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## Research Article

### ANALYSIS OF WATER QUALITY OF INDOOR SWIMMING POOLS AND ITS RELATED HEALTH HAZARDS

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#### ABSTRACT

Water quality of indoor swimming pools and its related health hazards are studied in this research. Swimming is one common recreational activity these days and numerous swimming pools have been installed in hotels and apartments for the people to have their leisure time. But apart from recreational purposes the water quality of the pool is to be considered equally, as there are many health risks posed as result of being exposed to the swimming pools regularly. In order to determine the water quality laboratory analysis of five samples of indoor swimming pools in Abu Dhabi Emirate were collected and tested for the concentration of chlorine, copper, iron, zinc, sulfate and nitrate, The pH, TDS and temperature were also measured. Based on all the parameters, values were collected and observations were made to see whether any of the disinfectant exceeded the limits and maximum standards as regulated by the government. Chlorine content exceeded the maximum value out forward by the government and there are many health hazards caused as a result of ingesting and inhaling chlorine gas and its byproducts formed. Health conditions such as asthma, chronic respiratory illness, and skin and eye irritations and numerous other diseases are caused by the exposure to chlorinated waters.

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#### INTRODUCTION

Swimming is the one of the common activities for the youngsters in the United States and holds the second place in being the famous exercise for all ages and the recreational water places are being visited by roughly 360 million people every year (Centers for disease control and prevention, 2007). Indoor swimming pools have been very common in this century and have been installed in most of the residents and hotel buildings as most of the people including adults and kids consider swimming as a great leisure. Being regularly exposed to indoor swimming pool waters also pose a greater risk to human health apart from benefits such as leisure and fitness. Proper Maintenance of the swimming pool must be done by maintaining proper hygiene and providing safe conditions for usage through the installment of proper filtration system and disinfection of the water (Government of Dubai).

Treatment of the pool water using chemicals is important to maintain the quality of the water and regular tests of the pool water to know the pH levels, level of disinfectants and chlorine must be done in order to ensure safety as pool waters that are not treated properly can worsen the water quality and make it dangerous for use (Barrett, 2013). If the chemicals and

disinfectants used in the swimming pools waters exceed the maximum limit, then it can cause adverse health effects to the people who are regular swimmers in the indoor pools. The byproducts generated as a result of disinfection of the pool can cause negative health effects to the swimmers, says Dr. Mary Pohlman (Barrett, 2013).

Microbial contamination of the swimming pool waters which is mainly caused by the people who use the swimming pool waters are also one main cause of spread of water borne diseases (Better health channel, 2015). Indoor swimming pools have more dangerous effects than the outdoor ones as some of the disinfectant by products can be broken down by the UV light for the outdoor pools, but indoor swimming pools are not exposed to outer environment and it is enclosed in a small area and thereby requires more treatment processes to be undertaken for the breakdown of disinfectant byproducts (Barrett, 2013). Therefore, it is important to assess the chemical and microbial contamination in the indoor pool waters and understand the risk and health effects such as chronic and infectious illnesses caused as a result of being exposed to it.

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## **LITERATURE REVIEW**

Humans regularly using the indoor chlorinated swimming pools are being exposed to high amounts of disinfection byproducts (Chowdhury, 2015). The most frequently used disinfectant to maintain the pool water quality is chlorine, says centers of disease control and prevention (Barrett, 2013). When exposed to chlorine by the swimmers, swimming pool workers and others the risk of developing respiratory diseases, breathing problems, cough and throat related diseases (Jacob & Cherian, 2015). The chlorine being used in the swimming pools as a disinfectant to stop the waterborne diseases from spreading will react with the components that is shed in to the water by the swimmers, natural organic matter (NOM), bromide, iodide and leads to the formation of disinfection by products apart from killing the pathogens in water (Chowdhury, 2015). Due to the increased temperature in the swimming pools the chlorine gets deteriorated and to balance it out more chlorine is added to the water forming more free residual chlorine which will also fuel up the formation of the disinfection by products, and chloramines, THMs, and HAAs are the most commonly found DBPs (Chowdhury, 2015).

1.0-3.0 ppm is the normal level of chlorine in the swimming pools and later on may increase depending upon how the surface water gets impure (Angione, Mcclenaghan, & Laplante, 2010). In order to avoid severe conditions of recreational water illnesses the governing bodies set certain standards for each chemicals; therefore, the level of chemicals to be added into the water are done by following the government rules and the ones who operate the pool and other responsible officials must abide the rules put forward by the government in order maintain the pool water quality (Angione, Mcclenaghan, & Laplante, 2010).

According to WHO, Trihalomethanes and chloramines are main types of irritants found in swimming pool waters (Jacob & Cherian, 2015). The chlorine in water also gets reacted with ammonia content present in the urine and thereby forms chloramine which is toxic and is present in greater amounts in the swimming pools (Chowdhury, 2015). Oxidants that are chlorine based is present in hot tubs, whirl pools and other enclosed areas other than swimming pools (Angione, Mcclenaghan, & Laplante, 2010). The chloramines stay in water or creates a strong odor by getting dissipated into the atmosphere; also, out of monochloramine, dichloramine and trichloramine, trichloramine gets evaporated easily and leads to more irritation and other health effects (Centers for disease control and prevention, 2007). Chloramine concentration is mainly caused due to factors such as chlorine concentration, pH, temperature, and when particles undergo aerosolization apart from number of people using the water (Centers for disease control and prevention, 2010). Trichloramine present in the gaseous phase is a highly concentrated oxidant (Angione, Mcclenaghan, & Laplante, 2010). More toxic effects to the cells and genetic information is caused by the DBPs that mostly contain nitrogen and bromine than the DBPs that mostly contain chlorine (Chowdhury, 2015).

The main routes through which chemicals in the water can enter to the human body are ingestion, inhalation of the chemicals and through the skin surface (Chowdhury, 2015). According to Department of Health and Community Services Disease Control and Epidemiology Division in Newfoundland

and Labrador, the main chemical parameters required for the proper functioning of pool includes pH, Total alkalinity, hardness, disinfectants, physical parameters include water temperature, biological standards include tests for E.coli, Staphylococcus aureus, Pseudomonas aeruginosa and standard Plate Count (2004).

In Illinois two outbreaks took place as a result of being exposed to indoor motel swimming pools in 2004, and it was reported that 72 persons, mostly including children, were affected by heart attack and other associated diseases due to the exposure to chloramine after few minutes of entering into the pool (Centers for disease control and prevention, 2007). Compared to confined and enclosed indoor swimming pools where the chloramines evaporate to the atmosphere and reach higher concentration levels posing a higher health risk, the outdoor swimming pools do not have any health risks related to chloramines (Centers for disease control and prevention, 2007). Acute respiratory tract and eye irritation, respiratory diseases including asthma, cough, chest tightness, wheezing can also be caused as a result of being exposed to chloramine (Centers for disease control and prevention, 2010).

During an investigation conducted by NIOSH in an indoor water park resort related to diseases like eye irritation and respiratory disorders, it was reported that almost 80 workers and other supporters in the workplace suffered from severe irritation in eyes and respiratory system, itchy and burning eyes and nose, cough, wheezing, and chest congestion within a month of opening of the park and its was caused due to the exposure to DBPs and endotoxins in the water (Centers for disease control and prevention, 2010). There exists some pathogens in the indoor swimming pools that is not inactivated by the disinfectant chlorine added and intake of this water which contain microbes and other chemicals can cause recreational water illnesses (Centers for disease control and prevention, 2015). Gastrointestinal, neurologic, skin, ear, respiratory, and eye related infections are the main types of infections resulted from recreational water illnesses (Centers for disease control and prevention, 2015).

In a study that took place in Belgium and Netherlands, it was found out that exposure of kids that are less than 2 years old to chlorinated swimming pools are likely to suffer from asthma, allergies related to respiratory system, and bronchitis (Dewar, 2013). A recent study found out that the disinfected waters have an impact on the DNA of mammals, which means that there is a risk of developing cancer in humans as a result of being exposed to DBPs in pools (Dewar, 2013). According to WHO, in an interview conducted for 128 individuals who were exposed to indoor swimming pool in a hotel the prevalent symptoms found out was cough (84%), eye irritation (78%) and rash (34%) and the people who are near or in the pool was affected by the chlorine exposure (Public Health Journal). According to WHO, serious illness and health disorders have been diagnosed in workers who are exposed to chlorinated swimming pool has been reported (Jacob & Cherian, 2015). The diseases that may be caused depending upon the severity of exposure and the diseases caused include laryngeal oedema, asthma attacks, chemical burns of the upper and lower airway mucosa, and chemical pneumonitis (Nemery, Hoet, & D, 2002). All in all, severe health problems has been identified which

resulted from the long-term exposure to swimming pools and the health effects has been listen in various articles.

### Objectives

The main objective of this research is to know the water quality of indoor swimming pools by analyzing the content of chlorine, sulphate, nitrate, zinc, copper, and iron, total dissolved salts (TDS), pH and Temperature of the five samples of water collected from different indoor swimming pools in Abu Dhabi. Also, the health hazards related to each element being present in the water samples is to be known. The concentration of each chemical element being present in the samples collected is to be compared to the standards and limits of chemical elements that are to be present in an indoor swimming pool put forward by the government and has to be concluded. The health hazards and risks posed by the excess accumulation of these chemicals will also be discussed in this report.

### Research Methodology

For this research to be conducted, both qualitative and quantitative methods were used.

### Research Questions

1. Do the chemical elements chlorine, sulphate, nitrate, zinc, copper and iron in the indoor swimming pool water samples tested exceed the limits put forward by the government?
2. Are there any health risks associated with exceeding the limits and standards of chemical elements in the indoor pools which is set by the government

As a part of quantitative method, laboratory experiment was conducted to identify the concentration of chemicals, the amount of Total dissolved salts, pH and temperature of the water samples collected. As a part of qualitative research method, literature review from various online resources were done in order to obtain adequate information regarding the health hazards of different chemical elements and the permitted concentrations of chemical elements to be present in the indoor pools according to the international rules.

Five indoor swimming pool water samples from five different sources were collected and tested in the lab using spectrophotometer after adding the required reagents for each chemical element.

### Experimental procedure

- Five samples were collected from various indoor pools in Abu Dhabi and as soon as the water was collected from the pool into the container, the pH, the temperature and the TDS of the water was measured, and the values were recorded.
- Within 12 hours the sample was brought to the laboratory to do tests for the concentration of Chlorine, iron, zinc, copper, sulphate, and nitrate.
- 10 mL of indoor swimming pool water from each sample was taken in cuvette and the reagent for each chemical element was added. Before adding the reagent the cuvette was placed in the spectrophotometer to make the value 0. The changes in the colour were noted after addition of reagent and the cuvette was placed in the spectrophotometer and the values were noted. The same

steps were repeated for each sample and for different chemical element tests. The results were tabulated and compared with international limits and standards for concentration of elements in indoor pool water.

### Results and Interpretation of Data

The results of the swimming pool water Analysis Lab will be explained in detail in this section. The results of Total Dissolved salts (TDS), pH and Temperature of the five samples of the swimming pool water are given below:

**Table 1** Temperature, pH and TDS in the samples tested.

Sample	Temperature	pH	TDS
Sample 1	29.5°C	7.7	123
Sample 2	29°C	7.9	107
Sample 3	30°C	7.7	240
Sample 4	29°C	7.4	106
Sample 5	29.5°C	8.1	250

### Temperature

The temperatures of all the 5 samples from different indoor pools when measured gave a value between 29°C – 30°C. According to WHO, temperatures that is between 26°C – 30°C is considered safe and agreeable for the swimmers (World Health Organization, 2006). If the water temperature goes high; for example, above 40°C, there are many health hazards associated with it. Conditions of high temperatures in the water can cause drowsiness, loss of consciousness, heart stroke, and in severe cases death it caused (World Health Organization, 2006). But in the samples that were tested, the temperatures were in the normal range.

### pH

According to WHO, swimming pools must maintain a pH of about 7.2-7.8, if the disinfectant used in the swimming pool is chlorine and this is the range of pH that has to be present in water and has to be maintained in order to ensure proper disinfection (World Health Organization, 2006).

- If the pH is low in the water than the given limits then it will cause health issues such as eye and mucous membrane discomfort and low pH water will cause negative effects on the pool liner and other parts of the pool (Pahlén).
- If pH is very high, there is will be decreased disinfection by chlorine, skin problems and other changes in properties of water such as cloudiness (Pahlén).

### Total dissolved salts

The TDS value obtained during the tests gave a maximum value of 250 in one sample. The recommended TDS values in normal swimming pool waters can be up to TDS level of 1500 ppm (pool wizard). TDS values usually gives a higher value when the water is contaminated and very high levels of TDS can cause water problems in the pool; for example, pool water being cloudy, color being stained at the different sides of the swimming pool, hard water, and tastes salty (pool wizard).

### Chlorine content

Wavelength in spectrophotometer: 530 nm

**Table 2** Chlorine concentration in the samples tested.

Sample	Chlorine content (Mg/L)
Sample 1	3.33
Sample 2	4.44
Sample 3	12.7
Sample 4	0.14
Sample 5	1.88

The chlorine level found in the samples that were tested ranged from 0.14 mg/L being the least from 12.7 mg/L of chlorine which is the highest of the results. According to World Health Organization, the regular levels of chlorine in indoor pools are 1 mg/L-3 mg/L (Angione, Mcclenaghan, & Laplante, 2010). WHO also advises that the chlorine level should not go beyond 3 mg/L in swimming pools (Angione, Mcclenaghan, & Laplante, 2010).

WHO also recommends that the pool water should follow the drinking water standards and the level of chlorine in swimming pool waters thereby should not go beyond 5 mg/L as the drinking water standards (National Collaborating Centre for Environmental Health ).

But in the samples tested, in two of the samples the chlorine level went beyond the acceptable levels, out of which one sample had a chlorine content of 4.44 mg/L which is slightly higher than the limits set by WHO and the other one gave a value of 12.7 mg/L which is very high compared to the standard set by WHO. This will pose a very high and serious health risk to the swimmers, the pool workers and others exposed to the pool area.

The strong odor of the Chlorine is one main problem associated with chlorinated water and this will lead to health problems like irritation of eyes and the respiratory system of human body which is mainly due to the evidence of chloramine in the chlorinated water (Angione, Mcclenaghan, & Laplante, 2010). The hypochlorite and ammonia compounds which are generated from the urine and sweat of the swimmers using the swimming pool will form the monochloramine and dichloramine (Angione, Mcclenaghan, & Laplante, 2010) The group of people who are at the greatest risk for developing respiratory illnesses and adverse conditions such as asthma which is caused due to the exposure of chlorine includes children, elite swimmers, lifeguards and employees of indoor swimming pools (Angione, Mcclenaghan, & Laplante, 2010). Other health effects include:

Acute effects such as Chlorine cause irritation to eyes in humans, irritation to upper respiratory tract and lungs (Environmental Protection Agency). Some health effects associated with short term exposure to chlorine at various concentration includes: at 0.014 to 0.054 ppm or mg/L tickling of the nose happens, at 0.014 to 0.054 ppm or mg/L tickling of throat happens, at 0.06 to 0.3 ppm or mg/L, nose itching, coughing, stinging, nose and throat dryness caused, at 0.35 to 0.72 ppm pain after a period of 15 minutes is noticed, and if the chlorine concentration is above 1 ppm or mg/L ocular and respiratory irritation, shortness of breath, and headaches may be caused (Environmental Protection Agency). At 1-3 ppm, which is increased concentration of chlorine the health effects caused is mild mucous membrane irritation at 30 ppm or mg/L chest pain, vomiting, dyspnea, and cough is notice. At 40-60 ppm or mg/L toxic pneumonitis, pulmonary edema and other

serious health effects are caused (Environmental Protection Agency). The higher level of irritation in the chlorine element leads to burns to the people being exposed to higher concentrations (Environmental Protection Agency).It has been found through animal tests that more toxic effects are caused to the body when chlorine is inhaled (Environmental Protection Agency). Chronically being exposed to the chlorine gas has made the people working in the indoor pool areas to develop airway restrictions (Environmental Protection Agency). Also for the test done for animals, it was evident that there is a decrease in the body and body irritations caused as result of being exposed to chlorine gas (Environmental Protection Agency).

**Sulphate Content**

*Wavelength in spectrophotometer:450 nm*

**Table 3** Sulphate content in the samples tested

Sample	Sulphate content (mg/L)
Sample 1	1
Sample 2	19
Sample 3	65
Sample 4	1
Sample 5	18

According to pool water treatment advisory group, the sulphate concentrations in the swimming pool waters have a standards limit of 300 mg/L(Pool Water Treatment Advisory Group, 2011). The values obtained during the laboratory analysis ranged from 1- 65 mg/L, which is within the standard limit and lower when compared to the standard limit. Therefore the indoor pool water has no excess of sulphate concentration in it to cause potential health effects.

**Zinc Content**

*Wavelength in spectrophotometer: 620 nm*

**Table 4** Zinc concentration in samples tested

Sample	Zinc content (Mg/L)
Sample 1	0.13
Sample 2	0.14
Sample 3	0.13
Sample 4	0.17
Sample 5	0.28

According to American National Standard for Water Quality in public pools and spas, the maximum limit set for the metal Zinc is 5.0 ppm (Association of pool and spa professionals, 2009). So compared to the limits set, the zinc concentration contained analyzed in the five samples very low. The results of zinc concentration the samples tested ranged from 0.13 ppm or mg/L to 0.28 ppm / mg/L, which is very low.

**Copper Content**

*Wavelength in spectrophotometer: 560 nm*

**Table 5** copper concentration in samples tested

Sample	Copper Content (Mg/L)
Sample 1	0.12
Sample 2	0.18
Sample 3	0.19
Sample 4	0.13
Sample 5	0.39

The concentration of copper as analyzed in the samples range from 0.12 mg/L to 0.39 mg/L in the 5 samples. The maximum and recommended limit of copper concentration in the swimming pool waters is 0.3 mg/L (Contra Costa Health Services). And according to American National Standard For Water Quality in public pools and spas, the maximum limit set for copper is 1.0 ppm / mg/L. Therefore, the values obtained are within the permissible range, except that in one sample the copper content was found to be 0.39 mg/L when compared to the limit 0.3 mg/L. In all other samples the concentration was found to be very low and was within the limit set by the government.

### Iron Content

#### Wavelength in spectrophotometer: 510 nm

**Table 6** Iron concentration in the samples tested

Sample	Iron Content (Mg/L)
Sample 1	0.01
Sample 2	0.03
Sample 3	0.02
Sample 4	0.03
Sample 5	0.07

The results obtained for the tests done to know the concentrations of iron in the sample ranged from 0.01 to 0.07mg/L. The maximum limit of iron that can be present in the swimming pool waters is 0.2 (Contra Costa Health Services). So compared to the standard limits set by the government, the iron concentration in the samples collected was very low and there will not be health risk associated with it as it is present in very minute quantities.

### Nitrate Content

#### Wavelength in spectrophotometer: 507 nm

**Table 7** Nitrate concentration in samples tested

Sample	Nitrate content (Mg/L)
Sample 1	0.02
Sample 2	0.02
Sample 3	0.05
Sample 4	0.01
Sample 5	0.01

As seen in the results displayed, the nitrate content is very low and almost near zero in the five indoor swimming pool sample waters tested. Usually the source of nitrates includes fertilizers and other toxic sources. In these swimming pool waters very low and negligible concentrations were obtained.

## CONCLUSION

In conclusion, from the lab analysis done it can be understood that chlorine is the one main disinfectant that is used in higher amounts in the indoor swimming pool waters in order keep the water free from pathogens and to prevent the spread of water borne diseases. But in the analysis done, it was found that in few of the samples the chlorine content was very high and it greatly exceeded the standards and limits set internationally by the government. The disinfectant chlorine when used in greater amount than the permissible limits have profound effects on the human health and pose dangerous health risks due to the adverse health conditions that it can lead to. The badly

regulated airflow or ventilation within the enclosed indoor swimming pool area, the chloramines that are being produced and the gas exchanges during breathing by the swimmers are the leading and obvious causes of severe respiratory illness that is being evident in the people who are regularly being exposed to swimming pool waters (Angione, Mcclenaghan, & Laplante, 2010). Allergies, bronchitis, asthma, eye irritation are the few among other types of diseases caused due to the exposure to indoor swimming pool (Angione, Mcclenaghan, & Laplante, 2010). On the other hand, the tests for other elements that were done gave results in favor of reduced health effects. There was very little or no concentration of metals such as zinc, iron, copper. The element sulphate and nitrates were present in very small amounts that were low compared to the maximum limit set by the government. The government has to take more steps in implementing the swimming pool safety, for the better health of the people. Regular checks must be done by the pool administrators to see if any disinfectant exceeds the limit; moreover, proper education and most importantly general awareness about the health effects of being exposed to indoor swimming pool regularly must be made understood for the community.

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