



# What levels of estrogen hormones can be found in swimming pool water?

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## Abstract

Estrogens are a group of sex hormones. The entry of this hormone into the human body causes premature puberty, breast, and uterus cancer, etc. Due to sustainability, harmful effects, and its skin absorption, the identification of this hormone in swimming pools is a must. The carrying out of this research was based on estrogen tracking from a collection of four swimming pools in various days of the week: exclusively masculine, exclusively feminine, and those used by both men and women alternatively. Estrogen and the remained chlorine of raw water of the pool inlet as well as water inside the pool were measured during hot and cold seasons of the year. The measurements of the samples were done using electrochemiluminescence apparatus. The sampling results show a significant increase in the pools relative to filling water. Also, the results verify that the average increase in estrogen concentrations in the feminine pool was 17.95 pg/ml, while the increase in the masculine was 8.96 pg/ml. The maximum estrogen of the feminine pools at 30.8 pg/ml occurred in hot seasons due to more usage. According to the obtained results, swimming pools have considerable level of estrogens. It needs more studies about the health risks of these levels of estrogen in swimming pools.

**Keywords** Estrogen · Swimming · Pool · Hormone · Cancer · Estradiol · Shiraz · Feminine pools · Masculine pools

## Introduction

The swimming pools could be ambiances for transmission of diseases owing to the skin and mucous secretions as well as dissolving ointments and medications used by the swimmers (Khodae et al. 2016). Hormones, and especially estrogens, are among the materials the existence of which in pool waters is less studied. Hormones are a group of chemicals which are produced in humans and animals and control many activities, so that a slight increase or decrease in which from the normal level may lead to extreme effects on the body and cause incidence of diseases.

Estrogens are subsumed in hormones including Estradiol (E3), Estradiol (E2), and Estrone (E1). They are female sex hormones made in the ovary, though they are made also in men's testicles to a low degree. Estrogens account for the development of reproductive system and secondary traits in women (Ryan 1982).

Besides the human body, the plants (Anderson et al. 2003), chemicals, some pesticides such as DDT, certain drugs combinations, detergents, plastics, and industrial materials are also likely possessors of compounds similar to estrogens.

Estrogens entering into water or sewage could mislead the controlled activities of natural body estrogens and may bring about diseases of testicles, ovaries, sperm reduction, and undesirable effects of reproduction such as infertility, cancers, and mutations (Wise et al. 2011).

Synthetic estrogens exist in pharmaceutical ingredients like anticonvulsants and antidepressants, pesticides, plastic products, household products, industrial chemicals, and contraceptives, so that they may lead to precocious puberty, breast cancer, testicular cancer, and uterus cancer, and birth of incomplete and bisexual infants (Anderson et al. 2003). Nonetheless, studies have shown positive effects of estrogens on skin rejuvenation in postmenopausal women by applying cosmetic creams containing estrogens (Stevenson and Thronton 2007).

The most important entering way into water sources is via urinating, disposal of pharmaceutical waste to swages, and birth control pills or hormonal drugs. Sometimes, the

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combination of these hormones changes in urine, but they might be restored after urination by the bacteria in aquatic environments and may be turned into the original form (Moore et al. 2011).

The main problem with pharmaceutical estrogens is that they are capable of being escalated by the synthetic environmental estrogens arising from pesticides, plastics, household products, and heavy metals. These materials play the role of the actual estrogen in the body that aggregates around fat tissues. These are not easily decomposed and remain intact in the environment and finally enter the food chain before taking in the body (Anderson et al. 2003).

Approximate solubility of the hormones of normal estrogen in aquatic environments is 3 mg/l and that of synthetic estrogen is 0.3 mg/l (Yin et al. 2002).

Besides human, aquatic living creatures may fall under the influence of estrogens (Kurihara et al. 2007) so that estrogens may cause reduced fertility even up to 50% (Vojda et al. 2011), reduction in sperms (Gadd et al. 2005), or genetic changes (Burki et al. 2006). An example thereof is the researches done upon horses making use of water containing estrogen compounds (Gibson et al. 2005).

The hormone of estrogen, though having very low solubility, is nearly ubiquitous in the environment so that it could infiltrate to human body as colloidal solution with high pH (Campbell et al. 2006).

Estrogen contamination has been seen in soil, surface water resources, groundwater, and especially in refined sewage effluents. In the latter case, the amount of the hormone depends on both the burden of sewage pollution and the type of filtration system. Observation of the estrogen hormone in groundwater resources is due to usage of animal dung, sewage effluent at ground level, and infiltration through runoff and washing. Even the empty plastic bottles of mineral water may be conducive to transfer of estrogen compounds in the water inside the bottle (Wanger and Oehlmann 2009).

Also, studies have been under way concerning successive methods of estrogen removal from water and wastewater with reverse osmosis membranes and nano-filter (Nghiem et al. 2004; Hashemi et al. 2018; Hashemi and Khodabakhshi 2016) biological treatment processes (Koh et al. 2007), and aerated lagoons (Mohebzadeh et al. 2013).

Various investigations were done about the ways this hormone could transfer to groundwater, as well as the role of soil layers in absorption of estrogen hormone (Soul et al. 2005; Labadie et al. 2007; Golzari and Taghizadeh 2016).

Researches show the possibility of absorption of estrogen compounds through skin. This absorption was shown to be even 10 times more in the condition of moist skin (Biedermann et al. 2010). Hence, whenever the concentration of this hormone in swimming pools' water goes high, its danger threatens the swimmers. Therefore, investigations on

existence and concentration increment of this contaminant are indispensable.

In this research, we engage in studying estrogen levels in the public pools of Shiraz city including the exclusively masculine pools, the exclusively feminine pools, and those used by both men and women alternatively.

## Materials and methods

The experiment was based on tracing estrogen hormone from a set of four swimming pools in Shiraz. The project implementation was sampling of the pools. The samples were sent to laboratory after free chlorine tests and pH measurement to figure out estrogen, thermal, and heterotrophic bacteria, alkalinity, and calcium hardness. (The remained chlorine and water pH as a chemical indicator were measured at the site.) Performance of microbial tests was done by multi-tube fermentation method. Water alkalinity by titration and hardness of water calcium through standard methods (APHA 2005) were carried out. The samples were taken from the depth of 10–30 cm from the water level near the outlet. While sending the samples to laboratories according to the standards, the microbial samples were transferred in the vicinity of ice and in the range of 0–4 °C, and the other ones were sent in the shortest time possible to minimize the test error. Overall, 74 samples were taken from the pools while all in sterilized containers to minimize the error of the experiment. Glass containers sterilized in autoclave were applied with sufficient amount of sodium thiosulfate to neutralize chlorine. In conducting chemical tests and examining estrogen, entirely clean plastic containers were needed.

Sampling locations: As stated above, four swimming pools were selected in the city. Table 1 shows the features of the sampled pools according to sexuality. The reason behind the selection of pools as masculine, feminine, and alternative is to evaluate the effects of sexuality on the amount of this hormone in the pools.

The method of estrogen experiment was on the basis of electrochemiluminescence which is a new way in recognition of the immunometric analytics. The building block of this method stays on the usage of antibody against the measured analyze. Thereby, the concentrations between 10 Mol and 15 Mol are measured in a short time. In this method, a platinum electrode is added to the system which causes the light focus on the place of detector and prevents the diffusion of light. The electrode also regulates the reaction time range so that the reaction of light production is started with establishing the electric current and ends with the current cutoff. A joint German and Japanese product of “Roche” and “Hitachi,” the Elecsy 2010 apparatus was used to measure estrogen having the measurement accuracy as  $\pm 0.05$  ml/pg. The results were determined through a calibration curve

**Table 1** Features of pools according to sexuality

Name	Pool no. 1	Pool no. 2	Pool no. 3	Pool no. 4
Type	Indoor	Indoor	Indoor	Indoor
Days used (feminine)	All the week	_____	Saturday, Monday, Wednesday, Friday	Sunday, Tuesday, Thursday
Days used (masculine)	_____	All the week	Sunday, Tuesday, Thursday	Saturday, Monday, Wednesday, Friday

**Table 2** Appearance information of pools

Pool characteristics	Pool no. 1	Pool no.2	Pool no. 3	Pool no.4
Pool volume (m <sup>3</sup> )	1700	2000	3600	1700
Capacity (person)	150	200	400	150
Source of pool water	Municipal piped water supply	Municipal piped water supply	Well	Municipal piped water supply
Treatment system	Recycled sand filter	Recycled sand filter	Recycled sand filter	Recycled sand filter
Chlorination system	Gas chlorinator	Gas chlorinator	Gas chlorinator	Gas chlorinator
Remained free chlorine concentration (ppm)	1.5–3	1.5–3	1.5–3	1.5–3
Pool temperature (C)	25–29	25–29	25–29	25–29
pH	7.2–8	7.2–9	7.2–8	7.2–8

generated by a two-point calibration and an indicator curve provided by the reagent barcode.

## Results and discussion

Table 2 contains the information taken from the general features of the swimming pools, while pH and temperature were obtained from long-term experiments statistics available at the pools' offices.

### Results of estrogen in inlet raw water

Table 3 shows the inlet water qualities such as pH, the remained chlorine, and the concentration of estrogen during two samplings.

As inferred from the results of Table 3, the inlet raw water into the pools contained some estrogen with the maximum value attributed to Pool 3 which has been fed by well water.

### Results of microbial and chemical experiments

Table 4 represents the microbial and chemical quality of the pools water.

The results tell us that the microbial and chemical factors extant in water are within the standard range recommended by WHO (2006). So, there is the hypothesis that these factors affect equally upon the samples.

**Table 3** Quality of inlet raw water into pools

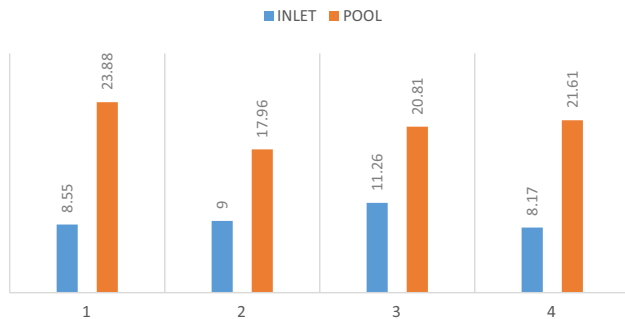
Pool no.	Estrogen (pg/ml)	mg/l cl <sub>2</sub>	pH
Pool 1	7.3	0.4	7.4
	9.8	0.3	7.4
Pool 2	9.3	0.5	7.4
	8.7	0.4	7.4
Pool 3	12.3	0	6.8
	10.22	0	7
Pool 4	9.05	0.2	7.2
Pool no	7.28	0.5	7.2

**Table 4** Microbial and chemical quality of the pools water

Pool no.	Pool no. 1	Pool no. 2	Pool no. 3	Pool no. 4
Coliforms (MPN/100 ml.)	< 1	< 1	< 1	< 1
Heterotrophs (No/100 ml.)		< 200	< 200	< 200
Alkanity (mg/l, cac03)	< 200			< 120
Ca. hardness(mg/l, cac03)		< 120	< 120	< 250

**Table 5** Results of estrogen measurements in different pools during six time stages

Sampling time	Estrogen concentration (POOL1) (pg/ml)	Estrogen concentration (POOL2) (pg/ml)	Estrogen concentration (POOL3) (pg/ml)	Estrogen concentration (POOL4) (pg/ml)
July	27.7	23.09	25.52	28.03
September	34.73	17.84	23	21.8
September	23.7	18.4	22.6	20.9
October	30.8	23.1	16.3	20.1
November	18.7	16.3	20.8	17.20
November	14.3	12.8	17.4	18.05



**Fig. 1** Results of estrogen existing in the inlet water and the average water for each pool

**Results of estrogen measurements in different pools**

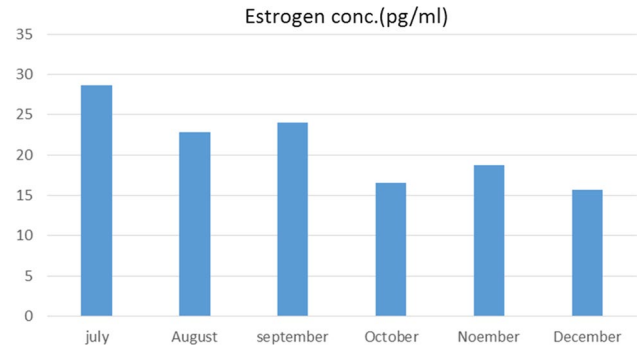
Table 5 shows the results of the samplings performed during six time stages.

Figure 1 illustrates the results of estrogen existing in the inlet water and the average water for each pool.

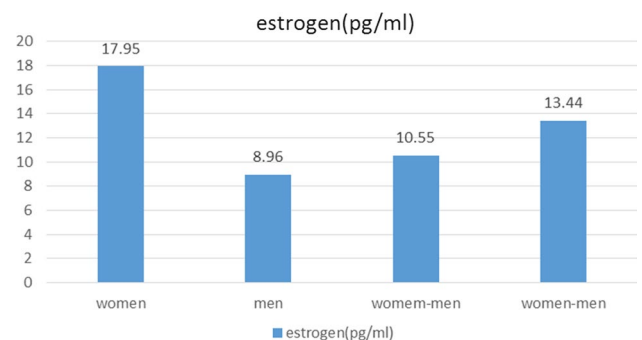
By using SPSS, a significant test was applied on the average estrogen existing in the water of each pool as well as the raw water thereof to conclude, as observed in Fig. 1, that the water estrogen has had a significant increase compared to the initial value ( $p > 0.05$ ). Therefore, one could deduce that estrogen has made its way into water via the swimmers. The increase in estrogen in the pools may be the outcome of the following:

1. The use of estrogen sunscreens prescribed by medics to protect skin against UV ray;
2. The use of anti-inflammatory and anti-aging skin ointments and lotions having estrogen compounds;
3. Physical discharges and not taking adequate showers before entering the pools.

Considering the results of water estrogen in the pools among the months of the year, it turns out, not surprisingly that in warmer seasons in which the use of referrals to the pools has been greater, estrogen was more waterborne, so



**Fig. 2** Concentration changes of estrogen during July to December



**Fig. 3** Average changes of estrogen in the pools

that numerical value of estrogen had a direct relationship with the user population.

According to the results of Table 5, the overall diagram of average estrogen in each pool per month is as Fig. 2.

As is seen in the figure, the effects of cold months of the year on the increase in estrogen hormone have been declining due to reduced user population.

The main purpose of selection of the pools according as masculine, feminine, and alternatively both sexes is to study the effect of sexuality on the estrogen existing in water. Figure 3 shows the average changes of this hormone in the pools.

With reference to the Fig. 3, Pool 1 used merely by women has been of the most estrogen level, as predicted. The level in Pool 2 had the least value, and as to Pools 3 and 4, the values were almost in concert. The statistical *T* test done by SPSS reveals the significant difference in estrogen level between the masculine and feminine swimming pools with 95% safety and *p* value = 0.097 > 0.05.

## Conclusion

As the results of experiments in the pools show, it is known that the estrogen level has increased significantly in proportion to the inlet raw water in each pool, which is a token of the estrogen increase via the swimmers. In warmer months of the year with more use of referrals, the estrogen level has increased, showing that the level had a direct relation with the user population. The pools used by women had more estrogen hormones than those referred to by men.

To prevent the effects of estrogen risks upon pathogenicity in men, it is suggested that the pools should be more separate. Also, according to the effect of user population on increase in estrogen concentration, it is recommended that the capacity of women's pools is considered to be less.

More medical studies are needed concerning increase in estrogen concentration as a result of bathing in pools. Typical estrogen removal methods in pool water treatment should be taken into account. Draining the pools water into water resources without treatment should be interdicted due to known effects of estrogen on the environment.

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