

POLLUTION STATUS OF SWIMMING POOLS IN SOUTH-SOUTH ZONE OF SOUTH-EASTERN NIGERIA USING MICROBIOLOGICAL AND PHYSICOCHEMICAL INDICES

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Abstract. Microbiological and physicochemical characteristics of swimming pools in South Eastern states of Nigeria (Akwa Ibom and Cross River) were investigated. The bacterial isolates included *Enterococcus faecalis*, *Clostridium perfringens*, *Bacillus cereus* and *Escherichia coli*. Others were *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Proteus vulgaris* and *Staphylococcus epidermidis*, while fungal isolates were *Penicillium* sp, *Rhizopus* sp, *Aspergillus versicolor*, *Fusarium* sp, *Trichophyton mentagrophytes*, *Mucor* sp, *Candida albicans*, *Aspergillus niger*, and *Absidia* sp. The total viable count of microorganisms in Ibeno (B) and Uyo (E) swimming pools were 6×10^6 cfu/ml and for Calabar (H) swimming pool, 3.3×10^7 cfu/ml. The total coliform counts were 10^6 cfu/100 ml for Calabar (G) swimming pools and 2×10^7 cfu/100 ml for Calabar (H) swimming pools while the fungal count ranged from 5×10^6 cfu/ml to 3×10^7 cfu/ml. Physical and chemical parameters known to be hazardous to health were also identified. The presence of high levels of coliform and fecal coliform bacteria (*E. coli*) revealed that the swimming pools have not met the World Health Organization (WHO) standard for recreational waters. The swimming pools constitute a serious public health hazard.

INTRODUCTION

Swimming pools are concrete tanks, large artificial basins, or large paved holes containing water for swimming. The swimming pool water should meet potable water standard by being transparent, odorless, and tasteless liquid having a freezing point of 0°C and boiling point of 100°C (Cairns and Dickson, 1973). Water is one of the most essential needs of man, both for food and for recreation. Natural waters are the major sources of swimming pool water. The potability of swimming pool water is enhanced by frequently changing the water and the use of disinfectant, such as chlorine. The highest possible concentration of about 1 ppm should be maintained because higher chlorine concentration irritates the eyes. Swimming pool operators prefer iodine to chlorine as a disinfectant because its action is less hindered by organic matter and there is less eye and skin irritation than with chlorine, according to Alice (1977). Bromine is also recommended. Each bather is expected to shower

with soap before entering the pool. People with infections of any kind should not be allowed entry into the pool. Despite these operations to ensure potability of the water and maintenance of good hygiene, Cruickshank *et al* (1975) reported that a swimming pool may be infected with pathogenic microorganisms entering the pool directly or indirectly through contaminated air, soil, dust, rain water, sewage, human or animal excrement and individual bathers. Unless the water is adequately treated, contamination may lead to outbreaks of diseases, such as skin ulcers, gastroenteritis, conjunctivitis, trachoma, ear infection such as otitis media, cholera, dysentery, eczema and skin rashes (Cairncross *et al*, 1980; UNDP, 1989). These views have been shared by other workers (Borchardt and Walton, 1971; Turk *et al*, 1978; Fair *et al*, 1981; Pelczar *et al*, 2000). Microbiological evaluation has, for many years, been the most significant method for sanitary and quality control of swimming pools. For effective quality control, a test for indicator bacteria is usually of primary importance.

As indicators of fecal pollution, their presence is a strong indication of the presence of enteric pathogenic bacteria, such as *Salmonella*

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typhi, *Salmonella paratyphi*, *Shigella dysenteriae*, *Vibrio cholerae* and parasites in the pool. Skin tuberculosis caused by *Mycobacterium baliteri* has been reported after swimmers had bathed in waters from which a large amount of microorganisms were found. Alice (1977) in her investigation of an outbreak of conjunctivitis in USA during summer camping reported that the incidence of contracting the illness increased by 50% amongst users at the camp swimming pool over non-users (Crone and Tee, 1974). Alcock (1977) highlighted the potential health hazards of *Pseudomonas aeruginosa* in swimming pool waters, adding that this organism is frequently being isolated from the ears of swimmers with otitis media. The principal indicator bacteria are fecal coliform (*E. coli*), total coliform, *Enterococcus faecalis* and *Clostridium perfringens*. Okafor (1985) reported that although bathing places are traditionally examined by total plate count and a coliform test, they do not provide specific information regarding *Staphylococcus aureus* and *Pseudomonas aeruginosa*, both of which are more resistant to disinfection. Disinfection by halogen is recommended.

The main objective of this work is to determine through cultural techniques whether swimming pools in South-South Zone of South Eastern Nigeria meet the WHO (1971) standard for recreational waters using microbiological and physicochemical indices.

MATERIALS AND METHODS

Sources and collection of samples

Water samples were collected aseptically from 10 different swimming pools in Akwa Ibom and Cross River States of Nigeria using the techniques earlier described (Cruickshank *et al*, 1975; Okafor, 1985). Samples were labelled A-J based on their collection sites.

Sample A Mobil Guest House, Eket, flow through pool 2.85 m deep; Sample B Ibeno, flow through pool 2.85 m deep; Sample C ALSCON Camp, Ikot Abasi, fill and draw pool 2.2 m deep; Sample D FERROSTAL Camp, Ikot Abasi, flow through pool 2.5 m deep; Sample E WINMOS House, flow through pool 2.22 m; Sample F Akwa Ibom State Government House, fill and draw pool 2.85 m deep; Sample G Calabar sports Stadium,

Calabar, Cross River State, fill and draw pool 50 m at its deepest point; Sample H Metropolitan Hotel in Calabar, Cross River State, flow through pool 2.3 m deep; Sample I Pyramid Hotel, Calabar, fill and draw pool 2.2 m deep; Sample J Marian Road, fill and draw pool 2.2 m deep.

The sampling periods were mostly in the morning before bath, afternoon and evening after bath.

Processing of samples

The pour plate technique of Harrigan and McCane (1976) and Collins and Lyne (1976) was adopted using standard plate count agar (Oxoid, England). This method was used for the determination of the total heterotrophic bacterial and fungal counts. The total coliform and *Escherichia coli* (fecal coliform) counts were enumerated on membrane lauryl sulphate broth (Oxoid, England), using 0.45 µm pore-size millipore filters as described by Oxoid (1985) and Itah *et al* (1996). The fecal coliforms (*E. coli*) were enumerated at 44 ± 0.5°C for 24-48 hours in a thermostatically controlled water bath (Gallenkamp, England) while the total coliform bacterial counts were enumerated on membrane lauryl sulphate broth at 37°C for 24-48 hours using a 100 ml-water sample. Cetrimide agar (Oxoid, England) was used for the isolation of *Pseudomonas aeruginosa* while 10% lactic acid malt extract agar (Oxoid, England) was used for the isolation of fungi. Anaerobic *Clostridium* species and *Enterococcus faecalis* were enumerated on 1% (w/v) cysteine HCl blood agar using a Baird and Tatlock anaerobic jar while *E. faecalis* was enumerated on Slanetz and Bartley's medium (Oxoid, England). After primary isolation, pure cultures were obtained by repeated subculture on fresh media using the streak plating technique.

Identification of isolates

All isolates were identified using the identification schemes of Beneke and Rogers (1970) for fungi and Cowan (1985) and Holt *et al* (1994) for bacteria.

RESULTS

Viable plate count determination

The viable count of bacteria and fungi from the various swimming pools are presented in Table

1. The mean heterotrophic bacterial count ranged from 3.3×10^6 cfu/ml to 6.4×10^7 cfu/ml for the Calabar swimming pools J and G respectively while the mean coliform count ranged from a nil count/100 ml to 2.5×10^6 cfu/100 ml and 2.6×10^6 cfu/100 ml for Calabar pools G and H respectively. Fungal counts ranged from a nil count/ml to 1.9×10^7 cfu/100 ml in Calabar swimming pool H.

Percentage occurrence of isolates from all the swimming pools

The results revealed the following percentage frequencies: *Enterobacter aerogenes* (50%), *Clostridium perfringens* (30%), *Bacillus cereus* (80%), *Escherichia coli* (20%), *Pseudomonas aeruginosa* (70%), *Staphylococcus aureus* (100%), *Staphylococcus epidermidis* (50%) and *Enterococcus faecalis* (30%) (Fig 1). The percentage distribution of fungal isolates were *Penicillium* sp (40%), *Rhizopus* (20%), *Aspergillus niger* (50%), *Candida albicans* (40%), *Fusarium* sp (70%), *Trichophyton mentagrophytes* (20%), *Mucor* sp (70%), *Aspergillus versicolor* (30%) and *Absidia* sp (20%) (Fig 2). Eight pools (A, B, C, D, E, F, I and J) out of the 10 swimming pools, yielded no growth of coliform bacteria. Fungi

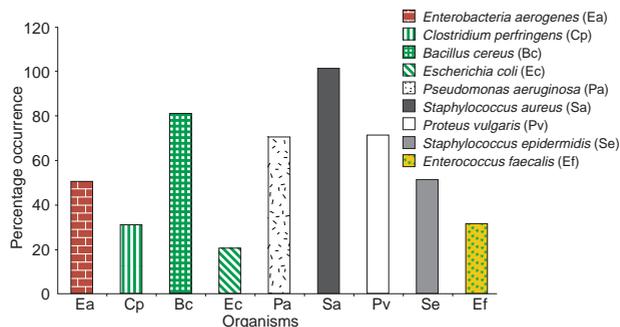


Fig 1—Percentage occurrence of bacterial isolates from all the swimming pools.

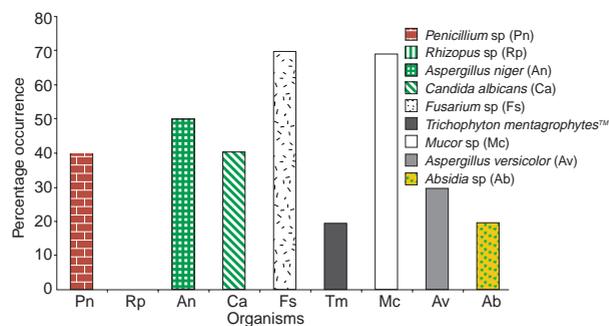


Fig 2—Percentage occurrence of fungal isolates from all the swimming pools.

Table 1
Bacterial count of organisms isolated from the ten swimming pools studied.

LGA	No. of samples	Mean heterotrophic bacterial count (cfu/ml)	Mean coliform count (cfu/ml)	Mean fungal count (cfu/ml)
Eket				
A	3	1.8×10^7	0	0
Ibeno				
B	3	3.3×10^6	0	0
Ikot Abasi				
C	3	3.9×10^6	0	0
Ikot Abasi				
D	3	3.6×10^6	0	0
Uyo				
E	3	4.7×10^6	0	0
Uyo				
F	3	1.5×10^7	0	7.3×10^6
Calabar				
G	3	6.4×10^7	2.5×10^6	3.5×10^6
Calabar				
H	3	2.5×10^7	2.6×10^6	1.9×10^7
Calabar				
I	3	1.9×10^7	0	2.0×10^4
Calabar				
J	3	3.3×10^6	0	3.3×10^4

were not encountered in three of the pools (A, C and D) while two (A and C) of the pools yielded growth of two bacterial colonies each.

Physicochemical analysis

The results of physicochemical analysis revealed that all the parameters were within the recommended standard for potable water except dissolved oxygen (DO) that ranged from 6.2 mg/l in some pools to 6.60 mg/l in others against the recommended standard of 6 mg/l by WHO (1971). Zn, Cu, and Pb were below detection levels in pools D, F and J.

DISCUSSION

The presence of significant numbers of any member of the coliforms in swimming pool water indicates either deficiencies in the treatment of the swimming pool or inadequate protection of the source of untreated water (Borchardt and Walton, 1971). Various species of bacteria and fungi, most of which are known human pathogens, were encountered in the various pools, probably as a result of fecal contamination by homoiotherms and poikilotherms. They included *Escherichia coli*, *Klebsiella* coliforms, *Salmonella*, *Enterococcus faecalis*, *Pseudomonas aeruginosa* and *Clostridium perfringens*. According to Carbell *et al* (1975) and Stanier *et al* (1987), *Enterococcus faecalis*, *Enterobacter*, *Klebsiella* and *Pseudomonas* species are associated with surface

run off water while *Escherichia coli*, *Staphylococcus aureus* and *Lactobacillus* species are usually contributed by bathers in the pools. Similar reports were made by Robinton and Mood (1986) in their quantitative and qualitative appraisal of microbial pollution of water by swimmers. Bonde (1985) and Itah *et al* (1996) reported that the presence of *E. coli* in water is a strong indication of the closeness of the sampling site to the source of pollution. *E. coli* is exclusively fecal in origin (Okafor, 1985) and its presence in water is a strong indication of recent fecal pollution because of the extra enteral behavioral pattern of this organism (Itah *et al*, 1996). The presence of *Clostridium perfringens* in some of the pools is an indication of remote pollution (Report 71, 1969) while *Enterococcus faecalis*, when found in water in the absence of *E. coli* because of its extra enteral behavior, is important confirmatory evidence of fecal pollution of swimming pools. The presence of these indicator bacteria indicate the possible presence of enteric pathogenic bacteria in the pool. This incidence constitutes a public health hazard because swimmers can accidentally swallow contaminated pool water during swimming which can result in outbreaks of diseases like cholera, shigellosis, typhoid and paratyphoid fever, gastroenteritis and diarrhea.

Trachoma, caused by *Chlamydia* species, is known to be associated with eye inflammation and partial or complete blindness. One cannot rule

Table 2
Physicochemical analysis of the ten swimming pools studied.

Characteristics	Units	A	B	C	D	E	F	G	H	I	J	WHO (1971)
1 pH		8.05	7.78	7.66	8.49	8.36	8.27	8.05	7.78	7.60	8.49	6.5-9.2
2 Temp	°C	27.0	27.0	27.0	26.9	26.8	27.0	27.0	27.0	26.9	26.8	27°C
3 BODs at 20°C	mg/l	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	4 mg/l
4 COD	mg/l	1.02	0.08	0.062	0.048	0.072	0.060	1.02	0.081	0.062	0.048	
5 DO	mg/l	6.20	6.20	6.20	6.40	6.40	6.60	6.20	6.20	6.20	6.40	6 mg/l
6 Chloride	mg/l	31.95	24.85	31.95	266.25	244.95	536.05	31.95	24.85	31.95	266.25	600 ppm
7 Zinc	mg/l	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d	5-15 mg/l
8 Cu	mg/l	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d	1-1.5 mg/l
9 Pb	mg/l	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d	0.1 ppm
10 Fe	mg/l	0.003	0.002	0.002	N.d	0.003	N.d	0.003	0.002	0.002	N.d	0.3-2 mg/l

N.d = Not detected

out the possibility of outbreaks of parasitic infections such as amebiasis, giardiasis, filariasis and scabies. The results of this work are in consonance with an earlier report by Alcock (1977) who isolated *Pseudomonas aeruginosa* from swimming pool waters and highlighted the potential health hazards of this organism, reiterating that it is frequently being isolated from the ears of swimmers with otitis media. The results differ from the work of Alice (1977) who reported skin tuberculosis caused by *Mycobacterium baliteri* after swimmers had bathed in waters from which large amounts of microorganisms were encountered, as in this work. Mycobacteria were not encountered in this investigation. The results compare favorably with the work of Robinton and Mood (1986), who isolated *Staphylococcus* species from swimming pools with low chlorine residuals. *Bacillus cereus* (Itah and Opara, 1994), *Escherichia coli* (Anozie and Antai, 1987; Itah, 1999) and *Staphylococcus aureus* (Snydman, 1989; Itah and Opara, 1997; Prescott *et al*, 2002) are known enterotoxin producers when ingested into the body, therefore their presence in pools is a threat to public health because they can be ingested with water by active swimmers.

It is important to note that drinking water standards differ from one country to another due to geographical locations and climate. Similarly, there are many swimming pool water standards based on physical, chemical and microbiological parameters, but the universally accepted standard is that of the WHO (1971). Nigeria has no swimming pool water standard but has adopted that of the WHO (1971). The high viable bacterial count up to 10^7 cfu/ml at 37°C and high incidence of coliforms and *Escherichia coli* obtained from some pools in this investigation do not meet the recommended criteria for swimming pool safety. This is because, according to Gray (1969), no sample from a pool should contain any coliform organism in 100 ml of water, and in 75% of samples the viable plate count at 37°C should not exceed 100 orgs/ml. The remaining 25% must not contain more than 100 colonies of bacteria. A standard of fewer than 100 *Staphylococcus aureus* per 100ml of water has been proposed by Mackereth *et al* (1989) and a free chlorine residual of 0.2-0.5 mg/l.

Some fungal pathogens of man were encountered in this work, namely: *Candida albicans*, *Penicillium*, *Aspergillus* species and the dermatophyte, *Trichophyton mentagrophyte*. Alice (1977) reported that *Aspergillus niger* is responsible for aspergillosis, usually an infection of the external ear (otomycosis) which may result in ulceration of the lining of the ear canal and perforation of the tympanic membrane. Such fungi normally live in the ear wax. *Candida albicans* causes candidiasis, which is an acute or subacute infection in stools, the vagina, and of the skin of normal persons. It may produce lesions in the mouth, vagina or lungs of infected persons. *Trichophyton mentagrophyte* is the etiologic agent of foot and nail infections. It is also responsible for ringworm of the scalp, beard hair, groin and buttocks. *Fusarium* is known for eye infections in humans and animals according to Prescott *et al* (2002).

The results of physicochemical analysis did not pose a serious threat to public health except that the dissolved oxygen was higher than the 6 mg/l recommended by the WHO (1971). The authors suggest that before a swimming pool is pronounced as satisfactory, the surface water should be bacteriologically and chemically examined, as well as the main body of water at varying depths. This is because anal, oral, and nasal microorganisms can collect in the surface film of fatty substances derived from the skin, nose and anus of swimmers and become protected by the fatty substances from residual chlorine action. In conclusion, none of the swimming pools met the WHO (1971) standard for recreational waters and therefore constitute a serious hazard to public health from a bacteriological view point, even though the chemical standards were usually met.

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