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Magnetic treatment of swimming pool water for enhanced chemical oxidation and disinfection.

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ABSTRACT

Magnetic water treatment is potentially of great benefit to pool water treatment in terms of the reduction in use of oxidising chemicals in water treatment. Magnetic treatment has been variously shown to stabilise solution pH, eliminate corrosion of materials and reduce system downtime. In addition to the reduction in running costs, physical water treatment is generally viewed as being more environmentally acceptable; reducing the use of the strong oxidising chemicals conventionally employed for disinfection.

This study determines the efficacy of a magnetic treatment device on the inactivation of a model micro-organism (Escherichia coli), chlorine consumption and concomitant disinfection by product formation in a swimming pool water analogue. Effects of magnetic water treatment on physical parameters such as scale deposition; conductivity and pH are reported, as well as the key performance determinands of chlorine consumption, micro-organism inactivation rate and trihalomethane (THM) formation. A commercially available magnetic treatment device (Magnetizer) was used throughout.

It was found that in all cases chlorine loss was more rapid in the control than in the magnetically treated water. The bactericidal efficiency of the free chlorine was unaffected by magnetic treatment, such that the E. coli kill rate for a given disinfectant dose was increased by an average of 25% by this physical conditioning. In addition, it was found that generation of THMs was reduced by magnetic treatment at any one free chlorine level.

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MAGNETIC TREATMENT OF SWIMMING POOL WATER FOR ENHANCED CHEMICAL OXIDATION AND DISINFECTION.

1 INTRODUCTION

1.1 Background

Many industries, including the swimming pool industry, are being urged by regulatory bodies such as PWTAG and pressure groups to use non-chemical treatment processes wherever possible (Gosling, 1996). PWTAG also places pressure on operators of swimming pools in the UK to employ the "least hazardous option" in terms of health and safety and environmental concerns (Gosling, 1996). The contaminants of swimming pool water are mainly urine, sweat and micro-organisms introduced by the swimmers. The major disinfectant used in swimming pool water treatment is sodium hypochlorite which has a bactericidal action that can be suppressed to some extent by interaction with other chemical contaminants (Black, 1996). Reaction with these organic contaminants result in the generation of disinfection by products (DBPs), the simplest of which are the trihalomethanes (THMs). The nature of these products and the extent to which they are generated depends upon the prevailing physical and chemical conditions (PWTAG, 1995). However, they are generally undesirable as they are all at least suspected carcinogens, teratogens and mutagens (Gosling, 1996).

1.2 Magnetic water treatment (MWT)

1.2.1 Chemical effects

The application of magnetic treatment to water has a long history, and has been used mostly to remove and control scale deposition (Donaldson, 1988; Baker and Judd, 1995). Calcium carbonate scale is estimated to cost industry around £ 1 billion per year (Darvill, 1993). The benefits of magnetic water treatment are claimed to include energy and water savings along with a range of benefits which prolong the life of the system's component parts and hence the life of the system itself. Magnetic treatment has been shown to stablise pH, eliminate corrosion, reduce downtime, maintenance and cleaning costs and bacteria and remove the risks associated with the handling of chemical detergents such as sodium hypochlorite used in swimming pool water treatment (Ifill, 1994). Magnetic treatment has been successful in a range of systems including industrial heat exchangers, cooling towers, water treatment plants and household use (Baker and Judd, 1995), and may prove useful to the leisure industry in reducing the heating and disinfection expenses involved in managing swimming pools. In addition to this physical water treatment is more environmentally acceptable than the use of strong oxidising chemicals.

1.2.2 *Biological effects*

Water is the major component of bacterial cells and the dissolved ion content in the intracellular water is the source of nutrition for the cell. One report shows that magnetic treatment of water can enhance the solubility of ions in the water, and proposes this the mechanism by which magnetic fields affect biological systems (Lin and Yotvat, 1990). It has also been proposed that magnetism may affect ion polarity, increasing membrane permeability and hence the amount of chlorine which can enter a cell, thereby enhancing its disinfecting properties (Ayrapetyan et al, 1994). A number of reports exist investigating the mechanisms by which magnetically treated water affects the cells and micro-organisms, the observed effects apparently varying from stimulatory to inhibitory depending on field strength and frequency of the magnetic field (Chizhov, 1975; Goodman et al, 1976; Moore, 1979; Berg, 1993). Many reports are concerned with the nature of the medium in which the micro-organisms exist (Berg, 1993; Okuno et al, 1993). Strong magnetic fields have been seen to enhance the growth of the model bacterium Escherichia coli cultured on a range of growth media (Okuno et al, 1993), but on the other hand, low strength alternating and pulsed fields have been shown to inhibit growth (Smith et al, 1993).

1.3 *Magnetic treatment of swimming pool water*

The last few years have seen the development of magnetic treatment devices (MTDs) for, amongst other applications, swimming pool water treatment. It is claimed by the suppliers of these devices that such devices have a number of beneficial effects including:

- The reduction of scale.
- The suppression of chlorine volatilisation.
- The inhibition of microbial growth.

Of special interest, and as a direct consequence of the above, is filter surface loading or fouling. Fouling of sand filters in swimming pool treatment can be largely attributed to clogging of the surface of the filter by organic materials, such that backflushing becomes necessary long before the full capacity of the filter has been reached. The application of a magnetic field via the specified magnetic treatment device might thus be expected to reduce the fouling of the filters by:

a) Inhibition of biological growth and/or
b) Enhanced breakdown of organic materials due to the maintenance of higher chlorine levels in the water

It is these two key phenomena that form the basis of the study.

One of PWTAGs stated main principles is that “the less disinfectant and other chemicals needed to maintain good water quality, the better”, and that “the only chemical you should use is a lot of water" (Gosling, 1996). In addition to this basic premise, enhanced disinfection would be of great benefit in terms of cost. At the moment, pools in the UK spend an average of £500 per annum on disinfectants. Should the 25% saving previously claimed be possible, the 1600 pools in this country would save a total of £2 million on disinfection costs per year (Ifill, 1994).

1 LITERATURE SURVEY

To assess the extent of the possible benefit MWT could have for the treatment of swimming pool water, the literature survey covered the following areas:

1) The operation and standards of swimming pools
2) Disinfection of swimming pools*
3) Chemical contamination of swimming pools
4) Biological contamination of swimming pools
5) Factors affecting disinfection
6) Magnetic treatment of water
7) The effects of magnetic fields on biological activity
8) The effects of magnetic fields on chemical activity

*Where "disinfection" is defined as the conscious inactivation of pathogenic organisms and viruses.

2.1 The operation and standards of swimming pools

The Pool Water Treatment Advisory Group's (PWTAG's) Pool Water Guide (1995) sets out guidelines and outlines legislation which ensures water quality and therefore public safety. The regulations control water temperature and chemical additions and bather load in order to ensure bather safety and good water quality. The treatment of swimming pool water is made compulsory by The Swimmers Pools Regulations of September 1991 4 (1) in Britain, and on the continent by other European legislation such as DIN standard 19 643 in Germany. PWTAG guidelines give maximum bather load as 1 bather per 2.5 m² for safety, whereas the Department of Environment (DOE) uses the formula below in order to maintain water quality. PWTAG lay down strict guidelines for pool water quality in terms of suspended and dissolved solids as well as physical properties (Table 1).

Materials

The study was conducted on the laboratory scale. The device was tested on simulated swimming pool water of known chemical and microbiological composition using a water of specification within PWTAG recommended concentration ranges (Table 8). Tests were restricted to relatively hard waters where scaling is more visible, although effects on scale formation were not rigorously quantified. Faecal coliform was used as the microbiological contaminant throughout the course of study, and human urine and sweat analogues were added (specified in Table A1, Appendix A). All tests were conducted using Spectrosol grade sodium hypochlorite with 12% free available chlorine (w/v) as the disinfectant and calcium bicarbonate to represent hardness of 200 ppm as $CaCO_3$, which would encourage scale formation while remaining within PWTAG's guidelines.

Limiting values of physiochemical parameters

Component	Low	High	Reference
Sodium Hypochlorite (mg/l)	0.42	1.40	1.05
Free chlorine (mg/l)	0.50	1.50	1.00
Sodium bicarbonate (mg/l)	168.00	336.00	336.00
Calcium Chloride (mg/l)	55.00	222.00	222.00
Sodium Humate (mg/l)	0.00	0.02	0.01
Sodium Chloride (mg/l)	0.00	2000.00	0.00
Sodium Sulphate (mg/l)	0.00	1500.00	0.00
PH	7.20	7.80	7.80
Temperature (°C)	28.00	32.00	32.00
*Body fluid simulant (ml/l)	0.00	0.05	0.05

** Simple analogue of human urine and sweat: Table A1.*

2 OBJECTIVES

The investigation was focused on the suppression of chlorine desorption, and increased bactericidal action. Previous work within the School of Water Sciences (Ifill, 1994) has revealed that magnetic treatment has a small but significant effect on the retention of free chlorine, as well as on calcium carbonate scale formation. It was intended that further work be carried out to verify trends observed in the previous study, and determine the extent to which the observed chlorine retention affects the formation of THM by-products. In addition, the direct influence of magnetic forces on bacteria viability will be studied.

The aim of the work was to test the efficacy of a magnetic treatment device (Magnetizer) in conditioning simulant swimming pool water so as to enhance chemical disinfection. To this end, the effect of the magnetic treatment on both microbiological and chemical activity was to be quantified.

It was intended that quantitative or semi-quantitative assessment of the effect of MTD's on free chlorine level, combined chlorine level, disinfection by-product formation, with specific reference to trihalomethanes and disinfection capability for faecal coliform would be provided, and that the results would refer to chemical conditions simulating those persisting in a normal swimming pool.

Mean chloroform concentrations after an initial free chlorine dose of 0.4 ppm

ANCOVA of mean chloroform concentrations at 0.4 ppm initial dose

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Covariates					
Combined CI (ppm)	1.090	1	1.090	0.307	0.058
Free CI (ppm)	0.976	1	0.976	0.275	0.601
PH	0.190	1	0.190	0.053	0.818
Temperature (°C)	1.769	1	1.769	0.507	0.479
Time (hours)	75.514	1	75.514	21.298	0.000
Main Effect					
Presence of MTD	20.429	1	20.429	5.660	0.000
Explained	120.415	6	20.069	19.000	0.000
Residual	283.651	80	3.546		
Total	404.006	86	4.698		

Summary of effects of MWT

1) **The pH of pool simulant solutions increased when organic compounds were present and decreased when they were absent.**

2) **No changes in solution conductivity were found.**

   Magnetizer comment: This is to be expected since there was no evaporative water loss.

3) **No scale was formed, so no conclusive results were obtained.**

   Magnetizer comment: With virtually no make up water or loss, scaling could not be significant.

4) **The turbidity of the solutions increased by an undetermined amount.**

   Magnetizer comment: If a filter would have been used in the test rig, particles could have been filtered out.

5) **No direct biocidal effects were observed.**

   Magnetizer comment: Test was only run in 8 - hour day shift.

6) **The cell death rate of E coli was significantly raised owing to increased aqueous chlorine.**

7) **Concentrations of free chlorine in solution were significantly increased by MWT at 0.8 and 1.2 ppm free chlorine doses.**

8) **Concentrations of combined chlorine in solution were significantly increased by MWT at and 1.2 ppm free chlorine doses.**

9) **Cell kill was improved at 0.4, 0.8 and 1.2 ppm initial free chlorine doses.**

10) **Chloroform production was suppressed at 0.4 and 1.2 ppm initial free chlorine doses; at 0.4 ppm this was significant.**