9th ICSPS
2021, Turkey

SÜLEYMAN DEMİREL ÜNİVERSİTESİ 1992

AL-QUDS UNIVERSITY

9. INTERNATIONAL CONFERENCE OF SWIMMING POOL & SPA

Abstract Book

19 NOVEMBER 2021

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CONTENTS

WELCOME

Dear Colleagues and Friends,

It is our great pleasure and honor to welcome you to 9th International Conference of Swimming Pool and Spa. The conference aims to provide the best platform for researchers and experts worldwide to discuss recent researches and developments in management of swimming pools and similar environments upon the health of users such as microbial contamination, exposure to chemicals and operational issues. The focus is on the perspective to maintain safe swimming pools and spas. Our conference first started to be held in Budapest in 2005. Afterwards, it was held regularly every two years in the cities of Munich, London, Porto, Rome, Amsterdam, Kos and Marseille. At today, we are very happy to host you in Turkey. The conference consists of three parts: keynote presentations, oral presentations and poster presentations within the different topics related to management of swimming pool and similar environments. Nearly 60 participants from 14 different countries and regions attended to share their knowledge and experience. On behalf of the committee, we would like to thank our keynote speakers, all the presenters, all the authors, reviewers who have contributed their best efforts and assistance in organizing the event and ensuring the success of it. We would like to extend our heartfelt thanks to all attendees who have joined this conference from all over the world. We are extremely pleased that the conference was well attended by various stakeholders. We have learned a lot from the keynote sessions delivered by the amazing keynote speakers, and presenters who have shared their interesting work. We sincerely hope that through presentation and discussion afterwards, all of us can contribute to manage swimming pools and similar environments problems in our own countries. Even though the contribution may be small, but it is still valuable. Let us wish all of us a lot of energy, enthusiasm, shared trust and resolve on our way towards achieving a better future for all. We are looking forward to meet you in Bologna, Italy, 2023.

On behalf of the Organizing Committee

Assoc. Prof. Dr. S. Sule KAPLAN-BEKAROGLU

Assoc. Prof. Dr. Bilgehan Ilker HARMAN

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Scientific Program

10:00-10:10

Opening and Welcome Program
Suleyman Demirel University & Al-Quds University

10:10-10:30

Turkish Ministry of Health

10:30-12:00 Keynote Lectures

Chairs: *Michele HLAVSA & James AMBURGEY*

10:30-11:00	**Sustainability of Sport and SPA Pools** *Vincenzo ROMANO SPICA, Università Degli Studi di Roma*
11:00-11:30	**Swimming Pools During the Corona Pandemic** *Maarten KEUTEN, Delft University of Technology*
11:30-12:00	**Swimming Pool in the Time of Covid-19: Practies and Knowledge** *Emanuele FERRETTI, Italian Institute of Health*

12:00-13:00

Break Time

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13:00-14:45 Session - 1

Chairs: *Vincenzo ROMANO SPICA & Maarten KEUTEN*

13:00-13:15	**Swimsuits and Photocatalytic Properties: Sustainability and Benefits for Health and Environment** *Lory Marika MARGARUCCI, Federica VALERIANI, Gianluca GIANFRANCESCHI, Vincenzo ROMANO SPICA,*
13:15-13:30	**Dynamic Water Quality Modeling of Pools with Varying Designs and Bather Loads** *James AMBURGEY, Amir ALANSARI*
13:30-13:45	**Enhancing the Public Health Response to Cryptosporidium Cases Linked to Swimming Pools** *Rachel CHALMERS*
13:45-14:00	**Particulate Pollution in Swimming Pool Water: A First Approach of the Characterisation of Particles in Water From a Real Swimming Pool** *Martin MARECHAL, Olivier CORREC, Anthony COUZINET, Nicolas CIMETIERE, Fabien GERARDIN, Jean-luc BOUDENNE,*
14:00-14:15	**Pool Chemical Injuries - United States, 2008-2017** *Michele HLAVSA, Kayla VANDEN ESSCHERT, Samaria ALUKO, Vincent HILL*
14:15-14:30	**Health Issues on the Swimming Pool During Covid-19 Pandemic: National Guidelines and Regulations in Italy** *Emanuele FERRETTI, Lucia BONADONNA*
14:30-14:45	**Impact of The Direct Wastewater Discharge From Hot Springs to Rivers** *Alexander REUSS, Yuly Andrea SANCHEZ, Mehrab MEHRVAR, Lynda MCCARTHY, Luis RODRÍGUEZ CHEU, Edgar QUİÑONES, Jairo ROMERO*

14:45-15:00

Break Time

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15:00-16:45 Session - 2

Chairs: *Jean-luc BOUDENNE & Emanuele FERRETTI*

15:00-15:15 **Experimental Investigation of the Feasibility of Chloramines Stripping**
Andrea COLETTO, Diego Savio BRANCIFORTI, Daniele DONDI, Pietro POESIO

15:15-15:30 **Challenges in Chemical Treatment of Therapeutic Thermal Waters**
Dora GERE, Márta VARGHA, Gyula ZÁRAY

15:30-15:45 **Chlorate in Dutch Pools During the Corona Pandemic**
Maarten KEUTEN, Jan BAKKER

15:45-16:00 **Analysis of Trichloramine in Diluted Aqueous Solutions. Analytical Development and Application to the Determination of Trichloramine in Swimming Pool Water**
Joseph DE LAAT, Yves LE MOT

16:00-16:15 **Trichloramine Sampling Method for a Complete Work Shift and Its Validation**
Elham AHMADPOUR, Isabelle VALOIS,Stephan HALLE,Maximilien DEBIA

16:15-16:30 **Pool Water and Indoor Air Trihalomethane Concentrations in Swimming Pools - A Preliminary Study in Izmir, Turkey**
Mesut GENİŞOĞLU, Yetkin DUMANOĞLU, Sait C. SOFUOĞLU

16:30-16:45 **The Dutch Approach to Swimming in Times of Covid-19**
Jan G. BAKKER, Maarten G.A. KEUTEN

16:45-17:15 Poster Session

Chair: *Nuray ATEŞ*

Principles of Operation of Swimming Pool Facilities During the COVID-19 Pandemic and Their Impact on the Quality of Swimming Pool Water
Joanna WYCZARSKA-KOKOT, Jerzy MENDAKIEWICZ, Anna LEMPART-RAPACEWICZ, Mariusz DUDZIAK

Biologically Active Compounds in Swimming Pool Water
Anna LEMPART-RAPACEWICZ, Edyta KUDLEK, Mariusz DUDZIAK, Joanna WYCZARSKA-KOKOT

Monitoring of Pollutant Concentrations in Private Backyard Swimming Pools
Edyta KUDLEK, Anna LEMPART-RAPACEWİCZ, Mariusz DUDZİAK, Joanna WYCZARSKA-KOKOT

Characterization of Bacterial Communities in Peloids By 16s Amplicon Sequencing
Isabella MARCHESI, Stefania PADUANO, Federica VALERIANI, Vincenzo ROMANO SPICA, Alessandro SIGNORINI, Giuseppina FREZZA, Sara TURCHI, Paola BORELLA, Annalisa BARGELLINI

Cancer Risk Modelling Caused by Disinfection by-Products in Swimming Pool
Mert MINAZ, Mesut GENİŞOĞLU, Sait C. SOFUOĞLU, S. Şule KAPLAN BEKAROĞLU, Nuray ATEŞ, Amer KANAN, Nevzat O. YİĞİT, Tuğba SARDOHAN KÖSEOĞLU, Qahtan Adnan ALI ALI, Mehmet KILIÇ, B. İlker HARMAN

17:15-18:00

Discussion and Closing Remarks
Chairs: *S. Şule KAPLAN BEKAROĞLU & Amer KANAN*

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KEYNOTE LECTURES

Sustainability of Sport and Spa Pools

Vincenzo ROMANO SPICA[1*]

[1]*Università Degli Studi di Roma*

*vincenzo.romanospica@uniroma4.it

Introduction and purpose: Swimming pools need water, but water is an increasingly rare precious resource. H_2O is required for drinking, farming, industry, hygiene and sanitation purposes, but also for sport, rehabilitation, adapted physical activity and recreational uses! Dramatic climate changes are further challenging humanity's capabilities to face hydrogeological instability, protect aquifers, and enable an equitable distribution of water for all the needs of every human being sailing along this small, "small world after all". Water shortage is not a future nightmare, but a current condition encountered in every continent at different local levels. Even the watery soil of the Rome district -that is well known since ancient times for the beautiful fountains, the routes of the Roman aqueducts or the SPA pools of the Thermae- even the eternal city -in the middle of the Mediterranean Sea-, had to deal with drought in the last years, restricting access to water. Especially when the shortage of water could limit essential sanitary uses, is it politically and ethically permissible to fill swimming pools for recreational, sport, rehabilitation or wellness uses? Is it right to "play" with water? Yes, but it requires a higher level of awareness and accountability: this answer is blowing in the water, in our education and empowerment, in our technologies and capabilities to respect and manage water by a sustainable and peaceful approach. "Sustainable" does not mean affordable for our today budget, but transferable in the future to the tomorrow generations. In any time, availability of pools required advanced technologies and an educated, peaceful and empowered civilization.

Materials and Methods: By briefly reporting statements and principles from documents such as the World Water Reports of the United Nations, National Regulations and international Guidelines, consensus papers from supranational organizations such as COPD26, and different technical data and scientific perspectives, a state of the art on the question of water sustainability will be briefly summarized and hints for further discussion proposed.

Findings: Playing with water is natural and ethically correct. It should be a right for any citizen of the world, at any age. Sport is a main human activity with a relevant cost and environmental impact, representing a positive flywheel for growing education and a peaceful progress. Access to water and its appropriate management is a present and challenging question, involving scientific, technical and political issues, but requiring also awareness on social and environmental issues in a modern and global perspective.

Results and conclusions: Swimming pools are often supplied with different kinds of waters including drinking water. Several alternatives are available and public health policies and procedures are required to assure safety and to support the diffusion of the access to recreational uses of water. Blue, Green and Grey waters can play a role. Pilot pools and experimental solutions have been described. Appropriate physical activity in water impacts on a healthy development and aging, and it should be promoted, everywhere. Sustainability of pools is part of a larger problem involving the approach to energy and natural resources and the evaluation of the impact of human activities on pollution, within a local and global scale. The ecological footprint of water is reported for sport and other activities, as a tool for measuring the environmental costs to address their needs, and to support a multidisciplinary approach to a sustainable progress.

***Keywords**: COP26, WWDR 2022, Water footprint, Rainwater, Recreational water*

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Swimming Pools During the Corona Pandemic

Maarten KEUTEN[1*], Jan BAKKER[2]

[1]Delft University of Technology, Delft, Netherlands
[2]Outdoor Clinic Swimming Pools, Amsterdam, Netherlands

*m.g.a.keuten@tudelft.nl

During the corona pandemic, various processes in swimming pools took place differently than usual. The disinfection parameters of the bathing water was increased, the number of visitors was reduced, combined with various restrictions. There were also many questions about coronavirus transmission in swimming pools, some of which were investigated by the Outdoor Clinic on Swimming pools in cooperation with Delft University. Results of a study on chlorine levels and aerosols in swimming pools were presented in previous online conferences by University of Rome "Foro Italico" and PWTAG. The last part of the study focused on medical aspects and behaviour of swimmers. Are there health complaints that can be related to the increased disinfection parameters, what about DBP's as THM's and chlorate, are they increased, do swimmers and pool staff keep to the corona rules of conduct and what about the technical aspects of the corona pandemic. In this presentation the results and conclusions of this research will be presented.

Keywords: *SARS-CoV-2 in swimming pools, Medical aspects, Behaviour of swimmers*

Swimming Pool in the Time of Covid-19: Practices and Knowledge

Emanuele FERRETTI[1*], Lucia BONADONNA[1]

[1]Italian National Institute of Health, Viale Regina Elena 299, 00161 Rome, Italy

*emanuele.ferretti@iss.it

Public health concerns, practices, and knowledge related to swimming pools at the time of COVID-19 and how to improve risk management while SARS-CoV-2 and its Delta variant are circulating in the population are presented. To date, no transmission of COVID-19 through water has been proven. According to the Centers for Disease Control, there is" no evidence" that SARS-Cov-2 can be spread through the water environment in pools, Jacuzzi, healthy spas, or water play areas. Viral units are likely to experience considerable decay and loss of infectivity rapidly after arriving in water and also when water is subjected to disinfection treatment with chlorine and other common disinfectants, such as bromine, ozone, or UV. Regardless, out of the water, SARS-CoV-2 virus can be transmitted by relatively large respiratory droplets, and exhaled aerosol droplets, which potentially pose a greater risk especially in indoor environments. The risk of the SARS-CoV-2 spreading within a sporting environment can be reduced by the implementation of appropriate COVID-19 protocols, thus several associations and authorities issued guidelines, standards, etc. to implement mitigation strategies for its members, staff, swimmers, and aquatic sports fans, advising to practice physical distancing, protect oneself when training, and to optimize hygiene practice of individuals, environment and equipments. Moreover, high vaccination coverage will reduce the spread of the virus and help prevent new variants from emerging. CDC and other international authorities recommend that everyone aged 12 years and older get vaccinated as soon as possible.

Keywords: *Swimming pools, Covid-19, SARS-CoV-2, Delta variant, Risk management*

ORAL PRESENTATIONS

Swimsuits and Photocatalytic Properties: Sustainability and Benefits for Health and Environment

Lory Marika MARGARUCCI[1*], Federica VALERIANI[1], Gianluca GIANFRANCESCHI[1], Vincenzo ROMANO SPICA[1]

[1]*University of Rome "Foro Italico", Rome, Italy*

*l.margarucci@studenti.uniroma4.it

Introduction: The history of swimsuits has ancient origin and in the last years the development of new products with innovative proprieties increased under the pressure of manufacturers and users. New materials, design and nanotechnologies have been introduced to improve the quality, comfort and to make textiles more functional with excellent fit and freedom of movement, resistance to chlorine and cleaning, a quickly drying capacities. All innovative solutions were introduced to guarantee specific properties and obtain higher performance in sport competitions as well as improve specific requirement of hygiene and safety requirements for users. Microbes as bacteria and moulds can grow very quickly on wet swimsuits and determine disease risk of skin, as folliculitis and other dermatitis. Research and development in textile sector view these hygiene aspects and implement, new solutions are constantly evolving. Antimicrobial functionalization of textiles is recently introduced with multiple advantages, as the protection of textiles from microbial growth and degradation of organic pollution with consequently reduction of undesirable odours. Fabrics with antimicrobial proprieties have a wide range of applications in domestic, commercial, and hospital settings. Several examples are the addiction of disinfectants, antibiotics, enzymes and biocides to fibers and textiles. However, these methods of decontamination can have different limitations, such as the exhaustion of antimicrobial substances after immersion or washing, the generation of chemical interactions or allergic reaction, and also release the polluting of chemical substances in the environments. The introduction of environmentally friendly materials within the fibers of the textiles could be an alternative to overcome these limits. Among alternative treatments, photocatalytic compounds, such as zinc oxide (ZnO) or titanium dioxide (TiO_2) seem promising. These photocatalysts in the presence of light, air, and water, can generate reactive oxygen species with antimicrobial capabilities. TiO_2 is a well-known photocatalyst that has been extensively tested and shown to e ectively decompose a wide range of organic substances and have antimicrobial activity in water and surfaces. In the present work, the antimicrobial functionalization by TiO_2 of textiles is evaluated. A series of experiments by depositing TiO_2 particles on two types of textiles used for swimsuits are prepared. The pieces of textiles were then contaminated with droplets of bacteria suspensions and the coatings were activated by light radiation at different wavelengths.

Material and Methods: Two typologies of textiles used for swimsuits and footwear are selected: a) 80 % polyamide and 20% elastane and b) 100% polyester. The textiles are coated with Titanium Dioxide (TiO_2) microparticles. Briefly, microparticle (1–4 µm and 1.2 ± 0.1 % w/w of concentration) suspensions in water were obtained from different producers (Sigma Aldrich, Saint Louis, MO, USA; Chem Spec srl, Peschiera Borromeo, Italy; NTT, Prato, Italy). All textiles were cut into pieces of about 7 × 5 cm and wetted only on one side with a suspension of TiO_2 microparticles, at concentrations of 1.2±0.1%w/w, dried in a microbiological hood at room temperature for about 24 h. Fabric samples non wet in the TiO_2 suspension have been used as control samples. Gram-negative Escherichia coli (ATCC 25922) and a Gram-positive Staphylococcus aureus (ATCC 25923) strains were used to test the photocatalytic antibacterial effects. The strains were cultured on Tryptic Soy Agar (Oxoid, Basingstoke, UK) and incubated aerobically at 37 °C overnight. To each piece of tissue 3 spots, with diameters of 0.5 mm by 2 μL of the suspension 104 CFU/mL, were applied. Coated textiles were exposed for 1, 5, and 15 min. At the end of the exposure, each piece of tissue was removed with sterile tweezers and placed on a selective growth medium to test microorganism growth, using Brilliance™ E. coli/coliform selective agar (Oxoid, Detroit, MI, USA) for E. coli and Mannitol Salt Agar (Oxoid, USA) for S. aureus. The plates were incubated at 37 ± 1 °C for 18–24 h. The bacterial concentration of each spot at Time 0 was evaluated. The number of bacterial concentration, at 1, 5, and 15 min, was determined counting bacterial colonies present in the agar plate and the number of CFU was reported as CFU/mL, and the percentage of surviving bacteria was calculated respect the T0 microbial load. The system of exposition was performed using a dedicated LED-based display system encompassing an UV source and light sources in the visible spectrum, and a system that include 5 LEDs at the following wavelengths: 395-400 nm, 450-455 nm, 515–525 nm, 590-595 nm, and 620-630 nm.

Results and discussion: All samples coated with TiO_2 contaminated with different microbes and showed a reduction of the bacteria load after 15 minutes of exposition at different light wavelengths. The mean values of CFU/ml of all exposed samples suggested the possibility of obtaining an antibacterial photocatalytic effect independently of the kind of exposition of source lights or dark. Higher antibacterial effects were observed with a combination of wavelengths in the visible spectrum and UV light. Exposure at different led with wavelengths of the visible spectrum showed 25% of survivors for the samples exposed at led 395-400 nm and 14% of survivors for the fabric samples exposed at 450-455 nm. The exposure with blue light (nm = 450– 455) induced a significant increase in CFU/mL reduction (>98%, $p = 0.0151$). The results allow for a series of considerations, supporting a disinfection by visible light, avoiding the risks related to UV irradiation leading to eye and skin damages. The possibility of micrometric TiO_2 activation by visible spectrum wavelengths can represent a safer, promising, and smart approach. In these experiments, no chemical or physical carriers were used to bind particles to surface; however, several methods, as chitosan with inorganic materials, are available for coating different matrices, including textiles. Furthermore, appropriate and optima fixing of particles would be a key issue for safety, by reducing the risks of dermal prolonged contact of powder traces with the skin. Otherwise, as for skin contact, TiO_2 is an active ingredient in many sunscreens and its use in this specific application is recognized as safe because it does not seem to penetrate the subcutaneous layers.

Conclusions: The application of antimicrobial agents onto the fibers of the swimsuits may a promising opportunity to prevent biological risks. These agents may reduce the bacteria proliferation and consequently the generation of bad odour that favour the degradation of the fibers and the need to use disinfectant products to cleanliness during the laundry wash. The photocatalytic materials applied to fibers may reduce the discharge of antibiotic or disinfectants in the environment and could positively impact the safety of swimmers/workers, and environmental sustainability in different occupational or recreational settings.

***Keywords**: Swimsuits, Textiles, Auto-disinfection, Photocatalysis, Biological risks*

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Dynamic Water Quality Modeling of Pools with Varying Designs and Bather Loads

James AMBURGEY*[1], Amir ALANSARI[1]

[1]*University of North Carolina at Charlotte, Charlotte, United States*

*jeamburg@uncc.edu

By combining accepted equations, measured values, and published data, a new software platform for modeling water quality in pools and spray pads was developed. It is now possible to computationally model the turbidity, UV-254 absorbance, and *Cryptosporidium* concentration over time based on the type of treatment system, turnover rate, and bather load. It is possible to quantify and compare water quality trends based on design or operational changes. For example, the water quality can be predicted based on a change in the turnover time, switching filters, and/or adding a UV disinfection system. The *SuperModel* program will allow designers, regulators, manufacturers, researchers, and operators to make informed decisions about managing water quality, risks, costs, and capacity limits. Contaminant loading events are based on a fluctuating bather count over time while contaminant loads are based on research measurements of swimmers on a per bather basis. Similarly, the filter performance is based on full-scale filter measurements. Accidental fecal releases (AFRs) and pathogen sloughing can both be simulated by the user over a 7-day period of pool operation. Simulations demonstrate that as filter efficiency varies from 22% (worst-case scenario) to 99% (best-case scenario), the pool's turnover rate can be decreased to compensate for inefficient filters. Some filter and turnover combinations could return a pool to "safe levels" within 24 hours of an ARF, while alternate designs could take a week or longer. Up to five simulated pool designs can be compared with the same bather load over a 7 day period to detect contaminant accumulation in the form of turbidity, *Cryptosporidium*, or organics (as measured by UV-Absorbance). Simulations could predict the maximum bather load for a variety of pool designs. Spray pads, with the relatively large numbers of bathers per gallon of water could see rapid accumulation of turbidity that could impair chlorination and organics that could impair UV disinfection systems both leading to increased risk of waterborne disease outbreaks. Pool designers and regulators could make well-informed decisions about the relative performance of different design options. Based on a peer-reviewed equation, it can be shown that poor filter efficiency can be partially or completely offset by decreasing the turnover time, which can be visualized using the *SuperModel*. For example, a filter operating at 98% removal efficiency with a 6-hour turnover would perform identically to a filter operating at 24.5% removal efficiency with a 1.5-hour turnover (because both values were decreased by a factor of exactly 4). However, filter efficiency is not currently used in comparing design alternatives or in setting government regulations or in determining maximum bather capacities of aquatic facilities.

Keywords: *Model, Filtration, Cryptosporidium, Ultraviolet disinfection, Turbidity*

Enhancing The Public Health Response to Cryptosporidium Cases Linked to Swimming Pools

Rachel CHALMERS[1*]

[1]*Public Health Wales, Swansea, United Kingdom*

*rachel.chalmers@wales.nhs.uk

Cryptosporidium is an important cause of diarrheal illness, and transmission through swimming pools has caused many outbreaks of cryptosporidiosis. For example, in England and Wales, 82 (46%) of 178 Cryptosporidium outbreaks in the period 2009 to 2017 were linked to swimming pools, the remaining linked to animal contact (42%), environmental contact (2%), person-to-person spread (2%), food (2%), drinking water supplies (1%), and the rest were of unknown source (5%). The swimming pool outbreaks were predominantly caused by C. hominis gp60 subtype IbA10G2 and were mainly in the second half of the year. This paper will describe how epidemiological investigations, swimming pool inspections, and improved microbiological characterization can be integrated to investigate clusters of Cryptosporidium cases, define the extent of complex outbreaks, understand the likely transmission pathways, and identify failings and improvements required in swimming pool management and operation.

Keywords: *Cryptosporidium, Gp60, Swimming pool, Outbreak, Epidemiology*

Particulate Pollution in Swimming Pool Water: A First Approach of the Characterization of Particles in Water from A Real Swimming Pool

Martin MARECHAL[1*], Olivier CORREC[1], Anthony COUZINET[1], Nicolas CIMETIERE[2], Fabien GERARDIN[3], Jean-luc BOUDENNE[4]

[1]Scientific and Technical Center for Buildings (CSTB), Nantes, France
[2]Rennes School of Chemistry (ENSCR), Rennes Institute of Chemical Sciences (ISCR), UMR 6226, Rennes, France
[3]French National Research and Safety Institute (INRS), Vandœuvre-lès-Nancy, France
[4]Laboratory of Environmental Chemistry (LCE), Aix-Marseille University, Marseille, France

*martin.marechal@cstb.fr

Dissolved pollution in swimming pool is often simulated by Body Fluid Analog (BFA), whose composition is supposed to be close to bathers' inputs, such as sweat, urine or saliva. The formulation of BFA - created around 20 years ago - varies depending on the authors (Borgmann-Strahsen, 2003; Goeres et al., 2004; Judd and Black, 2000; Judd and Bullock, 2003). Many studies used BFA to simulate dissolved pollution at laboratory scale (Kanan and Karanfil, 2011; Hansen et al., 2012b) and pilot scale (Judd and Black, 2000; Tsamba et al., 2020). On the other hand, pollution brought by bathers may also be made of particulate matter consisting of hair, skin flakes, microorganisms (Manasfi et al., 2017) or some components contained in personal care products such as titanium dioxide found in sunscreens to repel UV radiations (Jeon et al. 2016). This kind of pollution is not as referenced as dissolved pollution in the scientific literature so far, and only few studies deal with the potential effects of particulate matter on disinfection by-products (DBPs) formation in swimming pools (Kim et al., 2002; Hansen et al., 2012a). These studies showed significant contribution of particulate matter in DBPs formation and possibly, according to Hansen et al. 2012, higher formation of DBPs from particles than from BFA or natural organic matter. Currently, BFA only simulate dissolved compounds and does not take into account of the contribution of particles as chlorine consumption species or DBPs precursors. Thus a better understanding of the composition of particles loaded by bather will allow to formulate a more accurate description of BFA. This study presents results obtained from 2 sampling campaigns in a real indoor leisure swimming pool in western France. The first campaign aimed to investigate particulate pollution in backwashing water of sand filter over time. The second campaign aimed to estimate particulate pollution brought by schoolchildren in the same swimming pool during restrictions decided by French government due to the Covid-19 pandemic. pH and conductivity showed similar trends for both campaigns, and combined chlorine was higher in filter backwashing waters than in ultrafiltered (first campaign), pool and filling water. For the first campaign, turbidity was expected to reach a peak at 27 NTU. Total suspended solids (TSS) reached 90 $mg.L^{-1}$ and decreased to 20 $mg.L^{-1}$ for the four last backwashing samples. No TSS were found in ultrafiltered water, pool water and filling water. Particle sizes varied from 2 to 200 µm (96% of all particles) with a peak at 23.8 µm. Particulate and total organic carbon releases were estimated at 152.1 and 198.0 $mgC.bathers^{-1}.day^{-1}$ respectively and particulate carbon represented around 77% of total organic carbon released by bathers. For the second campaign, turbidity measurements showed a peak at 60 NTU. TSS reached 90 $mg.L^{-1}$ and

decreased to 20 mg.L^{-1} for the last backwashing water sample. Particle size analyses showed 2 peaks on 2 samples (those containing the most of particles) around 0.6-0.7 and 18-20 µm with slight differences between both samples. Particulate and total organic carbon releases were estimated at 15.0-16.0 and 28.0-29.0 mgC.$bathers^{-1}$.day^{-1} respectively (around 58% of particulate carbon). Remaining particles, as particulate carbon concentration for the last backwashing sample (0.8 mgC.L^{-1}) is low, were probably sand particles and/or aggregates with flocculant (aluminium chloride). Analyses of some disinfection by-products showed dichloroacetic acid (DCAA; around 75 µg.L^{-1}) and trichloroacetic acid (TCAA; around 122 µg.L^{-1}) as being the dominant species in backwashing water samples, followed by chloral hydrate (CH; around 28 µg.L^{-1}) and chloroform (around 18 µg.L^{-1}). Concentrations of DCAA and TCAA were higher in backwashing waters than in filling water (6.4 and 4.0 µg.L^{-1} respectively) whereas the opposite was found for bromodichloromethane (BDCM) and dibromochloromethane (DBCM) with around 3.3 and 2.0 µg.L^{-1} in backwashing waters respectively, 19.0 and 19.6 µg.L^{-1} in filling water respectively. Differences between haloacetic acids and trichloromethanes formation in drinking water and in swimming pool water were reported in the literature (Kanan and Karanfil, 2011; Hansen et al., 2012a). As a comparison with DBPs concentrations ranges reported by Tsamba et al. (2020), DBPs concentrations were within these ranges, except for CH (ranges in French swimming-pools: 96.5-430 µg.L^{-1}), but generally under mean values, except for DBCM (mean values in French swimming-pools : 1.2 µg.L^{-1}).

Keywords: *Particulate matter, Indoor swimming pool, Backwashing water, Schoolchildren*

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Pool Chemical Injuries — United States, 2008–2017

Michele HLAVSA[1*], Kayla VANDEN ESSCHERT[1], Samaria ALUKO[1], Vincent HİLL[1]

[1]U.S. Centers for Disease Control and Prevention, Atlanta, United States

*acz3@cdc.gov

Introduction: Pool chemicals are added to water in treated recreational water venues (e.g., pools, hot tubs, and water playgrounds) primarily to protect public health. Pool chemicals inactivate pathogens (e.g., chlorine or bromine), optimize pH (e.g., muriatic acid), and increase water clarity, which helps prevent drowning by enabling detection of distressed swimmers underwater. However, pool chemicals can cause injuries if mishandled.

Methods: To estimate the annual number of U.S. emergency department (ED) visits for pool chemical injuries, CDC analyzed 2008–2017 data from the National Electronic Injury Surveillance System (NEISS), operated by the U.S. Consumer Product Safety Commission.

Results: During 2008–2017, the median estimated annual number of U.S. ED visits for pool chemical injuries was 4,535 (range = 3,151–5,215). During 2015–2017, pool chemical injuries led to an estimated 13,508 total ED visits (95% confidence interval [CI] = 9,087–17,929; rate = 1.4 per 100,000 population), with persons ages <18 years accounting for 36.4% of patients (estimated 4,917 [95% CI = 3,022–6,811]). An estimated 93.9% (95% CI = 8,480–16,899) of patients seeking care in an ED for pool chemical injuries were either treated in the ED and released or examined in the ED and released without treatment. An estimated 5,245 patients (95% CI = 3,135–7,355; rate 0.5 per 100,000 population) had their injury diagnosed as poisoning. NEISS report narratives indicated that approximately 90% of patients who received a diagnosis of poisoning were injured via inhalation rather than ingestion. An estimated 3,745 injuries (95% CI = 2,497–4,994) were diagnosed as dermatitis or conjunctivitis, and an estimated 2,588 (95% CI = 644–4,533]) were diagnosed as chemical burn. No deaths were documented. Approximately two thirds (64.5%) of all ED visits occurred during the summer swim season (Saturday of Memorial Day weekend [late May] through Labor Day [first Monday in September]).

Discussion: Pool chemical injuries are preventable. CDC's Model Aquatic Health Code (MAHC) is an important resource that operators of public treated recreational water venues (e.g., at hotels, apartment complexes, and waterparks) can use to prevent pool chemical injuries. For example, the MAHC recommends including pool chemical safety in training for operators of public pools, hot tubs/spas, and water playgrounds, covering topics such as how to read product labels. Labels include information on what chemicals are incompatible (e.g., chlorine and acid) and which personal protective equipment to use. The MAHC also recommends automatic deactivation of chemical feeders in the event of no or low water flow in the recirculation system.

***Keywords**: Chlorine, Injury, Model aquatic health code*

Health Issues On the Swimming Pool During Covid-19 Pandemic: National Guidelines and Regulations in Italy

Emanuele FERRETTI[1*], Lucia BONADONNA[1]

[1]*Italian National Institute of Health, Rome, Italy*

*emanuele.ferretti@iss.it

Health issues on the swimming pool during Covid-19 pandemic: National Guidelines and Regulations in Italy Emanuele Ferretti and Lucia Bonadonna Italian National Institute of Health, Viale Regina Elena 299, 00161 Rome, Italy. From 9 March to 3 May 2020, strict quarantine measures were imposed in Italy to deal with the Covid-19 pandemic which, among other things, required the closure of all the Italian swimming pools. On 31 May 2020, the Istituto Superiore di Sanità, together with the Ministry of Health and other stakeholders, developed the Italian Swimming Pool Guidelines in relation to the spread of SARS-CoV-2. This document addresses regional health and environmental authorities and local institutions to provide specific technical guidance on risk analysis related to sport and recreational activities in swimming facilities, water parks and similar facilities in light of the ongoing COVID-19 pandemic. Specific recommendations for risk mitigation are provided in relation to: (a) control of environmental contamination, to be implemented by environmental and health authorities; (b) hygiene and behavioural standards to be followed by operators and bathers of swimming facilities. In particular, the guidelines report several control measures such as: new crowding limits set in water (7 m^2 per bather) and for solarium/green areas (7 m^2 per user) (indoor pool, outdoor pool, recreational baby's pool, aquapark); optimized water treatments in the pool (free chlorine 1.0 - 1.5 mg/L; combined chlorine ≤ 0.40 mg/L; pH 6.5 - 7.5); optimized airflow and microclimatic parameters in the pool as well in the annexed rooms; interpersonal distance of at least 1 metre between people in all areas (pool, solarium, changing rooms, etc.); recreational baby's pools (height less than or equal to 60 cm): if the operator fails to ensure the interpersonal distance of at least 1 metre between babies and crowding limits (7 m^2 per bather in water) he must prohibit its use. regulate the layout of the equipment (deckchair, chair, sunbed, umbrella) and access to the solarium also through dedicated paths in order to ensure the interpersonal distance of at least 1.5 meters between people who do not belong to the same family or cohabitants. Other control measures were foreseen for aquaparks, restrictions for «condominium/ shared» swimming pools. At the end of October 2020, in order to avoid aggregation conditions swimming pools, gyms and leisure centres were again forced to close due to the Covid-19 second wave hitting Italy. The Prime Minister Decree of 14 January 2021 confirmed the closure of gyms and swimming pools due to the great concern about the potential finding of aggregations between people in sports facilities, especially in closed and confined environments. On the other hand, the Italian Scientific Technical Committee considered "particularly important the return to the practice of physical activities, especially in children, elderly and individuals with chronic diseases, in which the psycho-physical well-being is fundamental to the state of health". The decision whether to reopen the pools everything depended on the trend of contagions in Italy. Three months ago, Annex 17 of the Prime Ministry Decree of 17 May 2020 set out several risk mitigation recommendations for the reopening of swimming pools for recreational and swimming use. Pools for special care, rehabilitation and spa use, and those supplied with seawater were excluded. On this

basis, since mid-May 2021, in some Italian Regions with a low Covid-19 positivity rate, public and private outdoor swimming pools reopened. The Italian Decree of 22 April provided guidance and set out a plan for a gradual reopening of swimming pools. Outdoor pool managers will have to keep a list of clients for 14 days and all entrances must be registered and spaces must be reorganised to maintain 2-meters interpersonal distance. During physical activity in the outdoor pool, the interpersonal distance must be seven meters. Outside the pool, an area of at least 10 square meters per parasol must be ensured. The last to open in Italy were indoor swimming pools from 14 June 2021, depending on the different epidemic situations in each Italian region. For swimming in indoor pools, a *"green pass"* certification in digital format and printable issued by the national platform of the Ministry of Health which is obtained in three cases (having had at least the first dose of the COVID vaccine, or being negative to the rapid molecular or antigenic test within the last 48 hours, or finally being cured of the coronavirus within the last six months), is mandatory.

Keywords: *Swimming pools, Covid-19, Health, Regulations, Guidelines*

Impact of The Direct Wastewater Discharge from Hot Springs to Rivers

Alexander REUSS[3*], Yuly Andrea SANCHEZ[1], Mehrab MEHRVAR[2], Lynda MCCARTHY[2], Luis RODRÍGUEZ CHEU[1], Edgar QUIÑONES[4], Jairo ROMERO[1]

[1]*Escuela Colombiana de Ingenieria Julio Garavito, Bogota, Colombia*
[2]*Ryerson University, Toronto, Canada*
[3]*Ospa Apparatebau Pauser GmbH & Co. KG, Stuttgart, Germany*
[4]*Universidad de Cartagena, Cartagena, Colombia*

*alexander.reuss@ospa.info

Hot springs have traditionally been a tourist attraction worldwide, such as Japan, Canada, Taiwan, Colombia among others. During the peak tourist season, wastewater is usually discharged into streams without treatment which can affect the quality of the receiving water, causing negative impacts to the aquatic ecosystems. Downstream ecological impacts of several major spa recreational sites in different parts of the world have been studied, and it has been found that wastewater discharges of hot springs have adverse ecological effects. The mineral composition in hot springs, derived mainly from groundwater, is usually greater than that of stream water. Studies carried out with models such as QUAL2K (or Q2K), the modernized version of the QUAL2E (or Q2E), simulate the effect of the hot spring discharges on surface water sources, mainly negative in nature. Despite the negative consequences of the impacts on ecosystems derived from hot springs' wastewater, it is interesting to note that there are regulations for wastewater discharges – including backwash water from swimming pools – into rivers and sewers (e.g., Germany and Canada), but not specifically for hot springs discharge. Nonetheless, this evidence indicates a necessity for the authorities to increase the control of the use of hot springs and the discharge of their untreated waters. In Colombia, Resolution 631 of 2015 regulates the discharge of wastewater into rivers and sewers. Yet, it does not consider parameters for the discharge of hot springs. However, the authors deem it necessary to advance in the investigation on the contamination of the wastewaters coming from hot springs, and think about a sustainable tourism of hot springs.

Keywords: *Discharge, Hot springs, Impact, Untreated*

Experimental Investigation of the Feasibility of Chloramines Stripping

Andrea COLETTO[1*], Diego Savio BRANCIFORTI[2], Daniele DONDI[2], Pietro POESIO[3]

[1]Myrtha Pools, University of Brescia, Castiglione delle Stiviere, Italy
[2]University of Pavia, Pavia, Italy
[3]University of Brescia, Brescia, Italy

*andrea.coletto@piscinecastiglione.it

Introduction: Chlorination is required by most of the standards for pool water disinfection, given that it can guarantee the presence of a disinfectant in pool water for secondary disinfection. Chlorine, after reacting with organic pollutants released by bathers, forms chloramines, halomethanes and other compounds, which are commonly known as disinfection-by-products. It was widely proved that such compounds, following a prolongated exposure, can cause chronical health problems. The present research aims at assessing the feasibility of chloramines via air stripping taking advantage of their volatility.

Methods: A reactor was made equipping a rectangular tank with polyethylene porous pipes at its bottom. The minor lateral faces of the tank were hydraulically connected with a recirculation line, through which a pump induced a flow inside the reactor along its major dimension. An electrical heater was installed on the recirculation line to keep water temperature at 28°C (typical of pool water). The tank was filled with tap water, inasmuch most of pools standard requires it as filling mean. Sodium dichloroisocyanurate was made react with urea in high excess; therefore, its concentration was constant during the experiment. After the reaction had been completed, air was insufflated through the porous pipe for producing bubbles in the reactor. Total and free chlorine were measured with DPD colorimetric method on samples spilled from the recirculation line. During all the tests pH was kept at a value between 6,5 and 7,5, as required by pool water standards.
Test were performed with the following conditions:

1. Chlorine with recirculation
2. Chlorine with recirculation and 2 m^3/h air
3. Chlorine and urea with recirculation
4. Chlorine and urea, recirculation and 2 m^3/h air

The use of urea in excess allowed for a pseudo first order approximation of the reaction kinetics; as a consequence, the reaction rate depended only on chlorine concentration, whose time evolution can be modeled as

$$\frac{dC_{chlorine}}{dt} = -k\, C_{urea}\, C_{chlorine} = -m\, C_{chlorine}$$

Equation 1. Mass balance of chlorine in the reactor.

Results: Table 1 shows the values of constant *m* (cf. equation 1) obtained with the various experiments. With reference to the third one, the obtained value of constant *k* was $1.4 \cdot 10^{-1}$ $l \cdot (mol \cdot s)^{-1}$. This result is in accordance with the value of $1.38 \cdot 10^{-1}$ $l \cdot (mol \cdot s)^{-1}$, which was computed based on the results reported in *Schmalz et al. (2011)*.

Table 1. value of constant *m* obtained from the various experiments

Experiment	m [min^{-1}]
Chlorine with recirculation	$7.42 * 10^{-4}$
Chlorine with recirculation and 2 m^3/h air	$1.15 * 10^{-3}$
Chlorine and urea with recirculation	$2.97 * 10^{-3}$
Chlorine and urea, recirculation and 2 m^3/h air	$7.49 * 10^{-3}$

Conclusion: A series of experiment was made for assessing the feasibility of chloramine stripping. The reactor used for the experiments was validate comparing the results of experiment 3 to the ones described in *Schmalz et al. (2011)*, finding a good agreement. This fact demonstrates that processes involving chlorine and urea in absence of stripping can be well reproduced with the reactor. Chlorine consumption in presence of urea was significatively enhanced by air insufflation, proving that stripping is a suitable technique for removing chloramines from pool water.

Keywords: *Disinfection-by-products; Stripping; Water treatment; Contaminants removal*

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Challenges in Chemical Treatment of Therapeutic Thermal Waters

Dora GERE[1*], Márta VARGHA[1], Gyula ZÁRAY[2]

[1]*National Public Health Center, Budapest, Hungary*
[2]*Hevesy György PhD School of Chemistry, Eötvös Loránd University, Budapest, Hungary*

*gere.dora@nnk.gov.hu

Therapeutic spas offer relaxation and healing to visitors in Hungary. The treatment of therapeutic waters is a challenge due to their high temperature and considerable organic matter and total dissolved solid content. The need to preserve the therapeutic components of the water adds a further difficulty. Due to these factors, in some countries, including Hungary, these pools are mostly operated without a recirculation-filtration system or disinfection. Continuous large-scale water exchange is used in flow-through, fill-and-drain pools to maintain adequate water quality. This mode of operation consumes large amount of water, and microbial quality is often compromised. The present study assessed the possibilities and challenges of chemical disinfection of therapeutic waters by on-site and benchscale experiments. In Hungary, seven spas used chemical disinfection for the treatment of therapeutic water at the time of the study. In some locations, disinfectant is added to the conventional flow-through system, while in other spas, a recirculation-filtration system is also installed. Spas were sampled three times to assess the microbial water quality and the fate of therapeutic components during the treatment. Samples were taken from the therapeutic water well, technological points and pool. The applied disinfectants were sodium-hypochlorite and hydrogen-peroxide based products. Both disinfectants were suitable for maintaining appropriate microbial pool water quality, when present in sufficient concentration. In the case of hydrogen-peroxide, there is no legal regulatory requirement for dosing. Concentrations required to ensure adequate water quality have varied over a wide range for waters with different compositions and for different modes of operation, between approx. 10 and 200 mg/l. In one spa using hydrogen-peroxide, Pseudomonas aeruginosa was detected in high concentrations (>200 CFU/100 ml). Laboratory model experiments confirmed that the hydrogen peroxide is less effective against Pseudomonas than hypochlorite, while against E. coli, the efficiency of the two disinfectants was similar. When using hydrogen-peroxide, it is particularly important to maintain adequate disinfectant concentration throughout the system and to take additional measures to prevent biofilm formation. For sodium-hypochlorite, the high ammonium content of the treated water was the main challenge in determining and maintaining adequate disinfectant levels. Its use also lead to the formation of disinfectant byproducts (DBPs), especially in warm waters with high organic content. In the presence of bromide ion – characteristic for many therapeutic waters – brominated DBPs predominate, which are more harmful to health than the chlorinated species. Brominated compounds are less volatile, which can reduce the risk, as therapeutic pools are generally used as sitting pools, where head immersion is not typical. Overall, hydrogen peroxide is a better choice in waters prone to the formation of chlorination by-products.

The following components should be present in water to qualify as therapeutic water according to the Hungarian national regulation: high total mineral content, lithium, sulfide-, bromide-, iodide-ions, metasilicic acid, free carbon-dioxide or radon gas (the so-called

therapeutic components). Hypochlorite reduced the concentration of therapeutic components sulfide, bromide and iodide ions, while hydrogen-peroxide treatment eliminated only sulfide ion. However, other technological steps beside disinfectant dosing – such as dilution with cold water for temperature adjustment or degassing – were found to have an impact on concentration of therapeutic compounds. The reaction of disinfectants and the therapeutic compounds was also confirmed in laboratory model experiments. Results shown that hypochlorite disinfection can primarily be recommended for thermal waters containing low concentration of organic compounds or ammonium ion, and non-oxidizable therapeutic components such as metasilicic acid, lithium ion or high total mineral content. Hydrogen-peroxide can be more widely recommended for the treatment of thermal waters of complex composition. For those waters that cannot be effectively treated, the use of individual therapeutic tubs filled with untreated well water is also an option.

Keywords: *Therapeutic water, Thermal water, Pool water disinfection, Sodium-hypochlorite, Hydrogen-peroxide*

Chlorate in Dutch Pools During the Corona Pandemic

Maarten KEUTEN[1*], Jan BAKKER[2]

[1]Delft University of Technology, Delft, Netherlands
[2]Outdoor Clinic Swimming Pools, Amsterdam, Netherlands

*m.g.a.keuten@tudelft.nl

Due to the Corona-pandemic, chlorine consumption in public swimming pools was reduced. As a result, the sodiumhypochlorite aged, resulting in the increased formation of chlorate. In this study we will present a study in >100 pool accommodations (>250 pool basins and >400 data points). The study started with an inventory of the situation and in a small number of cases the cause of the elevated chlorate was also investigated. Besides pools with sodiumhypochlorite, some also used calciumhypochlorite or salt-electrolysis. Chlorate level up to 360 mg/L were observed and lead to a study of the Dutch Health Organization (RIVM). In this presentation we will show the results of the inventory, the results of the study by the Dutch Health organization and we will share the results of some specific pools.

Keywords: *Chlorate, Type of disinfection, Health aspects, Source analysis*

Analysis of Trichloramine in Diluted Aqueous Solutions. Analytical Development and Application to The Determination of Trichloramine in Swimming Pool Water

Joseph DE LAAT[1*], Yves LE MOT[2]

[1]IC2MP, University of Poitiers, Poitiers, France
[2]ETHIS Ingenierie, Lorient, France

*joseph.de.laat@univ-poitiers.fr

Chlorination is the most common method of disinfection used to treat public pool water. In addition to its disinfectant action, chlorine reacts with pollution from bathers and make-up water to form a large number of undesirable organohalogen by-products as well as inorganic (monochloramine, dichloramine and trichloramine) and organic chloramines (such as N,N-dichloromethylamine, DCMA). Some chloramines are extremely volatile (DCMA and especially trichloramine) and are responsible for chlorine odors in indoor pools and health problems for bathers and indoor pool staff (eye and respiratory tract irritation, rhinitis, asthma). The determination of trichloramine in swimming pool water has been carried out for about 20 years by analytical methods that are not very simple to implement and/or require expensive analytical equipment (Shang et al., 1999; Gérardin and Subra, 2004; Chehab et al., 2020). The objective of this study was to test and develop a method for the analysis of trichloramine in dilute aqueous solution by a method based on liquid-liquid extraction with hexane followed by spectrophotometric determination at 224 nm (Schmalz et al., 2001). Experiments performed with trichloramine solutions prepared by chlorination of ammonia nitrogen at pH 2.5 - 3 allowed the determination of the partition coefficient of trichloramine between the water and hexane phases necessary for the calculation of concentrations in the aqueous phase. The limit of quantification of trichloramine was estimated to be 0.1-0.15 µM (i.e. 12-18 µg/L) in pure water. The partition coefficients and UV/visible absorption spectra in hexane of monochloramine, dichloramine, and DCMA were also determined and the data showed that these compounds as well as free chlorine will not interfere in the determination of trichloramine in swimming pool water. The analytical method was used to determine trichloramine production during chlorination of dilute aqueous solutions of ammonia nitrogen (0.5 and 1 mg N/L) and urea (3 mg/L), to demonstrate trichloramine decomposition by free chlorine and to determine a value for the kinetic constant for trichloramine decomposition by chlorine at pH 7. The application of the analytical method allowed the measurement of trichloramine concentrations in about 70 swimming pool water samples (concentrations measured between 0.4 and 1.2 µM).

Keywords*: Trichloramine, Liquid-Liquid extraction, Partition coefficients*

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Trichloramine Sampling Method for Complete Work Shift and Its Validation

Elham AHMADPOUR[1*], Isabelle VALOIS[1], Stephan HALLE[1], Maximillien DEBIA[1]

[1]*University of Montreal, Montreal, Canada*

*elham.ahmadpour@umontreal.ca

Exposure to airborne disinfection by-products, especially trichloramine, may cause various adverse health effects for the workers and users of indoor swimming pools. Most of the studies used Hery's sampling method to measure trichloramine concentration, which uses cassettes that consist of two-layer impregnated quartz fibre filters for two hours of sampling with a 1 L/min sampling pump flow rate. Trichloramine concentrations are usually determined by a single 2-hour ambient monitoring period when the swimming pool is busiest to document the highest trichloramine concentrations. This study aims to evaluate the temporal variations in trichloramine concentrations within and between swimming pools. Workplace measurements were carried out at four indoor swimming pools in Quebec (Canada) during the cold season. Sampling started two hours before the swimming pool opened and continued until two hours after closing to represent daily operating conditions fully. The results showed that trichloramine concentrations varied significantly in time. The 8-hour trichloramine concentrations were comparable to the average of the 2hr samples collected during the same period ($p < 0.05$). The observed daily variations in trichloramine concentrations suggest that the common practice of collecting a single 2-hour air sample does not represent daily pool trichloramine contamination levels and, consequently, does not represent the true exposure and health risks for workers that are present for a full 8-hour shift. This study recommends a new 8-hour sampling strategy or a full-shift strategy using a cassette with three impregnated filters as a valid and cost-effective solution for comparing time-weighted average (TWA) concentrations to permissible trichloramine exposure limits.

Keywords: *Trichloramine, 8-hour sampling, Time-weighted average (TWA), Swimming pool, Temporal variations*

Pool Water and Indoor Air Trihalomethane Concentrations in Swimming Pools – A Preliminary Study in Izmir, Turkey

Mesut GENISOGLU[1*], Yetkin DUMANOGLU[2], Sait Cemil SOFUOGLU[1]

[1]Izmir Institute of Technology, Izmir, Turkey
[2]Dokuz Eylul University, Izmir, Turkey

*mesutgenisoglu@iyte.edu.tr

Disinfection of swimming pool (SP) is essential to prevent waterborne diseases. However, carcinogenic disinfection by-products (DBPs) are formed with the reaction between disinfectants and precursors such as natural organic matters from source water, urine, saliva, sweat, and personal care products. For exposure and health risks, not only pool water, but also inhalation of indoor air may be a significant exposure route, especially for the volatile DBPs: trihalomethanes (THMs). This is the first study in Turkey, in which both SP water and indoor air sampling were carried out simultaneously. SP water and indoor air samples were concurrently collected from two different semi-olympic SPs: (i) a university campus SP (open for students and staff) and (ii) a public SP (open for public use and training for athletes). Activated charcoal sorbent tubes (SKC, Anasorb) were used for air sampling. Charcoal sorbents were extracted for 15 minutes with carbon disulphide using ultrasonic bath. SP water samples were extracted with tert-Butyl methyl ether according to the liquid-liquid extraction method. THMs were analysed in electron impact ionization mode using gas chromatography – mass spectroscopy (Agilent 6890N GC – 5973 MSD) with HP5-MS (30 m, 0.25 mm, 0.25 µm). The average TCM, BDCM, DCBM, BCM, and ΣTHM concentrations were determined to be 97.0, 1.10, 0.38, 3 in the campus SP, and 104, 7.89, 1.57, 0.33, and 115 µg/m^3 in the public SP. THM concentrations of indoor air and SP water were dominated by TCM, followed by BDCM, DBCM, and BCM. Higher indoor air concentrations in the public pool might be the result of the relatively higher pool water temperature, higher organic load from swimmers, and poor ventilation due to an insufficient HVAC system. Staff and swimmers might be exposed to THMs in the other micro-environments of swimming pools, such as dressing rooms, lobby, lifeguard resting rooms, and management offices with the routes of inhalation or dermal contact. The average TCM, BDCM, DBCM, BCM, and ΣTHM concentrations in lifeguard resting room of the campus SP were determined to be 1.01, 0.28, 3, respectively. TCM concentration in lobby and management room of the campus SP were determined to be 0.38 and 0.43 µg/m^3, respectively. The resulting average indoor air ΣTHM concentrations of dressing room and lobby in the public SP were determined to be 12.6 and 7.09 µg/m3, respectively. In conclusion, volatile THMs might be transported to different microenvironments within the building and cause exposure through inhalation of indoor air. Therefore, simultaneous sampling of all points in the pool building and modelling the risk levels of all possible exposure routes is important in terms of public health and prevention of occupational diseases.

Keywords: *Indoor air, Pool water, Swimming pools, Trihalomethanes*

The Dutch Approach to Swimming in Times of Covid-19

Jan G. Bakker[1*], Maarten G.A. Keuten[2]

[1] Clinical Occupational Physician, Dutch Outpatient Clinic Swimming Pools
[2] Researcher Swimming Pools, Delft University of Technology

*jan.g.bakker@amc.nl

A team of the Technical University of Delft, the Dutch Outpatient Clinic of Swimming Pools and two Laboratories on water quality developed specific Dutch guidelines for swimming in times of Covid-19, based upon governmental guidelines, scientific publications and conference proceedings of online swimming pool conferences. These guidelines were adopted by the national branche of swimming pools and spas. To investigate whether these guidelines would be effective to minimalize the risk on health effects and Covid-19 complaints in particular, the team observed the fate of aerosols, water quality, the behaviour of public and staff during different swimming activities and potential health complaints in four public swimming pools, financed by crowd funding. Al participants (swimmers, pool staff and researchers) where offered a COVID-19 speed-test and they were consulted by a medical physician 5-6 days after the swim, to monitor the development of any health complaints.

***Keywords**: Covid-19, Swimming pool, Health*

POSTER PRESENTATIONS

Principles of Operation of Swimming Pool Facilities During the Covid-19 Pandemic and Their Impact on the Quality of Swimming Pool Water

Joanna WYCZARSKA-KOKOT[1*], Jerzy MENDAKIEWICZ[1], Anna LEMPART-RAPACEWICZ[1], Mariusz DUDZIAK[1]

[1]*Silesian University of Technology, Gliwice, Poland*

*joanna.wyczarskakokot@polsl.pl

Swimming pools, regardless of the pandemic situation in the world and in individual countries, remain important facilities for recreation, rehabilitation and physical activity of the community. Like all public utility facilities, swimming pools have been treated with special procedures during the COVID-19 pandemic. In addition to the basic rules (DDM, i.e. social Distance + hand Disinfection + Masks), applicable to all citizens, the managers of swimming pools were obliged to reduce the number of swimmers and to increase the effects of water treatment by e.g. more frequent washings of filter beds, introduction of an additional disinfection stage, more frequent cleaning and disinfection of surfaces - walls, bottom and beach of the swimming pool, using disinfectants with high efficiency in destroying viruses, bacteria and fungi. Swimming pool waters, especially in the time of a pandemic threat, must be a bathing environment that is safe for health. Monitoring, control and quick response to adverse changes in the quality of swimming pool water are the basis for minimizing the risk of disease transmission or exposure of bathers to pathogens. The main objective of the paper is to analyse and compare the quality of swimming pool water in 4 selected swimming pools, located in recreational centres in Poland, before and during the COVID-19 infectious disease pandemic caused by the SARS-CoV-2 coronavirus. A series of physicochemical and bacteriological analysis of pool water samples were performed, divided into two stages, i.e. before and during the pandemic. The results of the research, based on real case studies, were compared with the documents on water quality in swimming pools in force at the time. Statistical analysis was performed to determine significant relationships between the swimming pool water quality before and during the COVID-19 pandemic. The analysed parameters determining the water quality were physicochemical parameters (pH, redox, turbidity, nitrates, oxidizability, total organic carbon TOC, free chlorine, combined chlorine, total trihalogenomethane THM, chloroform) and bacteriological parameters (colony forming units CFU of Pseudomonas aeruginosa, Escherichia coli and total number of mesophilic microorganisms determined at 36°C after 48 h). Based on the results of the analysis of the above-mentioned parameters, the validation of the procedures applied in the time of a COVID-19 hazard and their impact on the quality of swimming pool water were assessed. Determining the detailed rules for the operation of the water treatment plant WTP (before and during the pandemic) in each of the studied swimming pools was individual and largely dependent on the type and function of a tested swimming pool (school, public or public with separate hours for learning to swim and aqua aerobics). The results of the pool water quality tests are illustrated and discussed with particular emphasis on disinfection by-products (DBP) that are hazard to the health of swimmers and pool staff. Basic analysis of pool water quality parameters before and during COVID-19 showed that the statutory requirements in this regard were met. In contrast, a detailed analysis showed better water quality during the pandemic. The improvement of the pool water quality resulted mainly from the reduction in

the number of swimmers (50% - 75% attendance), the implemented hygiene and sanitary regime, including in particular the observance of personal hygiene by swimmers (absolute order to shower before entering the swimming pool hall). It was found: significantly lower number of mesophilic CFU bacteria during the pandemic; significantly higher concentrations of free chlorine (even up to 1.2 mg Cl2/dm3) during the pandemic and the resulting lower concentrations of combine chlorine compared to the time before the pandemic; lower oxidizability, TOC and nitrate content during a pandemic; lower THM concentrations and the percentage of chloroform in total THM (by approx. 30-50%) during the pandemic. COVID-19 pandemic, quality of swimming pool water, chemical quality, microbiological quality, disinfection by-products, risk of disease transmission, rules of the operation of the water treatment plant.

Keywords: *Covid-19, Swimming pool water, Pool facilities*

Biologically Active Compounds in Swimming Pool Water

Anna LEMPART-RAPACEWICZ[1*], Edyta KUDLEK[1], Mariusz DUDZİAK[1],
Joanna WYCZARSKA-KOKOT[1]

[1]*Silesian University of Technology, Gliwice, Poland*

*alempart@polsl.pl

Swimming pools are a specific aquatic environment in which the final chemical composition of water is influenced by many different factors. Swimmers introduce numerous products of metabolic activity into the pool water in the form of secretions, body fluids, epidermal cells, hair or cosmetic residues. The most frequently described chemical contaminants of swimming pool water in the literature are disinfection by-products. However, the latest scientific research describes the presence of numerous organic micropollutants from the gropus of pharmaceuticals and personal care products or flame retardant products in swimming pool water. All these compounds can react with chlorine or ozone residues, creating a large group of irritating or toxic secondary pollutants. This phenomenon may also occur under the influence of the swimming pool water irradiation (both with UV lamps in the swimming pool water treatment system as well as solar radiation or artificial lighting of the swimming pool hall). A significant problem in this matter is also the presence of biologically active substances in the washings waste streams generated in the filter washing process. The management of these waste streams, more and more often, is being considered, e.g. for the purposes of watering greenery. Meanwhile, the conducted scientific studies in the field of ecotoxicity show their toxic nature, resulting from the presence of biologically active substances. This paper presents a literature review, including authors' own research and observations in the field of presence of biologically active compounds in swimming pool water and related unfavorable phenomena occurring in swimming pools basins and water treatment installations.

Keywords: *organic micropollutants, swimming pools, biologically active compounds*

Monitoring of Pollutant Concentrations in Private Backyard Swimming Pools

Edyta KUDLEK[1*], Anna LEMPART-RAPACEWİCZ[1], Mariusz DUDZİAK[1], Joanna WYCZARSKA-KOKOT[1]

[1]Silesian University of Technology, Gliwice, Poland

*ekudlek@polsl.pl

Private backyard pools are becoming more and more popular among the inhabitants of suburban and rural areas. The water treatment and disinfection systems used in them differ between the producers of individual pools and are based mainly on the filtration processes supported periodically by the action of coagulants, algaeicides, pH stabilizers and chlorine-based disinfectants. The effectiveness of water treatment strictly depends on the users of swimming pools and their diligence in following the recommendations of the manufacturers of the technological solutions used. Unfortunately, unaware users of this type of devices, due to economic reasons, do not always follow any recommendations. Therefore, there is a risk of accumulating in the garden pools environment of pollutants introduced into the water both by the users and from the surroundings of the basin, or accessories in contact with water. Organic micropollutants from the group of compounds belonging to Pharmaceuticals and Personal Care Products seem to be a particularly serious threat in this context. Certainly, these compounds are not removed from the water in less technologically advanced systems of private backyards swimming pools. It should also be noted that the micropollutants from the PPCPs group in water exposed to solar radiation undergo a series of changes, creating new compounds that may have an adverse effect on the quality of swimming pool water. The aim of the presented research was to identify organic micropollutants from the PPCPs group present in swimming pool water collected from the garden pools and compare their concentrations depending on different factors.

Keywords: *Pharmaceuticals and Personal Care Products, private swimming pools, organic micropollutants*

Characterization of Bacterial Communities in Peloids by 16s Amplicon Sequencing

Isabella MARCHESI[1*], Stefania PADUANO[1], Federica VALERIANI[2], Vincenzo ROMANO SPICA[2], Alessandro SIGNORINI[3], Giuseppina FREZZA[1], Sara TURCHI[1], Paola BORELLA[1], Annalisa BARGELLINI[1]

[1]*University of Modena and Reggio Emilia, Modena, Italy*
[2]*University of Rome "Foro Italico", Rome, Italy*
[3]*Health Direction of "Terme di Sirmione", Sirmione (BS), Italy*

*isabella.marchesi@unimore.it

Introduction and purpose: Pelotherapy is the application of peloids for treating rheumatic and dermatological diseases, and also for wellness and relax purposes. Peloids are produced by mixing clayey materials with thermo-mineral waters, and are enriched with organic materials produced by the metabolic activity of microorganisms growing during the maturation process. Peloids have peculiar healing and cosmetic properties depending on the kind of clay minerals, the physical-chemical characteristics of the thermal water and the growth and colonization of microorganisms. The Next Generation Sequencing (NGS) and bioinformatics tools offer the opportunity for a more extensive approach than culture for examining the microbial diversity because NGS can detect not only single bacteria, but, simultaneously, all the different genera interacting in an ecological niche. The aim of our study is to characterize by NGS the bacterial community of thermal water and peloids used in two Italian spas.

Material and methods: Our study was conducted in a thermal facility of Northern Italy, where peloids are prepared in situ in open air pools by the maturation of natural mud (Spa A) or sterile clayey virgin materials (Spa B) mixed with sulphurous- bromine- iodine thermal water. Samples of peloids were collected at a depth of 10–20 cm into sterile 50 ml tubes after mixing the mud on the surface and at the bottom of the pool during two sampling sessions (July and February). All samples were collected in duplicate and analysed by using MiSeq Illumina sequencing platform to obtain information on bacterial diversity and community structure.

Results: A total of 70 samples of peloids was collected. Thirty-four samples were taken during the first sampling session in summer (16 from Spa A and 18 from Spa B) and the remaining in winter season (18 from each spa). No significant differences were observed for samples collected in July compared to those collected in February. *Thiobacillus* genus, a sulphur-oxidizing bacterium, was prevalent in peloids collected from both spas, as expected considering that peloids mature in sulphide-rich water. Another dominant genus was *Pelobacter*, a bacterium involved in the biosynthesis of lipids. Of note, anti-rheumatic effects of thermal mud could be related to the anti-inflammatory properties of its lipid fraction. Interestingly, a greater richness of microbial genera was found in peloids from spa A compared to those from spa B, probably due to the use of natural mud instead of sterile clay to produce peloids.

Conclusion: The microbial community of peloids is influenced not only by the thermal water, but also by mud and/or virgin clay employed in their formulation and maturation.

Keywords: *Microbiome, Mud, Bacterial diversity*

Cancer Risk Modelling Caused by Disinfection By-Products in Swimming Pool

Mert MINAZ [1*], Mesut GENISOGLU [2], Sait C. SOFUOGLU [2], S. Sule KAPLAN BEKAROGLU [1], Nuray ATES [3], Amer KANAN [4], Nevzat O. YIGIT [1], Tugba SARDOHAN KOSEOGLU [5], Qahtan Adnan ALI ALI [1], Mehmet KILIC [1], B. Ilker HARMAN [1]

[1] Suleyman Demirel University, Department of Environmental Engineering, Isparta, Turkey
[2] Izmir Institute of Technology, IZMIR, Turkey
[3] Erciyes University, Department of Environmental Engineering, Kayseri, Turkey
[4] Al-Quds University, College of Science and Technology, Palestine
[5] Applied Sciences University of Isparta, Department of Biomedical Engineering, Isparta, Turkey

*mert.minaz@erdogan.edu.tr

Introduction: The water quality of swimming pools is very important for the health of the swimmers. Therefore, an effective disinfection process is necessary to prevent diseases caused by pool water. However, disinfectants can react with various organic and inorganic compounds in pool water and then disinfection by-products (DBPs) can be formed. Swimmers are exposed to DBPs with ingestion, dermal adsorption and inhalation. These DBPs can caused the carcinogenic and chronic toxic effects in terms of human health. In current study, carcinogenic risk assessments were investigated by using the data obtained from the 1 year monitoring study conducted in a swimming pool.

Methods: Exposure and risk models developed by the United States Environmental Protection Agency (USEPA) were used to determine the risk of human carcinogenicity of DBPs (THM and HAA). The cancer risk models were considered individually for three different exposure routes (ingestion, dermal contact and inhalation). The results were compared with the limit value determined by USEPA and the possible cancer risks were estimated.

Results: The cancer risks in ingestion pathway were lower than the limit value for all swimmers profile. However, the cancer risk values of adult profile in dermal contact pathway increased to critical values for chloroform and TCAA. In addition, chloroform based risk assessment of inhalation is higher than the limit value for all scenarios.

Discussion: The risks examined within the scope of the study depend on the factors such as the ventilation condition of swimming pools, roof height from water surface etc. In addition of this factors DBPs precursors should be removed from waters to reduce the cancer risk in swimming pools.

Keywords: *Disinfection, Cancer, DBP, Swimming pool*

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