JASEM ISSN 1119-8362

Full-text Available Online at www.ajol.info and www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage. *Sept*, 2011
Vol. 15 (3) 517 - 522

The Ineffectiveness of Manual Treatment of Swimming Pools

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ABSTRACT: The University of Nigeria, Nsukka swimming pool was monitored for a period spanning about three months. The pool was constructed in 1961 and has been in operation since then except that many facilities including the treatment system are no longer functional forcing management to resort to treatment of the pool water by spraying the chemicals on the surface of the water and allowing swimmers to do the mixing. Prior to the physicochemical and microbial monitoring, questionnaires were administered to the swimmers which revealed that there was a level of dissatisfaction among the swimmers. Some of the swimmers were suffering from one form of skin disease or the other, some others had body itch after swimming while some others complained of foul odour. Water samples were collected from the swimming pool and analyzed, and the results were matched against swimming pool water standards. This comparison showed that the swimming pool water does not meet laid down standards as a result of poor management, infrequent treatment due to a permanent breakdown of treatment facilities, and general neglect of the swimming pool. Residual chlorine was detected only twice throughout the monitoring period, the COD was above 80mg/l, the pH was between 6.2 and 7.1 as against 7.2 to 7.8 recommended by standards. The total plate count was within limits but E-coli and coliform were detected in the pool more often than not as against the standard that recommends that E-coli or coliform should not be found in 100ml of the water sample. @JASEM

Yu Rin-rin (2005) observed that recreational water illnesses range from “swimmer’s itch” to serious infections such as gastrointestinal disorder, diarrhoea, haemolytic ureamic syndrome, hepatitis, giardiasis, asthma, bladder cancer, etc. some of which could result in death. Infections frequently occur on abraded elbows and knees and result in localized lesions, often referred to as swimming pool granuloma (Collins et al., 1984). *S. aureus* is shed by bathers under all conditions of swimming (Robinton & Mood, 1966), and is believed to have resulted in skin rashes, wound infections, urinary tract infections, eye infections, otitis externa, impetigo and other infections (Calvert & Storey, 1988; Rivera & Adera, 1991). Coagulase-positive *Staphylococcus* strains of normal human flora have been found in chlorinated swimming pools (Rocheleau et al., 1986). Research findings show that most of these infections occur because many pools do not meet standards for pool water quality (CDC, 2002, 2003). Faecal contamination may be due to faeces released by bathers or a contaminated water source or direct animal contamination - e.g. birds and rodents (CDC, 2001a). Non-faecal human shedding such as vomit, mucus, saliva or skin in the swimming pool water or similar recreational water environments is a potential source of pathogenic organisms. Swimmers are usually endangered when they swallow contaminated pool water, inhale toxic disinfection by products such as trihalomethane (Nickmilder and Bernard, 2007) or by skin adsorption (Villanueva et al, 2007). The chance of infection through swallowing of pool water increases with the amount of water swallowed, however, researchers have not reached a consensus on the amount of water swallowed by an average swimmer. While Evans et al, 2001 and Alen et al (1982) reported that swimmers ingest as much as 100ml and 160ml/hr respectively, Shuval (1975) suggested 10ml of pool water per bathing day, and WHO (2003) suggested 20 to 50ml per hour. However, in a more recent study by Dufour et al (2006) using cyanuric acid as a marker, it was found that children ingest about twice (37ml) as much pool water as ingested by adults (16ml) in a bathing period of 45 minutes.

In order to reduce the incidence of infection, White (1972) recommended that swimming pool water should be of the quality of drinking water. This requirement is usually achieved by constantly subjecting the pool water to treatment processes such as coagulation, filtration, dilution with freshwater and disinfection by chlorination, ozonation and ultra violet disinfection. While filtration helps trap organic matter such as hair, skin and dirt that are usually oxidized by chlorine, ozone or UV to nitrogen and CO_2 in addition to disinfection by-products (Villanueva et al, 2007); disinfection destroys pathogenic microorganisms that might have entered the pool via various sources. Properly operated filtration with coagulation can remove much of the pollution from the pool water resulting in lower levels of organisms, lower chlorine demand and less disinfection by-products (Bonnick, 2005). The absence of residual chlorine in pool water can be catastrophic, hence, the Iowa State Department for Public Health (2005) recommended that the pool should be closed if free chlorine falls below 0.6ppm. Pool water quality should be consistently monitored and any sign of serious contamination should be addressed by superchlorination (Villanueva et al, 2007). The consequence of neglect of swimming pool water qualities have been demonstrated by a number of researchers. Harley et al (2001) reported the presence of Adenoviruse as a result of inadequate chlorination and poor maintenance; Maunula et al (2004) isolated Norovirus from pool water as a result of chlorination failure; Mahony et al (1992) found Hepatitis A resulting from accidental faecal release; Kee et al (1994) found Echovirus 30 introduced by

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vomit; Martone et al (1980) reported an outbreak of pharyngo-conjuctivitis when residual chlorine fell below 0.4mg/l; Blostein (1991) reported the presence of Shigella spp resulting from accidental discharge; Cransberg et al (1996) isolated E coli O157 introduced by accidental faecal discharge; Greensmith et al (1988) and Galmes et al (2003) reported the presence of Giardia and Cryptosporidium respectively as a result of accidental faecal discharge. There are, no doubt, several other cases which might have gone unreported especially in developing countries.

METHODOLOGY

The swimming pool used for this study is the University of Nigeria, Nsukka swimming pool located at the north-eastern part of the university community close to the Health and Physical Education Department (6°52' N and 7°24' E, 70km North of Enugu, the capital of Enugu State). It was constructed and started its operation in 1961. The pool was designed for maximum number of 50 persons. The facilities constructed in the UNN swimming pool include: water reservoir, treatment plants and aeration system, shower rooms, toilets, toddlers pool, changing rooms, etc. However, facilities like the toddler pool, treatment plant and shower rooms are no longer in use due to technical faults. The pool has varying depths of 4feets, 6feets and 15feets. The dimensions of 4feets, 6feets and 15feets depth of the UNN swimming pool are 14.5m by 13.9m, 15m by 19.6m, and 12.7m by 9.7m respectively. The pool is used for instructional and recreational purposes and has only one lifeguard but hires part-time lifeguards when the need arises. The university also has an Olympic-sized swimming pool constructed in 2009, however, it is currently not being used by swimmers.

Preliminary Study: Firstly, questionnaires, observations and interviews were employed as means of ascertaining the necessity for the study. On this note, 50 questionnaires were distributed by hand to swimmers at the swimming pool. A return rate of 92% was recorded. Figure 1 shows that more than 70% of the swimmers think that the pool water is not clean while about 60% are dissatisfied with the general hygiene of the pool. Even though these respondents may not know standards for swimming pool, it is unlikely that that their personal yardsticks will be stricter than laid down standards. It was also found that 41% of the respondents would have preferred other pools if there were any but there is no other public pool in the Town. Also Figure 2 shows that 28% have body itch after swimming while 21% suffers from other forms of skin disease. This implies that either they were infected at the pool or from other sources in which case there are chances that they will contaminate the pool. It was also observed that 21% of the swimmers do not shower after swimming. This is because the shower room at the pool is no longer in use so these swimmers lose the urge or simply forget to shower by the time they get home hence, exposing themselves to infection. Figure 3 shows that 13% of respondents urinate in the pool while 30% spit in the pool. It is known that pathogens can be introduced into the pool via urine and saliva in addition to increasing the organic load of the pool so that some treatment chemicals are wasted in oxidizing the organic matter. Some (21%) of the swimmers believe that the pool has a foul smell. The foregoing is a strong sign that something is wrong with the pool and more so because the treatment facilities at the pool are faulty, chlorination is done manually, the pool water is replenished once a year and the pool water quality is not being monitored as recommended.

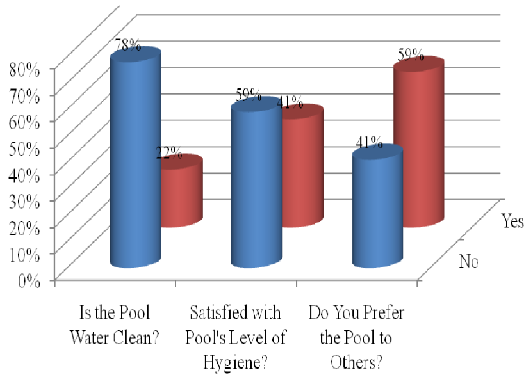

Fig 1: Swimmers' Opinion of the Pool

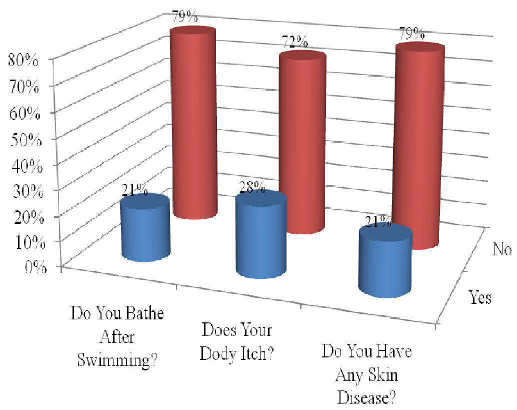

Fig 2: Swimmers' Welfare

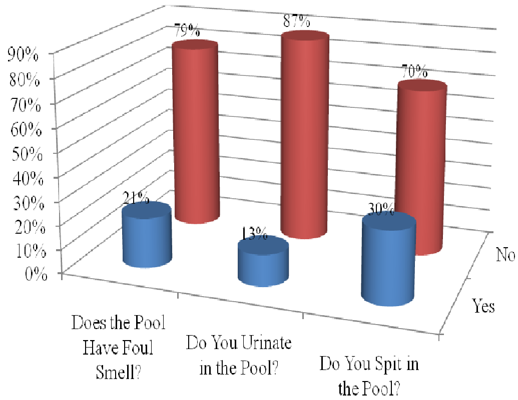

Fig 3: Swimmer's Attitude to the Pool

Water Sampling and Analyses: Samples were collected from the swimming pool during which an in-situ test for the dissolved oxygen and temperature were carried out. All the laboratory analyses were carried out in the public health laboratory of the Department of Civil Engineering, University of Nigeria, Nsukka. The samples used for the laboratory analysis were collected from the shallowest section (4ft) and deepest section (15ft) of the pool designated as the sample A and B respectively. The samples were collected between 8.00am – 12.00noon. All the pool water samples collected for laboratory analysis were analysed immediately they were brought into the sanitary laboratory. Sample which could not be analysed on the collection day were preserved in the refrigerator and analysed the following day. Bacteriological tests which include the plate count test, E-coli and total coliform tests were carried out first before other tests to avoid deterioration of the sample with time. Chlorine content was determined using iodometric method. Coliform test and E-coli test were performed using standard total coliform Most Probable Number(MPN) while COD (Chemical Oxygen Demand) test and suspended solid (SS) test were performed using the dichromate reflux method and gravimetric method respectively. The pH test was determined using glass electrode method while the plate count test was performed using the standard plate count empirical method.

RESULTS AND DISCUSSION

The complete breakdown of the treatment facilities at the pool has caused its management to resort to manual treatment. This is done by the lifeguard in the most uninformed way. He simply sprays the chemicals on the water surface in the evening and leaves them for swimmers to do the mixing the following day. In addition to this unhealthy approach, the treatment is both irregular and infrequent, and the pool water is replenished only once a year (usually in January).

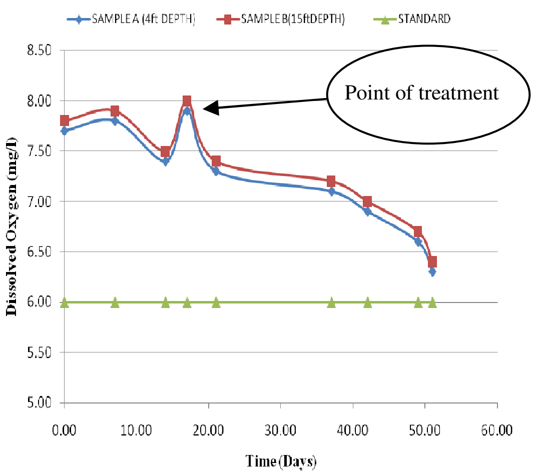

Fig 4: The level of Dissolved Oxygen

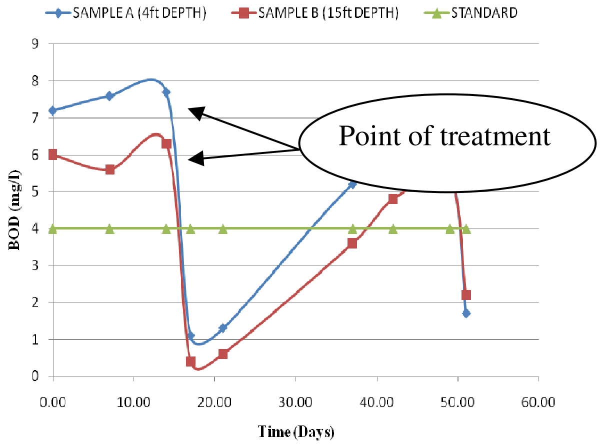

Fig 5: Biochemical oxygen Demand of the Pool for Three Months

The results of the physicochemical and the microbial analyses obtained for the three months period have been compared with laid down standards. Nigeria has no standard for swimming pool water; hence the World Health Organization Guidelines for Safe Recreational Water Environment (WHO, 2006) were used. The guidelines do not cover such physicochemical parameters as BOD, COD and dissolved oxygen, therefore, drinking water standards were used as a yardstick since it has been reported that swimmers swallow as much as 160ml per hour Alen et al (1982) and White (1972) recommended that swimming pool water quality should be of the same quality as drinking water. Generally, the pool is very poorly managed – all treatment facilities are spoilt and disinfection is done manually; the pool water is changed only once a year and its dilution comes from rainfall. No remarkable difference was seen between the results obtained from the 4ft and 15ft sections.

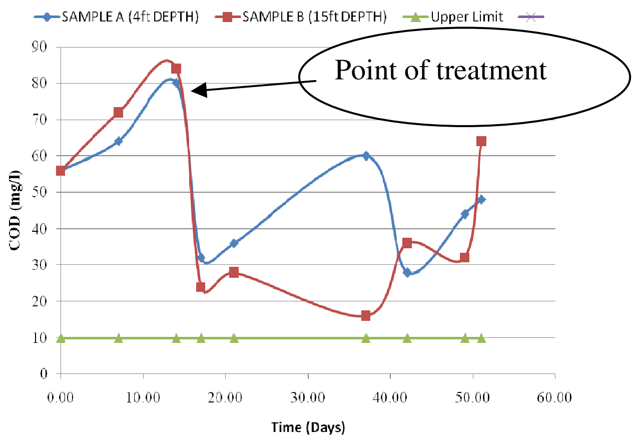

Fig 6: Chemical oxygen Demand of the Pool for Three Months

Figures 4 to 6 shows that, though the pool water has sufficient dissolved oxygen, the BOD and COD (as high as 80mg/l) are not in keeping with the standards. It is suspected the very high COD levels could be as a result of accumulation of disinfection by products produced by the reaction between chlorine and organic matter in the pool.

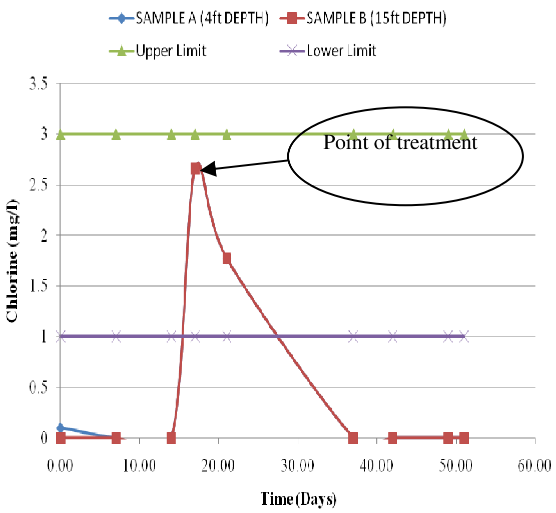

Fig 7: Residual Chlorine Content of the Pool for Three Months

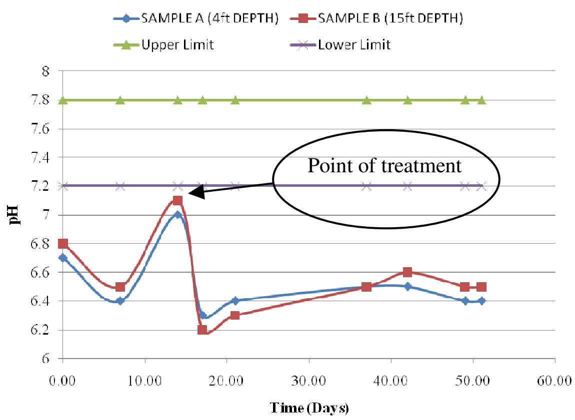

Fig 8: pH of the Pool for Three Months

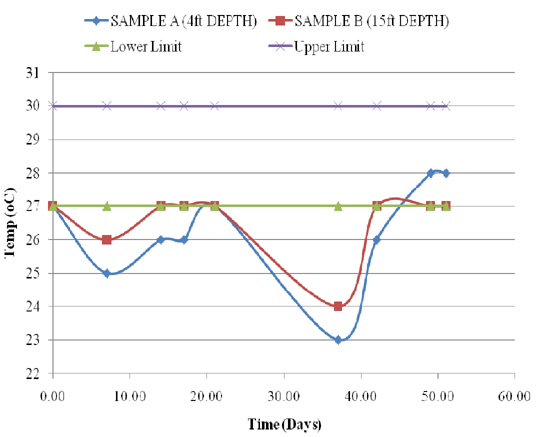

Fig 9: Mean Temperature of the Pool for Three Months

The preliminary study revealed that some of the swimmers urinate in the pool and since the pool is open to the atmosphere there is the possibility of organic pollution from the environment. The release of urine into swimming pools can cause substantial organic loading and has been estimated to average between 25 and 30 ml per bather (Gunkel & Jessen, 1988); and can be as high as 77.5 ml per bather (Erdinger et al., 1997a). It can be seen from Figures 7 and 8 that, for the most part, there was no residual chlorine in the pool. Residual chlorine was only detected twice after the pool had been disinfected by management. After this period, the residual chlorine level quickly declined to zero. The rapid loss of chlorine immediately after treatment can be attributed to the consistently low pH and the fact that a part of the chlorine is used to oxidize the organic matter in the pool.

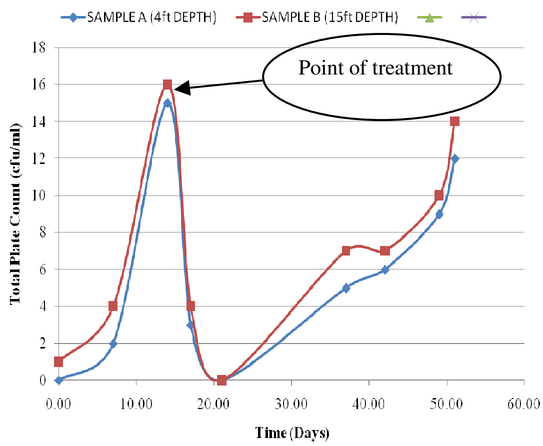

Fig 10: Total Microbial Population of the Pool for Three Months

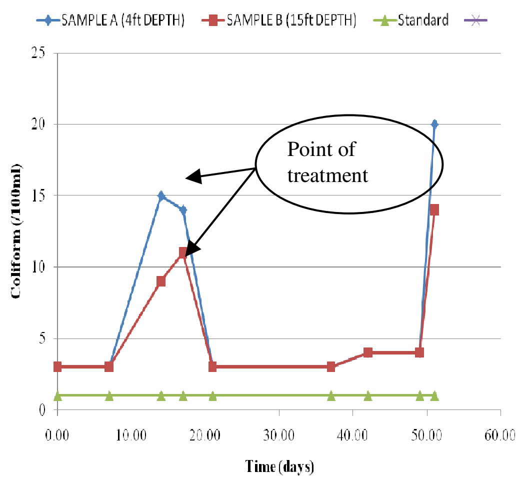

Fig 11: Coliform Count of the Pool for Three Months

This is obvious because the BOD level of the pool dropped sharply after the pool was treated (after third sampling), and then started building up again gradually. The most suitable range of pH for chlorine disinfection is 7.2 – 7.8 but the highest pH recorded during the sampling was 7.1, and at no point did the pH reach the minimum level required for optimal disinfection and sustenance of residual disinfection. Low pH as such prevailing in the pool facilitates the formation of chlorates which causes the formation of methemoglobin when ingested by swimmers (Beech et al, 1980). Also out-of-range pH can cause eye and skin irritation and this could be responsible for the body itch experienced by some of the swimmers. The

Iowa State Department for Health, Division of Environmental Health (2009) considers a pH of less than 6.8 critical enough as to warrant closing the pool. The pH of the pool water was less than this critical value throughout the monitoring period except for once. The recommended temperature range to ensure swimmers' comfort is 27^0C – 30^0C. The pool also failed in this aspect as the temperature was almost always below 27^0C. The total plate count result was well below 200cfu/ml recommended by the standard but the coliform result and Ecoli results (not shown) are in violation of the standard that recommends less than 1 per 100ml. The presence of E. coli indicates poor pool management (Barrell et al, 2000) and deficiencies in the treatment of the swimming pool or inadequate protection of the source of untreated water (Borchardt and Walton, 1971).

REFERENCES

Allen, L. M., Briggle, T. V. & Pfaffenberger, C. D. (1982) Absorption and excretion of cyanuric acid in long-distance swimmers. *Drug Metabolism* 13 (3): 499–516.

APHA, AWWA and WEF. (1998) Standard Methods for the Examination of Water and Wastewater (20th Ed). APHA, AWWA and WEF, Washington, DC, USA.

Barrell, R. A. E., Hunter, P. R. and Nichols, G. (2000). Microbiological standards for water and their relationship to health risk. *Commun Dis Public Health* (3): 8-13.

Beech, A. J., Diaz, R., Ordaz, C. And Palomeque, B. (1980) Nitrates, chlorates and trihalomethanes in swimming pool water. *AJPH*, 70: 1

Blostein, J. (1991) Shigellosis from swimming in a park in Michigan. Public Health Reports, 106: 317–322.

Borchardt, J.A. & Walton, G. (1971). Water quality and treatment: A handbook of public water supply. American Water Works Association, pp 1-52.

Calvert, J. & Storey, A. (1988) Microorganisms in swimming pools – Are you looking for the right one? *Journal of the Institution of Environmental Health Officers*, 96(7): 12.

CDC (2001a) Prevalence of parasites in faecal material from Chlorinated swimming pools – United States, Morbidity and Mortality Weekly Report, pp.50: 410–412.

CDC (2002) What All Pool Staff Should Know about Recreational Waterborne Illness. *The National Swimming Pool Foundation.* [Online] Summer 2002. http://www.nspf.org/Documents/cdcarticles/cdcwave2002news.pdf.

CDC (2003). Surveillance Data from Swimming Pool Inspections. *Centers for Disease Control.* [Online] June 2003. http://www.cdc.gov/mmwr/PDF/wk/mm5222.pdf.

Collins CH, Grange JM, Yates MD (1984) A review: Mycobacterium in water. *Journal of Applied Bacteriology*, 57(2): 193–211.

Cransberg K, van den Kerkhof JH, Banffer JR, Stijnen C, Wernors K, van de Kar NC, Nauta J, Wolff ED (1996). Four cases of haemolytic uremic syndrome – source contaminated swimming water? *Clinical Nephrology*, 46: 45–49.

Dufour, A. P., Evans, O., Behymer, T. D. and Cantu, R. (2006). Water ingestion during swimming activities in a pool: A pilot study. *Journal of Water and Health* 04. 4.

Erdinger L, Kirsch F, Sonntag, H. G. (1997a). Potassium as an indicator of anthropogenic contamination of swimming pool water. *Zentralblatt für Hygiene und Umweltmedizin*, 200(4): 297–308.

Evans O, Cantú R, Bahymer TD, Kryak DD, Dufour AP (2001) A pilot study to determine the water volume ingested by recreational swimmers. Paper presented to 2001 Annual Meeting of the Society for Risk Analysis, Seattle, Washington, 2–5 December 2001.

Galmes, A., Nicolau A., Arbona, G., Gomis, E., Guma, M., Smith-Palmer, A., Hernandez-Pezzi, G., Soler, P. (2003). Cryptosporidiosis outbreak in British tourists who stayed at a hotel in Majorca, Spain. *Eurosurveillance Weekly*, 7(33).

Greensmith, C. T., Stanwick, R. S., Elliot, B. E., Fast, M. V. (1988). Giardiasis associated with the use of a water slide. *Paediatric Infectious Diseases Journal*, 7: 91–94.

Gunkel, K. and Jessen, H. J. (1988). The problem of urea in bathing water. *Zeitschrift für die Gesamte Hygiene*, 34: 248–250.

Harley, D., Harrower, B., Lyon, M. and Dick, A. (2001) A primary school outbreak of pharyngoconjunctival fever caused by adenovirus type 3. *Communicable Diseases Intelligence*, 25(1): 9–12.

Kee, F., McElroy, G., Stewart, D., Coyle, P. and Watson, J. (1994) A community outbreak of echovirus infection associated with an outdoor swimming pool. *Journal of Public Health* Medicine, 16: 145–148.

Martone, W. J., Hierholzer, J. C., Keenlyside, R. A., Fraser, D. W., D'Angelo, L. J. and Winkler, W. G. (1980). An outbreak of adenovirus type 3 disease at a private recreation center swimming pool. *American Journal of Epidemiology,* 111: 229–237.

Maunula, L., Kalso, S., von Bonsdorff, C. H. and Pönkä, A. (2004) Wading pool water contaminated with both noroviruses and astroviruses as the source of a gastroenteritis outbreak. *Epidemiology and Infection*, 132: 737–743.

Nickmilder, M. and Bernard, A. Ecological association between childhood asthma and availability of indoor chlorinated swimming pools in Europe. *Occupational and Environmental Medicine.* 2007, Vol. 64.

Rivera, J. B. and Adera, T. (1991). Assessing water quality. Staphylococci as Microbial indicators in swimming pools. *Journal of Environmental Health*, 53(6): 29–32.

Robinton E.D. and Mood E.W. (1966) A quantitative and qualitative appraisal of microbial pollution of water by swimmers: a preliminary report. *J. Hyg*, 31: 489 - 99.

Rocheleau, S., Desjardins, R., Lafrance, P. and Briere, F. (1986) Control of bacteria populations in public pools. *Sciences et Techniques del'eau*, 19: 117–128.

Shuval, H. I. (1975). The case for microbial standards for bathing beaches. In: Discharge of Sewage from Sea Outfalls (ed. Gameson, A. L. H.), Pergamon Press, Oxford, England, pp. 95–101.

The Iowa State Department for Health, Division of Environmental Health (2009). Swimming Pools and Spa Programme, Swimming Pool Rules. Des Moines, Iowa State, USA.

Villanueva, C. M. et al. bladder cancer and exposure to water disinfection by-products through ingestion, bathing, showering, and swimming in pools. *American Journal of Epidemiology.* 2007, 165 (2).

White, G. C. (1972). Handbook of Chlorination. New York, Van Nostrand Reinhold Co. p466.

WHO (2006) Guidelines for Safe Recreational Water Environments Volume 2: Swimming Pools and Similar Environments. World Health Organization, Geneva Switzerland.

WHO (2003). Guidelines for Safe Recreational Water Environments. Volume 1, Coastal and Fresh Waters. WHO, Geneva, Switzerland.

Yoder, J. S., Blackburn, B. G., Craun, G. F., Hill, V., Levy, D. A., Chen, N., Lee, S. H., Calderon, R. L. and Beach, M. J. (2004). Surveillance of waterborne-disease outbreaks associated with recreational water –United States, 2001– 2002. *Morbidity and Mortality Weekly Report Surveillance Summaries*, 53: 1–22.

Yu, R. (2006). Air sickness. *Aquatics International.* [Online] October 2006. http://www.aquaticsintl.com/2006/oct/0610_air.html.

Yu, R. (2005). Fear of the water. *Aquatics International.* [Online] May 2005. http://www.aquaticsintl.com/archives/2005/may/rwi.pdf.