Probabilistic Risk Assessment of Indoor Air Quality in a Greek Hospital Facility

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Abstract

Indoor air quality (IAQ) in healthcare environments is a critical determinant of health outcomes, with the potential to affect both carcinogenic and non-carcinogenic risk. Hospitals demand environmental control strategies to combat airborne transmission of particulate matter (PM) and viruses, while protecting vulnerable populations. A comprehensive probabilistic risk assessment was conducted using ModelRisk software, comparing pre- and post-intervention scenarios in a hospital doctors' room. The analysis utilized real-time measurements of PM1, PM2.5and PM10 concentrations, viralcontaminants (including SARS-CoV-2 and Adenovirus genome copies)and environmental variables such as temperature and relative humidity (RH). Carcinogenic risk was calculated as lifetime excess cancer probability. Non-carcinogenic risk was quantified through Hazard Quotients (HQs). Short-term viral infection risk for Covid-19 and Adenovirus was also modeled for Day 1 and Day 2 exposures. Sensitivity analyses were performed to identify the main contributors to risk variability. The intervention achieved an estimated 9.92 reduction in carcinogenic risk, lowering mean lifetime cancer probability from 8.09×10^{-8} to 7.29×10^{-8}, remaining well below the U.S. EPA's de minimis threshold (10^6).Non-carcinogenic HQs showed consistent post-intervention improvements. PM1 HQ decreased by 14.9% (0.0281 to 0.0239),PM2.5 HQ by 9.2% (0.0209 to 0.0190), PM10 HQ by 8.1% (0.0091 to 0.0084).Overall Total HQ Risk decreased by 11.8% (from 0.0582 to 0.0514).Viral infection risk exhibited mixed results for Covid-19, risk on Day 1 was eliminated post-intervention (from 0.00435 to 0) and for Day 2, however, Covid-19 risk emerged post-intervention (from 0 to 0.01696), suggesting temporal variability in control effectiveness.Adenovirus risk was reduced to zero post-intervention across all days.Sensitivity analysis for Covid-19 Day 2 POST risk revealed that PM1 and PM2.5 exposures, indoor humidity, temperatureand exposure time were dominant drivers of risk variability, underscoring the complexity of controlling airborne infection risk in hospital settings. Environmental intervention significantly reduced carcinogenic, non-carcinogenicand viral health risks in this hospital environment. However, the observed persistence and variability of Covid-19 risk on Day 2, influenced by PM exposure, RH, temperatureand occupancy patterns, highlights the need for continuous monitoring andcontrol strategies to ensure the elimination of airborne health risks in healthcare facilities.

Keywords: Indoor Air Quality (IAQ), Carcinogenic Risk, Non-Carcinogenic Risk

Quantitative Microbial Risk Assessment of Pseudomonas aeruginosa in Municipal Swimming Pools: A Case Study from Patras, Greece

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Abstract

Often safety challenges are encountered in swimmingpools due to constant use and variable maintenance of water treatment systems. Pseudomonas aeruginosa, a prevailing waterborne opportunistic pathogen, poses a significant threat due to its potential to affect skin, blood, lungs and other parts of the body. This study applied a quantitative microbial risk assessment (QMRA) methodology to estimate the probability of infection per exposure in chlorinated diving pool environments, utilizing both microbial and operational parameters. Wefocused on threemunicipal athletic indoor and one outdoor pool. Sensitivity analysis and Quantitative Microbial Risk Assessment (QMRA) was performed using Monte Carlo simulation via ModelRisk software. The applied data included three indicator bacterial concentrations (E. coli, aerobic bacteria and coliforms) and two pathogen concentrations (Pseudomonas, Staphylococcus), water quality parameters (temperature, pH, chlorine, alkalinity) and exposure- related variables (duration of exposure, number of swimmers per hour, water ingestion volume) as modifying parameters. In Pool B,the average risk of P. aeruginosa infection per exposure was estimated 1.3×10^{-4} exceeding the acceptable limit of 0.0001 and approximately as low as 15-20% of simulations outweighed the threshold, indicating slightly elevated risk in the indoor pool environment. In contrast, outdoor pool (pool A)illustrated an essentially lower mean risk of 1.4×10^{-6} per exposure, with 0% of simulations surpassing the threshold, indicating the classification of outdoor pools as safe under current operational conditions. Themean risk per exposure in Pool C was 4.5×10^{-5}. No simulation exceeded the threshold of 10^{-4}, indicating low health risk. The mean risk per exposure in pool D was estimated at 2.8×10^{-4} and approximately 15-20% of simulation outcomes exceeded the threshold, indicating a non-negligible infection risk. Also, in bothpools B and D, chlorine was identified as one of the most influential factors in infection risk. Sensitivity analysisconsistently showed that deviations in chlorine concentration had a considerable impact on the probability of infection, with simulated values ranging from below 1 mg/L to above 6 mg/L, breaching international disinfection thresholds (1-3 mg/L). The analysis implies thatpoolsB and Dare considered of higher microbial health risk than the rest of pools. Pools A and C perform low infection risk from P. aeruginosa, with all outcomes remaining within internationally acceptable limits. The QMRA results indicate a possible scientific approach to managing interventions in swimming pools, highlighting the influence of microbial concentrations and chlorine levels.

Keywords: Microbial Risk Assessment, Swimming Pools, Public Health