



## **EVALUATION OF MICROBIAL QUALITY OF WATER IN THE FOUNTAINS IN KRAKOW**

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### ***Abstract***

Fountains are decorative elements that improve the attractiveness and visual qualities of urban environments. They can give refreshment to residents on a hot, sunny day. Despite the prohibitions on bathing in these facilities people often have contact with fountain water. It should be emphasized that poor quality of water from fountains can be dangerous for human health. This study was aimed at evaluating microbial contamination of water in Krakow fountains (fountain from Szczepański Square, fountain on the Groble Square, “Chopin” fountain near the philharmonic, “Stone” fountain on the Maria Magdalena Square and the fountain on the Main Market Square). Microbiological analyses were conducted to determine the total number of microorganisms at  $36\pm 2^{\circ}\text{C}$  after 48 hours (mesophilic bacteria) and the total number of microorganisms at  $22\pm 2^{\circ}\text{C}$  after 74 hours (psychrophilic bacteria). In addition, the coliform bacteria, *Escherichia coli* and *Clostridium perfringens* were also examined. The results have shown a high degree of microbiological contaminants in the tested water samples. The lowest contamination of water was observed in the fountain on the Szczepański Square and in nozzle water from the fountain on the Groble Square. The highest numbers of bacteria were found in “Stone” fountain at the Maria Magdalena Square.

**Key words:** fountains, bacteria, water quality

## INTRODUCTION

The word ‘fountain’ comes from Latin (*font, fontis*) which means a spring (Szczepańska 2010). During the Middle Ages fountains were seen as sources of water, but nowadays they are understood as various hydrotechnical devices of different architectural forms and construction solutions, which discharge water from the interior under pressure. Increasingly, these facilities use modern technological solutions to control water streams and create various light effects (Bartnik 2015). Fountains as an element of urban composition impress architecturally and increase the aesthetic values, they are often found in the history of many cities playing the role of tourist attractions. Apart from decorative role, fountains also have health, climatic and sanitary functions (Flores *et al.* 2013) and thanks to the sound of murmuring water in fountains facilitates they provide relaxation and leisure to people (Haber 2001). In addition, fountains create conditions for inhalation with moist air, enrich the atmosphere with steam and reduce the temperature of the environment. The sprayed water stream effectively removes particles of pollution and dust from the air. Unfortunately in Poland, the quality of water in fountains is not standardized by any regulations, and health services do not monitor its microbiological purity. It is because water is not intended for human consumption or bathing. Despite the bathing bans people break these rules (Eisenstein *et al.* 2006) and generally have contact with fountain water. Water in fountains is usually characterized by relative transparency, and is perceived as pure and clean. While very often it can be contaminated by birds, small animals and can be a dangerous for health (Michałkiewicz and Szumigala 2014). The risk to health may be associated primarily with drinking water from the fountain, but also with bathing or playing in it. In big cities, like Krakow, in hot weather, fountains are treated like a city bathing resort, so it is therefore important to supply up-to-date information to the public about this problem.

According to literature reports, fountains can be the source of many pathogenic bacteria (Carlos *et al.* 2013, Aleksandra Burkowska-But *et al.* 2013, Małecka-Adamowicz and Kubera 2017), fungi (Biedunkiewicz 2009) and other microorganisms (Di Carlo *et al.* 2017, Grzyb *et al.* 2014). Typical indicator microorganisms of water quality are: *Escherichia coli* (*E. coli*), total coliform and enterococci, which are often detected in fountain waters (Flores 2013, Małecka-Adamowicz and Kubera 2017). The *E. coli* in particular has been found to be the most specific indicator of faecal contamination and its presence indicates contamination of water with faecal matter that may contain other harmful or disease causing organisms, including bacteria, viruses or parasites (Gwimbi 2011). Pathogenic *E. coli* strains generally can cause diarrheal disease, urinary tract infection, sepsis and meningitis (Weintraub 2007, Sharma *et al.* 2017). Another dangerous bacteria associated with contaminated water are *Clostridium perfrin-*

*gens*. It is a pathogenic bacteria for humans, and it causes vomiting, abdominal cramps and diarrhea within 24 h (Gao and McClane 2012). *Clostridia perfringens* may serve as a good indicator for parasitic protozoa and viruses from sewage-impacted waters (Ferguson *et al.* 1996). The microorganisms determined at temperature  $36\pm 2^{\circ}\text{C}$  are mesophilic organisms for which the optimal growth and development is temperature between from  $30^{\circ}\text{C}$  to  $40^{\circ}\text{C}$ . Among them may be pathogenic bacteria. Their optimal temperature is the same as that of a human body, which is why they are considered potentially harmful to humans. They are microorganisms developing at  $22\pm 2^{\circ}\text{C}$  after 72 h, include primarily non-pathogenic water bacteria and classified as gram-negative bacteria producing toxic liposaccharides. For this reason, their number should be also monitored. A fountain can be also a source of bioaerosol, potentially contaminated with bacteria *Legionella*, that can lead to respiratory diseases called Legionnaires' disease. The infection follows an inhalation route, thus even staying close to the source of the aerosol may cause a danger. According to literature, water pollution in fountains is a big problem in many cities around the world (Flores *et al.* 2013, Di Carlo *et al.* 2017, Tyndrak *et al.* 2019), and – especially due to the real health risk – there should be obligatory monitoring of water quality in the fountains. Thus the present study aimed to evaluate the microbial quality of water in the fountains on an example of Krakow.

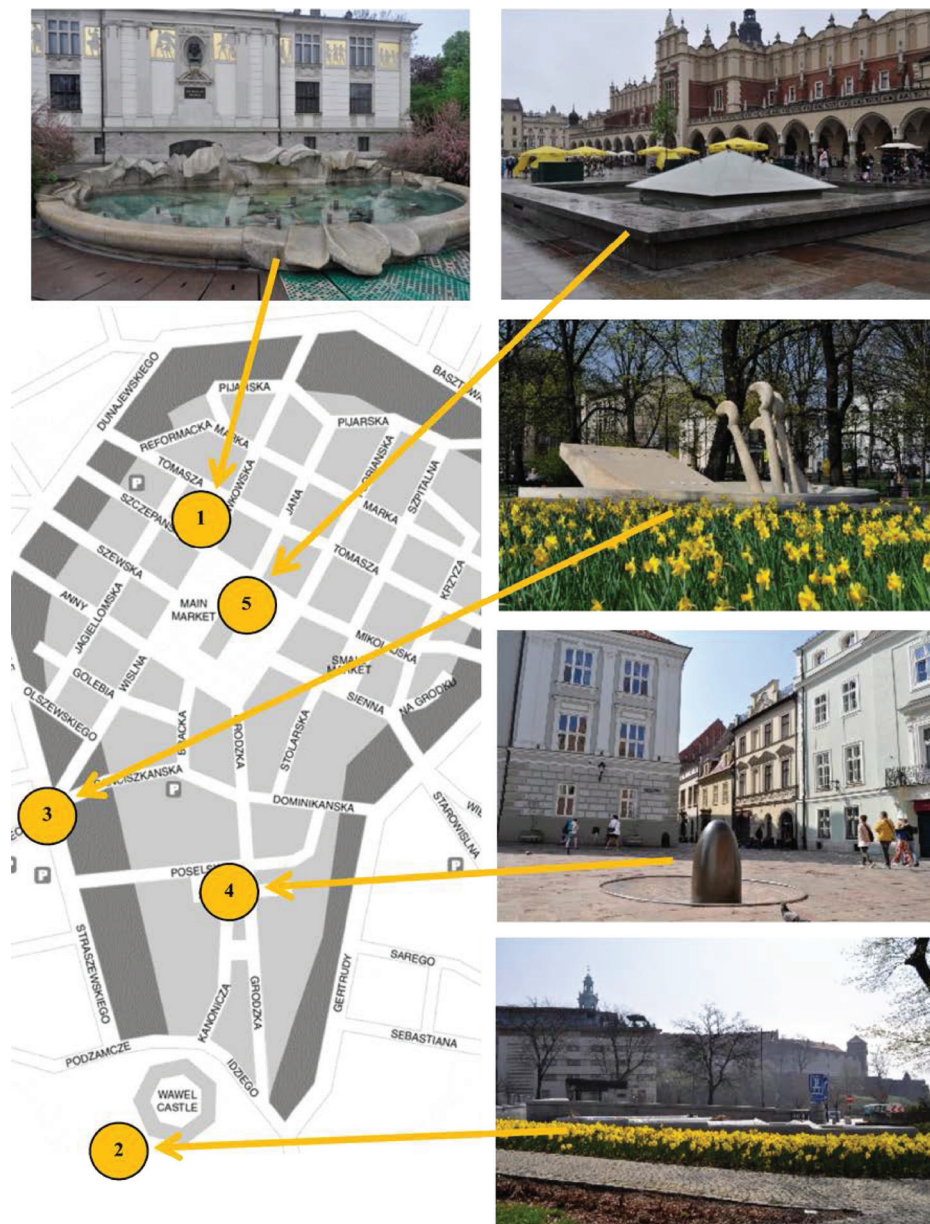
## MATERIALS AND METHODS

The research was carried out in Krakow and the study objects were 5 fountains. The water samples were taken from the following objects: the fountain on the Szczepeński Square, the fountain on the Groble Square, “Chopin” fountain near the philharmonic, “Stone” fountain on the Maria Magdalena Square, the fountain on the Main Market Square. The water samples were taken from the fountain basins, where water is stagnating (hereinafter referred to as ‘basin water’), as well as directly from fountain nozzles (‘nozzle water’). The water samples from “Stone” fountain were taken only from the fountain basins and “Chopin” from the fountain nozzles. In a case of “Stone” fountain water flows down a stone, which makes it impossible to take samples directly from the nozzle. While in the case of “Chopin” fountain only water from the nozzles was sampled, due to the insufficient volume of water stagnating in the basin. The tests were carried out throughout the whole year from June 2017 to June 2018 in summer and spring. 6 research series were carried out in the following dates: 21.06.2017, 11.07.2017, 17.07.2017, 28.08.2017, 07.05.2018, 07.06.2018. Water quality assessment was made on the basis of positive indicator bacteria given in the Regulation of the Minister of Health from 17 January 2019 on the water quality supervision in bathing facilities (Minister of Health 2019) and Regula-

tion of Minister of Health from 7 December 2017 on the quality of water intended for human consumption (Minister of Health 2017). The samples from the fountains were collected directly into sterile bottles and transported in a dark bag to a laboratory. The microbiological analysis of those samples were conducted, which included: the total number of psychrophilic, heterotrophic bacteria capable of growing at a temperature of  $22\pm 2$  °C and the number of mesophilic, heterotrophic bacteria capable of growing at a temperature of  $36\pm 2$  °C (in accordance with the Polish Standard PN-EN ISO 6222:1999); *Escherichia coli* (PN-EN ISO 9308-1); *Clostridium perfringens* (PN-EN ISO 14189). The locations and characteristics of selected fountains are shown in Figure 1 and Table 1.

**Table 1.** Characteristics of the studied fountains (ZIKiT 2019)

<b>Object</b>	<b>Characteristic</b>
Fountain on the Szczepański Square (1)	The facility has a closed water cycle and water treatment system, which includes filters, disinfection and pH correction. It is a multimedia fountain, has a system of highlighting water streams.
Fountain on the Groble Square (2)	The facility has a closed water cycle and water treatment system, which includes sand filters, disinfection, pH correction and algae removal agents.
“Chopin” fountain near the philharmonic (3)	The facility has a closed water cycle and water treatment system, which includes a filtering system, pH/Redox adjustment, electronic regulation of water level, inflow and outflow nozzle.
“Stone” fountain on the Maria Magdalena Square (4)	The facility has a closed water cycle and no water treatment system, no disinfection or water quality improvement agents.
Fountain on the Main Market Square (5)	The facility has a closed water cycle and water treatment system, which includes disinfection (chlorine tablets), pH correction (10%–30% sodium hydrogen sulfate).



Source: Own photos

**Figure 1.** Locations and views of the study objects: 1 – the fountain on the Szczepański Square, 2 – the fountain on the Groble Square, 3 – “Chopin” fountain near the philharmonic, 4 – “Stone” fountain on the Maria Magdalena Square, 5 – the fountain on the Main Market Square

## RESULTS AND DISCUSSION

The total number of bacteria in the water samples from the investigated fountains are shown in table 2.

**Table 2.** Total number of bacteria (cfu·cm<sup>-3</sup>) in the water samples from the studied fountains

Name of the fountains	Mesophilic bacteria			Psychrophilic bacteria		
	Min.	Average	Max.	Min.	Average	Max.
Fountain on the Szczepański Square – basin water	35	7301	29873	0	9138	28764
Fountain on the Szczepański Square – nozzle water	0	449	2164	0	445	2164
Fountain on the Groble Square – basin water	0	17438	74145	18	26235	76073
Fountain on the Groble Square – nozzle water	0	19983	98000	0	19703	70036
“Chopin” fountain near the philharmonic – nozzle water	1345	15580	67055	2264	18438	63709
“Stone” fountain on the Maria Magdalena Square – basin water	10	13931	25818	64	25656	76691
Fountain on the Main Market Square – basin water	0	7549	18255	18	16550	62545
Fountain on the Main Market Square – nozzle water	36	3822	10491	0	4379	13673

Source: Own study

The total number of mesophilic bacteria in the tested samples varied from 0 to 98 000 cfu·cm<sup>-3</sup> (cfu – colony forming units), and their average value in all fountains exceeded the Polish standards for bathing water quality (Minister of Health 2019). The highest value of mesophilic bacteria was observed in basin and nozzle water in the fountain on the Groble Square. The average number of bacteria in the water samples taken from these fountain was above 17 438 and 19 983 cfu·cm<sup>-3</sup> in basin and nozzle water respectively. Relatively large amounts of bacteria were also observed in the samples of nozzle water from “Chopin” fountain (15 580 cfu·cm<sup>-3</sup>) and basin water from “Stone” fountain (13 931 cfu·cm<sup>-3</sup>). The lowest values of mesophilic bacteria was observed in nozzle water in the fountain on the Szczepański Square (449 cfu·cm<sup>-3</sup>) and the fountain on the Main Market Square (3822 cfu·cm<sup>-3</sup>). In the case of psychrophilic bac-

teria, the highest amounts of microorganisms were observed in water samples taken from basins of the Groble Square Fountain (26 235 cfu·cm<sup>-3</sup>) and “Stone” fountain on the Maria Magdalena Square (25 656 cfu·cm<sup>-3</sup>). The lowest average number of psychrophilic bacteria was observed in the samples of nozzle water from fountains located on the Szczepański Square and the Main Market Square, where the number of bacteria was 445 and 4379 cfu·cm<sup>-3</sup> respectively. The results of the conducted experiment indicate that generally nozzle water is cleaner than basin water in terms of microbiological quality. It has also been confirmed that facilities in which no disinfectants are added are characterized by a high degree of microbial contamination. “Stone” fountain on the Maria Magdalena Square is a good illustration of this problem. Varying concentrations of bacterial contamination were noted by authors in their works. Research conducted by Budzyńska (Budzyńska *et al.* 2017) in Ciechocinek has shown that the total number of mesophilic bacteria in the samples from individual fountains ranged on average from 286 to 517 cfu·cm<sup>-3</sup>. While in water samples from fountains in Toruń, the number of mesophilic bacteria ranged from 5 to 1520 cfu·cm<sup>-3</sup> and psychrophilic 10 to 4900 cfu·cm<sup>-3</sup> (Burkowska-But and Walczak 2013). The similar values were observed in the fountains in Bydgoszcz, where the maximum number of heterotrophic bacteria capable of growing at temperature of 36°C was about 2710 cfu·cm<sup>-3</sup> and number of psychrophilic, heterotrophic bacteria capable of growing at temperature of 22°C up to 3010 cfu·cm<sup>-3</sup> (Małecka-Adamowicz and Kubera 2017).

The total number of *Clostridium perfringens* bacteria and *Escherichia coli* in the water samples from the studied fountains are shown in table 3.

In Poland the Regulation of Health Minister of 7 December 2017 on the quality of water intended for human consumption recognizes coliforms as an indicator of sanitary contamination of drinking and surface waters. The World Health Organization also takes into consideration the proper standards regarding the number of these bacteria. According to Polish standards the number of *Escherichia coli* cannot be higher than 1000 cfu·100 cm<sup>-3</sup> (Minister of Health 2019), while considering water in fountains as drinking water the presence of these bacteria is unacceptable (Minister of Health 2017). The number of *Escherichia coli* of all studied facilities varied from 0 to 7000 cfu·100 cm<sup>-3</sup>. In all the measurement series these pathogens were not detected in the water samples from the fountains on the Szczepański Square and the Groble Square. Consequently, the indicated standards have not been exceeded. The highest average value of *E. coli* (2875 cfu·100 cm<sup>-3</sup>) was observed in “Stone” fountain on the Maria Magdalena Square and such results are probably caused by the fact that no water treatment is employed in this facility and/or pigeons bathing there. Two out of five tested fountains did not meet any of the standards (“Chopin” fountain near the philharmonic, “Stone” fountain on the Maria Magdalena Square). However the level of pollution in the water samples from the fountain on the Main Market Square

treated as bathing do not exceed the limit values (Minister of Health 2019). The available literature reports suggest that the number of coliforms bacteria and *Escherichia coli* in the fountain water can vary widely. In Toruń the number of coliforms bacteria ranged in the studied fountains from 0 to 25000 cfu·100 cm<sup>-3</sup> and *E. coli* from 0 to 1960 cfu·100 cm<sup>-3</sup> (Burkowska-But and Walczak 2013). It significantly exceeded the values obtained in Krakow. Much lower values were observed in the city of Porto (Portugal) where an average number of *E. coli* was about 352 cfu·100 cm<sup>-3</sup> (Flores *et al.* 2013). Completely different results were noted by Mauritian scientists who conducted research about water quality in decorative fountains. They found absence *Escherichia coli* in all water samples (Heerah and Neetoo 2016).

**Table 3.** The number of *Clostridium perfringens* bacteria and *Escherichia coli* (cfu·100 cm<sup>-3</sup>) in the water samples from the studied fountains

Name of the fountains	<i>Clostridium perfringens</i>			<i>Escherichia coli</i>		
	Min.	Average	Max.	Min.	Average.	Max.
Fountain on the Szczepański Square – basin water	0	4	19	0	0	0
Fountain on the Szczepański Square – nozzle water	0	3	15	0	0	0
Fountain on the Groble Square – basin water	0	4	18	0	0	0
Fountain on the Groble Square – nozzle water	0	1	2	0	0	0
“Chopin” fountain near the philharmonic – nozzle water	0	6	21	0	660	2550
“Stone” fountain on the Maria Magdalena Square – basin water	0	20	73	61	2875	7000
Fountain on the Main Market Square – basin water	0	14	53	0	80	402
Fountain on the Main Market Square – nozzle water	0	1	5	0	82	360

Source: Own study

The Polish standards for *Clostridium perfringens* is 0 cfu·100 cm<sup>-3</sup> (Minister of Health 2019), thus all samples tested within the presented study had unacceptable quality. The samples taken from nozzle water from the fountains on the Main Market Square and on the Groble Square were characterized by the lowest average number of *Clostridia perfringens* (1 cfu·100 cm<sup>-3</sup>), while the



highest numbers of these bacteria were observed in basin water from “Stone” fountain located on the Maria Magdalena Square (on average  $20 \text{ cfu} \cdot 100 \text{ cm}^{-3}$  and maximum  $73 \text{ cfu} \cdot 100 \text{ cm}^{-3}$ ). Although clostridia probably do not grow in surface waters, the high resistance of their spores usually make their presence ubiquitous in environmental waters (Vilanova *et al.* 2004).

Water in fountains in Krakow does not correspond to the quality standards of drinking water and bathing water. High microbiological pollution may be caused by frequent birds carrying different germs around the fountains. Krakow is a city famous for its large number of pigeons, who often drink water from fountains. Another reason for water pollution may be too inadequate technical service of facilities and low concentration of water disinfectants. To ensure high-quality water, it may be possible through constant monitoring of the concentration of disinfectant and the level of contamination. In addition, cleaning operations can be helpful in solving this problem.

## CONCLUSION

The fountains are an integral part of Krakow. The technical and aesthetic condition of these objects is generally satisfying, but it is worth paying attention to the quality of water, which monitoring should be provided by the city government. Based on the results obtained from the presented study, it can be concluded that the fountain water is highly contaminated. Mesophilic and psychrophilic bacteria in all fountains occurred in high average numbers, in all studied facilities, and they exceeded the standards for the quality of drinking water, as well as those for bathing water. The purest water samples were found in the fountain on the Szczepański Square and the fountain on the Groble Square (in nozzle water). They did not contain coliform and *Escherichia coli* bacteria. These fountains were characterized by the lowest average numbers of *Clostridium perfringens* bacteria. As the most contaminated ones can be considered the water samples from “Stone” fountain on the Maria Magdalena Square, where the high average numbers of all indicator bacteria were observed. The presence of elevated levels of *Escherichia coli* bacteria indicates the faecal contamination of water in these fountains. The results of the experiments presented in the article confirmed that the objects, in which disinfectants are added, characterize with lower degree of microbial contamination. These problems show that there is a need to provide for procedure and regulations that determine the microbiological quality of water in fountains.

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