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SWIMMING POOL WATER QUALITY IN THE NORTHERN ZONE OF PORTUGAL

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Abstract: The use of swimming pools for recreational purposes is associated with several benefits for the health and well-being of its users, however it is necessary to monitor the quality of the water in terms of public health. With the aim of evaluating the microbiological quality of swimming pool water, the results of 1280 water samples from swimming pools in the North of Portugal were analyzed. The evaluation of the water quality was carried out through the research and quantification of microorganisms viable at 37ºC, Coliform Bacteria, Enterococci, Escherichia coli, Pseudomonas aeruginosa, Coagulase Positive Staphylococci and the Total Number of Staphylococci. The results showed that, in general, 68.4% of the samples were classified from the microbiological point of view as conforming water. The microbiological parameters that most frequently exceeded the limit value were Total Staphylococci 24.1% (n=309) and P. aeruginosa 6.3% (n=81). Enterococci and E. coli were the microorganisms that showed the lowest percentage of samples above the established limit value, 1.7% (n=22) and 0.8% (n=10) respectively.

The physical-chemical parameters most related to the occurrence of microorganisms in the water samples studied were pH and free residual chlorine.

Despite the microbiological quality of swimming pool water in the North of Portugal being, in general, acceptable, it is necessary to review the treatment process for swimming pool water whose results were Non-Compliant. And consequently, to verify the need for intervention to improve the general operating conditions of the pools.

Controlling the quality of these waters fundamentally depends on adequate management that combines disinfection, monitoring of water quality and increasing the knowledge of pool users about the risks of potential diseases.

Keywords: swimming pool water, microbiological quality, physical-chemical quality, indicator microorganisms, pathogenic microorganisms.

INTRODUCTION

Physical activity in swimming pools is a practice with numerous benefits for individual health. Depending on their typology, swimming pools provide a wide range of uses from learning, training, competition, leisure to maintaining physical well-being (Khodaee M, 2016; World Health Organization, 2006).

The awareness of the benefits of these aquatic practices and the increase and diversification of the sports offer is responsible for increased care in the process of maintaining the quality of the water in swimming pools (Khodaee M, 2016).

The proper functioning of these activities requires strict hygienic and sanitary conditions, which involve several complex processes. The identification of existing problems in swimming pools that can severely affect public health is essential. Therefore, it is crucial to know the possible sources of chemical and biological contamination of swimming pool water. The bather turns out to be the main responsible for the contamination of the system (World Health Organization, 2006).

The risk associated with chemical contamination of pool water comes from the chemicals used in water treatment. The use of these products to disinfect water is essential, as inadequate disinfection can lead to serious health problems for the user (Font-Ribera L, 2011; Lee J, 2009; Kanan A, 2011). However, such products can present, themselves or their disinfection by-products (SDPs), serious effects ranging from eye, dermal and upper respiratory tract irritation to certain types of neoplasms (bladder, colon and rectum)

(Font-Ribera L, 2011). Most of the substances belonging to the list of SPDs are toxic, carcinogenic and have harmful effects on human reproduction.

The risk associated with biological contamination is related to the presence of microorganisms of fecal and non-fecal origin, responsible for the development of various clinical conditions such as dermal, auditory, ocular, gastrointestinal and central nervous system infections (World Health Organization, 2006). Fecal contamination is due to the presence of fecal matter in swimming pool water, which can occur accidentally by bathers, through residues present in the body, by contaminated supply water or by animals in the case of outdoor swimming pools (World Health Organization, 2006; Pedroso MJ, 2009). Non-fecal contamination arises mainly from the existence of organic matter, such as sweat, urine, saliva and respiratory secretions, released by bathers into the water. The presence of organic matter from the environment (dust, soil, sand, leaves and grass) is another non-fecal contamination route that occurs in outdoor pools.

The microbiological quality of water is crucial for assessing and managing the risk to the health of pool users (Nogueira JMR, 2022).

At the national level, there are several applicable legal diplomas, but which, like Regulatory Decree nº 5/97 of March 31, Normative Circular nº 14/DA of 08/21/09 and Portuguese Norm 4542-2017 do not have legal power, and may only be used as a reference regarding the quality of swimming pool water.

The lack of mandatory legislation regulating the quality of water in swimming pools translates into disparate management practices influenced by economic constraints and the degree of awareness of pool operators in terms of environmental monitoring. That said, health surveillance actions for swimming pools, under the responsibility of the Health Authorities, must include standardized criteria and procedures, as well as ensure the existence of risk identification, monitoring and control plans, so that the health and safety of the users and workers is ensured.

The evaluation of the chemical and microbiological quality of the pools must be carried out by accredited laboratories. The communication of this assessment by the pool management entities to the Health Authorities, by sending the results of the microbiological and physical-chemical analyses, is essential for the characterization of the facility in terms of public safety (Nogueira JMR, 2022).

Tables 1 and 2 describe the guidelines of DR nº5/97, regarding the microbiological and physical-chemical analysis of water, respectively (Ministry of Equipment, Planning and Territorial Administration, 1997).

The count of viable microorganisms at 37ºC allows estimating the total number of microorganisms present in the water. This information is useful in the assessment and monitoring of water quality, so results above the limit value are indicative of pollution and need to be investigated (World Health Organization, 2006).

Total coliforms, E. coli, Streptococci and Enterococci allow the presence of fecal matter in the water to be evaluated. The presence of these indicators of faecal contamination in pool water is a warning sign indicative of contamination or treatment failure. E. coli and Enterococci, as pathogenic microorganisms to humans, cannot be present in recreational waters (Silva N, 2017; Carroll KC, 2019).

The presence of P. aeruginosa and Staphylococcus aureus is a good indicator of non-fecal contamination, since the vast majority are part of the normal flora of the skin, ears and nose in humans, so bathers are primarily responsible for their presence in swimming pools (Silva N, 2017; Rice SA,

Parameters	Expression of results	ANALYTICAL METHOD	Value of reference	
			VR	VL
Cultivable microorganisms at 37ºC – 24h	UFC/mL	ISO 6222	≤ 100*	-
Total coliforms	UFC/100mL	ISO 9308-1 modificada	0	10
Escherichia coli	UFC/100mL	ISO 9308-1 modificada	-	0
Fecal streptococci and enterococci	UFC/100mL	ISO 7899-2	-	0
Pseudomonas aeruginosa	UFC/100mL	ISO 12780 modificada	-	0
Coagulase-producing staphylococci	UFC/100mL	NP-4343	-	0**
Total staphylococci	UFC/100mL	NP-4343	≤20*	-

Table 1 - Microbiological parameters to be analyzed within the scope of DR nº5/97

Caption: VR – Recommended value; LV - Limit value

* The recommended value may be exceeded once per public opening season or per calendar year.

** 0/100mL in 90% of the samples, it being the responsibility of local health services to carry out the assessment at the end of the season or calendar year.

Parameters	Expression of results	ANALYTICAL METHOD	Value of reference	
			VR	VL
Temperature (heated pools)	ºC	Thermometry	-	< 24 a 30
Turbidity	UNT	Turbidimetry		< 6
pH	Unidades pH	Potentiometry	7,4-7,6	7-8
Free residual chlorine	mg/L CL_2	Colorimetry		0,5-1,2 mg/L - pH 7 a 7,4 1-2 mg/L - pH 7,4 a 8
Total residual chlorine	mg/L CL_2	Colorimetry	-	CRL + 0,6 mg/L
Conductivity	µS/cm a 20°C	Electrometry	< 900	1700
Oxidability	mg/L O_2	Oxidation (volumetry)	-	< Oxidity of supply water + 4mg/LO_2
Ammonia	mg/L	Molecular Absorption Spectrometry	0,5	1,5

Table 2 - Physical-chemical parameters to be analyzed within the scope of DR nº5/97

Caption: VR – Recommended value; LV - Limit value

2012). Most of these non-fecal bacteria have the ability to form biofilms on surfaces and for this reason are more resistant to water treatment (Pedroso MJ, 2009).

The presence of any previously mentioned pathogenic microorganism puts the bather's health and safety at risk. Therefore, it is essential to evaluate and monitor the quality of swimming pool water, in order to prove the effectiveness of the treatment.

Faced with a microbiological result above the limit value, it is important to check the chemical determinations carried out at the time of collection (pH, residual disinfectant, water temperature) and consult the health record book to verify the records relating to operation (pH, residual disinfectant, equipment breakdowns or accidents) and water quality, as well as evaluating the processes inherent to filtration and disinfection. In cases where the water is classified as inappropriate, the Health Authority must close the pool until it again presents the necessary conditions (Nogueira JMR, 2022).

GOALS

The present work aims to evaluate the microbiological and physical-chemical quality of swimming pool water in the North of Portugal, analyzed by a Portuguese company in the year 2021.

MATERIAL AND METHODS

Type of Study: Descriptive cross-sectional study.

Sample: The sample consists of the records of the results obtained from the microbiological evaluation of swimming pools, in the North of Portugal, analyzed during the calendar year of 2021.

Regarding the exclusion criteria, all inconclusive or invalid sample results were eliminated, namely those that did not present the necessary information for this study (non-characterized pools).

Instruments: The instruments used were the Excel ® database provided by a laboratory accredited by Norm NP EN ISO/IEC 17025 within the scope of water tests and responsible for carrying out the analyses. This database was imported into the IBM® SPSS® Statistics software for organization and statistical treatment of the data.

Procedures: According to the database provided and Regulatory Decree nº 5/97, this study includes the variables described in Table 1 and 2. The data used in this study were obtained through the following steps: a) sample collection; b) microbiological and chemical analysis; c) evaluation of microbiological and chemical analysis.

Sample collection and microbiological and physical-chemical analyzes were carried out by specialized laboratory technicians, according to protocol PE-DSQ10/V18 ISO19458:2006 and PE-DSQ-10/V20 ISO 5667-5:2006.

Table 1 lists the normative references for each microbiological and physical-chemical parameter.

Statistical analysis of the microbiological and physical-chemical results was performed using the IBM® SPSS® Statistics software. The data were organized and treated, using descriptive statistics, by analyzing absolute and relative frequencies. Finally, graphs and tables were prepared for the microbiological and chemical evaluation of the water in the pools under study, in order to respond to the proposed objectives. For this purpose, the microbiological profile of swimming pool water was analyzed, the frequency of non-conformities was evaluated and the results obtained by microbiological parameter were compared.

The pool typology variable was classified into indoor pools, outdoor pools and hydromassage tanks.

The analysis of the different microbiological

MICROBIOLOGICAL PARAMETER	Protocol performed
Cultivable microorganisms to 37ºC-24h (UFC/mL)	ISO 6222:1999
Coliform bacteria (UFC/100 mL) *Escherichia coli* (UFC/100 mL)	IT-DLM-03/V05
Enterococci (UFC/100 mL)	ISO 7899-2:2000
Pseudomonas aeruginosa (UFC/100 mL)	ISO 16266:2006
Total staphylococci (UFC/100 mL)	NP 4343:1998
Coagulase Positive Staphylococcus (UFC/100 mL)	
PHYSICOCHEMICAL PARAMETER	**Protocol performed**
Temperature *in situ* (ºC)	IT-DLQ-41/V01
pH (units of pH)	IT-DLQ-07/V04
Conductivity (µS/cm a 20ºC)	SMEWW 2510 B, 23ªed
Oxidability (mg/L O_2)	NP-731:1969
Turbidity (UNT)	ISO 7027-1:2016
Ammonia (mg/L NH_4)	IT-DLQ-89/V01
Free residual chlorine *in situ* (mg/L Cl_2)	IT-DLQ-08/V04
Total residual chlorine *in situ* (mg/L Cl_2)	

Table 1 - Protocol performed for each of the microbiological and physical-chemical parameters.

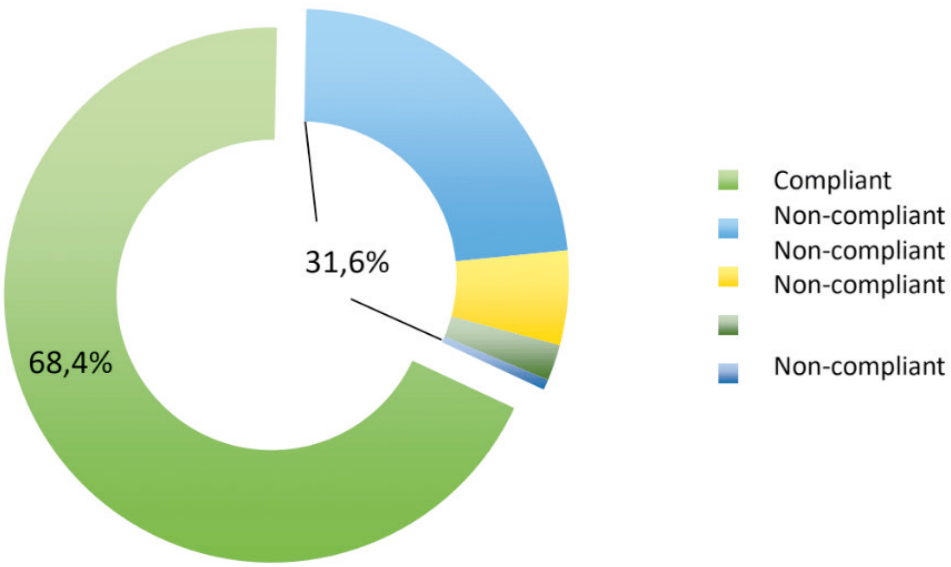

Figure 1 – Microbiological classification. Values expressed in percentage (%).

and physical-chemical parameters respected the limit values described in Tables 1 and 2. The samples were also classified as non-compliant when the presence of indicator and/or pathogenic microorganisms above the limit value was verified, according to the DR No. 5/97.

All procedures were uniformly performed, using the same materials and methods, in all determinations throughout the study period.

Ethics: The anonymization and confidentiality of the data was guaranteed by the responsible entity.

RESULTS

During the year 2021, of the 1280 water samples from swimming pools in the North of Portugal, 55.5% (n=711) were outdoor pools, 36.3% (n=464) indoor pools and 8.2% (n=105) hydromassage tanks.

Regarding the results obtained from the microbiological analyzes carried out, of the 1280 pool water samples, approximately 68.4% (n=875) were classified as Compliant and 31.6% (n=405) as Non-Compliant (Fig. 1).

In the different types of pool, the percentage of compliance was greater than 65% (66.7% in hydromassage tanks, 68.4% in outdoor pools and 68.8% in indoor pools).

In Figure 1 it is also possible to verify that the Non-compliant water samples were stratified according to the number of microbiological parameters above the established limit value. That is, of the 405 (31.6%) Non-compliant samples, 296 (23.1%) samples were due to 1 microbiological parameter above the limit value, 73 (5.7%) to 2 microbiological parameters, 28 (2, 2%) to 3 microbiological parameters and 8 (0.6%) to 4 microbiological parameters.

The microbiological parameters that exceeded, in a greater percentage, the established limit values were Total Staphylococci with 24.1% (n=309) and P. aeruginosa with 6.3% (n=81) (Fig. 2).

The relative frequency of microbiological parameters in the different types of pools followed the same distribution.

In the Non-compliant water samples due to 1, 2 and 3 microbiological parameter(s) above the limit value, the parameters with the highest frequency of non-conformities were Total Staphylococci, P. aeruginosa and Microorganisms viable at 37ºC. In non-conforming water samples due to 4 microbiological parameters above the limit value, the most frequent parameters were microorganisms viable at 37ºC and Enterococci (Table 3).

Of the 1280 pool waters analyzed, around 1.2% (n=15) had physical-chemical analysis results. Table 4 shows the broken down results of the 15 pools.

The physical-chemical parameters that most frequently presented results outside the limit range were pH (46.7%, n=7) and free residual chlorine (73.3%, n=11). Of the 7 pH results outside the threshold range, 2 were above pH 8 (pool 6 and 7). Of the 11 free residual chlorine results outside the limit range, 2 were below 0.5 mg/L CL2.

Of these 15 pool waters analyzed, 66.7% (n=10) presented results below the limit value for all microbiological parameters, 20% (n=3) presented 1 microbiological parameter above the limit value (pool 3, 7 and 15) and 13.3% (n=2) had 2 microbiological parameters above the limit value (pool 8 and 10).

In the 5 pool water samples that showed at least one microbiological parameter above the limit value, pH and free residual chlorine were the parameters whose values were most frequently outside the limit range.

In the 3 water samples with 1 microbiological parameter above the limit value, the parameters were microorganisms viable at 37ºC (n=2, pool 7 and 15) and Total

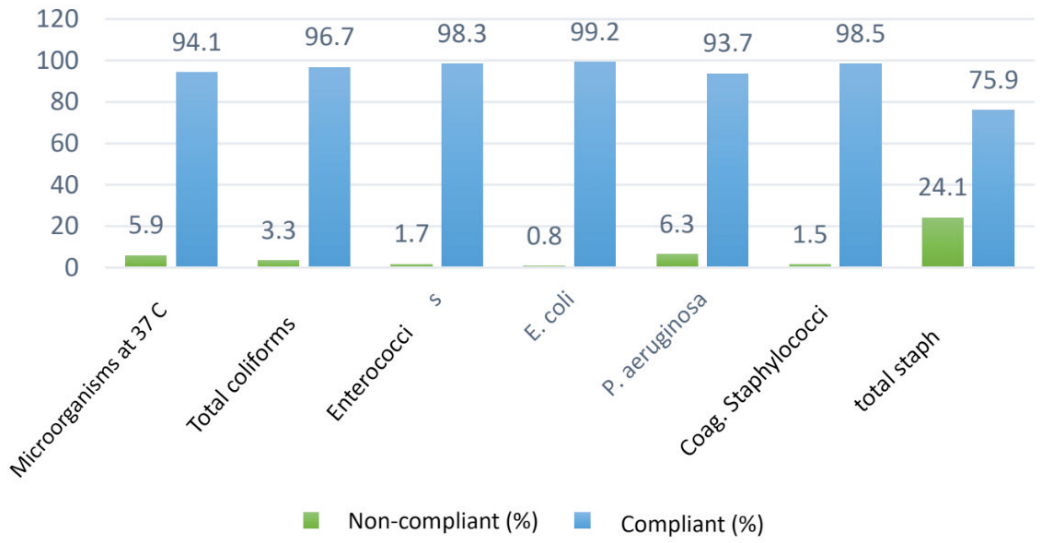

Figure 2 - Classification of the Microbiological Quality of Swimming Pool Water by Microbiological Parameter

	Viable microorganisms at 37°C	Total coliforms	Enterococci	*E. coli*	*P. aeruginosa*	Staphylococci Coagulase +	Total staphylococci
NC_1	26	7	4	1	27	1	230
NC_2	23	18	6	1	32	11	55
NC_3	18	12	5	5	19	6	19
NC_4	8	5	7	3	3	1	5

Table 3– Distribution of absolute frequency of microbiological parameters in non-compliant water samples with 1, 2, 3 and 4 microbiological parameters above the limit value.

	Temp. (°C)	pH (pH unit)	Conductivity (µS/cm to 20°C)	Oxidability (mg/L O_2)	Turbidity (UNT)	Ammonia (mg/L NH_4)	Free residual chlorine (mg/L Cl_2)	Total residual chlorine (mg/L Cl_2)
1	15	7,7 a 19°C	430	1,9	0,5	0,04	3,0	4,0
2	11	5,9 a 18°C	580	1,6	0,5	0,04	6,0	7,0
3	14	4,1 a 19°C	510	1,7	0,5	0,04	0,1	0,1
4	14	7,5 a 18°C	620	2,4	0,5	6	6,0	0,6
5	19	6,8 a 19°C	940	1,9	0,5	0,04	9,0	9,0
6	22	8,8 a 19°C	1200	1,1	0,5	0,04	9,0	9,0
7	22,7	8,3 a 18°C	1700	2,9	0,5	0,13	0,1	0,2
8	26	7,8 a 19°C	800	4	0,5	0,2	1,3	1,5
9	29	7,6 a 20°C	360	2,2	0,5	0,04	1,2	1,3
10	20	7,8 a 23°C	330	3,4	0,5	0,04	1,3	1,5
11	19	7,3 a 18°C	330	2,6	0,5	0,04	1,6	1,7
12	28	7,3 a 18°C	960	4	0,5	0,04	2,7	3,2
13	32	6,9 a 18°C	770	3,8	0,5	0,04	2,0	2,4
14	30	6,8 a 18°C	1100	3,7	0,5	0,04	2,5	3,0
15	32	7,1 a 19°C	790	2,5	0,5	0,04	1,0	1,4

Table 4 – Results of the physicochemical parameters of the analyzed pool water.

Staphylococci (n=1, pool 3). In the 2 water samples with 2 microbiological parameters above the limit value, the parameters were Total Coliforms + Staphylococci (pool 10) and Coliforms + Viable microorganisms at 37ºC (pool 8).

DISCUSSION

The results of this study showed that only 68.4% (n=875) of the pools analyzed were classified as compliant. Regulatory Decree No. 5/97 and NP EN 4542:2017, regarding the microbiological parameters for microorganisms cultivable at 37ºC and total staphylococci, states that "the recommended value may be exceeded once per public opening period or per calendar year", thus classifying the water as "Water as Conditioned" (9,12). Therefore, since: a) in this study it was not possible to access the history of each pool and b) we always considered the pool as "Non-Compliant" whenever the values of these two parameters were higher than the recommended value; we may have some pools that are considered "Water as Conditioned". However, ideally the number of pools with "Compliant" water must be higher.

In this study, of the microbiological parameters analyzed, Total Staphylococci and P. aeruginosa were the ones that most contributed to the non-compliances found in swimming pool water, with 24.1% and 6.3% of samples, respectively. These parameters are known as the most resistant to disinfection due to the fact that they form biofilms and resist high temperatures (World Health Organization, 2006; Pedroso MJ, 2009).

P. aeruginosa is resistant to sodium hypochlorite and can survive in water subjected to disinfection with residual free chlorine contents < 1 mg/L (Rice SA, 2012). And it is particularly problematic because it resists high temperatures, an important factor when it comes to indoor pools. The ability of Staphylococci to survive longer is due to their ability to lodge in the oily layer that forms on the surface of the water, as a result of lotions, creams and dirt carried into the water by bathers. Being able to resist disinfectants 5 to 20 times more compared to coliforms and Enterococci (World Health Organization, 2006).

These results show the importance of water renewal as an aid in the elimination of these bacteria.

Regarding the physical-chemical analyses, pH and free residual chlorine were the parameters most related to the occurrence of microorganisms in the studied water samples.

The ideal pH of swimming pool water must be the same as the liquid in the eyeball (7.4) and the optimum range corresponds to values between 7.4 and 7.6 – the value recommended by DR nº 5/97. If the pH is lower than 7, it can cause skin irritation and corrosion of pool equipment, while a value greater than 8 reduces the efficiency of the disinfectant action of chlorine, causes dermal and eye irritation, causes water turbidity and promotes the formation of fouling (World Health Organization, 2006).

Pools 3 and 7 showed a microbiological parameter above the limit value, Total Staphylococci and Viable Microorganisms at 37ºC respectively. In these pools, the parameters pH and free residual chlorine were outside the limit range, which indicates a reduction in the efficiency of disinfection and the possibility of microbiological multiplication (World Health Organization, 2006).

Pool 15 also showed a microbiological parameter above the limit value, namely viable microorganisms at 37°C. Temperature was the only physical-chemical parameter above the limit value (32°C). It is known that the increase in temperature favors microbial development, in addition to increasing the

speed of formation of DBPs and favoring disinfectant volatilization (World Health Organization, 2006, Kanan A, 2011).

Pools 8 and 10 were the only ones that presented two microbiological parameters above the limit value, but whose only physical-chemical parameter that was above the recommended value was the pH value - 7.8. Although the result of free residual chlorine is within the limit range, the presence of microorganisms of fecal and non-fecal origin: a) alerts to the presence of sources of contamination such as nasal secretions, urine, feces and sputum; b) indicates that the collection may have taken place in a period of high affluence and c) allows to assess contamination by bathers, due to the non-use of showers immediately before entering the pool and their own hygiene (World Health Organization, 2006; Pedroso MJ, 2003; Pedroso MJ, 2009).

Although in this study we were able to obtain the microbiological profile of pool water in the north of the country, it must be noted that it has some limitations. First, the fact that the study is cross-sectional, since it is not possible to know if the water samples are from different pools or if they are from different samples taken from the same pool, carried out during the year 2021.Other limitations imposed on the interpretation of the results, is both the scarcity of other similar works, the lack of access to results from previous years and the reduced number of physical-chemical analysis results, preventing an analysis of previous contaminations and even identifying flaws in the process in order to implement improvement actions.

The result of 31.6% of water considered "Non-Compliant" in the pools analyzed indicates that it is necessary to review the water treatment process in these pools. And consequently, to verify the need for intervention to improve the general operating conditions.

Proper swimming pool maintenance, prioritizing disinfection routines and water quality monitoring, is the key factor in preventing infectious diseases associated with their use (Nogueira JMR, 2022).

From a perspective of studying water quality and the impact on public health, it would be important to relate data from pools considered non-compliant with the clinical history (namely cases and outbreaks) of water-borne diseases in the population where these pools are located.

CONCLUSION

This study made it possible to evaluate the water quality of swimming pools in the North of Portugal, during the year 2021, following the rules imposed by Regulatory Decree No. 5/97, of March 31, in relation to microbiological and physical-chemical parameters.

The results obtained showed that there is still a considerable percentage of pools classified as Non-Compliant from the analyzed water samples, which must be taken into consideration, in order to carry out an adequate treatment of these waters.

The physical-chemical parameters most related to the occurrence of microorganisms in the water samples studied were pH and free residual chlorine.

For future works, it is suggested the inclusion of other microbiological parameters, namely Legionella spp, whose research acquires greater importance in hydromassage pools, and other physicochemical parameters, namely the quantification of trihalomethanes, cyanuric acid and chlorides, in order to obtain a perspective holistic assessment of the water quality of swimming pools. Therefore, allowing to evaluate possible causes for the non-compliant values found. It highlights the need to guarantee adequate levels of residual disinfectant and to maintain pH values

preferably between 6.9 and 7.4 in order to provide greater disinfection efficiency and ensure the microbiological quality of the water.

REFERENCES

CARROLL KC, BUTEL JS, MORSE SA. **Jawetz, Melnik, & Adelberg's Medical Microbiology**. Mc Graw Hill. 2019.

DA SILVA NEUSELY, JUNQUEIRA VCA, SILVEIRA NFA, TANIWAKI MH, GOMES RAR, OKAZAKI MM, IAMANAKA BT. **Manual de métodos de análise microbiológica de alimentos e água**. Blucher; 2017.

DIREÇÃO GERAL DA SAÚDE. **Circular Normativa nº14/DA Programa de Vigilância Sanitária de Piscinas**. 2009.

FONT-RIBERA L, VILLANUEVA CM, NIEUWENHUIJSEN MJ, ZOCK JP, KOGEVINAS M, HENDERSON J. **Swimming pool attendance, asthma, allergies, and lung function in the avon longitudinal study of parents and children cohort**. Am J Respir Crit Care Med. 1;183(5):582–8. 2011.

INSTITUTO PORTUGUÊS DA QUALIDADE. **Norma Portuguesa 4542 Piscinas - Requisitos de qualidade e tratamento da água para uso nos tanques**. Instituto Português da Qualidade. 2017.

KANAN A, KARANFIL T. **Formation of disinfection by-products in indoor swimming pool water: The contribution from filling water natural organic matter and swimmer body fluids**. Water Res. 45(2):926–32. 2011.

KHODAEE M, EDELMAN GT, SPITTLER J, WILBER R, KRABAK BJ, SOLOMON D. **Medical Care for Swimmers**. Vol. 2, Sports Medicine - Open. Springer. 2016.

LEE J, HAB KT, ZOHA KD. **Characteristics of trihalomethane (THM) production and associated health risck assessment in swimming pool waters treated with different disinfection methods**. Science of The Total Environment. 2009

MINISTÉRIO DO EQUIPAMENTO, DO PLANEAMENTO E DA ADMINISTRAÇÃO DO TERRITÓRIO. **Decreto Regulamentar n.º 5/97**. Diário da República, 75 Portugal; Mar 31, 1997 p. 1397–422.

NOGUEIRA JMR. **Programa de Vigilância Sanitária de Piscinas**. 2022.

PEDROSO MJ. **Exposição Ocupacional em Piscinas Cobertas do Tipo I e II**. Porto: Faculdade de Medicina, Universidade do Porto; 2009.

RICE SA, VAN DEN AKKER B, POMATI F, ROSER D. **A risk assessment of Pseudomonas aeruginosa in swimming pools: A review**. Vol. 10, Journal of Water and Health. 2012. p. 181–96

WORLD HEALTH ORGANIZATION. **Guidelines for safe recreational water environments. Swimming pools and similar environments**. Geneva: World Health Organization; 2006.