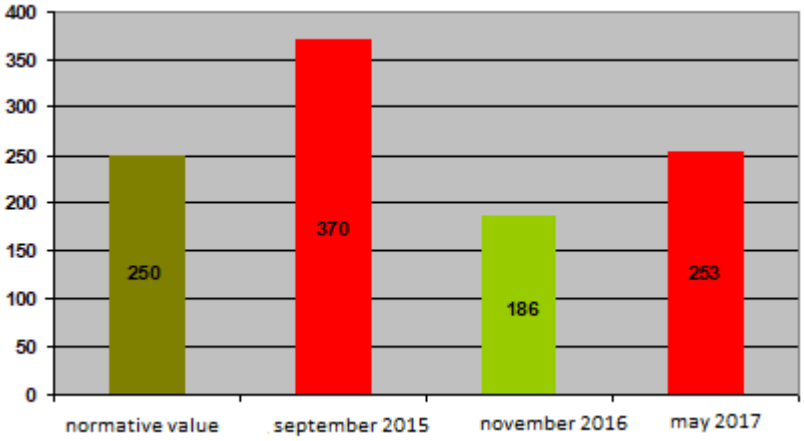

Fig. 13 Chloride concentration [mg/l] at the water intake point September 2015, May 2017.

In September 2015, a significant exceedance of chloride concentration was revealed at the water intake point Pniewo, Bedlno municipality, which was 48% higher than the permissible standard. In November 2016, the chloride content returned to normal, but was again slightly exceeded the following year. In May 2017 it was 253 mg/l compared to 250 mg/l allowed.

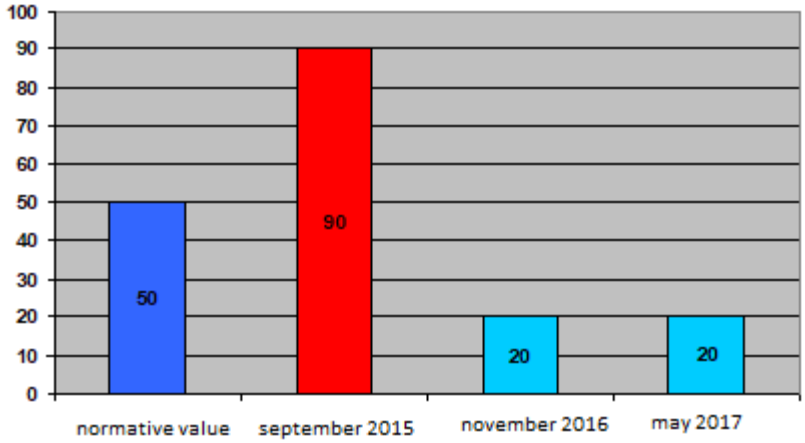

Fig. 14 Manganese concentration [µg/l] at the water intake point Pniewo - Bedlno commune, September 2015, May 2017.

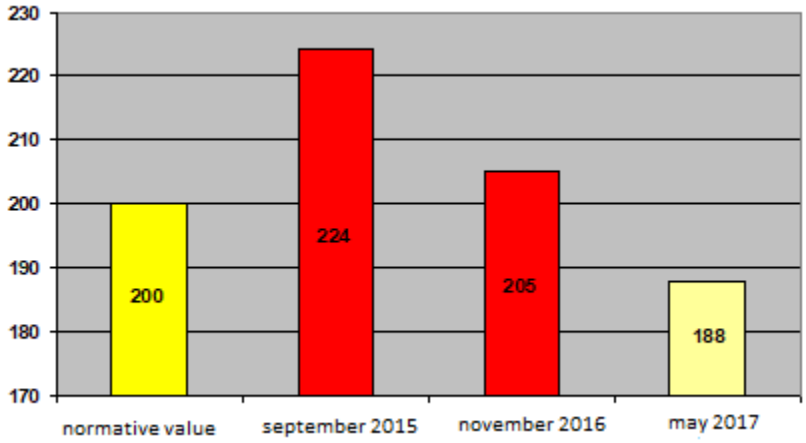

Fig. 15 Sodium concentration [mg/l] at the water intake point September 2015, May 2017.

An excess of manganese ions of 90 µg/l exceeding the permissible value of this element by 40 µg/l was also detected in the samples collected in 2015, this is shown in Figure 43. Sodium ions of 224 mg/l exceeding the prescribed standard by 12% appeared in the same samples. In 2016, the water sample did not show any exceedance of the permissible manganese standards and the concentration of sodium salts dropped to 2.5%.

Samples taken in May 2017 no longer contain any exceedances of the normative values.

WATER INTAKE POINT - BEDLNO - GŁUCHÓW

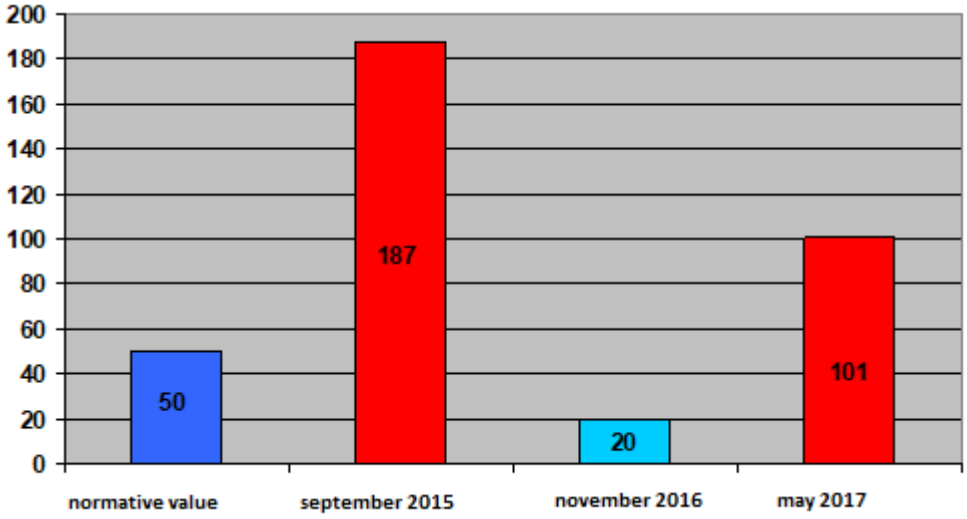

Fig. 16 Manganese concentration [µg/l] at the water intake point in the period September 2015 – May 2016.

The parameters of concern of the source located in Głuchów, Bedlno municipality, are the content of manganese and iron ions. Testing of water samples from September 2015 showed a very high content of manganese ions at 187 µg/l, where the standard stipulates only 50 µg/l. Also the iron ion standard was exceeded by 15 µg/l against the standard of 200 µg/l.

In 2016, manganese and iron ion contents were within the prescribed standard. Testing of the May 2017 samples again showed that the standards were exceeded. The amount of manganese ions was 101% higher than the standard, and iron increased slightly above the prescribed standard, only by 0.5%.

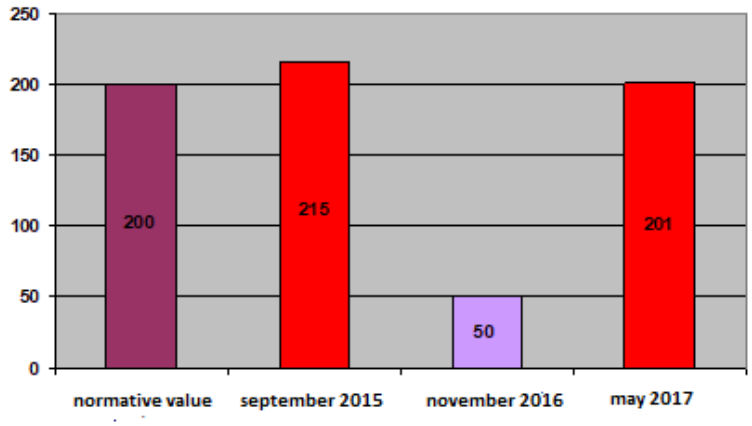

Fig. 17 Iron concentration [µg/l] at the sampling point during the period September 2015 – May 2016.

WATER INTAKE POINT — OPORÓW

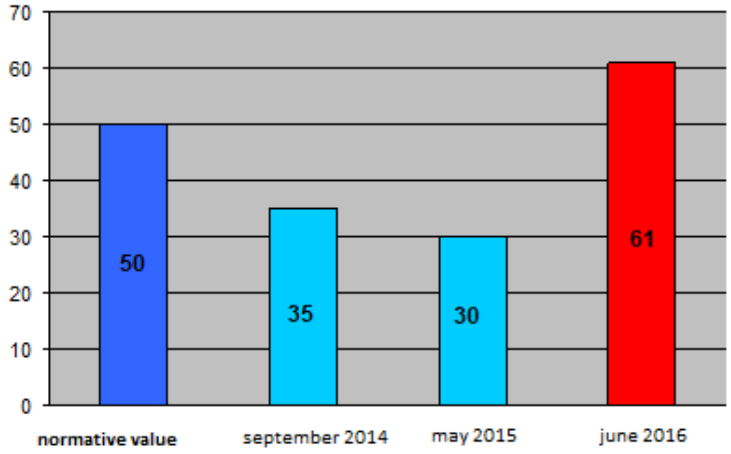

Fig. 18 Manganese content [µg/l] in samples taken between September 2014, and June 2016, at the water intake point.

Between 2014 and 2015, no exceedances of water quality standards were detected at the water intake point in Oporów. In June 2016 a manganese exceedance of 22% was recorded. The sample tested contained 61 µg/l of manganese.

WATER INTAKE POINT — OSTROWY – GROCHÓW

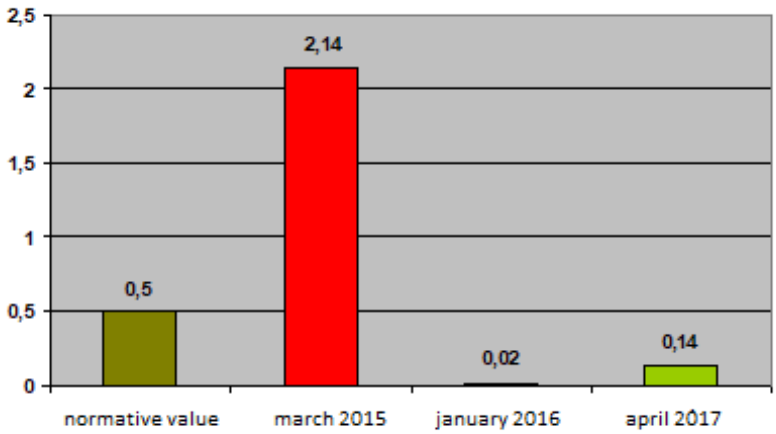

Fig. 19 Nitrite concentration[mg/l] at the water intake point, March 2015 - April 2017.

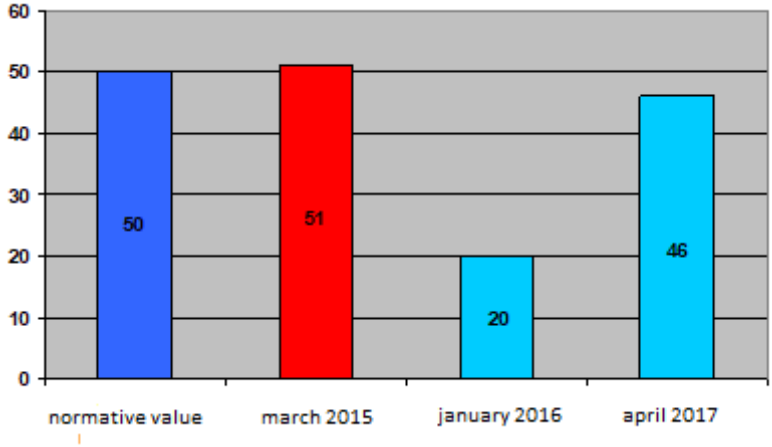

Fig. 20 Manganese concentration [µg/l] at the water intake point March 2015 – April 2017.

In March 2015, an elevated nitrite content was found in a water sample taken at the Grochów intake point, municipality of Nowe Ostrowy. The permissible value of 0.5 mg/l was exceeded by 328% and amounted to 2.14 mg/l. In the same sample the concentration of manganese was slightly exceeded – by 2% and amounted to 51 µg/l. The January 2016 survey of nitrite and manganese was within the normal range. The April 2017 survey also showed no anomalies.

WATER INTAKE POINT – OSTROWY – IMIELNO

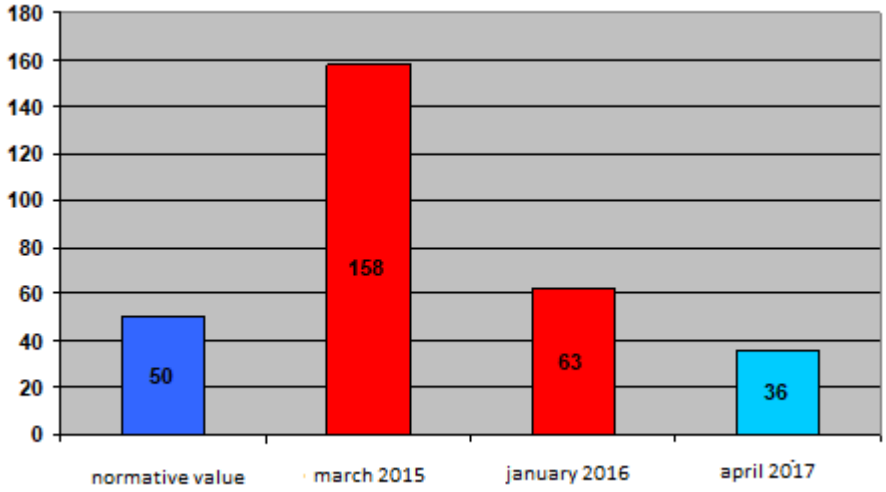

Fig. 21 Manganese concentration [µg/l] at the water intake point March 2015 – April 2017.

The testing of water in the village of Imielno, Nowe Ostrowy municipality in March 2015 and January 2016 showed that the permissible content of manganese in the intake was exceeded. In 2015 the manganese content was 216% higher and one year later it decreased and was only 26% of the permissible value. In April 2017 the manganese content was 36 µg/l which is a value after the lower normative value.

WATER INTAKE POINT — STRZELCE – MUCHNICE

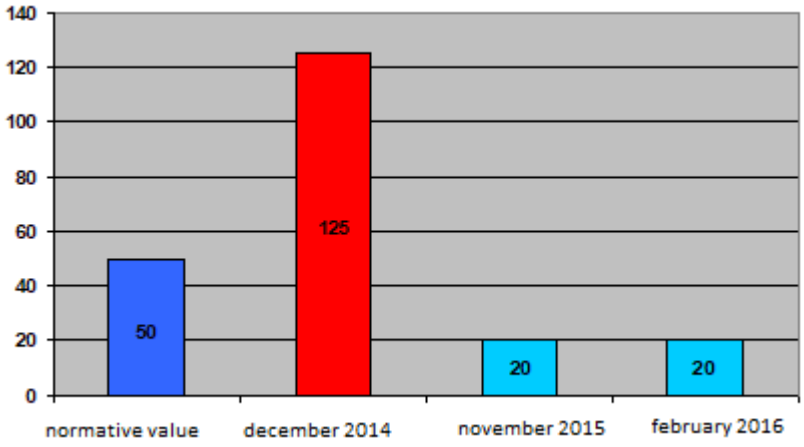

Fig. 22 Manganese concentration [µg/l] at the water intake point, December 2014, February 2016.

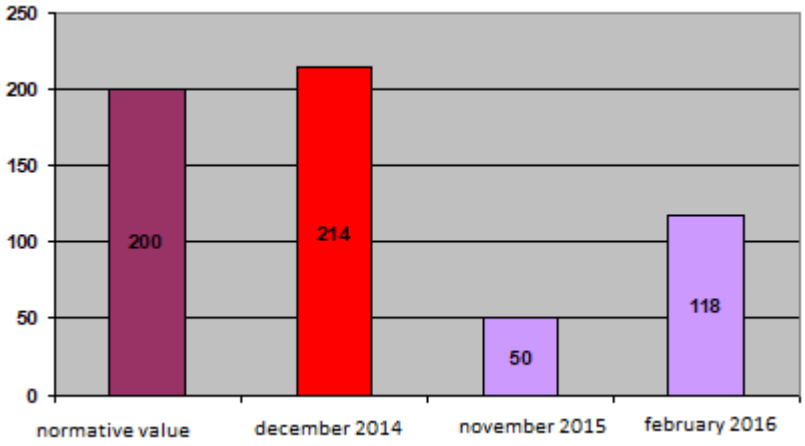

Fig. 23 Iron concentration [µg/l] at the water intake point December 2014, February 2016.

The only exceedance of the standards was detected in samples collected for testing in December 2014. The amount of manganese was 75 µg/l higher than the permitted value of 50 µg/l. Iron ions exceeded the limit of 200 µg/l that can be found in water permitted for consumption by 14 µg/l.

WATER INTAKE POINT — STRZELCE – KLONOWIEC

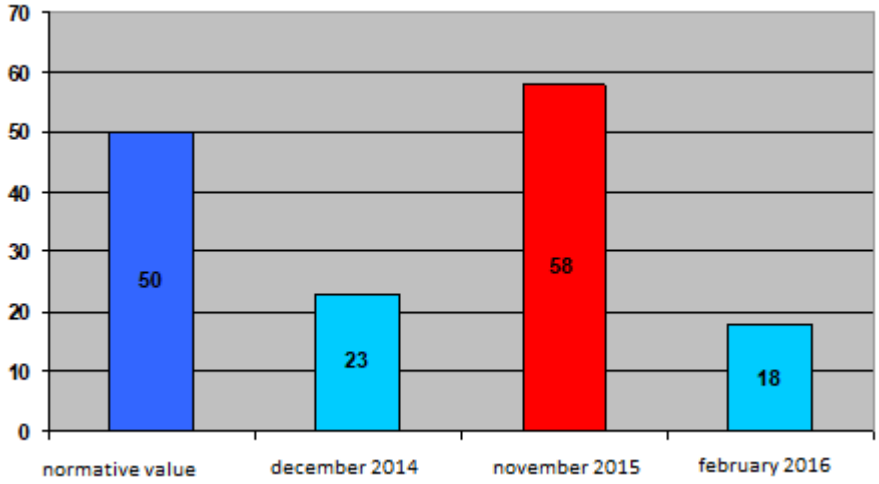

Fig. 24 Iron concentration [µg/l] at the water intake point, December 2014-February 2016.

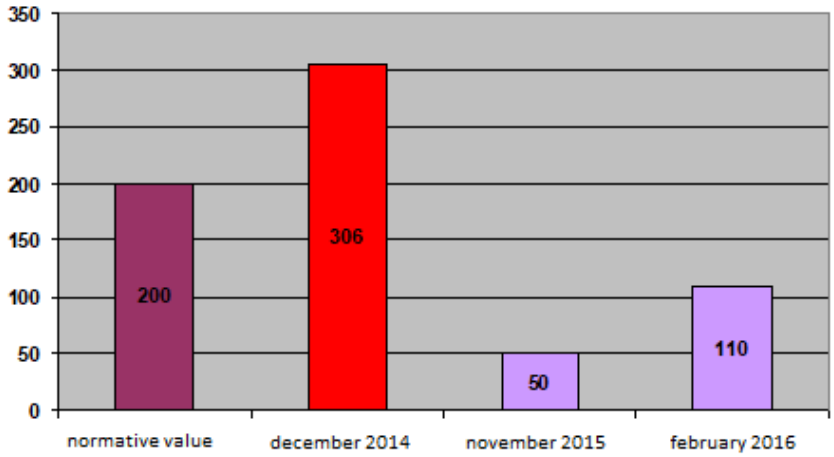

Fig. 25 Manganese concentration [µg/l] at the water intake point December 2014 – February 2016.

Among the questioned parameters at this intake point, which are colour, turbidity, ammonium ion, iron, manganese, the parameter of iron concentration was exceeded in 2014. The normative value of this parameter was exceeded by 53%. In November 2015, the iron concentration parameter was maintained within the norm. However, there was an exceedance of the manganese concentration parameter by 8 µg/l. In 2016, no exceedances of the parameters of water fit for consumption were found at the Klonowiec water intake point.

In the remaining water abstraction points during the study period, no exceedances of the reference values for the studied parameters were found.

DISCUSSION

All analysed water intake points extracted water from groundwater, which constitutes about 70% of water supply sources for the population of Kutno District.

Deep water resources come from the following strata:

- Jurassic,
- Miocene,
- Tertiary,
- Quaternary.

Tab. 1

Average, minimum and permissible values of water quality parameters.

Feature Parameter	$\bar{x}$	Variation coefficient (V) [%]	Min.	Max.	Normative value [mg/l].	Number of exceedances
pH	7,51	3	7,1	7,8	6,5÷9,5	- —
Ammonium ion	0,14	100	0,06	0,77	0,5	4
Nitrites (III)	0,07	373,4	0,02	2,14	0,5	1
Chlorides	41,29	148,5	7,0	370	250	2
Manganese	0,039	97,4	0,018	0,199	0,05	16
Iron	0,100	83,6	0,05	0,441	0,200	10
Sodium	32,76	139,2	10	224	200	2

Source: own elaboration.

Average minimum and maximum values of water quality parameters delivered by water supply systems of Kutno District are presented in Table 14.

The lowest variation was found in the pH value of V = 3%. The highest variation was found in the nitrite (III) content, which was V = 373% . The ammonium ion (V = 100%) chloride (V = 148.5%) and sodium (V = 139.2%) contents showed high variability. Within moderate variability was the occurrence of iron (V = 83.6%) and manganese (V = 97.4%).

Increased manganese was found in 16 cases and iron in 10 cases. Ammonium ion, chloride and sodium were found in two cases and increased nitrite was documented on one occasion.

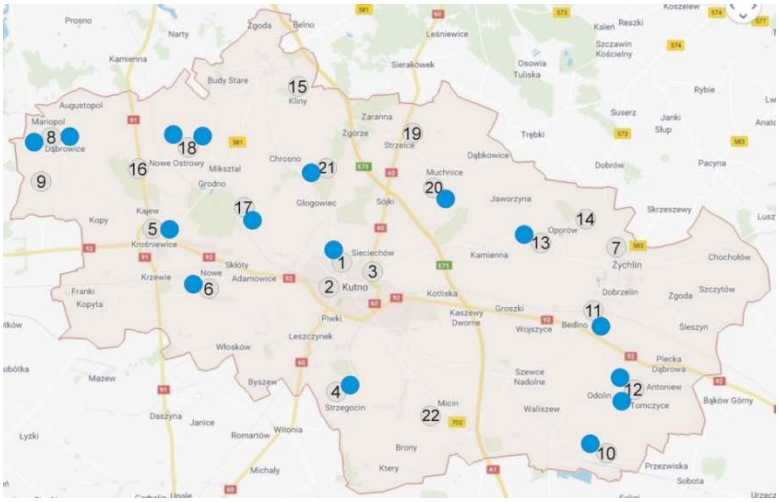

Fig. 26 Exceedences of manganese in Kutno district. Source: own elaboration.
1. Kutno, 2. Kutno – PKP, 3. Kutno – Żurawieniec, 4. Kutno – Strzegocin, 5. Krośniewice, 6. Krośniewice – Nowe, 7. Żychlin, 8. Dąbrowice, 9. Dąbrowice – Baby, 10. Bedlno – Orłów, 11. Bedlno – Pniewo, 12. Bedlno – Głuchów, 13. Oporów, 14. Oporów – Kurów, 15. Łanięta – Anielin, 16. Ostrowy, 17. Ostrowy – Grochów, 18. Ostrowy – Imielno, 19. Strzelce, 20. Strzelce – Muchnice, 21. Strzelce – Klonowiec, 22. Krzyżanów.

manganese (Mn)

Out of 22 controlled drinking water intakes of the Kutno district, exceedances of manganese contents were found in 13.

Tab. 1

Exceedances of manganese in the area of Kutno district in 2014-2017.

Station number (according to the map)	Town	Aquifer	Number of exceedances in the reference period				
			2014	2015	2016	2017	Total
1	Kutno	jurassic	—	—	—	1	1
4	Kutno - Strzegocin	tertiary	—	—	1	—	1
5	Krosniewice	tertiary	—	1	—	—	1
6	Krosniewice - New	tertiary	—	1	—	—	1
8	Dąbrowice	jurassic	1	—	1	—	2
10	Bedlno - Orłów	jurassic	—	1	—	—	1
11	Bedlno - Pniewo	jurassic	—	1	—	—	1
12	Bedlno - Głuchów	jurassic	—	1	—	1	2
13	Oporów	quaternary	—		1	—	1
17	Ostrowy - Grochów	quaternary	—	1	—	—	1
18	Ostrowy - Imielno	quaternary	—	1	1		2
20	Strzelce - Muchnice	quaternary	1	—	—	—	1
21	Strzelce - Maplewood	quaternary	—	1	—	—	1

Source: own elaboration.

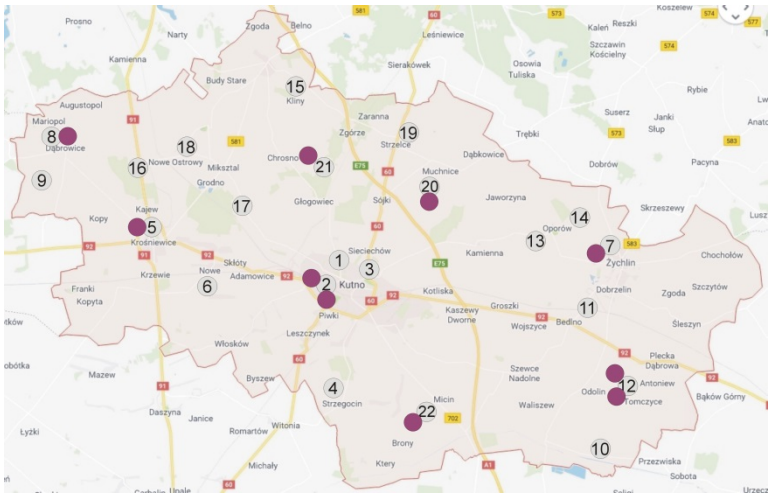

Fig. 27 Occurrence of iron exceedences in the area of Kutno district. Source: own elaboration.
1. Kutno, 2. Kutno – PKP, 3. Kutno – Żurawieniec, 4. Kutno – Strzegocin, 5. Krośniewice, 6. Krośniewice – Nowe, 7. Żychlin, 8. Dąbrowice, 9. Dąbrowice – Baby, 10. Bedlno – Orłów, 11. Bedlno – Pniewo, 12. Bedlno – Głuchów, 13. Oporów, 14. Oporów – Kurów, 15. Łanięta – Anielin, 16. Ostrowy, 17. Ostrowy – Grochów, 18. Ostrowy – Imielno, 19. Strzelce, 20. Strzelce – Muchnice, 21. Strzelce – Klonowiec, 22. Krzyżanów.

iron (Fe)

Out of 73 inspections carried out at 22 water abstraction points, 10 exceedances of iron standards were found at 8 water abstraction stations.

Tab. 3

Exceedances of iron on the territory of Kutno district in 2014-2017.

Station number (according to the map)	Town	Aquifer	Number of exceedances in the reference period				
			2014	2015	2016	2017	Total
2	Kutno - PKP	jurassic	1	1	—	—	2
5	Krosniewice	tertiary	—	1	—	—	1
7	Żychlin	tertiary	—	—	—	1	1
8	Dąbrowice	jurassic	—	—	1	—	1
12	Bedlno - Głuchów	jurassic	—	1	—	1	2
20	Strzelce - Muchnice	quaternary	1	—	—	—	1
21	Strzelce - Maplewood	quaternary	1	—	—	—	1
22	Krzyżanów	quaternary	—	—	—	1	1

Source: own elaboration.

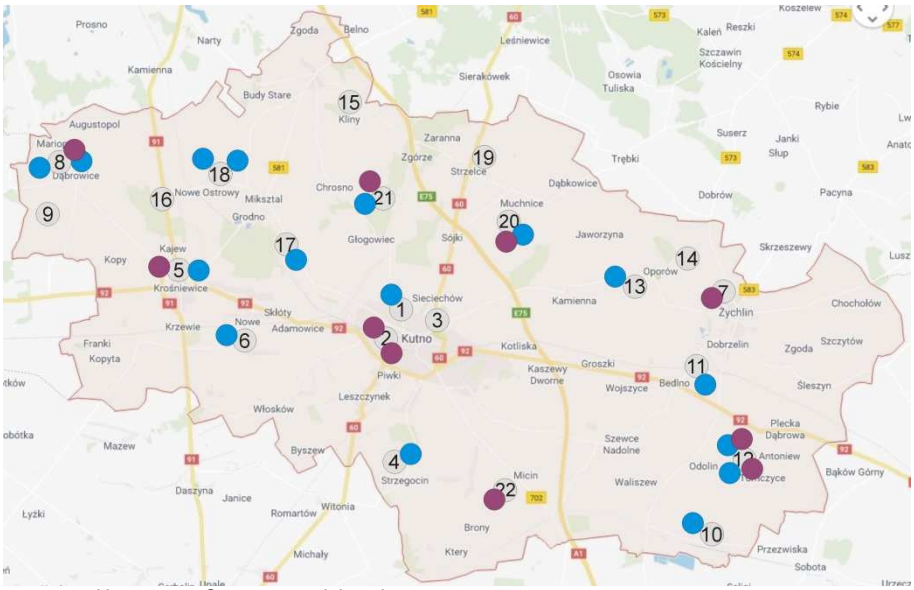

Fig. 28 Exceedances of manganese and iron norms. Source: own elaboration.
1. Kutno, 2. Kutno – PKP, 3. Kutno – Żurawieniec, 4. Kutno – Strzegocin, 5. Krośniewice, 6. Krośniewice – Nowe, 7. Żychlin, 8. Dąbrowice, 9. Dąbrowice – Baby, 10. Bedlno – Orłów, 11. Bedlno – Pniewo, 12. Bedlno – Głuchów, 13. Oporów, 14. Oporów – Kurów, 15. Łanięta – Anielin, 16. Ostrowy, 17. Ostrowy – Grochów, 18. Ostrowy – Imielno, 19. Strzelce, 20. Strzelce – Muchnice, 21. Strzelce – Klonowiec, 22. Krzyżanów.

manganese (Mn)

iron (Fe)

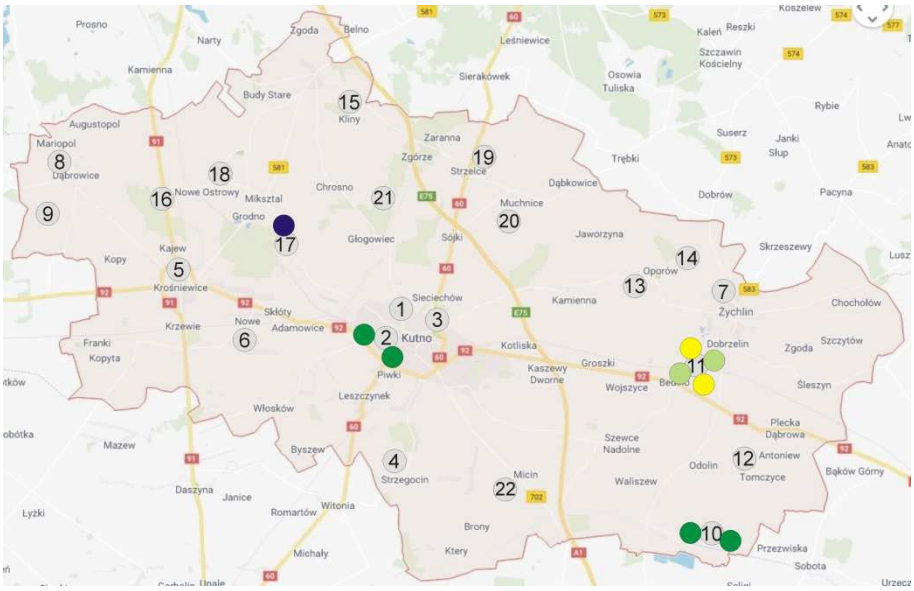

Fig. 29 Occurrence of exceedences of ammonium ion, chlorides, sodium and nitrites in the Kutno district. Source: own elaboration.
1. Kutno, 2. Kutno – PKP, 3. Kutno – Żurawieniec, 4. Kutno – Strzegocin, 5. Krośniewice, 6. Krośniewice – Nowe, 7. Żychlin, 8. Dąbrowice, 9. Dąbrowice – Baby, 10. Bedlno – Orłów, 11. Bedlno – Pniewo, 12. Bedlno – Głuchów, 13. Oporów, 14. Oporów – Kurów, 15. Łanięta – Anielin, 16. Ostrowy, 17. Ostrowy – Grochów, 18. Ostrowy – Imielno, 19. Strzelce, 20. Strzelce – Muchnice, 21. Strzelce – Klonowiec, 22. Krzyżanów.

ammonium ion (NH4+)

chlorides (Cl-)

sodium (Na+)

nitrites (NO2-)

Tab. 4

Exceedences of ammonium ion, chlorides, sodium and nitrites in Kutno district in 2014-2017.

Station number (according to the map)	Town	Aquifer	Number of exceedances in the reference period				
			2014	2015	2016	2017	Total
2	Kutno - PKP	jurassic	1	1	—	—	2
10	Bedlno - Orłów	jurassic	—	1	1	—	2
11	Bedlno - Pniewo	jurassic	—	2	1	1	4
17	Ostrowy - Grochów	quaternary	—	1	—	—	1

Source: own elaboration.

Nitrogen compounds occur mostly in the form of ammonium ions NH_4+, nitrite ions NO_2- and nitrate ions NO_3-. Larger quantities, of the order of a few or several mg/dm3, are found in some shallow waters which can be reached from surface pollution sources. The decomposition of proteinaceous substances results in the formation of ammonia (in faecal and industrial effluents, gasworks, coking plants, chemical factories) in cooperation with putrefactive bacteria. The ammonia is oxidised by nitrifying bacteria to nitrite, which is then converted to nitrate. The mutual ratio of ammonia, nitrite and nitrate is therefore an important indicator of its pollution. Ammonia or the ammonium ion NH_4+ of deep waters accompanies natural gas and oil deposits and can therefore be a valuable hydrogeochemical indicator in oil exploration [2]. The presence of ammonia in shallow water indicates a fresh source of pollution, while the simultaneous presence of ammonia, nitrite and nitrate indicates that the water has been polluted for a long time. Under anaerobic conditions, nitrates and nitrites are reduced to the gaseous form N2 with the participation of denitrifying bacteria [2].

The occurrence of ammonium ion in the water intakes of Kutno-PKP and Bedlno-Orłów in 2014÷2016 may have been caused by an environmental disaster. At the beginning of 2014, there was a failure of the sewage treatment plant in Kutno, which resulted in the ingress of large quantities of untreated organic waste. This waste water was the reason for the disappearance of biological life in the rivers Ochnia and Bzura. The Kutno-PKP water intake point is located near the Ochnia riverbed. Exceeding of ammonium ion standards occurred in this intake shortly after contamination. The examination of the state of water in the Bedlno-Orłów point in the following year also showed exceedence of the ammonium ion indicator. The return of the ecosystem of the Ochnia and Bzura rivers to normal in 2016 resulted in the disappearance of the occurrence of exceedances of the ammonium ion in the drinking water intakes Kutno-PKP and Bedlno-Orłów.

The occurrence of a significant increase in nitrites in the Ostrowy-Grochów water intake in March 2015 was also most likely a consequence of the failure of the treatment plant in Kutno. The Głogowianka River, which has its sources near Grochów and is a tributary of the Ochnia River, which was a source of organic waste contamination during this period.

The chloride ion is one of the most common, accompanying the sodium and potassium ions and causing the salinity of water. It negatively influences the taste and smell of water. In drinking water, the content of chloride ion must not exceed 250 mg $Cl-/dm^3$, the presence of free chlorine is allowed only if the water is chlorinated at 0.3-0.5 mg $Cl2/dm^3$ [3].

The occurrence of increased amounts of sodium and chloride ion in the Bedlno-Pniewo water intake in 2015÷2017 may have been caused by the storage in this area of large amounts of road salt improperly protected against weather conditions. Currently, work is being carried out on a new borehole for the Water Intake Station in Bedlno-Pniewo.

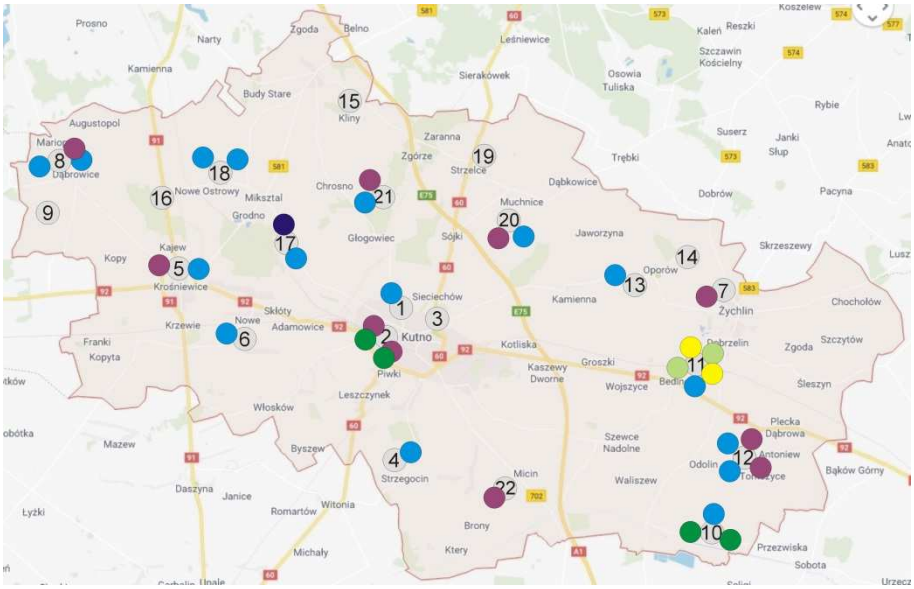

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Fig. 30 Location of all exceedances in the Kutno district. Source: own elaboration.
1. Kutno, 2. Kutno – PKP, 3. Kutno – Żurawieniec, 4. Kutno – Strzegocin, 5. Krośniewice, 6. Krośniewice – Nowe, 7. Żychlin, 8. Dąbrowice, 9. Dąbrowice – Baby, 10. Bedlno – Orłów, 11. Bedlno – Pniewo, 12. Bedlno – Głuchów, 13. Oporów, 14. Oporów – Kurów, 15. Łanięta – Anielin, 16. Ostrowy, 17. Ostrowy – Grochów, 18. Ostrowy – Imielno, 19. Strzelce, 20. Strzelce – Muchnice, 21. Strzelce – Klonowiec, 22. Krzyżanów.

- manganese (Mn)
- iron (Fe)
- ammonium ion (NH4+)
- chlorides (Cl-)
- sodium (Na+)
- nitrites (NO2-)

CONCLUSIONS

- Drinking water resources for the city of Kutno and the Kutno district are sufficient in relation to demand, have large underground water resources – deep water, and are chemically safe.
- The water for supply to the population met all the qualitative and quantitative requirements for the abundance of heterotrophic, psychrophilic and mesophilic bacteria contained in the Ordinance of the Minister of Health.
- Comparing the results of physicochemical studies from 2014÷2017, it can be concluded that the quality of groundwater in the Kutno district remains unchanged. The differences that occur are small and may be due to factors such as variation in the period of sampling (dependence on the time of year when samples are taken).
- Temporal exceedances of certain parameters do not alter the constancy of the composition of these waters.
- There are water intakes in the Kutno district which in the analysed period did not show any exceedance of the normative standards.

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1. J. Kowalski: Hydrology with fundamentals of geology, 3rd edition corrected and completed, Publishing House of the University of Life Sciences in Wrocław, Wrocław 2007, p. 116;
2. Ibidem, p. 116;
3. J. Kowalski: Hydrology with fundamentals of geology, 3rd edition corrected and completed, Publishing House of the University of Life Sciences in Wrocław, Wrocław 2007, p. 117.

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