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# Microbial pollution and physicochemical studies for quality control of Sharkia governorate swimming pools

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***ABSTRACT*:** Water samples of three swimming pools located in three different cities of Sharkia governorate in Egypt were collected and tested for physical and chemical parameters as well as microbial contamination to evaluate their compliance to the water quality standards. The measured parameters were compared to the national and international standards to assess the water samples compatibility to the international and Egyptian guidelines of swimming pools water. Detected microbes were isolated and identified to prove microbial contamination of the water samples and to evaluate the efficiency of the decontamination techniques used on pool water. Several antibiotics were selected to study the susceptibility of the isolated microbes to the commonly used antibiotics in order to evaluate the prevalence of antibiotic resistant bacteria in the tested water samples. Minimum inhibitory concentration and minimum bactericidal concentration of the tested antibiotics were determined for each isolate to fully assess the antimicrobial activity of the tested antibiotics against the isolated microbes.

***KEYWORDS: Swimming pools, Physicochemical characteristics, Microbial contamination, Antibiotics, MIC, MBC.***

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## I. INTRODUCTION

Swimming pools are supplied by water of environmental origin. The quality of swimming pool water is enhanced by frequently changing the water and the used disinfectants. Although it is known that swimming pool water should meet potable water standards, such standards are not normally adhered to in many countries **(Ekopai *et al*, 2017)**. In swimming pools, bathers may be affected by the physicochemical characteristics of water used during bathing. Good monitoring of physical and chemical standards of swimming pool water is a must considering their significant impact on the microbial safety of the pools water which has several health impacts on the public who use these pools **(Yedeme *et al*., 2017)**. Increase in the prevalence of water borne diseases and diseases related to public and private swimming venues in the past decades, has shown that microbial analysis of these facilities is necessary for protecting the health and safety of people using them (**Mansoorian *et al*., 2015)**. Although modern swimming pools have a recirculating system for water filtration, purification, and disinfection; recent studies revealed that neither advanced technological systems nor disinfectants can totally inhibit the colonization of pool water with some dangerous pathogens. It has also been reported that the surviving disinfectant tolerant pathogens might also be antibiotic resistant; which is already documented for bacterial isolates from treated drinking water and purified sewage effluents **(Ekopai *et al*, 2017)**. The Minimum Inhibitory Concentration (MIC) test determines the antimicrobial activity of a test agent against a specific bacterium. Minimum bactericidal concentration (MBC) is defined as the lowest concentration of antibiotic that kills 99.9% of the inoculum. Once the MIC is calculated, it can be compared to known values for a given bacterium and antimicrobial agent and is interpreted as susceptible, intermediate or resistant. The MIC and the zone diameter of inhibition are inversely correlated.

MIC gives valuable information, which will help to customize the treatment to direct only the causative bacterium **(Tille, 2021)**. The aim of this work is to scan the water quality standards of swimming pools water in terms of physical, chemical and microbiological characteristics and evaluate their compatibility to the national and international guidelines, as well as to study the efficiency of the used pool water decontamination techniques in eliminating microbial contamination of the pools and to evaluate the prevalence of antibiotics resistant bacteria in pool water.

## II. MATERIAL AND METHODS

### 2.1 Sampling and sample coding:

Three swimming pools located in 3 different cities of Sharkia governorate in Egypt [10th of Ramadan city, Zagazig and El-Salhya] were selected and tested. 54 water samples were collected from the chosen pools as follows; six time periods were designed, each period (60 Days) was divided into 3 sub periods of 20 days where 3 samples were collected every 20 days; first sample was collected before use at zero bathers and coded as (be), the second was collected after use at zero bathers and coded (af) and the third was collected during pool use at full load and coded as (fl). Water samples were collected from November 2016 to October 2017. Time periods design was inspired by **(Guidelines for safe recreational-water environments, 2000)**. Each sample code provided complete description of the sample definition and status at collection; for example, the code (B1BE) stands for: (B): code given to the Safwaa sports club swimming pool / 10th of Ramadan city. (1): time period [November and December / 2016]. (BE): Before use.

### 2.2. Samples collection and laboratory analysis:

200–500 ml of water was collected in sterile labeled 500 ml bottles. For microbiological examination, neutralizing agent [Sodium thiosulfate, 100 mg/l)] was used to dechlorinate the water samples **(Bartram & Rees, 2000)**. Temperature, residual chlorine, and pH were measured at swimming pool side during sample collection. All samples were transferred to the laboratory in an ice box within 1–2 hours after collection **(Amine *et al.*, 2017)**. For physical analysis; colour, odour, turbidity, temperature, pH and conductivity were measured. For chemical analysis; total hardness, alkalinity, sulphate, bio-chemical oxygen demand (BOD), chloride, nitrate, dissolved oxygen (D.O.), total phosphorus, manganese, residual chlorine and combined chlorine, KMno4, phenol, Oil & Grease salinity were measured. While for microbiological analysis all water samples were tested for bacterial contamination indicator organisms, cysts or parasite eggs and fungal contamination. Heterotrophic plate count (HPC), Total coliforms (TC), *Escherichia coli*, *Staphylococcus aureus* and *Pseudomonas aeruginosa* were the indicator organisms selected according to **(Guidelines for safe recreational-water environments, 2000)** and **(Egyptian fresh water swimming pool standards, 1995)**.

### 2.3. Scanning for indicator organisms:

Enumeration of HPC Was performed by standard pour plate technique **(Amine *et al.*, 2017)** where water samples were subjected to serial 10-fold dilutions, duplicate Petri dishes for each dilution were prepared. Plates were incubated at 37°C for 48 hours. Colony count was calculated and expressed as CFU/ml. Using membrane filtration technique, enumeration of TC, *Escherichia coli*, and *P. aeruginos*a was performed according to **Amine *et al.* (2017)** while *S. aureu*s was performed according to **El-Hadedy & Abu El-Nour (2012).** Membrane filtration using chromogenic agar media and sterile cellulose acetate membrane filters (0.45 um pore size, 47 mm diameter) was performed as the membrane filters were placed directly onto chromogenic agar and then plates were incubated at 37°C for 24 hours. Blue *E. coli* colonies on (Chromagar ECC) were clearly differentiated from mauve total coliform colonies, *S. aureus* colonies on (CHROMagarTM *Staph. aureus*) appeared as pink to mauve. For detection of cysts or parasite eggs 150 ml of samples were filtrated through 0.45 micrometers pores filters, the filter paper was washed with 2 ml of sterile physiological serum and the residual water was centrifuged at 3000 rpm for 8 minutes, the sediment was examined for any trophozoites, protozoa cysts or worm eggs. For detection of fungal contamination, samples were cultured on Saboroud–dextrose agar (S) and Saboroud –dextrose agar + chlor-amphenicol + cycloheximide (SCC) and plates were incubated at room temperature for 2 weeks and examined for any fungal growth **(Rasti *et al.*,**

**2012).** Microscopic examination and staining with Gram's stain **(Bergey *et al.*, 1994),** cultivation on MacConkey agar and biochemical tests were carried out to confirm the identified organisms. Biochemical tests included; coagulase test **(Bradbury, 1999),** catalase test, indole test **(Cheesbrough, 2004)** and citrate test **(MacWilliams,2009).**

### 2.4. Antibiotic sensitivity test with MIC and MBC determination:

Was measured by the disc diffusion method as described by **Bauer *et al.* (1966)**. Isolates were swabbed on the surface of Muller-Hinton agar plates and the antibiotic discs were placed on the top of the agar and then plates were incubated at 37o C for 24 hours and inhibition zones were measured. Sensitivity was evaluated according to standard tables of **Clinical & Laboratory Standards Institute (CLSI) (2013)**. Antibiotics used were chosen to cover all characteristics of the identified isolates; Gentamicin (10µg), Ceftriaxone (30µg), Cefoperazone (75ug), Cefepime (30ug), Ciprofloxacin (10ug), Levofloxacin (5ug), Nitrofurantoin (300ug), Amoxicillin -Clavulanic acid (30ug), Ampicillin-sulbactam (20ug) and Meropenem (10ug). MIC measurement was performed according to **Lorian (2005)**, where stock solutions [10000 and 1000 ug/ml] of the selected antibiotics were prepared and serial dilution was made for each antibiotic. Doubling dilutions were chosen [4096, 2048, 1024, 512, 256, 128, 64, 32, 16, 8, 4, 2 and 1 ug/ml] as they provide the narrowest integer series on a logarithmic scale. MBC was performed according to **Yamamoto (2003)**.

## III. Results

### 3.1 Physical analysis:

Highest number of physical parameters conformed samples was obtained with pools B and I (27.8 % non-conformity), while the lowest was obtained with pool K (55.6 % non-conformity). 34 samples (63 %) were conformed to physical parameters while 20 samples (37 %) were non-conformed as demonstrated in table (1). Among all tested parameters, temperature had the highest number of non-conforming samples [20 samples (100%)] followed by turbidity with 1 non-conforming sample (5 %), while none of the tested samples showed non- conformity to the other parameters. The results were stated in table (2).

**Table (1) Distribution of physical parameters conforming and non-conforming samples for each swimming pool.**

| Swimming pool code | Conformed | Non-conformed | Non-conformed samples (%) |
|---|---|---|---|
| B | 13 | 5 | 27.8 % |
| I | 13 | 5 | 27.8 % |
| K | 8 | 10 | 55.6 % |
| Total number of samples | 34 | 20 | |
| Percentage to total number of samples | 63 % | 37 % | |
| Mean | 11.3 | 6.7 | |
| Median | 13 | 5 | |
| Standard deviation | 2.9 | 2.9 | |

**N.B.:** (B): Safwaa sports club swimming pool [10th of Ramadan city], (I): Sharkia Sports club swimming pool [Zagazig] and (K): Public swimming pool [El-Salhya].

**Table (2) Number of non-conformed samples for each physical parameter.**

| Measured parameter | Number of non-conformed samples | Percentage to total number of non-conforming samples |
|---|---|---|
| Color | 0 | 0 % |
| Turbidity | 1 | 5 % |
| Temperature | 20 | 100 % |
| Odor | 0 | 0 % |
| pH | 0 | 0 % |
| Conductivity | 0 | 0 % |

**3.2. Chemical analysis:** 15 parameters; Total hardness, Alkalinity, Sulphate, Bio-chemical oxygen demand (BOD), Chloride, Nitrate, KMno4, Dissolved oxygen (D.O.), Phenol, Total phosphorus, Manganese, Oil & Grease, Salinity, Residual chlorine and Combined Chlorine; were measured and their conformity was decided according to the Egyptian guidelines **(Egyptian fresh water swimming pool standards, 1995)**. The highest number of chemical parameters conformed samples was obtained with swimming pool B (0 % non-conformity); while swimming pools [I and K] showed non conformity of (16.7 %) and (27.8 %) respectively. Out of the total 54 tested water samples 46 samples (85.2 %) were conformed to chemical parameters while 8 samples (14.8 %) were non-conformed as demonstrated in table (3).

**Table (3) Distribution of chemical parameters conforming and non-conforming samples for each swimming pool.**

| Swimming pool code | Conformed | Non-conformed | Non-conforming samples (%) |
|---|---|---|---|
| B | 18 | 0 | 0 % |
| I | 15 | 3 | 16.7 % |
| K | 13 | 5 | 27.8 % |
| Total number of samples | 46 | 8 | |
| % | 85.2 % | 14.8 % | |
| Mean | 12 | 2.7 | |
| Median | 15 | 3 | |
| Standard deviation | 7.9 | 2.5 | |

**N.B.:** (B): Safwaa sports club swimming pool [10th of Ramadan city], (I): Sharkia Sports club swimming pool [Zagazig] and (K): Public swimming pool [El-Salhya].

Among the 15 tested chemical parameters Dissolved oxygen and Combined chlorine had the highest number of non-conforming samples [5 samples (62.5 %) and 4 samples (50 %) respectively]; while none of the tested samples were non-conformed to SO4, NO3, KMno4, Phenol, PO4, Mn, Oil & Grease or Salinity [0 % non-conformity]. The results were illustrated in table (4).

**Table (4) Number of non-conforming samples for each chemical parameter.**

| Measured parameter | Number of non-conforming samples | % |
|---|---|---|
| Total hardness | 3 | 37.5 % |
| Alkalinity | 3 | 37.5 % |
| $SO_4$ | 0 | 0 % |
| BOD | 3 | 37.5 % |
| Chloride | 2 | 25.0 % |
| $NO_3$ | 0 | 0 % |
| $KMno_4$ | 0 | 0 % |
| DO | 5 | 62.5 % |
| Phenol | 0 | 0 % |
| $PO_4$ | 0 | 0 % |
| Mn | 0 | 0 % |
| Oil & Grease | 0 | 0 % |
| Salinity | 0 | 0 % |
| Residual chlorine | 3 | 37.5 % |
| Combined chlorine | 4 | 50 % |

**N.B.**: (SO4): Sulfate, (BOD): Biochemical oxygen demand, (NO3): Nitrate, (KMno4): Potassium permanganate, (D.O.): Dissolved Oxygen, (PO4): phosphate and (Mn): Manganese.

**3.3. Microbial analysis:** Swimming pool [B] was completely conformed to the swimming pools microbial standards [0 % non-conformity], while swimming pool (K) had the lowest number of conformed samples (11 % non-conformity). Out of the total 54 tested water samples 51 samples (94.4 %) were conformed to microbial parameters while 3 samples (5.6 %) were non-conformed to the standards of microbial parameters as demonstrated in table (5). Among the different tested indicator organisms, Staphylococcus aureus showed the highest number of non-conforming samples [2 samples (66.7 %)]; while none of the tested samples were non-conformed to the HPC standards [ Zero samples (0 % non-conformity)]. The results were illustrated in table (6).

**Table (5) Distribution of microbial standards conforming and non-conforming samples for each pool.**

| Swimming pool code | Conformed | Non-conformed | % Of non-conformed samples |
|---|---|---|---|
| B | 18 | 0 | 0 % |
| I | 17 | 1 | 5.5 % |
| K | 16 | 2 | 11 % |
| Total number of samples | 51 | 3 | |
| Percentage of samples | 94.4 % | 5.6 % | |
| Mean | 17 | 1.0 | |
| Median | 17 | 1.0 | |
| Standard deviation | 1.0 | 1.0 | |

**N.B.:** (B): Safwaa sports club swimming pool [10th of Ramadan city], (I): Sharkia Sports club swimming pool [Zagazig] and (K): Public swimming pool [El-Salhya].

**Table (6) Number of non-conforming samples for each Microbial standard.**

| Indicator organism | Number of non-conformed samples | % Of non-conformed samples to total number of non- conformed samples |
|---|---|---|
| HPC | 0 | 0 % |
| Total coliform | 1 | 33.3 % |
| *Escherichia coli* | 1 | 33.3 % |
| *Pseudomonas aeruginosa* | 0 | 0 % |
| *Staphylococcus aureus* | 2 | 66.7 % |

**N.B.:** (HPC): Heterotrophic plate count.

**3.4. Distribution of non-conformity according to different chosen time periods:** From table (7), the highest number of non-conformity to physical parameters were in time period (2) [January and February / 2017] with 9 (45 %) non- conforming samples, while the lowest number of non- conforming samples were in time periods (3) and (6). The highest number of non-conformity to chemical parameters were in time period (4) [May and June /2017] with 5 (62.5 %) non- conforming samples while the lowest number of non- conforming samples were in time periods (1), (2) and (3). The highest number of microbial standards non-conforming samples were in time period (4) [May and June /2017] with 3 (100 %) non- conforming samples, while zero non-conformity was noticed at all remaining time periods.

**Table (7) Distribution of non-conforming samples among different time periods for physical, chemical and microbial parameters.**

| Time periods | Physical parameters | | Chemical parameters | | Microbial parameters | |
|---|---|---|---|---|---|---|
| | Number of non-conformed samples | (%) | Number of non-conformed samples | (%) | Number of non-conformed samples | (%) |
| (1) [November and December / 2016] | 1 | 5 % | 0 | 0 % | 0 | 0 % |
| (2) [January and February / 2017] | 9 | 45 % | 0 | 0 % | 0 | 0 % |
| (3) [March and April / 2017] | 0 | 0 % | 0 | 0 % | 0 | 0 % |
| (4) [May and June /2017] | 3 | 15 % | 5 | 62.5 % | 3 | 100 % |
| (5) [July and August / 2017] | 7 | 35 % | 1 | 12.5 % | 0 | 0 % |
| (6) [September and October / 2017] | 0 | 0 % | 2 | 25 % | 0 | 0 % |
| **Total** | **20** | **100 %** | **8** | **100 %** | **3** | **100 %** |

### 3.5. Distribution of non-conformity according to different operating conditions:

No significant difference in the rate of non-conformity to physical standards was observed with different operating conditions, as shown in table (8), after use category had the highest number of non-conforming samples [8 samples (40%)] while before use category had the lowest number [5 samples (25%)]. For chemical parameters, after use category had the highest number of non-conforming samples [4 samples (50%)] and the lowest number was obtained in before use category [1 sample (12.5%)]. Microbial standards non-conformity was the same in all three categories with [1sample (33.33%)] in each category.

**Table (8) Relation between non-conforming samples and different operating conditions.**

| Operating conditions | Physical parameters | | Chemical parameters | | Microbial parameters | |
|---|---|---|---|---|---|---|
| | Number of non-conformed samples | (%) | Number of non-conformed samples | (%) | Number of non-conformed samples | (%) |
| Before use (be) | 5 | 25 % | 1 | 12.5 % | 1 | 33.33% |
| After use (af) | 8 | 40 % | 4 | 50 % | 1 | 33.33 % |
| Full load (fl) | 7 | 35 % | 3 | 37.5 % | 1 | 33.33 % |
| **Total** | **20** | **100 %** | **8** | **100 %** | **3** | **100 %** |

### 3.6. Confirmatory identification of the bacterial isolates:

Confirmatory identification of the isolated bacteria was performed by; microscopic examination [Gram's stain], culturing on MacConkey agar and performing biochemical tests. Results were summarized in table (9) below.

**Table (9) Biochemical identification results of indicator organisms.**

| Test | Results | | |
|---|---|---|---|
| | Total coliform | *Escherichia coli* | *Staphylococcus aureus* |
| Gram's stain | Gram-negative bacilli | Gram-negative bacilli | Gram-positive cocci |
| Chrome agar medium | Mauve colonies | Blue colonies | Pink/Mauve colonies |
| MacConkey agar | Pink colonies | Red/Pink colonies | Pale pink colonies |
| Indole test | // | Indole positive | // |
| Citrate test | // | Citrate negative | // |
| Coagulase test | // | // | Coagulase positive |
| Catalase test | // | // | Catalase positive |

### 3.7. Antibiotic sensitivity test:

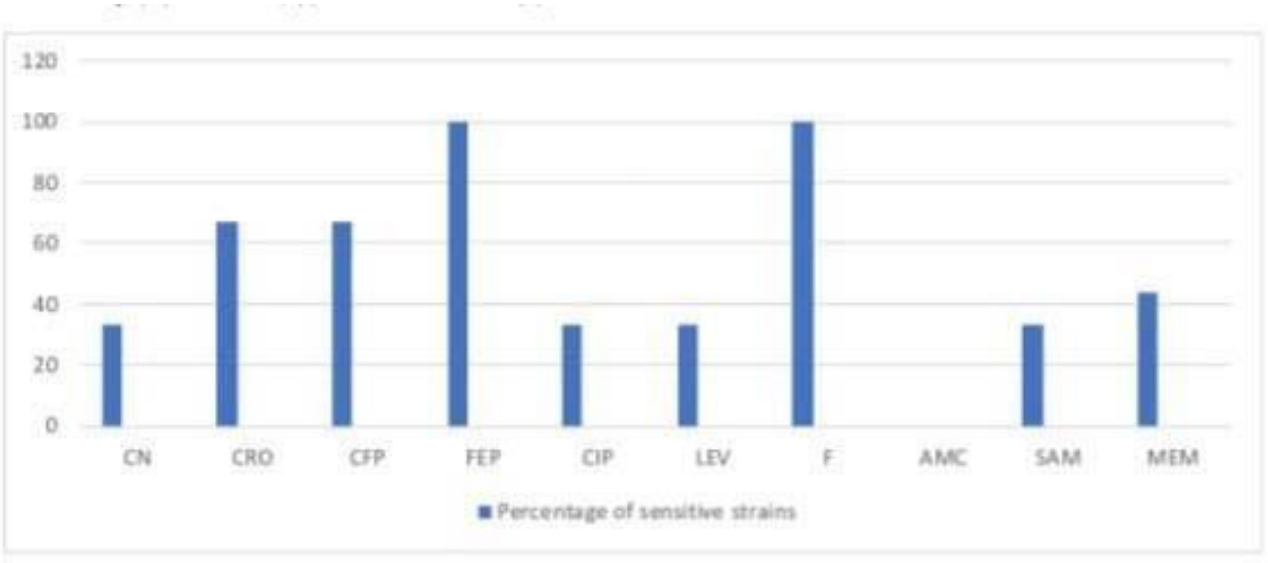
From table (10) and figure (1), the most effective antibiotics were Cefepime and Nitrofurantoin [3 (100%) sensitive isolates], while the least effective was Amoxicillin -Clavulanic acid [Zero (0 %) sensitive isolates].

**Table (10) Antibiotic sensitivity test of the isolated bacteria.**

| Bacterial isolates | Tested antibiotics | | | | | | | | | | Number of resistant, intermediate & sensitive strains for each isolate |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | CN | CRO | CFP | FEP | CIP | LEV | F | AMC | SAM | MEM | |
| I af (4)-*E. coli* | 18 (S) | 10 (R) | 14 (R) | 20 (S) | 23 (S) | 17 (S) | 20 (S) | 16 (I) | 15 (S) | 15 (S) | 2 (R) – 1 (I) – 7 (S) |
| K af (4)-*Staphylococcus sp.* | 0 (R) | 25 (S) | 23 (S) | 20 (S) | 17 (I) | 15 (I) | 17 (S) | 15 (I) | 0 (R) | 13 (I) | 2 (R) – 4 (I) – 4 (S) |
| K fl (4)-*Staphylococcus sp.* | 0 (R) | 24 (S) | 23 (S) | 21 (S) | 19 (I) | 15 (I) | 17 (S) | 15 (I) | 0 (R) | 13 (I) | 2 (R) – 4 (I) – 4 (S) |
| Number of sensitive strains for each antibiotic | 1 | 2 | 2 | 3 | 1 | 1 | 3 | 0 | 1 | 1 | |
| Sensitive strains of each antibiotic (%) | 33.3% | 66.7 % | 66.7 % | 100 % | 33.3% | 33.3% | 100 % | 0 % | 33.3% | 33.3% | |

**N.B.: (CN):** Gentamicin, **(CRO):** Ceftriaxone, **(CFP):** Cefoperazone, **(FEP):** Cefepime, **(CIP):** Ciprofloxacin, **(LEV):** Levofloxacin, **(F):** Nitrofurantoin, **(AMC):** Amoxicillin -Clavulanic acid, **(SAM):** Ampicillin-Sulbactam, **(MEM):** Meropenem, **(*E. coli*):** *Escherichia coli*, **(I):** Sharkia Sports club swimming pool [Zagazig], **(K):** Public swimming pool [El-Salhya], **(af):** After use, **(fl):** Full load, **(4):** [May and June /2017], **(R):** Resistant, **(I):** Intermediate and **(S):** Sensitive.

**Figure (1) Percentage of sensitive strains for each antibiotic.**




**CN):** Gentamicin**, (CRO):** Ceftriaxone**, (CFP):** Cefoperazone**, (FEP): Cefepime, (CIP):** Ciprofloxacin**, (LEV):** Levofloxacin**, (F):** Nitrofurantoin**, (AMC):** Amoxicillin -Clavulanic acid**, (SAM):** Ampicillin-Sulbactam**, (MEM):** Meropenem**.**

From tables (11) and (12), Lowest MIC values was recorded with Cefepime (MIC ranged from 8 ug/ml to 16 ug/ml) followed by Meropenem (MIC ranged from 8 ug/ml to 256 ug/ml) and Nitrofurantoin (MIC ranged from 32 ug/ml to 256 ug/ml); while highest MIC values were recorded with Ampicillin-sulbactam (MIC ranged from 16 ug/ml to > 4096 ug/ml). MBC values for all tested antibiotics were either the same value of MIC or one or two concentrations above the MIC of the tested antibiotic. For MIC values (> 4096 ug/ml) MBC were not measured.

**Table (11) MIC for the tested isolates.**

| Bacterial isolates | MIC of the tested antibiotics (ug/ml) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | CN | CRO | CFP | FEP | CIP | LEV | F | AMC | SAM | MEM |
| I af (4)-*E. coli* | 8 | 2048 | 1024 | 16 | 8 | 4 | 32 | 1024 | 16 | 8 |
| K af (4)-*Staphylococcus sp.* | 2048 | 16 | 64 | 8 | 2048 | 512 | 256 | 512 | >4096 | 256 |
| K fl (4)-*Staphylococcus sp.* | 4096 | 16 | 64 | 8 | 2048 | 1024 | 256 | 512 | >4096 | 256 |

**N.B.: (CN):** Gentamicin**, (CRO):** Ceftriaxone**, (CFP):** Cefoperazone**, (FEP):** Cefepime**, (CIP):** Ciprofloxacin**, (LEV):** Levofloxacin**, (F):** Nitrofurantoin**, (AMC):** Amoxicillin -Clavulanic acid**, (SAM):** Ampicillin-Sulbactam**, (MEM):** Meropenem**, (*E. coli*):** *Escherichia coli*, **(I):** Sharkia Sports club swimming pool [Zagazig]**, (K):** Public swimming pool [El-Salhya]**, (af):** After use**, (fl):** Full load**, (4):** [May and June /2017]**, (R):** Resistant**, (I):** Intermediate**, (S):** Sensitive and **(MIC):** Minimum inhibitory concentration.

**Table (12) MBC for the tested isolates.**

| Bacterial isolates | MBC of the tested antibiotics (ug/ml) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | CN | CRO | CFP | FEP | CIP | LEV | F | AMC | SAM | MEM |
| I af (4)-*E. coli* | 16 | > 4096 | 2048 | 64 | 16 | 16 | 64 | 2048 | 64 | 16 |
| K af (4)-*Staphylococcus sp.* | 4096 | 64 | 128 | 16 | 4096 | 2048 | 512 | 1024 | ND | 512 |
| K fl (4)-*Staphylococcus sp.* | 4096 | 64 | 256 | 16 | 4096 | 2048 | 512 | 1024 | ND | 512 |

**N.B.: (CN):** Gentamicin**, (CRO):** Ceftriaxone**, (CFP):** Cefoperazone**, (FEP):** Cefepime**, (CIP):** Ciprofloxacin**, (LEV):** Levofloxacin**, (F):** Nitrofurantoin**, (AMC):** Amoxicillin -Clavulanic acid**, (SAM):** Ampicillin-Sulbactam, **(MEM):** Meropenem**, (*E. coli*):** *Escherichia coli*, **(I):** Sharkia Sports club swimming pool [Zagazig]**, (K):** Public swimming pool [El-Salhya], **(af):** After use**, (fl):** Full load**, (4):** [May and June /2017]**, (R):** Resistant**, (I):** Intermediate**, (S):** Sensitive and **(MBC):** Minimum bactericidal concentration.

## V. Discussion

54 water samples were collected from three different cities of Sharkia governorate/Egypt [Zagazig, 10th of Ramadan city and El-Salhya]. Physical, chemical and microbiological analysis of the samples was performed to assess their conformity to the Egyptian guidelines **(Egyptian fresh water swimming pool standards, 1995)**. Conductivity, pH, Odor, Temperature, Turbidity and Color were the physical parameters measured for each pool. Percentages of conformed and non-conformed samples were respectively (34%) and (20%). (100%) of the samples were non- conformed to temperature standards declared by the **Egyptian fresh water swimming pool standards (1995)**. Time period (2) [January and February / 2017] had the highest number of non-conforming samples [9 (45%) samples], that could be linked to the high rate of temperature nonconformity of the tested samples. After use (af) category had the highest number of non-conformed samples, which can be interpreted as, the after-use category (af), logically, possessed the highest non-feacal pollution rate. This agrees with the conclusion of **Peters (2016)** which stated that bathers sweat rate was found to increase linearly with elevation of water temperature. For chemical parameters; Total hardness, Alkalinity, Sulphate, Bio-chemical oxygen demand (BOD), Chloride, Nitrate, KMno4, Dissolved oxygen (D.O.), Phenol, Total phosphorus, Manganese, Oil & Grease, Salinity, Residual chlorine and Combined Chlorine were measured. Percentage of conforming and non-conforming samples were respectively (85.2%) and (14.8%). Percentage of samples non-conformed to Dissolved oxygen and Combined Chlorine were (62.5%) and (50%) respectively, making them the tow chemical parameters influencing the chemical conformity of the tested pools the most. Highest rate of non-conformity was detected for time period number (4) [May and June /2017] and that may be related to the excessive use of pools during summer vacation **(Hlavsa *et al.*, 2011)**. After use (af) category had the highest percentage of non-conformed samples (50 %). Positive growth of indicator organisms was carefully noticed for assessment of microbial contamination of the pools as recommended by **Egyptian fresh water swimming pool standards (1995)**. Percentages of conformity and non-conformity to microbial standards were respectively (94.4%) and (5.6%) which implies that microbial contamination is the least type of non-conformity affecting the tested pools, despite the fact that it is the riskiest among all the parameters measured as demonstrated by **Mansoorian *et al.* (2015)** due to its significant impact on the health and safety of bathers. Highest prevalence (66.7 %) was of *Staphylococcus aureus* followed by Total coliforms and *Escherichia coli* (33.3 %). Time period (4) [May and June /2017] had the highest percentage of non-conformity (100 %), this was supported by the reports of the **(Guidelines for Safe Recreational-water Environments, 2000)**. Before-use, after-use and full load categories had the same level of non-conformity (33.33%).

All selected isolates were subjected to antibiotic susceptibility testing, Cefepime (FEP) and Nitrofurantoin (F) had the highest percentage of sensitive strains (100%) while Amoxicillin -Clavulanic acid (AMC) had the lowest percentage of sensitive isolates (0%). Isolates were then tested to determine the minimum inhibitory concentration and minimum bactericidal concentration, where, the lowest MIC values were recorded with Cefepime (MIC ranged from 8 ug/ml to 16 ug/ml) followed by Meropenem (MIC ranged from 8 ug/ml to 256 ug/ml) and Nitrofurantoin (MIC ranged from 32 ug/ml to 256 ug/ml); while highest MIC values were recorded with Ampicillin-sulbactam (MIC ranged from 16 ug/ml to > 4096 ug/ml). MBC values for all tested antibiotics were either the same value of MIC or one or two concentrations above the MIC of the tested antibiotic.

This agrees with the results obtained by **(Khan *et al.*, 2008)** in that Ampicillin-sulbactam had the highest MIC while it disagrees with the same study in the fact that Gentamicin had the lowest MIC.

## VI. Conclusion

A defect in compliance to national standards regarding swimming pools water safety in Sharkia governorate/ Egypt is significantly noticed for physical, chemical and microbial standards. More care should be given to monitoring physical, chemical and microbial standards of the swimming pools with adherence to the national and international guidelines. Also, paying special attention and censorship to the hygienic limitations and before-use arrangements of the bathers must be considered. It is recommended that, more suitable forms of antibacterial treatments should be developed to provide new alternatives for the sterilization of swimming pool water, enhancement of the already used sterilizers or even reduction of the amount of chemicals used to avoid microbial contamination of the pool. Further studies are mandatory and essential in order to achieve this goal.

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