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CHLORINE DISTRIBUTION IN THE INDOOR AND OUTDOOR SWIMMING POOLS

ROZKŁAD CHLORU W BASENIE KRYTYM I OTWARTYM

Abstract: The results of research on the distribution of chlorine content in the characteristic points of the outdoor pool (SPO) and indoor pool (SPI) are presented. Sports and recreational pools for swimmers were selected for the study. Technical and technological parameters of these pools are presented. Free chlorine and combined chlorine were the basic parameters affecting the quality of pool water. Their quick and easy estimation allowed to assess the spread of the disinfectant in swimming pools and the effectiveness of its operation. In both swimming pools, there was a large variation in the chlorine content and non-compliance with the requirements in this area (in SPI, content of combined chlorine > 0.3 mg Cl_2/dm^3, in the SPO content of free chlorine > 0.6 mg Cl_2/dm^3). In the SPI, in contrast to the SPO, a significant variation in chlorine concentrations was observed in samples taken from various points in the same series. Based on the analysis of the chlorine content in the characteristic points of swimming pools and physio-chemical and bacteriological supplementary parameters, an attempt was made to determine reliable sampling points to assess the quality of water. The test results were compared with the recommendations regarding the quality of swimming pool water.

Keywords: indoor swimming pool, outdoor swimming pool, free chlorine, combined chlorine, reliable sampling point

Introduction

Regardless of the type of swimming pool (outdoor or indoor), the quality of pool water should meet the microbiological and physicochemical requirements specified in the sanitary and hygienic guidelines appropriate for a given country. Similarly, the construction of swimming pool basins, the type of hydraulic system and water treatment technology are regulated by normative and technical regulations [1-3].

In order to make the swimming pool water safe in terms of health, cooperation between the hydraulic system and the swimming pool geometry is necessary. The flow of water through the pool basin mustn't cause "dead zones" that do not participate in the circulation, where the degree of mixing the disinfectant with water may vary and lead to an ineffective deactivation of microorganisms [4-6].

Disinfection with chlorine compounds is required in public pools. These, as it has been proved, have the ability to oxidize organic and inorganic compounds, resulting in the formation of disinfection by-products (DBP). The amount and type of DBP in swimming pool water depends on the treatment technology, the number of swimmers and the intensity of swimming (pool load), the pool's hydraulic system, the number of water exchanges during the day, swimming pool construction (capacity, water surface area) and the type of pollution introduced into the water together with the bathers. Most DBPs are harmful to health [7-14].

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Free chlorine (due to its antiseptic effect) and combined chlorine (as an indicator of the content of DBP) are the basic parameters of pool water quality. In addition, an easy *in-situ* method to determine them allows to assess the spread of the disinfectant in the swimming pool basin and thus the effectiveness of its action. Based on the analysis of the chlorine content at various points of swimming pool basin and supplementary parameters, the Authors made an attempt to find reliable sampling points to assess swimming pool water quality. Such search should aim to determine the places where the worst quality water is expected. It is very likely that if the water meets the requirements at these "worst points", the more it meets them in others, regarded as "better" ones [4-6, 15].

Characteristics of research objects

Two swimming pools (called SPI and SPO) with the same function but different degrees of use were selected for the study. These are swimming pools of a sport and recreation nature, intended for people who are already able to swim. The SPI pool is an indoor swimming pool - used throughout the year, regardless of weather conditions, while the SPO swimming pool is an outdoor swimming pool - used only during the summer time (from 1 June to 31 August). In both of them, water treatment takes place in closed circuits with active overflow in the system as presented in Figure 1. For the measurement and regulation of the basic water quality parameters, microprocessor sets with electrodes enabling the measurement of temperature, water pH, free and combined chlorine concentration and redox potential are used.

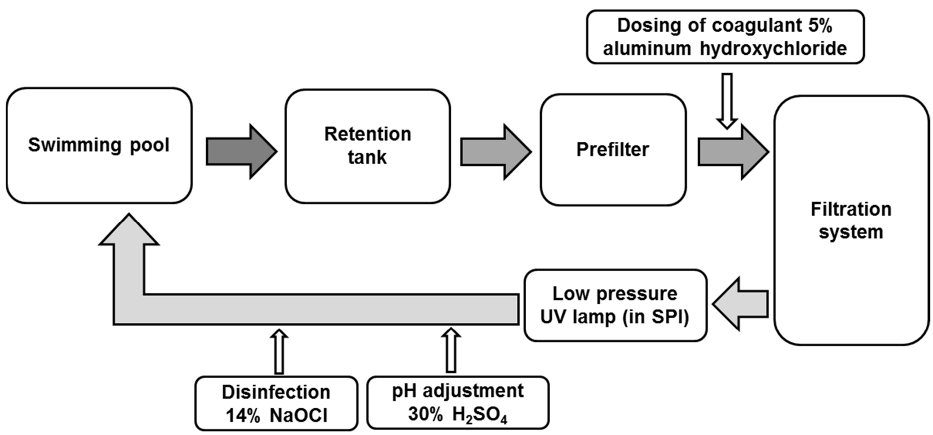

Fig. 1. Scheme of water treatment in the tested SPI and SPO swimming pools

In the SPI, the time of one full water volume exchange is 2.4 hours (10 exchanges during the day), and in the SPO it is 2.8 hours (8.6 exchanges during the day). The water is supplied to the swimming pool basin through nozzles (SPO) or channels (SPI) placed in the bottom of the basin. Therefore, a vertical water flow that is more advantageous for regular shaped pools, is ensured [6]. Basic technical and technological parameters of the tested swimming pools are presented in Table 1.

Table 1

Technical and technological parameters of the tested swimming pools

Swimming pool	SPI	SPO
Dimensions of the pool basin [m×m]	12.5×25	12.4×25 (with hydromassage area)
Depth of the pool basin [m]	1.1-1.8	1.2
Volume of the pool basin [m^3]	453	342
Usable area UA [m^2]	312.5	285.0
Attendance [person/h]	16-18	34-54
Actual UA [m^2/person]	17.4-19.5	5.3-8.4
Filter type	pressure, closed	vacuum, open, washed with diatomaceous earth
Number of filters	2	1
Filter size [mm]	ø 2000	4183×1870×1500
Type of filter bed	sand-anthracite	diatomite (diatomaceous earth)
Filtration flow [m^3/h]	188.6	123.0
Filtration velocity [m/h]	30	5
The time of one water change in the pool basin [h]	2.4	2.8

Materials and research methodology

In order to determine the distribution of chlorine concentrations in the analysed pool basins, characteristic locations were chosen as sampling points for physico-chemical and bacteriological analyses. Based on the results of model tests on hydraulic systems in swimming pools [4, 5] and the results of previous authors' research in this area [6], points located near the walls, in corners, on shallower and deeper side and in the central part of the pool have been selected as characteristic. In the SPI, 9 points have been determined, and in the SPO - 8 points (Figs. 2 and 3).

Water samples for tests were collected, after a night break, before the opening of swimming pool. Samples were taken from a depth of about 30 cm below the water surface. Five measuring series were carried out for both pools.

The concentration of free chlorine and combined chlorine (colorimetric method, Pocket ColorimeterTM II, Hach®) was determined (*in-situ*) in each sample. In order to check the overall quality of swimming pool water, for medium samples mixed on each day of testing, the pH of water, redox and temperature (potentiometric method, sensION meter + MM150 DL, Hach®), turbidity (nephelometric method, TN 100 turbidity meter, Eutech®), nitrate content, oxidation and total trihalomethanes - THM (spectrophotometric method, DR 5000 spectrophotometer; Hach®), total organic carbon - TOC (non-dispersive infrared spectrometry NDIR, TOC-L total organic carbon analyser; Shimadzu®), number of colony forming units (CFU), *Pseudomonas aeruginosa* (membrane filtration method according to PN-EN ISO 16266: 2009 [16]) and the *Escherichia coli* CFU number (membrane filtration method according to PN-EN ISO 9308-1: 2014-12 / A1: 2017-04 [17]) were determined.

The results of the analysis were compared with the guidelines included in the documents specifying the requirements for water in swimming pools [1-3].

Results and discussion

The distribution of free and combined chlorine in the selected points of the basins SPI and SPO are shown in Figures 2 and 3 respectively. Both in the SPI and SPO pool, there was a large variation in the chlorine content. In SPI, free chlorine concentrations ranged from 0.24 to 0.68 mg Cl_2/dm^3, and in SPO from 0.55 to 1.16 mg Cl_2/dm^3. In both swimming pools, non-compliance with the requirements in this regard was found. Free chlorine concentrations should be in the range of 0.3-0.6 mg mg Cl_2/dm^3. Such large differences in the free chlorine content resulted mainly from the type of pool. While in the case of SPI, deviations from the recommended values were small, in the case of the SPO, almost every measurement indicated an excess of free chlorine. The specificity of the outdoor swimming pools compared to the indoor swimming pools (greater load of swimmers, more intense sunlight on the surface of the water, the same depth in the whole swimming pool basin, greater exposure to contaminants from the pool beach and cosmetics) made the owner of this pool decide to use doses of disinfectant well above the requirements in order to limit the formation of disinfection by-products (including chloramines) and the growth of unwanted bacteria.

Concentrations of combined chlorine in the SPI ranged from 0.32 to 0.80 mg Cl_2/dm^3 and at each sampling point exceeded the limit value, i.e. 0.3 mg Cl_2/dm^3. On the other hand, in the SPO, the combined chlorine concentrations were very small, from 0.02 to 0.18 mg Cl_2/dm^3. Such a significant difference in the content of combined chlorine (chloramines) was the effect of using different doses of disinfectant (14 % NaOCl solution).

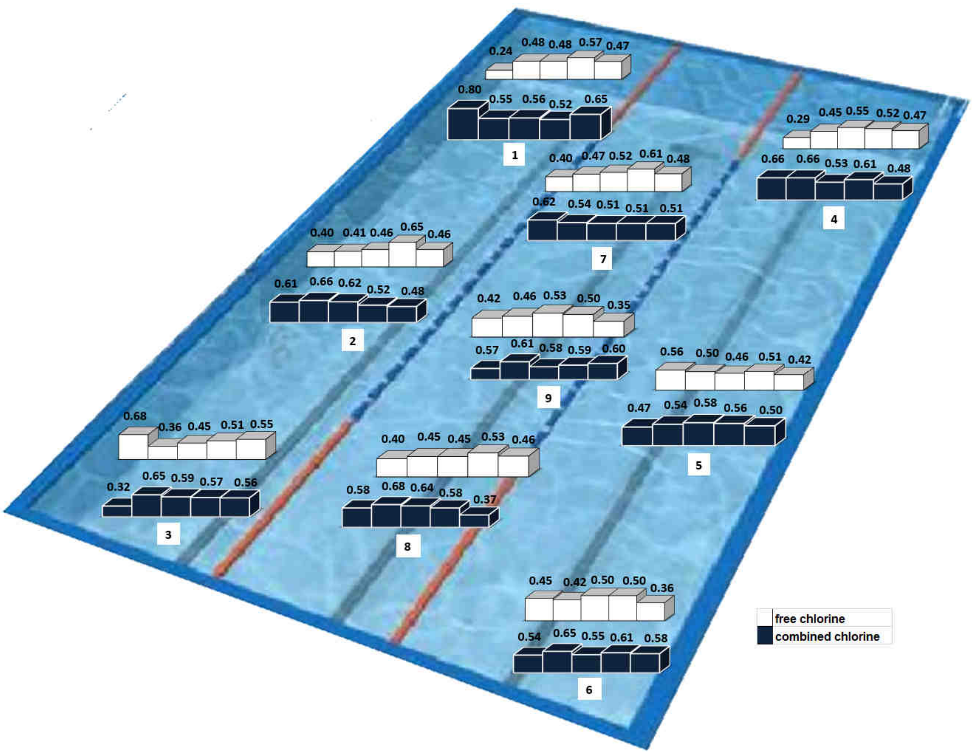

Fig. 2. Distribution of free and combined chlorine concentrations in pool SPI

In the SPI there was a significant variation in the concentration of chlorine in the samples taken from different points at the same time. For example, on the first day of measurement in point 1 (deep part of the basin) free chlorine concentration was 0.24 mg Cl_2/dm^3, i.e. below the minimum required value, and in point 3 (shallow part of the basin) 0.68 mg Cl_2/dm^3, i.e. above the maximum acceptable value. Such differences were not observed in the SPO. The same depth in the whole basin, a place with intense mixing of water (hydromassage zone) and an additional nozzle system for supplying treated water were the most likely reasons for this condition.

Significantly higher doses of NaOCl in the SPO influenced also other water quality parameters. For comparison, the average redox value in the SPO pool was 700 mV, while in the SPI it was 628 mV. The average oxidation value in SPO was 0.53 mg O_2/dm^3, and in SPI 1.51 mg O_2/dm^3. The average content of OWO in SPO was 0.72 mg C/dm^3, while in SPI 3.29 mg C/dm^3. The other analysed parameters didn't differ significantly (turbidity in SPO 0.20 NTU, in SPI 0.18 NTU, nitrate in SPO 3.5 mg/dm^3, in SPI 2.7 mg/dm^3, THM in SPO 0.041 mg/dm^3, in SPI 0.040 mg/dm^3).

In terms of bacteriology, the quality of water did not raise any objections. No CFU of *Pseudomonas aeruginosa* and *Escherichia coli* were found.

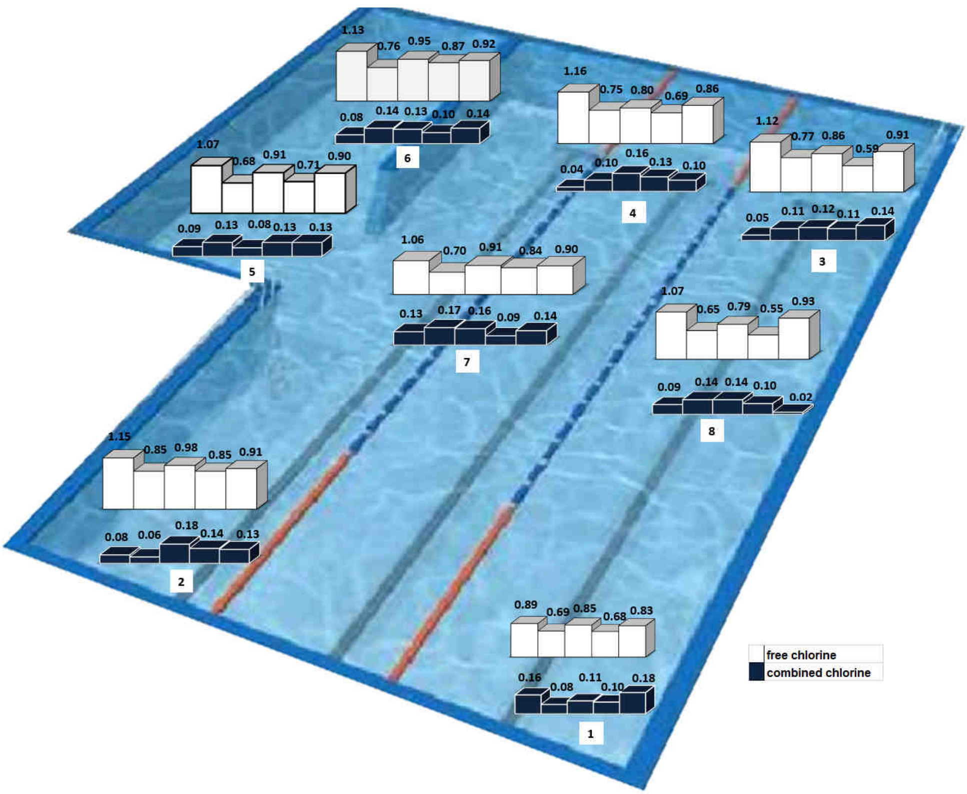

Fig. 3. Distribution of free and combined chlorine concentrations in pool SPO

Summary and conclusions

The distribution of free and combined chlorine concentration was analysed in two basins differing in seasonality of use - in outdoor (SPO) and indoor (SPI) swimming pools.

The analysis of free chlorine concentrations in the characteristic points of swimming pools made it possible to assess the antiseptic effect of the disinfectant. Whereas the analysis of combined chlorine concentrations understood as a measure of disinfection by-products, allowed to assess the comfort and safety of swimming in terms of health.

On the basis of the obtained research results, the following conclusions were formulated:

- There was a large variation in the chlorine content and non-compliance with the requirements in this matter in both analysed swimming pools. In the SPI, the combined chlorine content was exceeded (in each test series and at all measuring points > 0.3 mg Cl_2/dm^3). In the SPO, the free chlorine content was exceeded (> 0.6 mg Cl_2/dm^3), with the exception of two samples taken from points 3 and 8 in the 4th measurement series.
- Very low concentrations of combined chlorine (0.02-0.18 mg Cl_2/dm^3) in the SPO resulted from the use of high doses of disinfectant and the maintenance of free chlorine concentration in the range of 0.8-1.0 mg Cl_2/dm^3.
- In SPI, in contrast to SPO, a significant variation in chlorine concentrations was observed in samples taken from various points in the same measurement series. The biggest differences occurred in the points located in the corners of the basin, both on the deep and shallow side. The most likely reasons for this state were the differences in the design and equipment of the basins, and the solution of the water treatment system.
- Low values of redox potential (about 700 mV in SPO and about 628 mV in SPI) indicate insufficient ability to oxidize organic compounds as precursors of disinfection by-products. This may have resulted in relatively high THM concentrations (> 0.03 mg/dm^3 in 2 SPO and SPI water samples) and high concentrations of chloramines > 0.3 mg Cl_2/dm^3 in SPI.
- The other analysed physical, chemical and bacteriological parameters of water quality corresponded to the requirements in this area.
- Considering the high content of combined chlorine in SPI and high free chlorine content in the SPO, the possibilities of modernization of the water treatment system have been proposed, with particular emphasis on the disinfection system.

The authors continue research on the distribution of chlorine concentrations in pool basins of various constructions, various hydraulic systems and various functions. They will allow to establish representative sampling points for swimming pool water to assess its quality and hence the health risk for bathers.

Acknowledgements

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ROZKŁAD CHLORU W BASENIE KRYTYM I OTWARTYM

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Abstrakt: Przedstawiono wyniki badań nad rozkładem zawartości chloru w charakterystycznych punktach niecek basenu otwartego (SPO) i krytego (SPI). Do badań wybrano baseny o charakterze sportowo-rekreacyjnym, dla osób umiejących pływać. Przedstawiono techniczne i technologiczne parametry tych basenów. Chlor wolny oraz chlor związany były podstawowymi parametrami wpływającymi na jakość wody basenowej. Szybki i łatwy sposób ich oznaczenia pozwolił ocenić rozprzestrzenianie się środka dezynfekcyjnego w nieckach basenowych i skuteczność jego działania. W obu basenach stwierdzono duże zróżnicowanie zawartości chloru i niezgodność z wymogami w tym zakresie (w SPI zawartość chloru związanego > 0,3 mg Cl_2/dm^3, w SPO zawartości chloru wolnego > 0,6 mg Cl_2/dm^3). W basenie SPI w odróżnieniu od SPO obserwowano znaczne zróżnicowanie stężeń chloru w próbkach pobranych z różnych punktów w tej samej serii pomiarowej. Na podstawie analizy zawartości chloru w charakterystycznych punktach niecek basenowych oraz uzupełniających parametrów fizyczno-chemicznych i bakteriologicznych podjęto próbę wyznaczenia miarodajnych punktów poboru próbek wody basenowej w celu oceny jej jakości. Wyniki badań porównano z zaleceniami, jakim powinna odpowiadać woda w pływalniach.

Słowa kluczowe: basen kryty, basen otwarty, zawartość chloru, miarodajne punkty poboru próbek