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Experimental Tests for Ozone Disinfection Treatment In a Small Backyard Swimming-Pool

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Abstract

This paper reports experimental assays on the utilisation of the ozone technology to disinfect backyard swimming pool waters. Tests were carried out utilizing a semi-batch reactor in which various samples containing 10^3 CFU/mL of *E. coli, E. hirae, S. aureus* and *P. aeruginosa* were treated considering different dissolved ozone doses. Results show a low disinfection activity at ozone concentration of 0, 05 mgO_3/L, a potential to disinfect water in 5-15 seconds at concentration around 0, 10 mgO_3/L and a drastic abatement of the disinfection capabilities under the concentration of 0, 01 mgO_3/L. Some ozone purging and microorganisms revitalization trials were carried out too.

Keywords: Ozone; Swimming pool; Disinfection; *S. aureus*; *E. hirae*; *P. aeruginosa; E. coli*

Introduction

Swimming pool water disinfection (legislation and institutional references in Italy)

The disinfection of swimming pools is introduced as a necessary practice because of potential microbiological contamination occurring in various swimming, relaxing or therapeutic activities [1, 2, 3].

At the present time, Italian regulation about swimming pools is represented by an agreement between Central Government and Local Administrations achieved in 2003 [4]. This Italian regulation highlights sanitary and heath-related problems of swimming pools and gives more importance to private and public swimming pools administrations introducing internal management program for water control and treatment systems maintenance.

Recently new European Norm (EN 15288) [5] appended new evaluation rules to define design and management of swimming pools, this gives new interest about architectural, structural and hygienical aspects of swimming pool building, management and control. This document confirms further importance to the choices planned by designers and administrators of the swimming pools in order to guarantee the best sanitary and management performances. Certainly in the case of the private management and control a good engineering choice can lead to reduction of a potential sanitary risk.

The disinfection problems of little backyard swimming pools are similar to public swimming pools or thermal baths even if sometimes little swimming pools are not subjected to the same controls by the public health administration.

However people pay a lot attention about sanitary condition of their own backyard swimming pool but they are often not provided by valid sanitary efficient systems.

In little backyard swimming pools drinking water is generally used and the pond is built outdoor, exposed to sunlight, air and sometimes contaminated by several substances brought by the wind, the rain or coming from the vegetation.

Some have a constant change of water and are used regularly. In this case optimal water characteristics are generally preserved. In other situations best conditions are not assured because of seasonal and occasional use.

Some different conditions can degrade little backyard swimming pool water quality at such point that water appears turbid, rich of algae and organic matter: this environment favours the development of pathogenic microorganisms, like *P. aeruginosa*, *L. pneumophila*, *E. coli*, fecal coliphorms, *S. aureus*, *C. albicans*, and many others virus and protozoa species. The main pathologies caused by these microorganisms are intestinal, dermatologic and respiratory diseases, eye and hear inflammation.

Above all the water of a little backyard swimming pool must be treated in order to remain clear and clean, free from harmful substances, bacteria, viruses, algae and other pathogens.

To preserve pool water hygiene, efficient water disinfection is the key treatment because it prevents potential infections by a variety of pathogenic microorganisms.

A self-made disinfection practice by traditional chlorine-base chemical disinfectants lead often to inadequate performances and to uncontrolled generation of common DBPs (Disinfection Byproducts) [6]. It is well known that some of DBPs are organic-halogen priority pollutants with severe human health concern [7], but the presence of DBPS in swimming pools is not well regulated yet.

Swimming pool water is often recirculated to care for water consuming and the disinfection together with the filtration can be performed before the water returns to the main tank. These treatments are common hygienic practices also in the little backyard swimming pools together with a occasional cleaning of the pool bottom and walls.

All these procedures can be achieved accurately designing an efficient water recirculation system and an effective disinfection treatment (physical or chemical) with a regular maintenance of the auxiliary settings and controls.

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In this note we have reported some results of tests designed to propose a ozone disinfection system to be installed in the recirculation pipeline of a little backyard swimming pool.

Ozone disinfection treatment in swimming pools

Ozone technology is widely used in the water treatment [8] but only few studies are carried out about designing ozone disinfection treatment in little swimming pools, some of these are ozone-combined disinfection techniques that persist in DBPs related problems [9, 10].

Ozone disinfection represents an useful alternative to chlorine techniques because it does not produce chlorine-related by-products and the additional oxidation power bound to the dissolved ozone supports the degradation of many organic residuals.

Moreover, since specific health associated risk of ozone partial oxidation by-products have not been currently demonstrated by epidemical evidence, the ozone disinfection of waters has to be considered a valuable practice [11, 12].

In some applications ozone is preferred because of its minor odour effect at low concentrations, its colour and taste absence and its effective viral inactivation potential [13, 14]. But above all ozone appear an excellent microbicide, because good sanitary efficiencies are obtained with small doses of ozone and short treatment application time [15].

Otherwise, ozone treatment is generally more expensive and needs particular systems and specialized expertises for gas production and devices maintenance. Ozone toxicologic effects can affect swimmer skin: some data demonstrate that 0.8 mg/L ozone doses can induce cellular stress responses in the outermost stratum corneum layer and in the deeper cellular layers of the skin, because of the activation of heat shock proteins, metalloproteinases and oxygenases [16, 17, 18]. However, very few is known about ozone potential effects on cellular responses in deeper layers of the skin, like dermis and epidermis.

Gaseous ozone could cause many effects on health after inhalation [19]. Its inhalation of high ozone concentration causes neurological effects like general fatigue, lethargy, cephalea and sleep disturbance [20]. American Conference of Governmental Industrial Hygienists (ACGIH) proposes concentration values ranging from 0.4 $mgO_3\ m^{-3}$ for two hours or less exposure time (for heavy, moderate and light work loads) to 0.1 $mgO_3\ m^{-3}$ (for heavy work).

An evident hygienical and safety-related feature is the use of ozone as a water disinfection treatment in closed and weakly aerated rooms such as thermal baths, but nevertheless when ozone is applied for the open swimming pools water disinfection, a potential pollution effect in the air quality over the water surface must be considered.

Materials and Methods

Experimental set-up

The experimental session was designed to evaluate the application of ozone treatment for water disinfection in the recirculation system of a little backyard swimming pool. At this scope a semi-batch ozone disinfection system was designed (Figure 1) and some experiments were carried out.A synthetic water was prepared adding microorganisms which are suggested in control lists by the Italian regulation [4].

By this way a severe microbiological pollution, that can occur in a little backyard swimming pool, was reproduced in experimental trials. The disinfection of every single bacterial strain was performed together with the case of a mixture of all the considered bacteria.

The prepared solutions were treated, working in semi-batch mode in a one liter glass reactor, changing ozone flows and concentrations. In this way, an hypothetical disinfection system able to be connected to the water recycle pipeline of a little pool was simulated and some design parameters were obtained.

The tests aimed to verify the amount of dissolved ozone necessary to abate the microbiological charge present in the water and to minimize the ozone residue venting for the safety of the air above the pool.

In the water recycle pipeline two batch reactors were installed: in the first reactor a controlled ozonation was performed by gurgling ozonated-air from a bottom diffuser and the second reactor was arranged as a residual ozone purging module by air bubbling (Figure 1).

Ozone production and calibration

Ozone was produced by an Ervin Sander S 500 EDOG generator (Electrical Discharge Ozone Generator), 12 Watt power consumption with air-cooling system, connected to an air pump with a flow rate of 1.7 L/min, working at 20°C and 0,1 bar pressure. Ozone flow was controlled by the regulation of the electric potential applied to the generator: four different settings (25%, 50%, 75%, 100% of maximum power) were chosen to produce different amounts of ozone in air flowed into the water.

Ozone in the air flow was quantified as described in the semi-batch method of Standard Methods for the Examination of Water and Wastewater [21] in order to control the real ozone potential production of the ozonator.

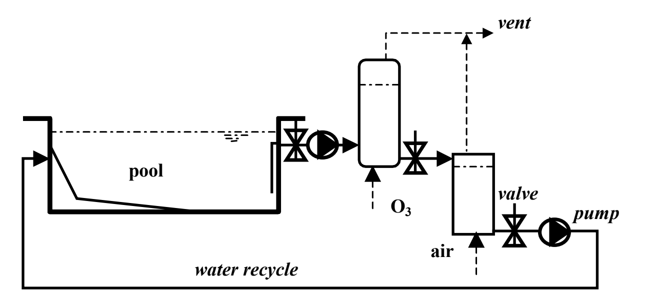

Figure 1: Schematic representation of the semi-batch ozone disinfection system for experimental tests.

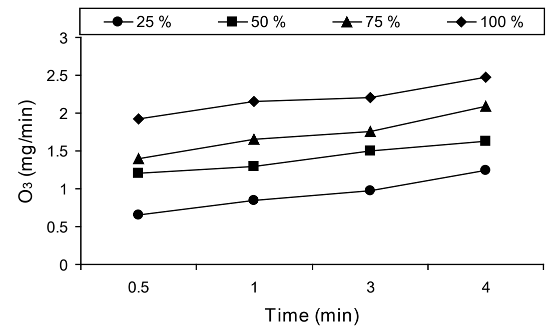

Figure 2: Calibration curves of the ozonated air produced versus time at various percent of the ozonator maximum power.

In the Figure 2 are depicted the real curves of the air-ozone gas production (mg/min) in a range of times (0.5 - 4 min) fixed for calibration. It can be noted that in the selected working conditions real ozone production is comprised in a range from 0.5 to 2.5 mg/min.

Disinfection treatment was performed at different times from 5 to 300 seconds, depending on the ozone concentration achieved in solution.

Dissolved ozone concentration into the reactor was calculated by the Indigo colorimetric method [22]. By this method a real curve of dissolved ozone concentration into the reaction mixture versus time of gurgling was carried out. Real dissolved ozone concentration obtained in the reactor by gurgling 1.7 L/min of ozonated-air flow at various disinfection times for various percent of the ozonator power is reported in (Figure 3).

Bacterial strains

During the disinfection experiments, particular strains (toxin free for safety protection) of *E. coli* (DSM 11250), *E. hirae* (DSM 3320), *S. aureus* (DSM 799) and *P. aeruginosa* (DSM 939) were used. The strains, stocked at –80°C, were revitalized using Trypton Soya Broth and incubated at 37°C for 24 h. Bacterial concentration used during the disinfection tests was about 10^3 CFU/mL (to reproduce a sufficient grade of contamination and to simulate a strong bacterial presence into the backyard swimming pool). The bacteria were diluted in the same backyard swimming pool water to reproduce the attended concentration.

Ozone treatment

The ozone disinfection of the prepared waters was performed considering samples of the four single bacteria and their mixture, all at the concentration of 10^3 CFU/mL.

The reaction times for the disinfection were fixed at 5, 10, 30, 60 and 180 seconds to assay a wide range of disinfection performances.

When the reaction time ended the ozone generator was stopped and 1 mL of the sample was collected for the measures. Successively 3 minutes aeration reaction was started to provide the ozone stripping under a dissolved concentration of 0.01 mg/L.

In this phase a potential revitalization of the bacteria was expected, for this reason two samples of bacterial mixture were collected, stocked for 24 and 48 hours at room temperature and successively analysed to test the revitalization capability.

It is well known that the survived bacteria after the disinfection treatment are able to revitalize causing an increase in bacterial count after the ozonation, because they can metabolize part of the substances derived from the own microrganism cellular degradation [23, 24].

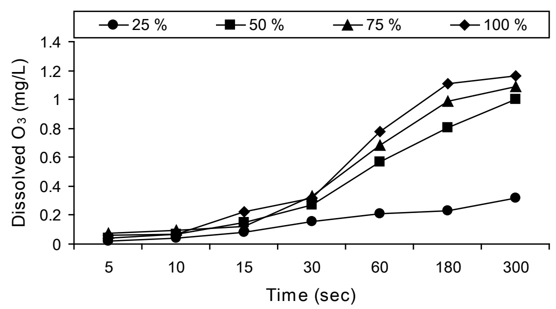

Figure 3: Real dissolved ozone concentration in the reactor at various disinfection times and different percentage of total power gain.

The ozonated and aerated samples were inoculated into 20mL of Trypton Soya Agar on Petri dishes. After an incubation time of 24 hours at the temperature of 37°C the plates were checked for the number of colonies developed, as a result the resistance or revitalization capability was express as bacterial survival (CFU/mL).

Results and Discussion

The experimental section was set to evaluate some design parameters in a disinfection treatment of a backyard swimming pool located in the water recirculation system.

During the experiments, we examined real behaviour of the disinfection process controlling different variables: ozone flow from the selected ozonator, dissolved ozone concentration in the reactor, treatment times and microbial count, these parameters are to be calibrated and verified when a scale-up must be performed.

In our case the main first goal was to obtain information about the achievement of the total abatement of the microbiological charge by means of the lesser amount of ozone flow (taking into account to use an ozonator with air cooling) and the maximum dissolved ozone consumption or venting (leaving minor residues in the pool). Further, to calibrate the ozone flow and the dissolved ozone in an electronically controlled (percentage of maximum power of the ozonator) range give the possibility to regulate the microbial abatement and the ozonated-air venting.

In Figure 4 the disinfection treatment experiments on drinking water inoculated with each single bacterial species (*E.coli* (DSM 11250), *E. hirae* (DSM 3320), *S. aureus* (DSM 799) and *P. aeruginosa* (DSM 939) are depicted.

Controlling the bacterial viability by inoculating the sample into the solid medium and counting the number of colonies grown, a good disinfection efficiency of the single bacterial species and on the bacterial mixture was verified.

In the selected functioning condition of the reactor a minimal dissolved ozone concentration about 0.05 mg/L demonstrated an almost complete disinfection of the single bacterial strain (at a concentration of 10^3 UFC/mL), this ozone concentration in the reactor was reached, for example, within about 5-10 seconds gurgling at minor total power percentage of the ozonator potential.

This dose was too little to assure a complete disinfection of the four microbial mixed species, successive tests demonstrated that an ozone concentration more than 0.15 mg/L (obtained e.g. by a 30 seconds gurgling at 25 % of total power gain), led to the total bacterial mixture disinfection.

In the design of the disinfection system in the recirculation line, it was proposed a second step of air gurgling to eliminate ozone in excess, in order to prevent toxicological risks and to eliminate the unpleasant smell due to residual ozone dissolved before the water enters into the pool. This ozone stripping unit could intensify the revitalization with risk to compromise the ozone disinfection target. For this reason the experimental section was completed by some revitalization tests in order to consider the bacterial potential to survive after reached disinfection effect. The revitalization procedure (3 minutes aeration to assure absence of dissolved ozone in the mixture

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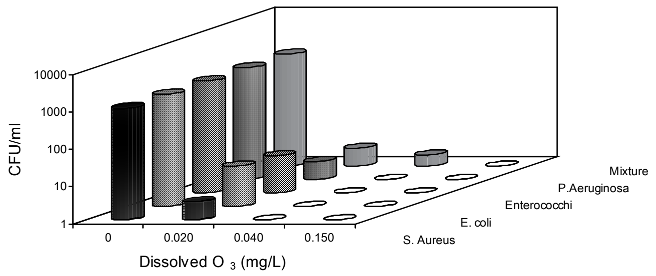

Figure 4: Bacterial abatement during semi-batch disinfection treatment experiments.

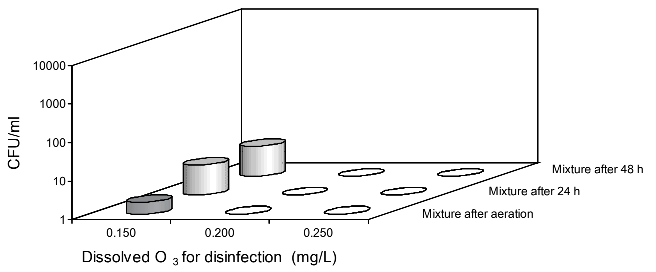

Figure 5: Revitalization outcomes for the mixture disinfected by a given dissolved ozone dose.

and conservation for 24 and 48 hours at 20 °C) was carried out after the mixture disinfection with the above mentioned dissolved ozone concentrations. At maximum dissolved ozone concentration (0.15 mg/L) efficient for disinfection a measurable revitalization occurred. No revitalization was demonstrated by tests when disinfection ozone concentration in the water was over 0.20 mg/L, this was an important outcome to respect in the process design if a scheme with an aeration step has to be planned. The results obtained in these experiments are shown in Figure 5.

Conclusions

In this study the possibility of the treatment of a backyard swimming pool water by ozone was considered. Some experimental tests were performed in order to test disinfection efficacy based on some Italian regulated microbiological parameters. A semi-batch system was built and ozone production by the ozonator as well as dissolved ozone potential into the reactor were controlled to assure real assessment of the trials.

By the experimental tests some useful suggestions to design a backyard swimming pool ozone disinfection system have been obtained and some conclusions were drawn:

- The trials have given the possibility to value the disinfection efficiency of an ozone treatment in the case of an hypothetical severe contamination of bacteria present in the backyard swimming pool;
- Following instructions about maximum microbiological pollution given by Italian regulation and standard norms, experimental results demonstrate that a 10^3CFU/mL bacterial concentration can be disinfected by a minimal dissolved ozone amount (around 0.20 mgO_3/L) and a short treatment time (5-15 seconds). These conditions support the idea to achieve an ozone disinfection in the recirculation system and with an air-cooling ozonator.
- Ozone disinfection activity starts to drop when the dissolved concentration in the reactor becomes less than 0.05 mgO_3/L that could be considered the minimum dissolved ozone quantity to maintain in the mixture during the treatment.
- Following Italian regulation and because of insalubrious odours, ozone dissolved in water re-entering into the pool must be reduced under 0.01 mg/L, so it must be planned an air stripping stage in the system. Bacteria revitalization tests showed aeration treatment does not compromise the disinfection efficiency if a dissolved ozone concentration more than 0.20 mgO_3/L is used.
- Even if there are not rigorous control policies for backyard swimming pools, a positive and health care swimming pool owner should consider that the ozone treatment could get to efficient disinfection supporting wide range of microbiological treatment, nevertheless chlorine alone use presents some health related problems which backyard swimming pool owner by itself is not able to control.

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