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Inorganic Chemical Composition of Swimming Pools in Amman-Jordan

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Abstract: Monitoring was carried out during summer 2011 in three types of swimming pools in Amman-Jordan. Thirty six water samples, collected from three users type of swimming pools (adults, family and infants), were examined for its major ionic composition (HCO_3^-, Cl^-, NO_3^-, $SO_4^=$, Ca^{+2}, Mg^{+2}, Na^+, K^+ and PO_4^{+4}) in addition to its BOD and COD content. All of the examined samples from the swimming pools water were acceptable according to the local and WHO standards. The type and number of users as well as the maintenance of the swimming pool water influenced the water quality. The results showed that there was a noticeable increase in NO3, PO4 and Cl than other ions. All of the examined samples from the swimming pools water were acceptable according to the local and WHO standards and although the water of the infant's users changed frequently, it showed the highest concentration of most of the parameters and Adults' pool showed the lowest.

Keywords: Bathers, infants, nitrate, phosphate, pollutants

INTRODUCTION

Pollutants of swimming pool water are usually introduced by the bathers as the swimming pools are used by a variety of people of various ages, health status and standards of hygiene. Bathers introduce a range of pollutants to the pool water such as micro-organisms, body secretions including saliva, fat, urine and other foreign matter including skin, hair and sunscreen lotions. Swimming pool water quality is mainly affected by contaminants introduced by bathers and the efficiency of treatment installed.

Proper water chemistry is essential to maintaining safety for the users of swimming pools as there is a direct contact between the users and the swimming pool waters. There are many factors playing an important role in the water quality of swimming pools quality such as water quality at sources, disinfectants chemicals used in the swimming pools, the swimming pool operation as well as the type of users.

Many studies were done on swimming water quality in different parts of the world. In Athens, Rigas (1998) found that the water quality in terms of microbial constituents was not satisfying and it was attributed to poor design of pools and lack of sufficient vocational training of the technical personnel operating the water treatment installations. A similar study was done by Al-Khatib and Salah (2003) in some of the swimming pools in the West Bank of Palestine where they found that all of the examined samples from the swimming pools water were unacceptable according to the Palestinian and WHO standards.

Reiss *et al*. (2006) estimate acute, chronic and lifetime from the average practice durations for youth, adult Masters and collegiate teams were 9.1, 6.4 and 17.0 h/week, respectively.

An elevated level of trihalomethanes which results from chlorination of swimming pool water was reported in the blood and urine of swimmers using indoor swimming pools (Kozlowska *et al*., 2006).

Papadopoulou *et al*. (2008) investigated the microbiological quality and susceptibility of bacterial isolates of swimming pool waters in Greek, they found 67% of the examined water samples conformed to the microbiological standards and 32.9% exceeded at least one of the indicated limits.

Swimming pool water is processed, filtered and disinfected repeatedly in order to maintain hygienic conditions However; it cannot be avoided, that the concentrations of certain components of swimming pool water will increase in the course of time especially in an arid country where addition of fresh water is restricted.

Most of the work done on water quality worldwide was connected to either organic constituents or microbial content of swimming pools, but very few researches were done for the inorganic part of these swimming pools and for the different users. One of the main routs of chemical in swimming pools is the direct ingestion of water; during swimming a considerable amount of swimming pool water is ingested. This ingested water volume is dependent on swimmer age and type; children especially are thought to swallow large amounts of water that can reach 500 mL during a

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swimming event (Kanan, 2010). So the aim of this study is to investigate the change in water chemistry of swimming pools water in Amman Jordan and the impact of type of users on this parameter.

MATERIAL AND METHODS

Study area: In Jordan, swimming pools activities usually restricted to the summer season which starts by June and ends in September, therefore water sampling was done between June and July 2011 once every five days. The source of water in swimming pools are from groundwater resources from areas around Amman city and the water is kept for the whole summer period but processed, filtered and disinfected repeatedly in order to maintain hygienic conditions.

For each sampling day three samples were collected from three types of users of swimming pools. One from medium sized pool used only by adults over18 years old, a large size swimming pools used by families where the users are of various ages and a small shallow swimming pools used only by infants mostly at the age of younger than four years old. From each of the swimming pools, sampling was done three times a day once in the early morning before swimming activities starts and once at mid-day where swimming activity is at peak and once at the end of the day when swimming activities stopped.

Analysis: For each site and period, pH and electrical conductivity was measured on site using WTW conductivity meter (LF 320) and WTW 525. Sampling of the water was done using two types of container one of 1-L polyethylene type used for estimating major ionic composition and the other of another dark bottle of 1-L used for BOD and COD analysis. Collected samples used for BOD_5 and COD were analyzed the same day of sampling whereas the samples collected for major ionic composition were stored at 4°C for only few days until time of analysis.

Major cations and anions in the collected water samples were analyzed using ion chromatography (Dionex-100). For anions (Cl, NO_3 and SO_4) AG4A-SC guard column, AS4SC separating column and SSR1 anion self-regenerating suppressor and conductivity meter and for major cations (Ca, Mg, Na and K) the CS12 column (250 × 4 mm ID), CG guard column (50 × 4 mm ID) and CDM-2 detector were used. The sample was injected through 25.l sample loop and eluted at 2.0 mL/min. using Na_2CO_3 in milli-Q water. Data were collected by 4400 integrator from Dionex.

For carbonate and bicarbonate determination, titration with 0.01 meq/L hydrochloric acid was used and it was done at the same day of sampling.

RESULTS AND DISCUSSION

The major ionic composition of the three types of swimming pools users and at different collection periods are summarized in Table 1.

The salinity of the swimming pools showed an increase with time as it ranged for all collected swimming pool water samples ranged from 341.3 to 564.2 with an average value of 453.5 ppm for adults swimming pool and from 387.3 to 585.5 ppm with an average value of 487.7 ppm for family swimming pool and from 421.6 to 740.2 with an average value of 565.6 ppm for infants swimming pools. The source of salinity could be from sweating of the bathers as the average salinity was lower in the adult's pool type than family type which is attributed to the number of users as they were lower in the adults' type than family type and very high in the infants' types due to other sources such as urine and others. However, all types were below the Jordanian standard of 1500 ppm.

The results showed that water quality in term of salinity was better in the morning time than noon and after noon periods and there was a slight increase in salinity with time which can be attributed to evaporational effects in addition to salts resulting from the bodies of swimmers in these pools, The average TDS value range between 429.7 ppm in adults pools to 561.3 ppm in infant pools and these values are less than the limits for water drinking standard?

PH of the water which is the most important parameter in swimming pool water chemistry and it affects every other chemical balance in pool water. As shown in Table 1, the pH in all collected sample where its ranged between 6.8 and 7.6 with an average value of 7.1 which is suitable for swimming as the most desirable pH of the swimming pool must be slightly alkaline with pH range between 7.2 and 7.8 as at this range it gives the optimum use of chlorine and it is comfortable for human eyes. The total alkalinity which is closely associated with pH as a result of alkaline materials including carbonate is important as it prevents variation in the pH of the water due to neutralizing effects. It was noticed that there is a slight variation in alkalinity in different types of users as well as in the different periods. This can be attributed to alkaline rich water sources.

The calcium content of water ranged from 47-79 ppm with an average value of 58.3. These values are lower than the recommended value of 250 ppm and therefore, it is expected that the type of water used can leach Ca from pool wall when it is made of concrete. However, leaching phenomena was not observed at the sampling sites as the walls of the swimming pools are made of ceramic which is known to be resistant to dissolution.

Table 1: The major ionic composition of the three types of swimming pools users and at different collection periods

Time	Age		pH	EC	TDS	Ca	TH	Na^+	K^+
Morning	Adults	Min	7.1	1193.8	341.3	47.0	79.0	38.7	10.0
		Max	7.5	1249.7	533.8	67.0	117	47.0	15.3
		Mean	7.2	1220.3	429.7	55.3	95.1	42.5	11.5
Noon		Min	6.9	1200.7	365.3	52.0	83.0	40.0	10.0
		Max	7.2	1251.8	541.1	64.0	117	46.3	14.7
		Mean	7.0	1227.7	456.9	57.8	99.6	43.2	12.3
Afternoon		Min	6.8	1204.7	379.1	50.0	81.0	39.3	9.40
		Max	7.6	1256.0	564.2	53.0	94.0	43.3	10.5
		Mean	7.3	1230.6	470.1	52.0	87.5	41.7	10.1
Morning	Family	Min	6.5	1207.3	387.8	51.0	80.0	41.3	9.90
		Max	7.3	1259.2	566.7	79.0	127	47.3	21.4
		Mean	7.2	1235.3	487.1	63.8	91.3	44.3	15.2
Noon		Min	7.1	1210.5	398.9	52.0	87.0	40.3	10.2
		Max	7.5	1258.3	570.6	63.0	108	46.3	14.3
		Mean	7.2	1236.2	489.2	57.8	98.8	43.5	12.3
Afternoon		Min	6.9	1212.4	405.6	53.0	87.0	42.0	10.1
		Max	7.3	1264.6	585.1	65.0	114	48.0	14.8
		Mean	7.1	1239.4	498.3	60.0	104.5	45.6	13.4
Morning	Infant	Min	6.8	1217.1	421.6	52.0	87.0	42.6	10.3
		Max	7.3	1300.9	710.2	65.0	120	48.5	14.7
		Mean	7.1	1259.0	561.3	59.0	103.8	45.2	12.5
Noon		Min	6.7	1217.1	421.6	51.0	86.0	41.0	0.80
		Max	7.6	1305.0	702.4	68.0	112	47.7	15.6
		Mean	7.1	1253.4	546.0	58.8	99.6	43.9	10.2
Afternoon		Min	6.9	1218.7	427.0	51.0	89.0	23.8	10.2
		Max	7.4	1309.7	740.2	66.0	121	50.0	15.7
		Mean	7.1	1258.2	560.2	61.3	105.6	40.1	13.8

Time	Age		HCO_3^-	F^-	Cl^-	NO_3^-	PO_4^{-3}	SO_4^{-2}
Morning	Adults	Min	188.0	1.3	22.7	6.100	3.30	46.8
		Max	246.0	6.0	42.6	83.00	32.7	94.3
		Mean	224.3	2.7	29.0	62.40	13.5	60.6
Noon		Min	179.0	0.0	19.5	5.300	9.20	46.6
		Max	238.0	1.1	44.4	151.7	40.5	87.8
		Mean	211.5	0.8	34.9	71.20	22.7	66.7
Afternoon		Min	185.0	1.0	17.0	15.50	5.60	42.6
		Max	222.1	1.9	43.6	163.6	9.30	50.3
		Mean	206.0	1.3	33.0	106.2	8.10	46.9
Morning	Family	Min	176.0	0.3	29.0	54.90	3.00	41.3
		Max	218.0	1.2	169.7	81.40	30.0	84.9
		Mean	203.0	0.9	72.3	69.90	15.7	66.2
Noon		Min	215.0	1.1	23.4	71.50	7.70	45.4
		Max	247.0	1.8	41.2	149.4	33.0	88.9
		Mean	229.8	1.4	29.1	97.30	15.7	67.6
Afternoon		Min	201.0	1.1	19.6	75.90	9.40	47.6
		Max	234.0	1.2	27.4	203.6	35.5	90.4
		Mean	217.3	1.2	22.6	138.7	26.8	78.4
Morning	Infant	Min	205.0	1.1	19.8	82.60	11.7	47.0
		Max	251.0	1.4	167.1	143.9	33.2	90.4
		Mean	227.8	1.2	65.6	108.4	23.5	68.1
Noon		Min	199.0	1.3	28.5	72.40	9.30	45.3
		Max	230.0	7.3	123.4	208.5	31.9	98.2
		Mean	214.8	3.5	58.3	127.6	18.0	69.5
Afternoon		Min	216.0	1.0	22.9	81.60	9.30	44.9
		Max	241.0	1.5	209.4	190.0	40.5	89.7
		Mean	228.3	1.2	74.9	150.8	25.1	77.2

Water samples collected from the three swimming pools were tested for free chlorine residual which ranged from 1.1-1.5 ppm which is within the recommended level for swimming pools of 1-3 ppm. The excess chlorine in water resulted in a very low BOD level of <4 ppm in all samples.

All types of water used in the three swimming pools are from the same source which is fresh groundwater extracted from areas surrounding Amman city. Any variation in the chemistry of swimming pools water will be introduced mainly from the bathers. Therefore, the changes in the water chemistry between

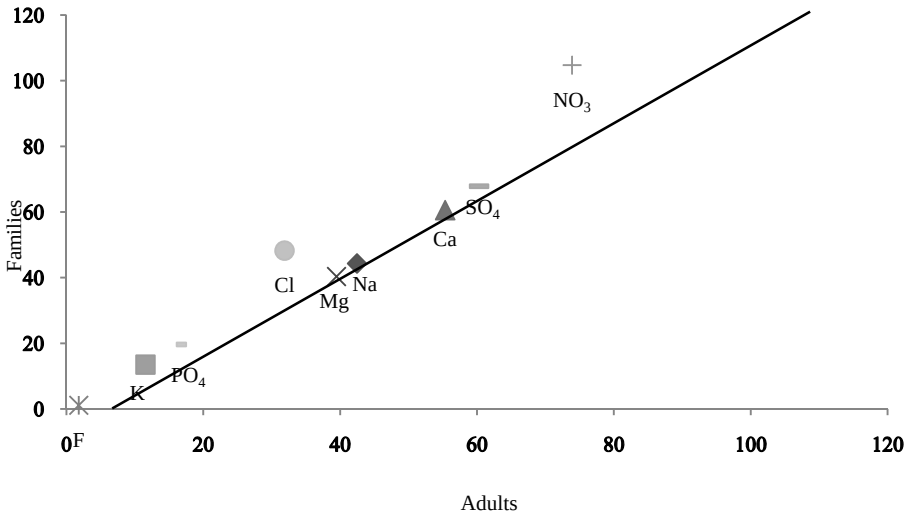

Fig. 1: Average ionic comparison of swimming pools used by adults versus families

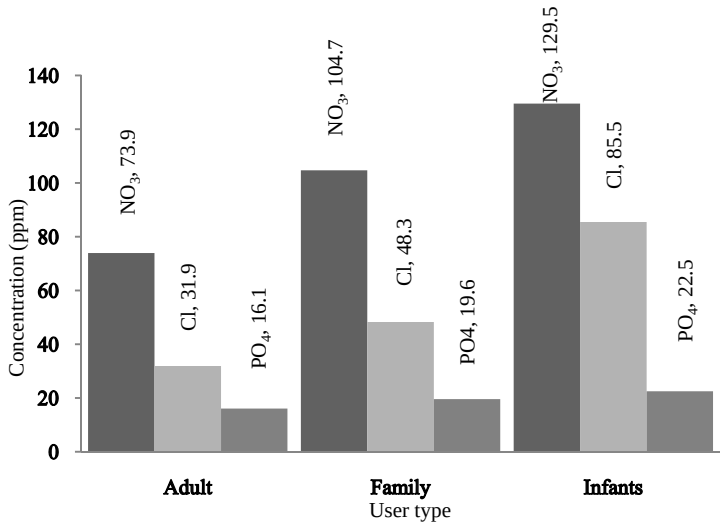

Fig. 2: Average ionic concentrations of NO_3, Cl and PO_4 in ppm for different users of pools

the three types of swimming pool will be attributed to the number, age of bathers.

By comparing the water chemistry of swimming pools used by adults' verses families (Fig. 1), it was noticed that they were very similar except an increase in NO_3, PO_4 and Cl which was introduced by bathers.

Initially the nitrate concentration of the swimming pools will be of low nitrates content. The nitrate concentration of all types of swimming pools increased with the use of these waters by bathers. As shown in Fig. 2, the average nitrate concentrations for whole sampling period was highest in the infants swimming pools followed by families swimming pools and the lowest was in the adults swimming pools. This can be attributed to the number of bathers as it was higher in the family's swimming pools than adult's swimming pools. For infants it was highest due to uncontrolled urine input by the infants.

The main source of nitrate contaminant in the swimming pools is the reactivity of chlorine with urea introduced by bathers (De Laat *et al*., 2011). Each bather introduces 340 to 850 mg of nitrate in form of urea and sweater (Gunkel and Jessen, 1988). The chlorine used for disinfection purpose reacts with urine and sweat react to form nitrates. Therefore the nitrate concentration increased with time as the water of swimming pools in Amman are not changed for the whole summer period except addition of small amount of water when the water level drops during the summer seasons However the amount of water used for infant's

swimming pools is low therefore its water was changed more often than other pools to ensure hygienic water.

Phosphate concentrations showed a similar trend as nitrate where the average phosphate concentrations were 16.1, 19.6 and 22.5 ppm for adults, families and infants swimming pools. The most probable source of phosphate is the use soaps and shampoos which are frequently used by bathers next to the swimming pools before swimming.

CONCLUSION

This survey aims at investigating the water quality of three types of users in swimming pools at Amman Jordan. The results showed relatively high concentrations of NO_3, PO_4 and Cl were found in Amman's swimming pools. The levels correlated with the number and age of people in the pool. The variation in concentrations of major ions was greater in the infants' pool than adults and families pools. Generally the water quality of adults and families types of swimming pools was acceptable but infant's water must be changed more often.

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