Noise in indoor swimming pools: Insights from a survey and acoustic measurements

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ABSTRACT

Indoor swimming pools are supposed to be a place to exercise, recreate and enjoy free time. However, many indoor swimming pools show a deficit in appropriate acoustics which can have negative effects on employees and guests. For instance, in previous work surveying sports teachers, acoustics was the ambient condition rated as least satisfying and insufficient speech intelligibility was reported which can be fatal when it comes to security aspects. The presented work contributes to this topic by surveying over 140 employees working in indoor swimming pools and combining these results with room acoustic measurements. Results include the identification of most annoying noise sources, overall satisfaction with ambient conditions and noise-induced health effects among others. Selected results from room acoustic measurements (e.g. sound level, reverberation time) in different indoor swimming pools complement the presentation in order to evaluate the current state of acoustics in indoor swimming pools both subjectively and objectively.

INTRODUCTION

Indoor swimming pools are intended to be a place for exercise, recreation and leisure, for individuals, groups or as part of swimming classes or clubs. An appropriate acoustic condition is a prerequisite to ensure that users feel comfortable, to minimize health and safety risks, and to reach educational objectives [1]. Therefore, the KOK guidelines define acoustic requirements for indoor swimming pools in Germany [2].

However, previous work showed that, from a practical point of view, a lack of appropriate acoustics and a discontent of users can be observed [1]: in one of the few studies on this topic, 81% of surveyed school teachers instructing swimming rated loudness in the indoor swimming pool they work in as very loud or extremely loud. Consequently, the respondents stated a strong discontent with acoustics, which was the ambient condition rated as the least satisfactory compared to other ambient conditions like lighting or room temperature.

The survey results can be underpinned by acoustic measurements during swimming classes which reach an $L_{A,eq}$ of 81 dB(A) and a maximum sound pressure level of 101 dB(A) [3]. This is in contrast to a German regulation, which states that an average noise exposure of 80 dB(A) per eight hours of work can lead to adverse health effects [4]. Moreover, existing regulations will not necessarily lead to satisfied users, given that the regulations are mostly based on a few technical parameters only.

Previous significant work was limited to a sample of school teachers who only spend a few hours per week in swimming pools. Swimming pool employees, however, are particularly exposed to these ambient conditions as they spend a significant amount of time there. Thus, the goal of this work was to gain insights into the acoustic situation in indoor swimming pools with a special focus on employees. It is hypothesised that swimming pool employees are particularly affected by insufficient acoustics. For this purpose, results from subjective (survey) and objective (measurement) evaluations are shown and discussed. Both methods are described below.

METHODS

Survey

An online study was conducted in summer 2019 via the platform Limesurvey in order to survey German swimming pool employees. The questionnaire was distributed by the German Association for Public Swimming Pools (Deutsche Gesellschaft für das Badewesen e. V.) via email newsletter to all German municipal indoor swimming pools. Participation was on a voluntary basis. The survey was based on the questionnaire used in the previously mentioned study on school teachers [1] and was modified in cooperation with the German Association for Public Swimming Pools. First, the respondents were queried about the characteristics of the swimming pool like type of use, use of equipment, type and number of pools, year of construction, and number of weekly visitors. Second, the respondents evaluated parameters of building physics with a focus on acoustics. Third, respondents were asked to indicate whether noise control or other measures are taken in their swimming pools. Then, respondents were asked to describe how they feel after working in the swimming pool to identify work-related psychological and physiological stressors and consequences, e.g. voice exhaustion. Last, the respondents specified occupational characteristics as well as demographic information. Data protection regulations were met. The respondents took around 15 minutes to complete the survey.

Sample

A total of 301 swimming pool employees filled in the survey, but only 164 completed it. Since further eight data sets had to be excluded due to a conspicuously short time to complete the survey, this resulted in 156 complete data sets. Around 75% of the participants were male. The mean age was 42.76 years (*SD* = 11.52; range = 20-64). 88% of the respondents were employed full-time in the swimming pool. On average, they had been employed at their current working place for 14 years, with a range from 0.5-44 years. Further analysis is limited to the employees who worked at least partly close to the water (i.e., not only in the office or the sauna area; *n*=147).

Measures

In order to complement the subjective evaluations, objective acoustic measurements were performed. The background noise $L_{A,eq}$ was measured in a quiet condition, the level of different operating modes, full-day level records and the reverberation time T_{20} were collected. Further, the type of use and the number of visitors were assessed at random. The results were compared to the applicable requirements. For a detailed description of the measurements see [5].

Sample

The measurements were performed in six swimming pools in south-west Germany. Note that the survey data and the measurements do not necessarily stem from the same swimming pools. The survey was rather broadly distributed while concerning objective measurements, a few use cases were selected.

RESULTS

Survey

Characteristics of the swimming pools

Around one third of the swimming pools from which survey data was collected was built in the 1970s. Overall, the age range of the pools (year of construction) was quite wide from pools that were built in 1931 up to new constructions. The majority (92%) of the swimming pools contained more than one pool. The most common kinds of pools were a non-swimmers pool and pools for children (both 68%), while wave pools were the least present (7%). Concerning further facilities, almost all pools were reported to have overflow channels (97%), followed by lane ropes, starting blocks (both 87%), and jets (70%). In contrast, only a few swimming pools had a flow channel (24%), a slide or a water mushroom (both 22%).

A wide range of weekly visitors was indicated (between 60 and 14000 visitors) with an average of 3045 visitors per week. In 86% of the cases, multiple user groups (e.g. normal swimming, schools, clubs and events) were present at the same time, which has been indicated as a contributing factor to noise in previous studies [1].

Acoustic evaluation

On a scale from *0 not annoying at all* to *10 extremely annoying*, shouts (M = 6.84, SD = 2.63) and water sounds (M = 5.26, SD = 2.73) were rated as most annoying noise sources, whereas impact sound (M = 3.56, SD = 2.89) and outside noise (M = 0.80, SD = 1.50) barely play a role (Figure 1). They are probably masked by the background noise. Further, for some noise sources (e.g. aids in form of whistles: M = 3.86, SD = 3.41), quite a large variance can be observed.

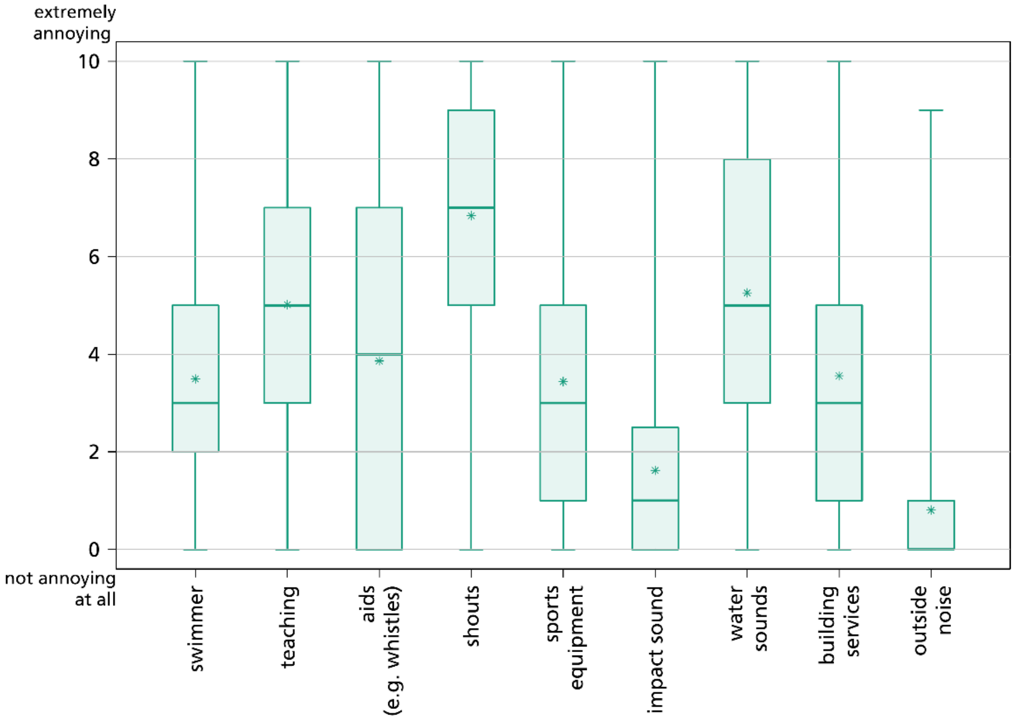

Figure 1. Level of annoyance of noise sources. Horizontal lines in the boxes indicate medians and asterisks means.

The acoustic situation in the swimming pools was rated as loud by 27% of the respondents and as very loud by 3%. Around half of the respondents rated the loudness as medium and 22% as quiet (Figure 2). Further, 32% of the employees indicated that noise control measures were installed or used in the swimming pool where they work. In contrast, 50% of the respondents stated that no noise control measures were installed or used in the swimming pool where they work, and the remaining 18% did not know.

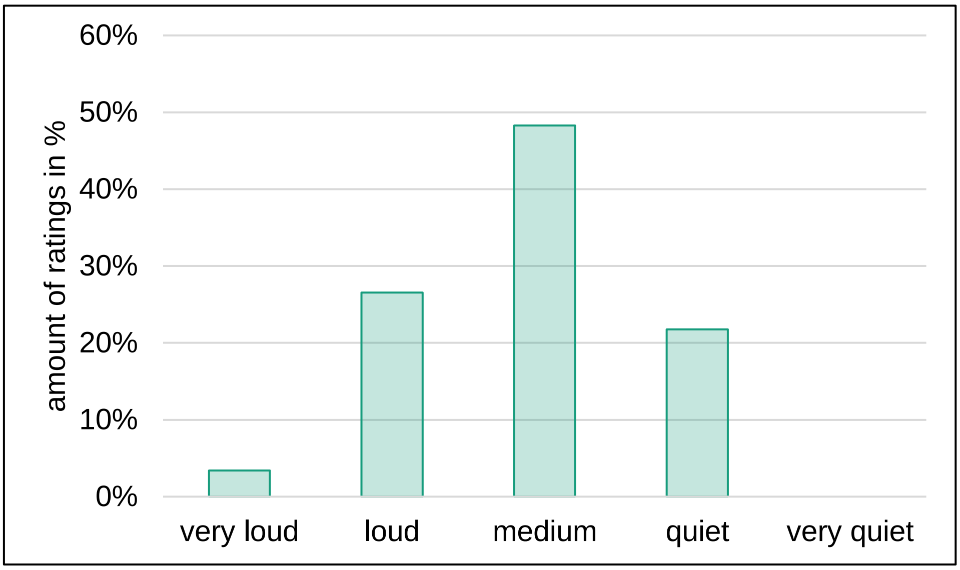

Figure 2. Evaluation of the loudness

Perceived loudness correlated positively with speaking effort (r = .550, p < .001) and listening effort (r = .558, p < .001) during the work in the swimming pool. Further, perceived loudness correlated positively with subjective health condition after working in the swimming pool (Table 1**Table *1***). Higher perceived loudness was associated with a higher incidence of health problems after work in the swimming pool.

Table 1. Correlation of the incidence of health problems and perceived loudness

Health problem	***r***	***p***	**Evaluation of effect size according to Cohen [6]**
Feeling stressed	.508	< .001	Large
Feeling of lack of concentration	.438	< .001	Medium to large
Feeling exhausted	.391	< .001	Medium
Having a headache	.438	< .001	Medium to large
Being hoarse	.356	< .001	Medium
Having a ringing in the ears	.462	< .001	Medium to large
Feeling of temporarily hearing worse	.457	< .001	Medium to large

No statistically significant correlation was found between perceived loudness and year of construction. Moreover, no statistically significant correlation was found between perceived loudness and number of weekly visitors. It has to be noted that it remains unclear how the number of visitors is distributed throughout the week and how reliable the employees' estimates of year of construction and number of weekly visitors are. It is not guaranteed that these numbers are correct.

Comparison of different building physics factors

In order to take into account the whole environment, multiple building physics factors were assessed (Figure 3**Figure *3***). Acoustics, room temperature, air humidity and quality range slightly dissatisfying, with acoustics having a broader range into a more positive evaluation. Compared to previous work, acoustics performs better in this study (*M* = -0.71, *SD* = 1.74) [1]. The slightly positive assessment of lighting (*M* = 0.74, *SD* = 1.56) is more comparable to the previous study [1].

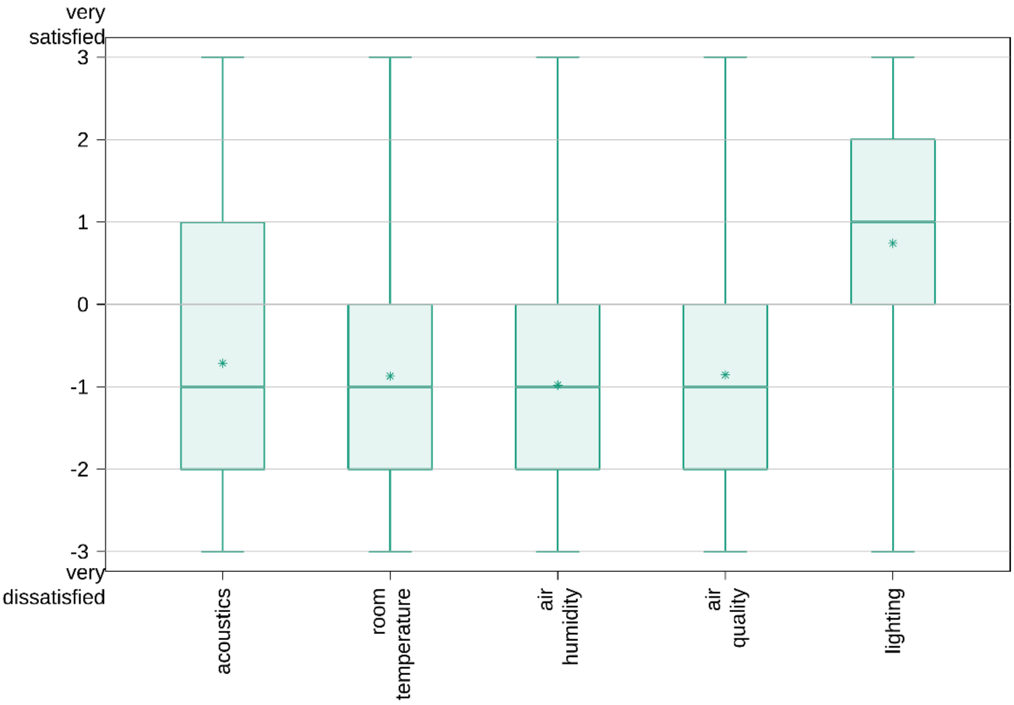

Figure 3. Comparison of different building physics factors. Horizontal lines in the boxes indicate medians and asterisks means.

Measurements

In almost all of the investigated swimming pools, DIN 18041:2018-03 A5 was met with respect to reverberation time. Acoustic deficits in terms of high sound pressure levels could be detected in all swimming pools evaluated. The background noise level generated by technical systems was continuously at least 60 dB(A), even when no visitors were present. Further, in swimming pools with mixed use, a correlation between number of visitors and the level could be clearly observed (see Figure 4 for an example recording). Concerning SPL in the diffuse field (with visitors present), peak values of 99 dB(A) were reached. Maximum SPLs were mostly caused by kids shouting and playing (Table 2). A more detailed description of results can be found in [7].

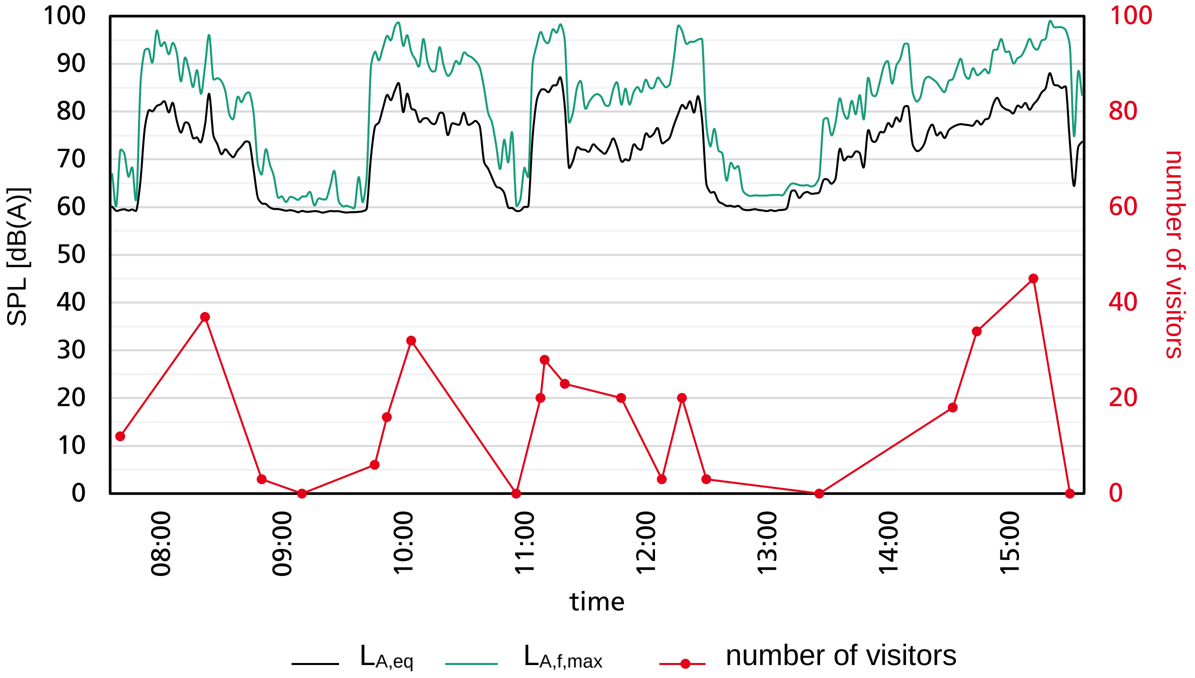

Figure 4. SPL, maximum SPL and number of visitors

Table 2. Sound sources of max. SPLs

Sound source	**$L_{A, f, max}$**
Loudspeaker announcement	92
Kids shouting	93
Kids playing with swimming noodles	99
Jumping of a 3m tower	98

DISCUSSION AND OUTLOOK

In this work, the acoustic situation in German municipal indoor swimming pools was evaluated both subjectively and objectively. Around 150 swimming pool employees responded to an online survey and measurements were performed in six swimming pools in Germany. It was expected that, in comparison to school teachers, swimming pool employees would suffer more from the acoustic conditions given that they spend a significant amount of time in the swimming pool. However, it was found that acoustics were rated as only slightly dissatisfying, comparable to other physical parameters of the room. This is probably due to the fact that many swimming pool employees complete varying tasks throughout the day, and thus, also spend time in quieter areas. Moreover, given that employees were employed in their current positions for an average of 14 years, habituation may also play a role. It also has to be noted that participation in the study was voluntary and that a self-selection bias can have an impact on the results. Given that 2800 swimming pools with a total of 10000 employees were contacted, the response rate was rather small. Further, some data on the building were probably estimated by the respondents, reducing the reliability of the information.

Nevertheless, multiple health effects occurring after work were indicated by the respondents in the swimming pool, which increased in incidence with increasing perceived loudness. Further, insufficient acoustics can also have an impact on safety, e.g., when speech is masked in hazardous situations or due to low speech intelligibility, and interfere with teaching and learning goals. Also, the acoustical measures indicate a need for action. SPLs of up to almost 100 dB(A) were recorded. The required reverberation times, however, were sufficiently met. Even though the structural situation in swimming pools is challenging, for example, due to hard, reflective materials, it is not impossible to apply noise abatement measures. In addition to structural interventions like improvements of the noise sources, the placement of absorbers and organizational measures like reducing the class sizes or improving utilization planning can be taken.

This work is a next step to better understand the acoustic situation in indoor swimming pools, and the related impacts on employees. It has been shown that the acoustic situation is inadequate. As mentioned before a direct comparison between subjective and corresponding objective evaluations (the same swimming pools) was not possible and should therefore be addressed in future research. In the long run, it has to be discussed whether existing regulations [2] are sufficient or have to be improved for the sake of the health of everyone involved.

Acknowledgements

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