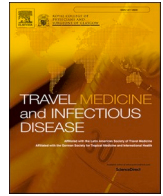




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# Travel Medicine and Infectious Disease

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## Environmental surveillance of *Pseudomonas aeruginosa* in recreational waters in tourist facilities of the Balearic Islands, Spain (2016–2019)

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### ABSTRACT

**Background:** *Pseudomonas aeruginosa* is a major opportunistic human pathogen commonly connected with recreational water activities. Spain is a tourist destination where most of the establishments have swimming pool. Nevertheless, the prevalence of *P. aeruginosa* in public swimming pools in our country is unknown. This work aimed to survey the *P. aeruginosa* presence in tourist Spanish recreational waters.

**Method:** Tourist recreational water in hotels in the Balearic Islands were visited for four years (2016–2019). The levels of selected parameters were determined, and their correlation with *P. aeruginosa* contamination investigated.

**Results:** We evaluated 11,014 samples from 254 facilities. Unacceptable levels of at least one legislated parameter were detected in 30.7% of cases, implicating closure in 15.9%, being *P. aeruginosa* the leading cause of closure. The prevalence of the pathogen was 14.2%, with lower presence in outer swimming pools. Disinfectant levels influence *P. aeruginosa* contamination, and bromine-maintained pools were more often contaminated than those treated with chlorine. Prevalence remained constant over the years, although it increased in 2019.

**Conclusions:** *P. aeruginosa* prevalence in our recreational waters is similar to other countries, and the contamination rates depend on the installations and type and disinfectant levels. Corrective measures are still needed to improve pathogen control.

### 1. Introduction

*Pseudomonas aeruginosa* is a versatile bacterium capable of colonizing and thriving in a wide range of environments, including inert surfaces, living beings such as plants, animals, and humans, thanks to its exceptional metabolic versatility and adaptability [1]. This microorganism is responsible for numerous human pathologies, affecting various body parts as the skin, ears, eyes, respiratory, and urinary tracts. A alarming aspect is that *P. aeruginosa* primarily affects immunocompromised patients, causing significant respiratory and bloodstream infections that often result in high morbidity and mortality rates [2]. Furthermore, the development of antimicrobial resistance in this pathogen leads to frequent therapeutic failures. In Europe, *P. aeruginosa* isolates exhibit a high level of resistance to antimicrobial agents, with approximately

30.1% of isolates resistant to at least one antimicrobial group, and 9.4% of isolates showing resistance to three or more antimicrobials [3]. Additionally, antibiotic-resistant infections caused by *P. aeruginosa* generate substantial additional hospital care costs, which were estimated to be around €1.6 billion in Europe in 2012 [4]. Due to the severity of the situation, multidrug-resistant *P. aeruginosa* is considered a “Priority 1 Critical Pathogen” by the World Health Organization, which highlights the need for research and development of new antibiotics to address the problem [5].

Recreational water, such as swimming pools, whirlpools, aquatic parks, and similar facilities, provide opportunities for well-being, proper fitness, leisure, and health. However, exposure to recreational water can lead to infections caused by various microorganisms, including *P. aeruginosa*, which causes a range of illnesses such as otitis externa,

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folliculitis, dermatitis, hot-foot syndrome, and ocular infections in swimmers, and can even cause pneumonia and urinary infections [6–10]. Therefore, maintaining proper water quality through filtration and disinfection processes is crucial to prevent infections among users of these facilities. However, establishing the conditions for a well-managed swimming pool is challenging due to the lack of uniformity among the standards set by different countries [11]. Until 2013, local authorities in Spain set separate legislation and guidelines, leading to a lack of standardization throughout the country [12].

As one of the most popular Mediterranean tourist destinations [13], the Balearic Islands prioritize ensuring safe and healthy conditions for tourists. Swimming pools are a popular feature of hotels, and their proper maintenance is essential to avoid health problems and associated financial losses. Although various studies have investigated the microbiological conditions of swimming pools in different countries, information on Spanish pools, especially concerning *P. aeruginosa*, is limited. Two previous studies have examined the presence of *P. aeruginosa* in Spain, but their scope was limited, and they were conducted before the current legislation [14,15]. Yet, limitations to the number of samples and the covered period arise. Moreover, they were performed before the current legislation. Therefore, there is a need for extensive and up-to-date research to understand the current situation of recreational waters in Spain, particularly in the tourist sector.

The present study aims to survey recreational water installations in hotels in the Balearic Islands (Spain) over four years to assess compliance with current standards, determine the prevalence of *Pseudomonas aeruginosa*, and examine its relationship with various physicochemical and microbiological parameters. The findings of this study will enable the development of specific measures to reduce the risk of *P. aeruginosa* infection associated with these facilities.

## 2. Methods

### 2.1. Tourist facilities

This investigation involved 254 different tourist accommodations in the Balearic Islands, Spain, which represents 18% of the Balearic Islands' tourist facilities. The accommodations included hotels, apartments, and rural tourism resorts and were visited from January 14th, 2016, to December 18th, 2019. The investigation aimed to obtain an accurate picture of the current situation, and therefore, the visit dates were not previously notified to the management, and samples were obtained under current working conditions. The average number of visits per installation was 11, with some differences due to seasonal variations and operational differences between indoor and outdoor swimming pools. The recreational water analyzed included swimming pools, cold wells, whirlpools, hot tubs, and other SPA-associated warm water accommodations. For simplicity, these facilities will be referred to generically as “whirlpools” from this point forward.

### 2.2. Sampling procedure

Sampling points were established based on the worst-case scenario, considering the characteristics of the pools (shape, deep, the position of injectors, skimmers, drains, etc.). We designated one sampling point for each swimming pool, where we sampled the water at 30 cm depth. One 1 L sterile plastic bottle was filled with water, and the disinfectant was neutralised by sodium thiosulphate already in the recipient. The samples were introduced into a portable refrigerator and arrived at the laboratory in less than 8 h after sampling.

In situ, we measured several parameters, including temperature, pH, and disinfectant and cyanuric acid levels. We used a Testo 104 thermometer (Testo, Spain) to determine the temperature in water-temperature-controlled installations such as inner swimming pools, whirlpools, and cold wells. We used the Lovibond® portable MD100 instrument (Lovibond, Germany) to determine disinfectant levels (free

and combined chlorine or bromine) as well as cyanuric acid levels using the colorimetric method [16]. The pH was also determined by the colorimetric method using the same instrument [17]. Ten mL of sample were used in all cases.

### 2.3. Laboratory investigation

After the samples arrived at the laboratory, we analyzed the turbidity, conductivity, and total dissolved solids (TDS) using methods previously described [17]. For microbiological analyses, we performed detection and enumeration for *Escherichia coli* and *Pseudomonas aeruginosa* in 100 mL of water each. In both cases, we used technology based on bacterial enzyme detection that signals the presence of the target microorganism. We used Colilert-18® to detect *E. coli* in water (ISO 9308-2:2012), and Pseudalert® was the standard for *P. aeruginosa* (ISO: 16266-2:2018). Briefly, for *E. coli* 100 mL were introduced into a QuantaTray®, sealed and incubated at 35 °C ± 0.5 °C for 18 h. The yellow/fluorescent wells were considered as positive and MPN was calculated. In case of *P. aeruginosa*, 100 mL were equally processed but incubated at 38 °C ± 0.5 °C for 24 h. The blue fluorescent wells were considered as positive and MPN was calculated.

### 2.4. Data analysis

First, information was transferred from the QUAASS-LAB® LIMS into a Microsoft Excel® 2021 file. Then, we curated the data for duplicates and inconsistencies, and finally, we assessed values for 11,014 samples. The D'Agostino & Pearson normality test was performed on quantitative parameters, followed by the two-tailed Mann-Whitney test. The two-sided Fisher's exact test was applied to qualitative parameters and the Baptista-Pike used for confidence intervals of the odds ratio. Finally, we used the Spearman r for correlation analysis. Results were considered statistically significant when the P value was <0.05. All the statistical analyses were performed using GraphPad Prism 9.4.1. software.

## 3. Results

### 3.1. Compliance of swimming pools in tourist facilities with water standards

The study collected and analyzed 11,014 samples from 254 tourist facilities over four years (2016–2019), with a mean of 43 samples per hotel and a median of 23 samples per hotel. Of the surveyed samples, 30.7% (3386 samples) had at least one parameter that was outside of the acceptable range set by current legislation [12]. The parameters that most often exceeded the established limits were disinfectants (free chlorine and bromine) and water temperature. It is important to note that values outside of the established range do not necessarily indicate a danger for users, but rather that they do not meet regulatory standards. The parameters that would require closure of the facility if exceeded were temperature >40 °C, pH < 6.0 or >9.0, turbidity >20 NFU, free chlorine >5 mg/L, combined chlorine >3 mg/L, cyanuric acid >150 mg/L, and bromine 10 mg/L.

Microbiological levels were also analyzed, and 15.9% of the sampled installations did not meet the mandatory parametric values, indicating that they should be closed. *Pseudomonas aeruginosa* was found to be the main parameter responsible for pool closure. The different types of installations analyzed had varying levels of non-compliance, with cold wells being the worst maintained (82% of non-complying samples), followed by inner swimming pools (45%) and whirlpools (36%). Outer swimming pools showed 27% of non-compliance. The figures showing acceptable and unacceptable sample results based on the parametric values are presented in Table 1.

**Table 1**

Compliance with water standards of legislated parameters in the investigated pools, Balearic Islands, Spain, 2016–2019 (n = 11,014).

Parameter	Parametric value [12]	Total samples	Acceptable		Unacceptable		Closure <sup>a</sup>	
			n	%	n	%	n	%
Temperature	24–30 °C <sup>b</sup>	2,847	2,234	78.5	613	21.5	6	0.2
pH	7.2–8	11,014	10,196	92.6	818	7.4	52	0.5
Turbidity	≤5	11,014	10,990	99.8	24	0.2	4	0.0
Free chlorine	0.5–2 mg L <sup>-1</sup>	9,235	7,277	78.8	1,958	21.2	131	1.4
Combined chlorine	≤0.6 mg L <sup>-1</sup>	9,235	8,819	95.5	416	4.5	3	0.0
Cyanuric acid	≤75 mg L <sup>-1</sup>	9,235	9,090	98.4	145	1.6	52	0.6
Bromine	2–5 mg L <sup>-1</sup>	1,779	1,310	73.6	469	26.4	50	2.8
<i>P. aeruginosa</i>	0 CFU 100 mL <sup>-1</sup>	11,014	9,451	85.8	1,563	14.2	1563	14.2
<i>E. coli</i>	0 CFU 100 mL <sup>-1</sup>	11,014	10,865	98.6	149	1.4	149	1.4
Total		11,014	7,628	69.3	3,386	30.7	1747	15.9

<sup>a</sup> Unacceptable samples with values exceeding the limits established for the pool's closure due to its dangerousness.<sup>b</sup> ≤36 °C for whirlpools.

### 3.2. *P. aeruginosa* contamination in different types of recreational water installations

The recreational water installations found in hotels and other tourist facilities were classified into four groups: outer and inner swimming pools, whirlpools, and cold wells. This classification based on the physical location, the type of installation, the exposure risk and the regulations and standards. The prevalence of *P. aeruginosa* contamination in each group is presented in Table 2. Across all installations, *P. aeruginosa* was detected in 14.2% of samples. Notably, outer swimming pools were significantly less contaminated (12.5%) than the other groups, which showed higher contamination rates: inner swimming pools (16.7%,  $p < 0.01$ ), whirlpools (20.0%,  $p < 0.01$ ), and cold wells (17.5%,  $p < 0.05$ ).

We also differentiated the recreational waters based on their users. Thus, in this study, we compared the contamination in pools used by children to those used by adults. The figures of the analysis are displayed in Table 3. The percentages of contaminated samples were almost identical in both sets of data (14.2%). Consequently, no significant differences were detected between the two groups.

### 3.3. Relationship between the presence of *P. aeruginosa* and the disinfectant used for water treatment

Different methods are used to treat the water in pool basins, with chlorine being the most common in our region, as per previous studies [17]. However, in this survey, we included facilities that use bromine for water treatment, and so we analyzed the possible differences in the contamination levels between recreational waters treated with chlorine and bromine. The findings are presented in Table 4, which shows that the type of disinfection treatment significantly affects the contamination by *P. aeruginosa*. Specifically, the percentage of contaminated samples in bromine-treated installations (23.1%) is almost twice that of those treated with chlorine (12.5%).

We also examined the levels of disinfectant individually. The concentration of free chlorine was typically between 1 and 2.5 mg L<sup>-1</sup>

**Table 2**Contamination of *P. aeruginosa* in the different types of investigated pools, Balearic Islands, Spain, 2016–2019 (n = 11,014).

Type of installation	Absence		Presence		Total	
	n	%	n	%	n	%
Outer swimming pools	7,143	87.4	1,024	12.5 <sup>a</sup>	8,167	100
Inner swimming pools	642	83.2	129	16.7	771	100
Whirlpools	1,488	80.0	372	20.0	1,860	100
Cold wells	178	82.4	38	17.5	216	100
Total	9,451	85.8	1,563	14.2	11,014	100

<sup>a</sup> Significantly lower ( $p < 0.01$  for inner swimming pools and whirlpools,  $p < 0.05$  for cold wells).**Table 3**Contamination of *P. aeruginosa* in water samples from adults and children pools, Balearic Islands, Spain, 2016–2019 (n = 11,014).

Type of use	Absence		Presence		Total	
	n	%	n	%	n	%
Children	1,441	85.7	240	14.2	1,681	100
Adults	8,010	85.8	1,323	14.1	9,333	100
Total	9,451	85.8	1,563	14.2	11,014	100

**Table 4**Contamination of *P. aeruginosa* in water samples with different disinfectant treatments, Balearic Islands, Spain, 2016–2019 (n = 11,014).

Type of use	Absence		Presence		Total	
	n	%	n	%	n	%
Bromine	1,386	76.8	411	23.1 <sup>a</sup>	1,797	100
Chlorine	8,083	87.4	1,152	12.5	9,235	100
Total	9,451	85.8	1,563	14.2	11,014	100

<sup>a</sup> Significantly higher ( $p < 0.01$ ).

(Fig. 1), and contaminated samples had a statistically significant lower level of free chlorine ( $p < 0.001$ ). In the case of bromine, the concentration was primarily between 2 and 6 mg L<sup>-1</sup> (Fig. 2), and we observed statistically significant differences when comparing the presence or absence of the pathogen in water samples ( $p < 0.001$ ).

### 3.4. Evolution of *P. aeruginosa* contamination over the time

The study was conducted over a period of four years, allowing for an analysis of changes in *P. aeruginosa* contamination over different periods. Firstly, we investigated the evolution of pathogen contamination over the years and found that the contamination rate remained relatively constant at around 13.5% from 2016 to 2018 (Table 5). However, in 2019, there was a significant increase in the *P. aeruginosa* contamination rate, which rose to 16.8%.

Additionally, we monitored the seasonal variation of the pathogen monthly. A heatmap displaying the frequency of sample contamination by month and installation is shown in Fig. 3. The results indicate that *P. aeruginosa* was most commonly present in recreational waters during July, August, October, and November, while the pathogen presence decreased in the winter and spring seasons. However, we did observe some variations from this pattern when examining specific installations. For example, high levels of the pathogen in inner swimming pools and cold wells were detected in January.

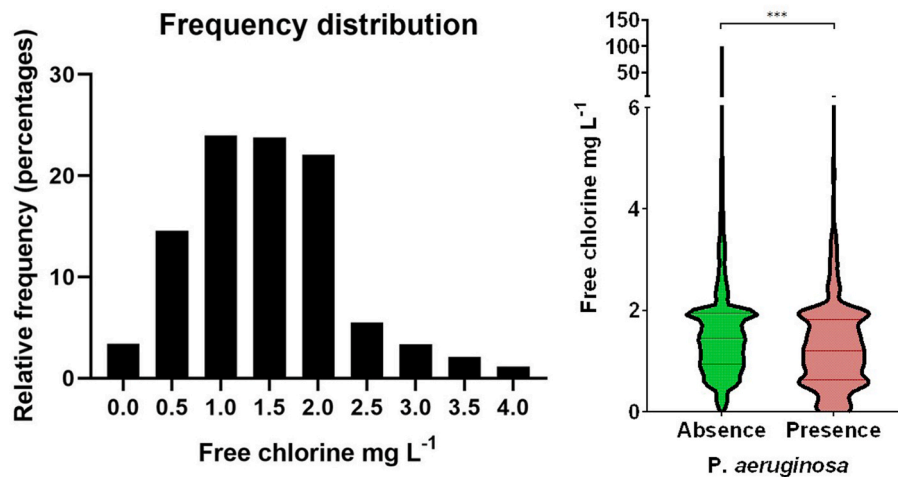


Fig. 1. Frequency distribution of free chlorine levels in *P. aeruginosa* contaminated and not contaminated pool samples, Balearic Islands, Spain, 2016–2019 (n = 8,976). Left, histogram showing the concentration of free chlorine in ranges of 0.5 mg L<sup>-1</sup>. Right, violin plot representing individual levels of free chlorine in pools contaminated or not with *P. aeruginosa*. (\*\*\*, p < 0.001).

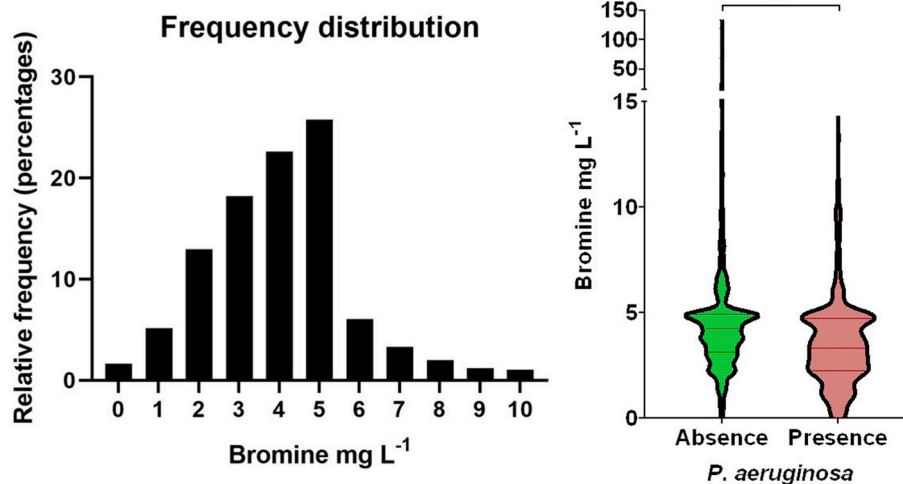


Fig. 2. Frequency distribution of bromine levels in *P. aeruginosa* contaminated and not contaminated pool samples, Balearic Islands, Spain, 2016–2019 (n = 1,779). Left, histogram showing the concentration of bromine in ranges of 1 mg L<sup>-1</sup>. Right, violin plot representing individual levels of bromine in pools contaminated or not with *P. aeruginosa*. (\*\*\*, p < 0.001).

**Table 5**  
Evolution of the contamination of *P. aeruginosa* over the years, Balearic Islands, Spain, 2016–2019 (n = 11,014).

Year	Absence		Presence		Total	
	n	%	n	%	n	%
2016	2,330	86.4	366	13.5	2,696	100
2017	2,534	86.7	386	13.2	2,920	100
2018	2,667	86.3	421	13.6	3,088	100
2019	1,920	83.1	390	16.8 <sup>a</sup>	2,310	100

<sup>a</sup> Significantly higher (p < 0.01 in all cases).

### 3.5. Effects of water parameters on *P. aeruginosa* presence

The present study included the measure of several parameters to monitor the sanitary conditions of the pools. That allowed the investigation of their effects on *P. aeruginosa* presence. The main parameters of the correlation analysis are shown in Table 6. We considered a significant correlation when p < 0.05. Thus, we found a positive correlation between *P. aeruginosa* and *E. coli* (r<sub>s</sub> = 0.19), turbidity (r<sub>s</sub> = 0.11), and

temperature (r<sub>s</sub> = 0.07). A negative correlation was observed between *P. aeruginosa* and bromine (r<sub>s</sub> = -0.20), conductivity (r<sub>s</sub> = -0.12), TDS (r<sub>s</sub> = -0.12), and free chlorine (r<sub>s</sub> = -0.11). We did not observe any correlation between *P. aeruginosa* and pH, combined chlorine and cyanuric acid. In any case, the Spearman correlation coefficient is very close to zero in all cases, indicating a very low correlation, if any, between the water characteristics and the *P. aeruginosa* contamination.

### 4. Discussion

Spain is widely recognized as a prominent tourist destination in the Mediterranean region, boasting a well-developed and highly regarded hotel industry. Among the many services provided by hotels, recreational water facilities rank high in demand amongstourists. It is well-documented that the use of swimming pools and similar facilities can lead to infections, with *P. aeruginosa* being one of the most commonly associated pathogens [9,10]. However, limited information exists regarding the prevalence of this bacterium in recreational water facilities in Spain. Hence, this study aimed to investigate the prevalence of *P. aeruginosa* in hotels located in the Balearic Islands, a significant tourist

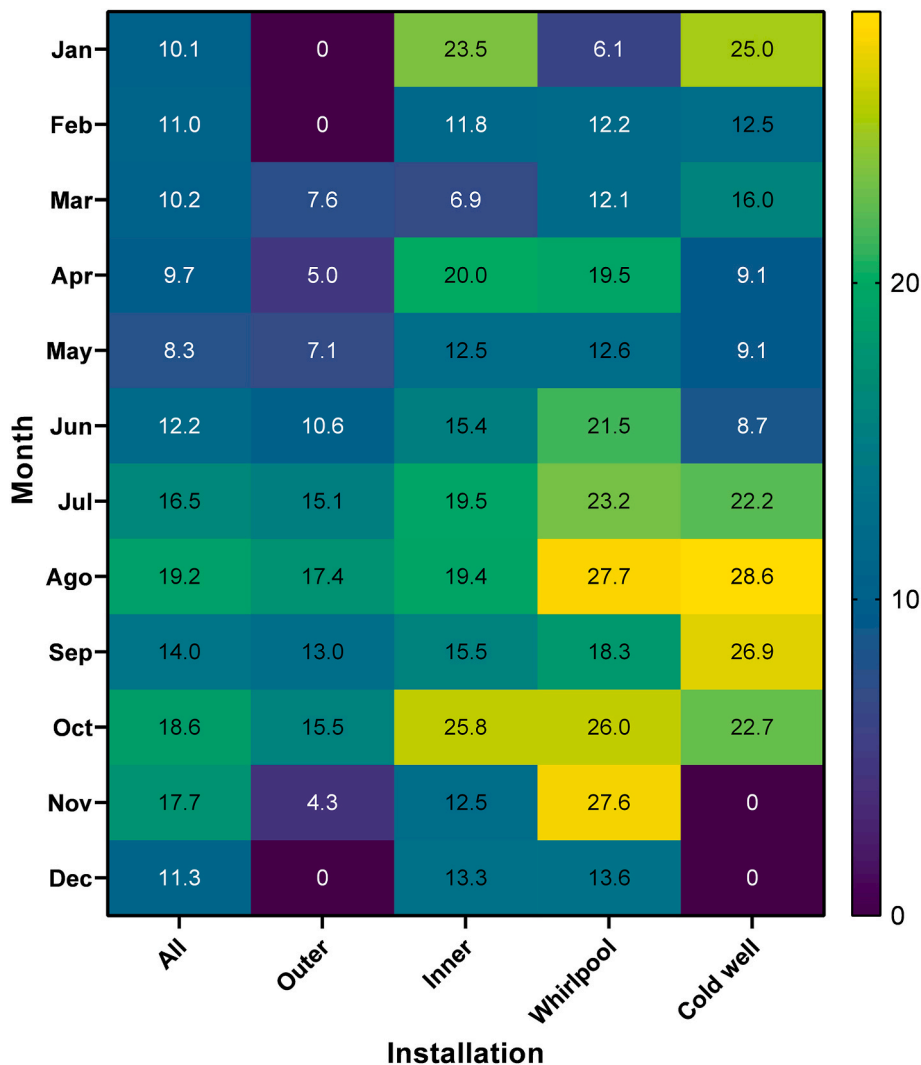


Fig. 3. Seasonal frequency of *P. aeruginosa* contamination, Balearic Islands, Spain, 2016–2019 (n = 11,014).

**Table 6**  
Correlation analysis of water characteristics associated with *P. aeruginosa* contamination, Balearic Islands, Spain, 2016–2019 (n = 11,014).

Parameter	Spearman r	Confidence interval	P
Temperature	0.07	0.03 to 0.10	<0.001
pH	0.02	-0.00 to 0.03	0.128
Free chlorine	-0.11	-0.13 to 0.9	<0.001
Combined chlorine	-0.01	-0.03 to 0.01	0.321
Cyanuric acid	0.02	-0.00 to 0.05	0.062
Bromine	-0.20	-0.25 to -0.15	<0.001
Turbidity	0.11	0.09 to 0.12	<0.001
Conductivity	-0.12	-0.19 to -0.05	0.001
Total dissolved solids	-0.12	-0.19 to -0.05	0.001
<i>Escherichia coli</i>	0.19	0.17 to 0.21	<0.001

destination in Spain.

Initially, we examined whether the water conditions of the visited installations met the parameters regulated by current legislation. Our results revealed that 30.7% of the samples did not comply with the regulations (Table 1). Non-compliance was mainly associated with disinfectant levels, water temperature, and the presence of *P. aeruginosa*. Remarkably, in 15.9% of cases, the examined parameters were considered dangerous for users, and pools should have been closed, with *P. aeruginosa* being responsible for non-compliance in most cases (14.2%). We observed significant differences in compliance among

different types of installations, with outer swimming pools showing better sanitary conditions (27% incompliance rate) than the others. Conversely, cold wells were the worst maintained, only meeting the standards once in five cases. Notably, the percentage of non-compliance in Spanish facilities was higher than that reported in Bologna, Italy [18], where the rate was 19.1%, with outer swimming pools showing similar figures (25%). However, compliance in inner pools was much lower (16% vs. 45%). In Milan, Italy, the non-compliance rate was higher, reaching 72.3% in some cases [19]. Nevertheless, comparing standards among countries is challenging due to the variations in regulations and practices. Despite the high rate of non-compliance, only 1.5% of cases led to pool closure, compared to our 15.9%.

Next, we focused on the characteristics associated with *P. aeruginosa*. Our investigation revealed a prevalence of 14.2% of this pathogen in the analyzed samples (Table 2). Within the European context, these levels are comparable to those reported in Greece (12–16%) [20,21], lower than in North Ireland (50.8%) [22], and higher than in Croatia (4.6%) and Italy (3.8%) [18,23]. Non-European countries, such as Australia, Egypt, and Brazil, have reported higher levels of *P. aeruginosa* contamination [24–26]. Our study also identified differences in *P. aeruginosa* contamination levels among the different types of recreational water facilities (Table 2). The prevalence of the pathogen was significantly lower in outer swimming pools (12.5%) than in the other facilities (inner swimming pools, whirlpools, and cold wells). This finding is consistent with results from Greece [21] and Egypt [24], but differs from those in

Italy [18], where authors attributed the results to the user traffic in inner swimming pools. However, this does not seem to be the case in our analyzed facilities. Furthermore, *P. aeruginosa* contamination in our whirlpools (20.0%) was higher than reported in Croatia [23] and Greece [20], where prevalence rates were 4.7% and 8.2%, respectively. Therefore, it is necessary to implement specific preventive measures for these facilities. In this regard, the new recommendations for the prevention of legionellosis in our region include daily nocturnal hyperchlorination for whirlpools, which could help reduce the frequency of *P. aeruginosa* contamination.

Notably, our study is the first to investigate the influence of children on *P. aeruginosa* contamination in recreational water facilities. We found no significant difference in the presence of *P. aeruginosa* between children's and adults' pools (Table 3), but observed a higher incidence of *E. coli* contamination in children's pools (data not shown).

The proper treatment of swimming pools is crucial to ensure safe conditions for users, particularly in preventing microbial contamination. In our region, chlorine and bromine are the most widely used disinfectants in swimming pools, with alternative treatments being negligible. Previous surveillance studies on *P. aeruginosa* in swimming pools focus on chlorine-based disinfectant treatments. Our study stands out as the first to evaluate bromine-based treatments, revealing that chlorine was more effective than bromine. The pathogen's presence was twice as high in the bromine-treated pools compared to the chlorine-treated ones. Most health authorities consider chlorine the best disinfectant for swimming pool water, as it works well both in indoor and outdoor pools, unlike bromine, which is less effective when exposed to sunlight and is costlier. However, chlorine may cause a strong smell and may cause eye or skin irritation. Nevertheless, our findings provide valuable information for disinfectant selection. Additionally, we compared disinfectant concentration in contaminated and non-contaminated samples, and unsurprisingly, the disinfectant levels were significantly lower ( $p < 0.001$ ), irrespective of whether the pools were treated with chlorine or bromine.

The present investigation spanned a four-year period, allowing for an analysis of the evolution of *P. aeruginosa* contamination over time. We observed a relatively constant prevalence of around 13.5% annually, but an increase to 16.8% in 2019. A similar trend was noted in Croatian pools during the same period [23], although the increase was attributed to a record influx of tourists. In contrast, the number of tourists visiting our region remained stable at around 16.4 million annually between 2017 and 2019 [27], indicating a different cause for the rise in contamination. Disinfectant levels remained comparable over the years, eliminating this factor as a contributing cause. Additionally, we conducted a monthly comparison of contamination levels (as depicted in Fig. 3), revealing higher prevalence during July, August, October, and November, with prevalence decreasing during the winter and spring seasons. These findings share similarities with the Croatian study [23], but notable differences were observed when analyzing data from various types of facilities, suggesting that pool location plays a significant role in these differences.

Lastly, we examined the associations between *P. aeruginosa* contamination and various physicochemical and microbiological parameters. Our analysis using the Spearman correlation coefficient revealed very weak or no correlations between the pathogen presence and most parameters (Table 6). The correlation found between *P. aeruginosa* and *E. coli* is consistent with previous studies [23,24,28,29], supporting that both faecal and non-faecal shedding are essential sources of *P. aeruginosa* contamination of pool water and the environment. We also observed a weak positive correlation between the pathogen and turbidity and temperature, two factors previously linked to microbial contamination in water [30]. Conversely, we found a very weak negative correlation between *P. aeruginosa* and disinfectant levels, as expected from previous investigations [23,24,26] reinforcing the importance of maintaining adequate disinfectant levels, especially for bromine-treated installations, to ensure correct water sanitation. The correlation between

*P. aeruginosa* and pH differs among studies, with some finding a positive correlation [24], while others did not [26]. In our analysis, we did not find any correlation between these two parameters either.

Several nonexclusive factors might explain the differences between our study and the different published surveys, such as national standards (when available), the number of pools and samples investigated, the selected parameters, the quality of pool maintenance, and the nature of installations and users. However, our study is unique in its comprehensiveness, as it covers a large number of samples from various types of recreational waters and includes most of the parameters required by legislation. Additionally, we evaluated the impact of bromine treatment and child users on *P. aeruginosa* contamination in recreational waters, which, to our knowledge, has not been previously investigated. Therefore, our findings provide a highly reliable estimate of *P. aeruginosa* colonization in swimming pools in tourist facilities, at least within our country. Despite the strengths of our study, there are some limitations to consider. For instance, the number of cold well samples was relatively low, which may have impacted our statistical analysis. The number of people using a pool, a factor influencing the contamination status, was not considered. Additionally, we did not include *Legionella* spp., another parameter mandated by legislation. Nevertheless, a recent and extensive survey of this pathogen in our region has already been published [31]. Finally, it is worth noting that our study was conducted prior to the COVID-19 pandemic, and current practices may have changed in response to new preventive measures.

In conclusion, this study provides a comprehensive characterization of the prevalence of *P. aeruginosa* in tourist recreational water installations in the Balearic Islands, Spain. Our results demonstrate diverse degrees of contamination among different types of facilities, and we have considered parameters like bromine use or children's presence for the first time. Our findings highlight the importance of maintaining adequate disinfectant levels, especially for bromine-treated installations, and implementing systematic whirlpool hyperchlorination. Nevertheless, further studies are required in different Spanish regions, as regional variability in *P. aeruginosa* contamination has been reported.

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## CRediT authorship contribution statement

**Antonio Doménech-Sánchez:** Conceptualization, Methodology, Investigation, Writing – original draft, Supervision, Project administration, Funding acquisition. **Elena Laso:** Investigation, Writing – review & editing. **Sebastián Albertí:** Conceptualization, Methodology, Writing – review & editing, Supervision.

## Declaration of competing interest

No potential or actual conflict of interest exists in this work.

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