Effect of Nano-Silica on the Efficacy of Swimming-Pool Water Treatment

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Abstract: This study reviews the efficacy of nano-silica on swimming-pool water treatment. The research involved an experimental study and was performed in-vitro and experimentally. At first, a nano-particle, called "nano-silica," was prepared in the laboratory and herbal additives such as turmeric, curries, saffron, and cinnamon were used to increase its antibacterial properties. Then, for microbiological tests, water samples of Urmia University's swimming pool were studied in a two-stage process: water samples before adding the nano-particle and after the addition of the nano-particle. Finally, to study the chemical and physical contaminations, among the relevant factors, the pH and turbidity were studied in the laboratory, again in two parts: before and after the addition of the nano-particle. The results showed a decrease in averages from 2.0633 to 1.0325 before and after adding the nano-particle respectively ($P < 0.05$). Among the mentioned additives, the curries (92 percent) and the turmeric (85 percent) had the most antibacterial properties. Although the nano-particle did not adjust the swimming pool water pH to the optimal level of 7.2, it reduced the pool water turbidity significantly. This study showed that by using the nano-silica and adding herbal additives, swimming pool water reaches a better quality.
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1. Introduction

Swimming is a popular sport that takes place in the swimming pools, water parks, ponds, lakes, rivers, and oceans. Over the past century, modern disinfecting systems for pools have improved the quality of aquatic entertainment (1). However, in recent decades, disease incidence due to swimming has increased significantly (2). The pool is a suitable location for transmission of infectious diseases. The health and hygiene of swimming pools can be investigated by considering microbial and chemical contaminations. Swimming is an important exercise with many health benefits, but many countries do not pay enough attention to the health and hygiene of these amusement parks. Unfortunately, chlorine alone cannot eradicate all risky contaminants. Furthermore, even if chlorine is administered, there can be no assurances that the water is free of human excrement and waste. All pathogenic microorganisms such as bacteria, viruses, and protozoa and parasite worms exist in human excrement and can be easily transmitted through public waters.

Swimming pools are often contaminated by the addition of substances from swimmers' bodies such as hair, fat, respiratory and digestive microbes, and other harmful bacteria and waste material in the skin. Since this contamination is increasing frequently and regularly as the pool is used by more people, pools are an ideal location for contamination of a lot of people. Extensive studies have shown that respiratory and gastrointestinal diseases are more common among swimmers than non-swimmers. To prevent such diseases, health and hygiene standards for swimming pools must be considered. These include: limpidness and clarity of pool water, temperature, amount of free chlorine, and residual amounts of microscopic organisms. While the pool is in use, the water should be clear, limpid, and clean. Some diseases occur due to improper operation or inappropriate handling of pool chlorine, which subsequently results in a swimmer getting in contact with or swallowing contaminated water, leading to a range of possible diseases such as typhoid, diarrhea, infectious hepatitis, gastrointestinal disease, conjunctivitis, trachoma, leptospirosis, fungal diseases and skin infections, schistosomiasis and giardiasis, swimmer's itch, upper-respiratory illnesses (such as sinus infections), infectious pharyngitis, middle-ear infections, or recurrent inflammations of mucous covering the eyes, ears and throat (1).

Pool chlorine intensifies the risk of asthma and allergies by triggering asthma and chest wheezing in children (3). New research from Lovine University of Brussels shows that swimming in pools

disinfected with chlorine puts children at risk of asthma and a variety of allergies. Children and adolescents who swim more than 1,000 hours in these pools (indoor or open) have more than eight times greater susceptibility to asthma. However, swimming in pools disinfected with a copper-silver method poses no danger. The Belgian researchers analyzed 190,000 teenagers from 13-14 years old in 21 countries (4). These adolescents were asked to explain their respiratory problems, hay fever, and allergic eczema. The researchers found a higher incidence of asthma and chest wheezing in small and large towns, where the density of indoor pools was higher. The prevalence of asthma and chest wheezing increased per one unit of indoor pool as 2.73 percent and 3.39 percent, respectively. Such problems were more common in West Europe than East Europe, perhaps owing to a greater number of pools in the western part of the continent (5).

The presence of chlorine in pool water has a very important effect on the occurrence of allergic diseases in the studied group. The nitrogen tri-chloride was identified as increasing asthma prevalence in users of indoor pools. The nitrogen tri-chloride is an irritating gaseous substance that can easily enter the lungs. This chemical, also called tri-chloramines, is released when chlorinated water reacts with urine, sweat, or other organic materials from swimmers' bodies. However, if chlorine is used properly, it is safe and effective. However, since a tremendous amount of chlorine is often used for water disinfection, it causes irritations in the organs that are in contact with the air and water in the indoor pool environment. As a result, long-term swimmers are more vulnerable than the average person to allergies and asthma (6).

As chlorine reacts with bacteria and other organisms' proteins and destroys them, it canalso react with skin proteins. This reaction causes the horned layer of cells or stratum corneum cells to lose their cohesion and effectiveness. This is the basis of skin damage caused by chlorine. People with sensitive skin will experience dryness, and itching due to contact with chlorinated water. The chlorine in pool water, especially high concentrations can cause stimulation, itching, irritation, and eye inflammation (especially in susceptible individuals). The allergy symptoms present as redness, irritation, itching, and pimples under eyelids. Vulnerable people should use waterproof goggles. Chlorine also can cause hair loss (6). Colored hair is very sensitive to chlorine and loses its color through chlorine exposure. Inhaling chlorine from pool water over the long term damages the lungs (especially in patients with respiratory irritations and asthma). If the chlorine concentration is not controlled properly, it can cause bronchitis over the long term. Chlorine gas has a sharp, nasty smell, and is yellowish-green. The industrial uses of chlorine include production of bleaching powders, paper and textile industries, drinking-water disinfectants, swimming pools, waste treatment, preparation of chlorinated organic and mineral compounds and metal chloride combinations, production of solvents and pesticides, polymers, and coolants (7). Chlorine gas is a strong stimulant of skin mucosa and the respiratory system. This gas combines with body moisture to produce an acid and is considered as a suffocating substance, since it causes severe contraction of the laryngeal muscles and mucosa swelling (6).

This study attempted to find alternatives to chlorine and its derivatives using updated technologies, which would be healthier and safer - but more costly compared to chlorine (8). The purpose of this study was to gauge the impact of nano-silica on the efficacy of cleaning swimming pool water. The following were the research objectives:

- To determine the effect of nano-silica on swimming-pool-water quality
- To determine the effect of nano-silica on chemical contaminations of swimming-pool water
- To determine the effect of nano-silica on physical contaminations of swimming-pool water
- To determine the effect of nano-silica on microbiological contaminations of swimming-pool water

2. Material and Methods

This was an experimental study and was performed experimentally using nanochemistry laboratory materials and equipment. At first, the nano-silica was prepared and synthesized. Then, the nano-particle was tested to measure other variables in the hypotheses. Finally, the comparison with samples collected from the pool was performed. In this study, the herbal materials such as turmeric, curry powder, cinnamon, and saffron were added to increase the antibacterial properties of the silica nanoparticles by applying the adsorption technique. Some amount of these spices was dissolved in alcohol and passed through filter paper. Then, the silica nanoparticles were added and the mixture was slowly stirred for 24 hours at environment temperature. Microbiological tests were performed in the laboratory in two steps: before and after adding the nano-silica. A spectrophotometer device was used to measure turbidity and pH.

3. Results

The test results showed that the research tool had a good reliability (Cronbach's alpha equal to 0.9).

The results are shown in the Table 1. The first hypothesis investigated the impact of nano-silica on the efficacy of water treatment in swimming pools. The average total, standard deviation and t-level were obtained as 12.1474, 1.51618, and 9.471, respectively. In the second test, we measured the impact of nano-silica on reducing chemical contaminations of swimming-pool water. The average total, standard deviation, and the t-level were obtained as 1.2650, 2.29249, and 1.104, respectively.

Table 1. Results of assumptions overview

Hypothesis		**Average**	**Standard deviation**	**Conclusion**
The use of nano-silica is effective on the efficiency of water treatment		12.1474	1.51618	Significant relationship
The use of nano-silica is effective on the reduction of chemical contaminations of the swimming pool water		1.2650	2.29249	Hypothesis rejection
The use of nano-silica is effective on the reduction of physical contaminations of the swimming pool water		.1571 PURE	.37573	Significant relationship
		.1691 D	.38156	
		.1730 K	.38751	
		.2676 ZM1	.39004	
		.1611 ZM2	.37705	
The use of nano-silica is effective on the reduction of microbiological contaminations of the swimming pool water	Before adding the nano-particle	2.0633	16781.63679	Significant relationship
	After adding the nano-particle	1.4000	1145.64392	
		26.6667	46.18802	
		40.0000	69.28203	
		6.4367	871.56201	

The third test studied the use of nano-silica to reduce physical contaminations of swimming-pool water. The average totals were:

- Water sample without chlorine: 1571
- d sample (cinnamon): 1691
- k sample (curries): 1730
- zm1 sample (saffron): 2676
- zm2 sample (turmeric):1611.

The standard deviations were 37573, 38156, 38751, 37705, and 3900, respectively. The last test reviewed the impact of nano-silica in reducing microbiological contaminations of swimming-pool water. The average total in swimming-pool-water samples before the nano-silica was added was 2.0633. After addition of the nanoparticle, the average total values in the D, K, ZM1 and ZM2 samples were 40.0000, 26.6667, 1.4000, and 6.4367, respectively. The standard deviation in the pure sample was 16781.63679 and in the test samples were 1145.64392, 46.18802, 69.28203 and 871.56201, respectively.

4. Discussions

This study reviewed the effects of nano-silica on reducing physical contaminations of swimming-pool water. These contaminations include insoluble impurities and colloidal materials introduced by swimmers and from the surrounding pool environment, and cause water turbidity. Based on the t-test used, the t values in D, k, zm1 and zm2 samples were more than the t value in pure water, which is equivalent to 5.928. The degree of freedom was 200 and the obtained t values in all groups were greater than the significance level. Since the calculated significance level was smaller than critical level, we failed to reject the hypothesis. Accordingly, we conclude that the impact of chlorine on reducing the physical contamination of pool water is positive. Jennifer Lynn used nano-titanium to remove sunscreen particles from swimming pools and concluded that this nano-particle can remove 100 percent of the particles (9).

The effect of nano-silica in reducing microbiological contaminations of pool water was evaluated. The t-test was used, and the average before adding the nanoparticles was equal to 2.0633. After adding nano-silica, it was 1.0325, which is larger. Thus, the significance level of the table was smaller than error ($P < 0.05$), confirming the hypothesis. Comparing the table data, we conclude that nano-silica is effective in reducing

microbiological contaminations in swimming pools. This hypothesis is confirmed by 95 percent confidence and is stronger than other variables. Additionally, Osman San studied antimicrobial properties of borosilicate glass powder with a spherical shape and concluded that adding silver oxide to nano-silicate significantly increases antibacterial properties of the powder (10). In a similar study, F. Barzegar used nano-titanium to reduce staphylococcus aureus and E. coli bacteria. The bacteria growth showed a reduction of 5.6 percent in the presence of nano-titanium with 1.5 percent concentrations (11). Acceptable results were not obtained in this study regarding pH reduction. Also, we found no research regarding the use of nano-silica to adjust pH. However, the results showed with 95 percent reliability that the use of nano-silica will generally significantly increase pool-water quality. Also, we achieved acceptable results regarding the reduction of physical and microbiological contaminations. Herbal additives in different combinations of nano-particles can be used in future research and by other researchers.

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