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SANITARY EVALUATION OF THE WATER FROM WATER INTAKE POINTS SITUATED IN GORZOW WIELKOPOLSKI AND NEIGHBOURING LOCALITIES

OCENA SANITARNA WODY POCHODZĄCEJ Z UJĘĆ WODNYCH NA TERENIE GORZOWA WIELKOPOLSKIEGO ORAZ OKOLIC

Abstract: Water is an essential component necessary for sustaining life. Nevertheless, it may pose a serious threat to human life resulting from possible occurrence of pathogenic and potentially pathogenic microorganisms. Therefore, monitoring and continuous microbial surveillance of the water intended for consumption is extremely important. The requirements referring to qualitative parameters which should be met by water are set out in the Regulation of the Minister of Health of 29 March 2007, as amended on 20 April 2010, and the EU directives. The quality of water being supplied to consumers depends on many factors, among other on the type of water intake (surface water or groundwater), efficiency of water treatment and disinfection, and technical condition of the water supply network.

The analysis of the sanitary condition of drinking water has been conducted from water intakes in the city of Gorzow Wielkopolski, *ie* Centralny Kosynierow Gdynskich intake, Klodawa intake and Siedlice intake, and in neighbouring localities, *ie* Maszewo and Marwice. The research material was raw and treated water samples. The population size of *Faecal streptococci*, coliform bacteria, including *E. coli*, and total mesophilic and psychrophilic bacteria counts was determined. The analysis of the sanitary condition of drinking water has been conducted.

The number of coliform bacteria, including *E. coli*, and streptococci was determined by the method of membrane filters, whereas total mesophilic and psychrophilic bacteria counts using the plate method under incubation conditions conforming to the standards.

The presence of mesophilic and psychrophilic bacteria was observed in all examined water intake points. Differences in their counts over the whole year being significant. In three research points, *ie* Centralny Kosynierow Gdynskich intake, Maszewo intake and Marwice intake, psychrophilic bacteria count was exceeded ($100 \text{ CFU} \cdot \text{cm}^{-3}$). In the case of pathogenic bacteria, their occurrence was occasionally observed in the drinking water intake points. The water treatment processes applied and, as the final result, water sanitary assessment according to the existing standards and the provision stipulated allow it to be collected for consumption purposes and do not pose the threat to human health and life.

Keywords: drinking water, bacteria, *E. coli*, *E. faecalis*, water contamination

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Introduction

Seas and oceans cover about 75 % of the Earth's surface. The volume of this water is estimated at about $2 \cdot 10^{18} \text{ m}^3$, of which the most is saltwater, while barely 0.025 %, *ie* $500\,000 \text{ km}^3$ is freshwater. This is the freshwater to which surface water and ground water, being a reservoir of drinking water, are classified [1]. Excessive and non-scientific chemicalisation in agriculture, illegal and uncontrolled domestic and industrial wastewater discharge, landfill leachate or discharge of slurry and liquid excrement in the close vicinity of water intake protection zone are not indifferent to the quality of water. These different manifestations of human activity lead both to anthropogenic and microbial contamination. Pathogenic and potentially pathogenic microbes are being introduced into water bodies [2–4]. These micro-organisms may then pass over into water supply network, also with treated water (water disinfection at water treatment plant not effective enough) as a result of fault or mechanical damage during operation, or from soil pollution during water supply network repair works [5–6]. Water supply network creates good conditions for their development and survival. Organic and inorganic compounds contained in the water from water intake, pipeline corrosion products as well as biofilm and internal pipeline sediments, being a habitat for microbial biomass, constitute nutrients for them [7–8]. Therefore, the application of effective water purification processes and the use of chemical reagents, as well as the preservation of adequate technical condition of water supply network, is so important to ensure clean and safe water, not threatening consumer's health or life [9–11].

The water intended for consumption has to meet requirements being set to it at water intake point by consumers. For this reason, permanent residents of human and animal intestinal flora, *ie* coliform bacteria (*Escherichia coli*), *Faecal streptococci* (with a typical species *Enterococcus faecalis*) and *Clostridium perfringens*, are considered useful sanitary indicators for drinking water quality control [12–14]. According to the standards the presence of these biological indicators should not be proven per each sampled 100 cm^3 of water [15–16]. The water intended for human consumption is also analysed in terms of the total number of bacteria being present in it, *ie* psychrophilic and mesophilic bacteria. Psychrophiles include heterotrophic bacteria which are adapted to live in cold environment. Their optimum temperature does not exceed $15 \text{ }^\circ\text{C}$, whereas the maximum one $20 \text{ }^\circ\text{C}$. The occurrence of psychrophilic bacteria in tap water is evidence of the presence of nutrients and allows assessment of the efficiency of water treatment processes (coagulation, filtration and disinfection) [17–18]. Mesophiles comprise the bacteria developing at moderate temperature, the optimum of which is in the range of $25\text{--}40 \text{ }^\circ\text{C}$. They include pathogenic bacteria, the thermal optimum of which is a temperature of human body. The presence of mesophilic bacteria in water is indication of its pollution with wastewater and, consequently, of the possibility of water contamination with pathogenic bacteria, too [19].

The objective of this study was to analyse and assess bacteriologically the freshwater and treated water collected from water intakes in the city of Gorzow Wielkopolski and neighbouring localities.

Material and methods

The object of microbiological analysis was the samples of freshwater and treated water collected from the groundwater intakes supplying the city of Gorzow Wielkopolski, *ie* Centralny Kosynierow Gdynskich intake, Siedlice intake and Klodawa intake. These water intakes and the water supply network are operated by Przedsiębiorstwo Wodociągów i Kanalizacji (Water and Sewage Service Co. Ltd) in the aforesaid city. The Centralny Kosynierow Gdynskich intake is the oldest and the only water intake situated entirely in the city and supplies water to about 15 % of the city. The Siedlice intake is situated along the left side of the Warta River and supplies water to about 59 % of the city. The Klodawa intake is located about 5 km to the north of the centre of Gorzow Wlkp., outside the city limits. It supplies water to about 26 % of the city [20]. The research material came also from neighbouring localities. *ie* Maszewo and Marwice. Maszewo is a rural borough situated in the western part of the Lubuskie Province, whereas Marwice is a village situated about 10 km to the north-west of Gorzow Wielkopolski. At all waterworks there are water purification plants where the water undergoes aeration, filtration and disinfection. In the Central Waterworks and Siedlice Waterworks the aeration takes place with the use of open systems at aeration towers and then the water flows through open high-rate filters. In Klodawa Waterworks, Maszewo Waterworks and Marwice Waterworks the aeration takes place in a closed pressure aerator and then the water flows through closed pressure high-rate filters. Both closed and open filters are filled with high-silica sand. After the filtration the water is subject to disinfection: in Central Waterworks, Siedlice Waterworks and Klodawa Waterworks they apply chlorine dioxide manufactured from hydrochloric acid and chlorite directly at the water purification plant. In Marwice Waterworks and Maszewo Waterworks sodium hypochlorite is used.

The collection of water samples for analyses was conducted from January to December 2012, several times depending on the research point. Freshwater samples from three water intakes, *ie* Centralny Kosynierow Gdynskich intake, Siedlice intake and Klodawa intake, were collected three times a month, whereas those of treated water five a week. Freshwater samples from two water intakes, *ie* Maszewo intake and Marwice intake, were collected two times a month, whereas those of treated water, on average, four times a month.

The number of coliform bacteria, including *E. coli*, was determined on Endo Les medium (Merck & Co., Inc.), using the method of membrane filtration. Water samples, 100 cm³ each, were filtered through paper discs, with pore size of 47 µm, and then incubated at 36 °C for 24 h [16]. *Faecal streptococci* were determined on Slanetz-Bartley medium (Merck & Co., Inc.), also using the method of membrane filtration. Water samples, 100 cm³ each, were filtered through paper discs with pore size of 47 µm, which were then incubated at 36 °C for 24–48 h [15]. Total bacterial count was determined on nutrient agar medium (Merck & Co., Inc.) by the plate method. Water samples, 1 cm³ each, were transferred onto Petri dishes and flooded with liquid agar medium. After the agar hardened, Petri dishes were incubated at 36 °C for 48 h (mesophilic bacteria) and at 22 °C for 72 h (psychrophilic bacteria). After incubation,

bacterial colonies that developed on Petri dishes were counted. The readings were converted to colony forming units per a specific water unit [19].

The research results were analysed statistically using Statistica 10.0 software package. The variance analysis (ANOVA) with the use of Duncan's test has been conducted.

Results and discussion

The research results showed the presence of psychrophilic and mesophilic bacteria in the treated water being collected from water intake points under examination. The highest average annual number of psychrophiles, $61 \text{ CFU} \cdot \text{cm}^{-3}$, was found in the Centralny Kosynierow Gdyskich intake (Fig. 1). In this water intake point, an increase in the number of these bacteria was recorded in spring and summer when it exceeded the standard limit value, *ie* $100 \text{ CFU} \cdot \text{cm}^{-3}$. In autumn and winter seasons the increased values of this type of bacteria have not been observed. Relatively high number of psychrophilic bacteria in water was also observed in the Maszewo intake, where in autumn their acceptable number has been exceeded (Fig. 4). Relatively high number of psychrophilic bacteria in water was also observed in the Maszewo intake, where The least average annual number of the bacteria mentioned above was recorded in the Klodawa, Siedlice and Marwice intakes, where they numbers were similar. In case of the test points mentioned above, the quantity of psychrophiles was not exceeded (Fig. 2, 3, 5). The analysis of variance performed showed significant differences in the number of psychrophilic bacteria between respective water intake points. Significant difference number of psychrophilic bacteria in the Centralny Kosynierow Gdyskich intake than in other water intake points being examined may result from the technical condition of water supply network, connections and water system. The Centralny Kosynierow Gdyskich water intake point is the oldest one in Gorzow Wielkopolski, where old

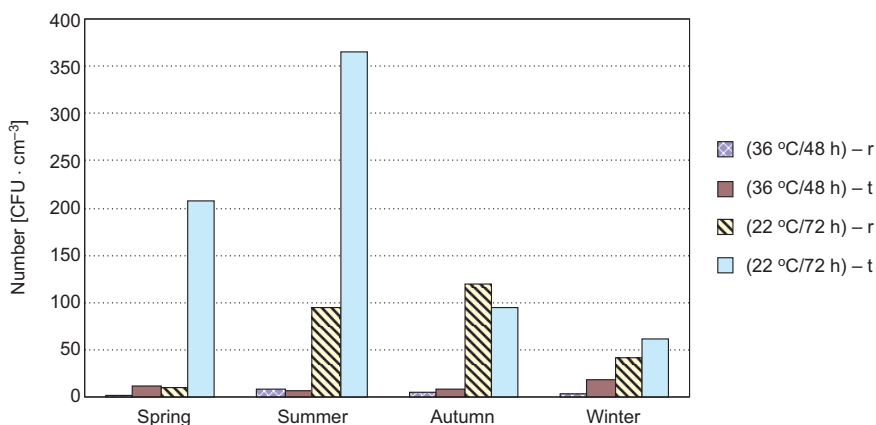


Fig. 1. The number of bacteria in the raw and treated water sampled from the Centralny Kosynierow Gdyskich water intake depending on the season of the year; incubated at $36 \text{ }^{\circ}\text{C}$ for 48 h – mesophilic bacteria, incubated at $22 \text{ }^{\circ}\text{C}$ for 72 h – psychrophilic bacteria; r – raw water, t – treated water

water systems continue to be operated. Multi-annual operation of the water supply network and water system, made of steel and cast-iron elements, could induce deposition of chemical and biological sediments on the internal surfaces of pipelines. Higher number of psychrophilic bacteria in the spring and summer season in the water intake being discussed above than the values being observed in other months may be evidence of not very effective disinfection at water treatment plant, as well as of a higher temperature creating better conditions for their development, which is also confirmed by Libudzisz and Kowal [17]. It can be assumed that the spring and summer season, when higher temperatures occur, also affected an increase in the temperature of water in water supply network, which, as a consequence, induced a lower efficiency of

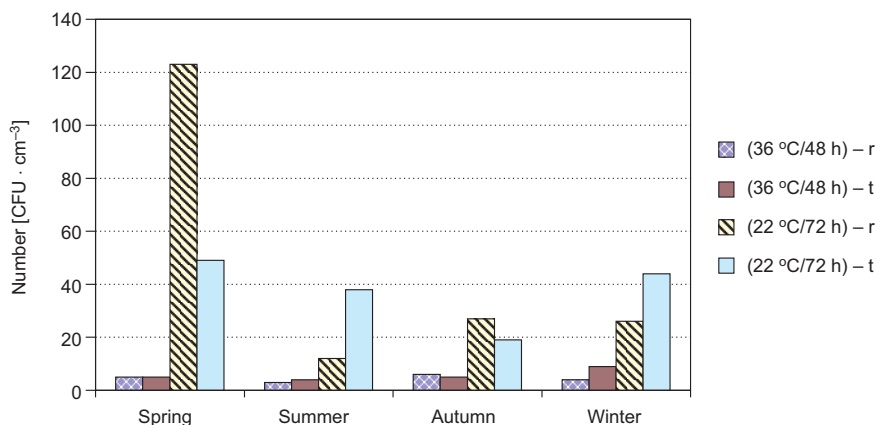


Fig. 2. The number of bacteria in the raw and treated water sampled from the Klodawa water intake depending on the season of the year; incubated at 36 °C for 48 h – mesophilic bacteria, incubated at 22 °C for 72 h – psychrophilic bacteria; r – raw water, t – treated water

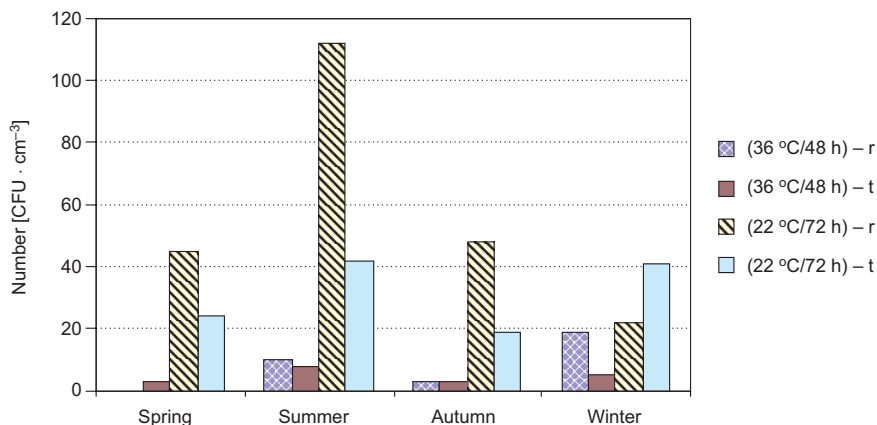


Fig. 3. The number of bacteria in the raw and treated water sampled from the Siedlice water intake depending on the season of the year; incubated at 36 °C for 48 h – mesophilic bacteria, incubated at 22 °C for 72 h – psychrophilic bacteria; r – raw water, t – treated water

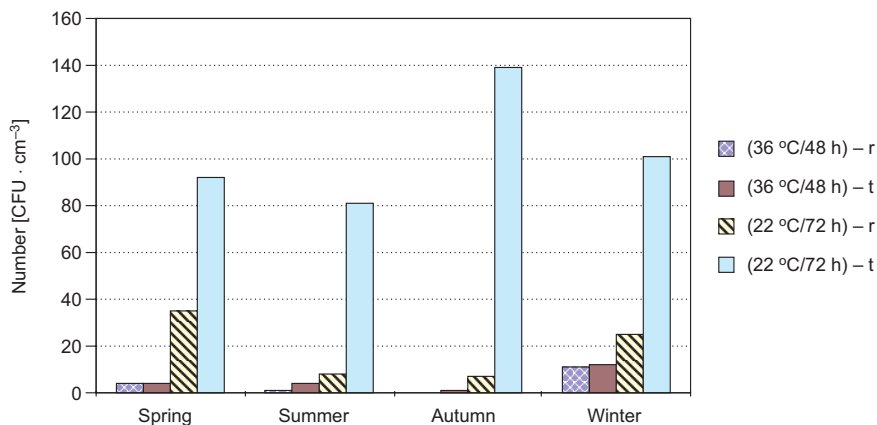


Fig. 4. The number of bacteria in the raw and treated water sampled from the Maszewo water intake depending on the season of the year; incubated at 36 °C for 48 h – mesophilic bacteria, incubated at 22 °C for 72 h – psychrophilic bacteria; r – raw water, t – treated water

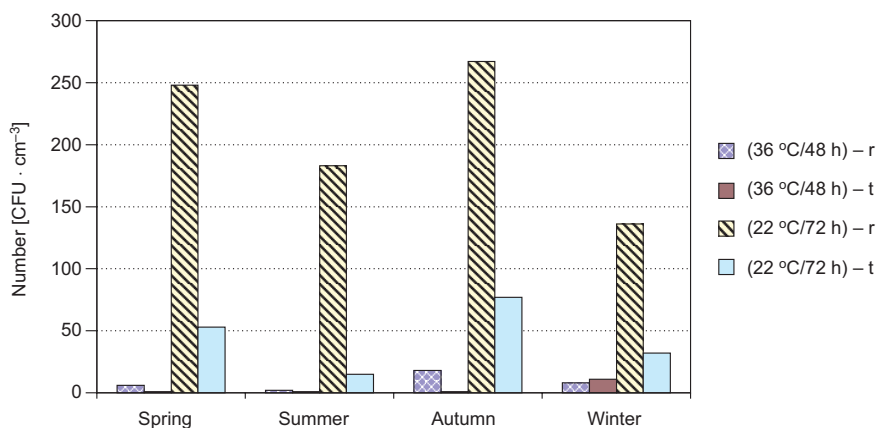


Fig. 5. The number of bacteria in the raw and treated water sampled from the Marwice water intake depending on the season of the year; incubated at 36 °C for 48 h – mesophilic bacteria, incubated at 22 °C for 72 h – psychrophilic bacteria; r – raw water, t – treated water

disinfectants and caused development of bacteria. Cycon and Wiera [21] report that this is summer and early autumn months when normal values for development of micro-organisms in water are exceeded the most, which is induced by more favourable conditions for their growth and development.

The number of mesophilic bacteria in treated water was within normal limits, irrespective of the water intake point being examined, and differences between them were not significant. In all water intake points under examination, the allowable number of these bacteria, *ie* 50 CFU · cm⁻³, was not exceeded.

The water purification being performed at the water treatment plants of this waterworks did not ensure complete elimination of psychrophilic and mesophilic

bacteria, as suggested by their presence in tap water. This is in agreement with the study by Zacheus et al [22], who showed that biofilm developed on polyvinyl chloride, polyethylene and stainless steel within three weeks, despite water purification by coagulation, sedimentation, filtration on sand filters and ozonisation. Although psychrophilic bacteria were found to be present in the treated water collected from all water intake points being examined, it is possible to state that they are not a threat to the health of consumers. Grabinska-Loniewska and Sinski [5] report that psychrophilic bacteria are generally considered harmless to humans. Similarly, Smylla [24] reports that psychrophiles do not seriously endanger water consumers because they do not develop at human body temperature, as is the case of mesophilic bacteria.

Because freshwater samples for analyses were collected from the test points with different frequency, *ie* 3 times a month in the Centralny Kosynierow Gdynskich, Klodawa and Siedlice intakes and 2 times a month in the Maszewo and Marwice intakes, this did not allow its quality to be clearly assessed and compared bacteriologically. It is only possible to suppose that, from among the water intake points being examined, low quality of freshwater was observed in the Marwice intake. In this water intake point, the number of psychrophilic bacteria was exceeded three times. Their quantity in water throughout the whole year as higher than in other test points (Fig. 5). This might have resulted from the application of natural fertilizers in the direct neighborhood of the water intake because this area is typically agricultural one. Also poorly developed sewerage network, or even its lack in some parts of the village, could have a significant effect. The process of water treatment applied contributed to a significant improvement of the quality of drinking water.

Indicator bacteria in water were found occasionally. At some water intakes single units of the bacteria have been observed (Table 1).

Table 1

Presence of indicator bacteria in the water collected in test points (100 cm³)
in the city of Gorzow Wlkp. and around it

Location of sampling points	Sampling period	Coliform bacteria, including <i>E. coli</i>	<i>Faecal streptococci</i>
Centralny Kosynierow Gdynskich Waterworks	June August	+	+
Kłodawa Waterworks	July September	+	
Siedlice Waterworks	January August	+	+
Maszewo Waterworks	July August	+	+

“+” – single bacterial units

According to the standards, however, the presence of coliform bacteria in such a quantity within one year did not endanger the human health and was acceptable. The regulations allow the occurrence of single *coli* bacteria in test samples provided that they are not observed in the succeeding test [24–25]. Szumilas et al [26] confirm that

a substantial quantity of indicator and pathogenic bacteria is eliminated during water purification processes, in which the extent of their reduction exceeds 99 %.

Conclusions

1. The research results showed the presence of psychrophilic and mesophilic bacteria in the treated water being collected from water intake points under examination. Their quantity was within the normal values throughout the whole year, despite being occasionally exceeded.

2. The highest number of psychrophilic bacteria in treated water was recorded in the Centralny Kosynierow Gdynskich intake, where allowable quantities for these bacteria were exceeded three times.

3. Pathogenic bacteria were rarely observed in the water being examined.

4. Most often, water disinfection process showed effective elimination of bacteria at the water treatment station being part of the waterworks under examination. However, the processes being applied at some water intake points did not have a 100 % effect in the elimination of micro-organisms from water.

5. The best water quality in sanitary respect after water treatment was observed in the water intake points in Siedlice, Klodawa and Marwice. A slight deterioration of the water quality is associated with the greater presence of micro-organisms being observed in two test points, *ie* Maszewo intake and Centralny Kosynierow Gdynskich intake.

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Abstrakt: Woda jest podstawowym składnikiem niezbędnym do utrzymania życia. Jednakże, może ona stworzyć poważne zagrożenie dla zdrowia człowieka wynikające z możliwości wystąpienia mikroorganizmów chorobotwórczych i potencjalnie chorobotwórczych. W związku z tym, niezwykle istotna jest kontrola oraz stały nadzór mikrobiologiczny nad wodą przeznaczoną do spożycia. Wytyczne co do parametrów jakościowych, jakim powinna odpowiadać, zawarte są w Rozporządzeniu Ministra Zdrowia z dnia 29 marca 2007 r. wraz ze zmianą z dnia 20 kwietnia 2010 r. oraz Dyrektywach Unii Europejskiej. Jakość wody dostarczanej konsumentom zależy od wielu czynników m.in.: rodzaju ujęcia (woda powierzchniowa lub podziemna), skuteczności procesów uzdatniania i dezynfekcji oraz stanu technicznego sieci wodociągowej.

Przeprowadzono analizę stanu sanitarnego wody pitnej pochodzącej z ujęć wodnych zaopatrujących miasto Gorzów Wielkopolski, tj. ujęcie Centralne Kosynierów Gdyńskich, Kłodawa, Siedlice oraz sąsiadujące miejscowości, tj. Maszewo i Marwice.

Materiałem badawczym były próbki wody surowej i uzdatnionej. Określono liczebność paciorkowców kałowych, bakterii z grupy *coli*, w tym *E. coli* oraz ogólnej liczebności bakterii mezofilnych i psychrofilnych. Liczebność bakterii z grupy *coli*, w tym *E. coli* oraz paciorkowców kałowych oznaczono metodą filtrów membranowych, zaś ogólną liczebność bakterii mezofilnych i psychrofilnych metodą płytkową w warunkach inkubacji zgodnych z normami.

We wszystkich badanych punktach stwierdzono obecność bakterii mezofilnych i psychrofilnych. Różnice w ich liczebności na przestrzeni całego roku były istotne. W punktach badawczych, tj. Centralne Kosynierów Gdyńskich, Maszewo oraz Marwice odnotowano przekroczenie norm ilości psychrofilii $100 \text{ j.t.k.} \cdot \text{cm}^{-3}$. Obecność bakterii chorobotwórczych w badanych próbkach wody pitnej wykryto sporadycznie. Zastosowane procesy uzdatniania i w efekcie końcowym ocena sanitarna wody według obowiązujących norm i zawartej klauzuli pozwalają na jej pobór do spożycia i nie stanowią zagrożenia dla zdrowia i życia ludzi.

Słowa kluczowe: woda pitna, bakteria, *E. coli*, *E. faecalis*, zanieczyszczenie wody