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Article

Analysis of Residual Chlorine Content in Swimming Pool Water on Eye Irritation Complaints

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Abstract
Residual chlorine is a residue from the chemical compound chlorine, which is used as a disinfectant in swimming pool water. When in contact with the eyes, these chemicals can cause conjunctiva inflammation, known as conjunctivitis. Symptoms include redness, swelling, pain, and itching in the eyes. Research purposes analyzing the effect of residual chlorine content in swimming pool water on complaints of eye irritation in swimming club members. The type of research used is analytical observational with a cross-sectional approach. The research subjects were visitors to swimming pools in the Surabaya area using purposive sampling. The data collection techniques were questionnaire sheets, observations, and laboratory results. Data analysis used the Spearman Correlation test. The results showed that water pH was a protective factor for residual chlorine in swimming pool water with a value of (PR < 1), and Alkalinity was a protective factor for residual chlorine in swimming pool water with a value of (PR < 1). There was no influence of residual chlorine on complaints of eye irritation with a value (pv = 0.602). It is recommended that swimming pool managers install information boards that guide swimming pool cleanliness and ethics. They have added soda ash to stabilize the pH. Future researchers can examine other factors that influence complaints of eye irritation and residual chlorine content.

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Introduction

Swimming pools as a place for recreation and exercise have become very popular throughout the world. Swimming pools offer health and fitness benefits, but using chemicals such as chlorine to keep the water clean has raised concerns about the negative impact on users health. The chemical used as a disinfectant is chlorine for the chlorination process. This process is carried out by adding chlorine or hypochlorite to swimming pool water to kill certain bacteria and microbes. Free chlorine will produce effective residual chlorine from chlorination to kill bacteria, viruses, and other organisms [1].

Effective residual chlorine is residual chlorine that meets quality standards so that it remains clean and safe to use. These quality standards are regulated in Minister of Health Regulation No. 2 of 2023 in parameters such as physical, biological, and chemical parameters. The remaining chlorine and the Potential of Hydrogen (pH), Alkalinity, bromine, and Oxidation-Reduction Potential (ORP) are

included in the chemical parameters. Non-compliance with quality standards occurs due to a lack of physical supervision in the swimming pool water treatment process, which makes the water appear cloudy and green. In line with research by Rahmawati, the residual chlorine levels in the two public swimming pools studied exceeded the SBMKL. The pH value of the swimming pool water influences residual chlorine that exceeds the SBMKL [2]. According to Ratajazk's research, chlorination is the most commonly used disinfection method because it maintains the cleanliness of swimming pool water [3]. Residual chlorine in the water can interact with organic materials in the pool to produce byproducts called chloramines, which can cause eye, skin, and respiratory tract irritation.

The effectiveness of the pH value of the water will have an impact on the presence of HOCI and OCI- in the water, which is very important in killing bacteria [4]. The pH value of the swimming pool water at the FIO Unesa Swimming Sub Laboratory tends to be acidic, below seven, due to the lack of soda ash or sodium carbonate (Na2CO3) [5]. Giving soda ash aims to increase pH and Alkalinity, however, giving too much soda ash can increase Alkalinity [6]. Alkalinity or basicity is an alkaline salt that dissolves in water. Alkalinity can neutralize acids in water and keep the pH stable [7]. Complex pH adjustments can make swimming pool water cloudy and hamper water circulation. This shows that the Alkalinity value affects the pH value of swimming pool water. An imbalance in Alkalinity values can cause eye irritation [8].

Eye irritation occurs due to interactions between chlorine compounds in water and the eye's conjunctiva. Inflammation of the conjunctiva shows signs of swollen blood vessels, soreness, itching, and discharge from the eyes [9]. Complaints of eye irritation are the same as inflammation of the conjunctiva in the eye. According to research by Azizaturrahmah et al., 62% of Lampung University Swimming Pool visitors experienced eye irritation after swimming [10]. Study Rozanto & Windraswara shows that visitors complain of eye irritation in the form of sore, red, and itchy eyes after swimming. Eye irritation occurs because chlorine still high in swimming pool water exceeds quality standards [11]. High residual chlorine can cause health problems such as eye and skin irritation, chest tightness, throat problems, and coughing [12]. More detailed studies are needed to understand the exact residual chlorine levels that cause eye irritation and their impact on different populations, including children and individuals with certain health conditions. This research aims to analyze the effect of residual chlorine content in swimming pool water on complaints of eye irritation among visitors to swimming pools in the Surabaya area.

Recent research has revealed that exposure to chlorine residue in swimming pool water can cause various health problems, especially eye irritation. Chloramines, which form from the reaction of chlorine with organic materials, can be a significant irritant agent. According to a study by Richardson et al., long-term exposure to chloramines in swimming pool water can cause significant eye irritation. This study found that individuals who frequently used swimming pools with high chlorine levels were more susceptible to eye irritation than those who swam in pools with lower chlorine levels [13].

Various studies have been carried out to understand the effect of residual chlorine content on eye irritation complaints; according to Azizahturrahman's research, there is a relationship between eye complaints and chlorine levels. This research indicates that swimming pools with poor chlorine management can cause eye irritation in visitors [10]. Another study by Rahmawati showed a relationship between residual chlorine content and complaints of eye irritation in swimmers. This indicates that chlorination can cause direct contact between chlorine and the eyes because chlorine is a chemical product. Additionally, chlorine levels in swimming pool water vastly exceed established quality standards, with 69.8% of swimmers swimming in pool water failing to meet these standards. The researchers recommend that to reduce this risk, it is essential to closely monitor and control chlorine levels in swimming pool water [2].

Materials and Methods

Research subject. The subjects in this study were 33 swimming pool visitors who were members of swimming clubs aged 13 - 25 years and water from swimming pools in the area, which was taken as a sample to measure residual chlorine concentration, pH, and alkalinity.

Research design. This research uses an analytical observational research type with a cross sectional approach.

Research procedure. Testing for residual chlorine content in swimming pool water samples was carried out using the colorimetric method using DPD reagent. Measurement of residual chlorine levels in swimming pool water uses the color comparison method with a chlorimetry table. Table observations were carried out in a well-lit area to ensure reading clarity. During field practice, water acidity levels are measured using a pH meter. The numbers on the pH meter are measured after remaining still until stability is achieved [2]. Swimming pool water samples were taken twice, namely after cleaning (in the morning) and before cleaning (in the afternoon). Determination of sample points uses a sampling technique, namely Momentary Sample (Grab Sample). Grab Sample is a sample taken at a particular time and place [14]. Water sampling uses 2 points in the swimming pool because each point represents a different depth of the swimming pool.

Instruments and Equipment. This research used instruments and equipment, namely jerry cans and interview sheets.

Method of collecting data. Data collection techniques used interviews and laboratory tests. This research instrument uses a questionnaire sheet and laboratory tests for swimming pool water. The interview method used a questionnaire sheet to determine eye irritation complaints felt by swimming club members. This questionnaire sheet has gone through validation and reliability tests.

Data analysis. Water sample analysis was carried out at the BBLK Surabaya Laboratory due to limited testing equipment in the field. This research is located in a swimming pool in an area in Wonokromo District, Surabaya City. In bivariate analysis, statistical tests were used to determine the existence of an influence, namely the Spearman Correlation Test and Prevalence Ratio with the SPPS (Statistical Product and Service Solutions) application version 16.0.

Research Ethics. Before data collection, this research had passed ethical clearance by the Ministry of Health Surabaya Health Polytechnic Research Ethics Commission on April 19, 2023, with No. Ethics 2313-KEPK.

Results

Swimming Pool Water Chemical Parameters

Measurement of swimming pool chemical quality includes residual chlorine levels, pH, and Alkalinity of swimming pool water. Based on Table 1, the results for residual chlorine in the morning are 0.05 mg/l and 0.04 mg/l, which is below the quality standard, and in the afternoon, the residual chlorine is no longer in the swimming pool water. In the morning, the pH of the water was found to be 7, which met the requirements at point 1, and at point 2, the pH was 6.97, but in the afternoon, the water pH value decreased by 6.78 and 6.66. Regarding water alkalinity, the results obtained in the morning were 11 mg/l and 9 mg/l, and in the afternoon, it was 11 mg/l and 15 mg/l, where the alkalinity results were below the quality standards. The quality standards used are regulated in Minister of Health Regulation No. 2 of 2023.

Table 1
Results of Measurement of Swimming Pool Water Chemical Parameters

Collection Time	Point	Residual chlorine For Quality Standard of Minister of Health Regulation No. 2 of 2023 (1-1.5 mg/l)		pH For Quality Standard Minister of Health Regulation No. 2 of 2023 (7 – 7.8)		Alkalinity For Quality Standard Minister of Health Regulation No. 2 of 2023 (80 – 200 mg/l)	
		Results	Note	Results	Note	Results	Note
After Cleaning (08.00 WIB)	1	0.05	Not eligible	7.03	Qualify	11	Not eligible
	2	0.04	Not eligible	6.97	Not eligible	9	Not eligible
Before Cleaning (16.00 WIB)	1	0.00	Not eligible	6.78	Not eligible	11	Not eligible
	2	0.00	Not eligible	6.66	Not eligible	15	Not eligible

Complaints of Eye Irritation

According to the data in Table 2, complaints of eye irritation were experienced by swimming club members after swimming in swimming pools in the Surabaya area. This complaint was felt by 18 people (54.5%), and as many as 15 people (45.5%) had no complaints of eye irritation.

Table 2
Distribution of Eye Irritation Complaints among Visitors

Complaints of Eye Irritation	Frequency (N)	Percentage (%)
There are complaints	18	54.5
No Complaints	15	45.5
Amount	33	100

Based on Table 3, it shows that swimming club members experienced 5 complaints of eye irritation after swimming, namely complaints of sore eyes, red and watery eyes, gritty and itchy eyes, swollen eyes, and blurred or less clear vision. The most common complaints experienced by swimming club members were complaints of sandy and itchy eyes, 17 people (51.5%) experienced complaints of gritty and itchy eyes and 16 people (48.5%) did not experience complaints of sandy and itchy eyes. Regarding complaints of swollen eyes, 26 people (78.8%) did not experience those of swollen eyes, and as many as 7 people (21.2%) experienced those of swollen eyes. Complaints of swollen eyes are the least common complaint experienced by swimming club members.

Table 3
Frequency Distribution of Complaints of Eye Irritation Experienced While Swimming

Complaints of Eye Irritation	Number of Members Experiencing Complaints of Eye Irritation			
	No Complaints (n)	Percentage (%)	Experiencing Complaints (n)	Percentage (%)
Painful Eyes	22	66.7	11	33.3
Red and Watery Eyes	17	51.5	16	48.5
Gritty and Itchy Eyes	16	48.5	17	51.5
Swollen Eyes	26	78.8	7	21.2
Blurred/Poor Vision	23	69.7	10	30.3

Effect of pH and Alkalinity of Water on Residual Chlorine Content in Swimming Pools

Based on Table 4, the results of the analysis of the influence of pH and alkalinity of water on the residual chlorine content show that the value PR = 0 is less than 1, so the pH and alkalinity of the water on the residual chlorine of swimming pool water are protective factors, not risk factors. Laboratory results show that the pH of the swimming pool water meets the requirements only in the morning, the remaining chlorine does not meet the requirements, and the alkalinity does not meet all the requirements.

Table 4

Analysis of the Effect of Water Ph on the Residual Chlorine Content of Swimming Pool Water

Variables	Category	Residual chlorine		Total	PR
		Qualify	Not eligible		
pH	Qualify	0	1	1	0
	Not eligible	0	3	3	
Alkalinity	Qualify	0	0	0	0
	Not eligible	0	4	4	

The Effect of Residual Water Chlorine on Eye Irritation Complaints in Swimming Pool Visitors

Based on Table 5, there were 15 people (45.5%) who did not experience complaints and 18 people (54.5%) experienced complaints when the remaining chlorine did not meet the requirements. The P-Value result of 0.262 from statistical tests shows that there is no relationship between residual chlorine in swimming pool water and complaints of eye irritation among swimming pool visitors in the Surabaya area.

Table 5

Analysis of the Effect of Residual Chlorine in Swimming Pool Water on Complaints of Eye Irritation among Swimming Pool Visitors in the Surabaya area in 2024

Factor Risk		Complaints of Eye Irritation		Total	*P – Value*	Wald
		Experiencing Complaints (n)	No Complaints (n)			
Residual Chlorine	Qualify	0	0	0	0.602	0.272
	Not eligible	15	18	33		

Discussion

Table 4 shows that the pH of the water meets the requirements because the chlorine provided by the swimming pool staff is by the provisions. The strength of the pH influences the effectiveness of chlorine disinfection. If the pH of the water is acidic or below 7, it affects the health of swimming club members. The health of club members can be affected by the pH of the water because the human body has a pH between 7.35 – 7.45 [15]. The degree of acidity, commonly called pH, is the degree of acidity and Alkalinity used to express the level of acidity and Alkalinity of water. Causes of a decrease in water pH include excessive use of chemicals, the density of swimmers exceeding capacity, afternoon sampling conditions so that the water is heavily contaminated with other substances, and the decomposition of organic materials. Causes of a decrease in water pH include excessive use of chemicals, the density of swimmers exceeding capacity, afternoon sampling conditions so that the water is heavily contaminated with other substances, and the decomposition of organic materials. Chlorine functions as an efficient and effective disinfectant at low pH levels, however, chlorine can also produce an unpleasant odor and taste in water. One of the chlorine used is chlorine. The addition of chlorine causes the pH level to decrease. This is because chlorine in water undergoes hydrolysis to form

Ca(OH)2 and HOCl compounds. The HOCl compound immediately decomposes to form H+ ions, so the ratio of H+ ions is more significant than OH ions, which causes the solution to be acidic [16].

The decrease in water pH levels is still within normal limits, so it does not affect the residual chlorine content of swimming pool water. According to Achmit et al., chlorine levels decrease with increasing pH; this is caused by a decrease in the active percentage of hypochlorous acid (HOCl) [17]. The chlorine reaction of hypochlorous acid (HOCl) is more efficient than hypochlorite ion (OCL-). The pH value can control the amount of hypochlorous acid (HOCl). The effectiveness of chlorine is optimal when the water pH is 7, if the water pH is more than 6.7, around 90% of the hypochlorous acid will ionize into hypochlorite ions and result in the ability of chlorine as a disinfectant to decrease in killing pathogenic bacteria [18]. This is in line with research by Lisna, which states that changes in pH in water are related to the working power of chlorine. Swimming pool water alkalinity is essential in maintaining pH stability, user health and comfort, and system maintenance efficiency, however, swimming pool water alkalinity in table 4 shows that Alkalinity is a protective factor for residual chlorine content [19].

Swimming pool water alkalinity measures the concentration of chemicals in the water that can neutralize acids and maintain pH stability. Swimming pool water alkalinity is essential in preserving pH stability, user health and comfort, and system maintenance efficiency. Researchers assume that Alkalinity is a protective factor for residual chlorine in water because it influences each other and water pH. This is in line with research by Masitoh, which states that low alkalinity can cause an unstable pH, which can make the chlorine work less efficiently or be used up more quickly because it has to adjust to changes in pH [5]. High Alkalinity will be followed by a high pH value and vice versa [20]. Low Alkalinity requires pH neutralization by providing soda ash as a pH balancer because it has strong alkaline properties and can balance chlorine, which is a weak acid. When the pH is low (too acidic), Alkalinity acts as a buffer that helps increase the pH gradually by adding base. Conversely, if the pH is high (too alkaline), Alkalinity acts as an acid buffer that helps lower the pH.

Based on Table 5, which shows the results of the statistical tests obtained, P-Value = 0.262, it can be concluded that there is no influence between residual chlorine in swimming pool water and complaints of eye irritation among swimming pool visitors in the Surabaya area. The remaining chlorine is below quality standards, and swimming club members have complained of eye irritation. Researchers assume that the residual chlorine content does not affect visitors' complaints of eye irritation due to the sampling conditions in the morning because the residual chlorine content is negligible. This is because there were already visitors swimming and the water was contaminated in the afternoon. Knowing the volatile nature of chlorine so that sunlight can quickly reduce the residual chlorine levels in swimming pool water, the remaining chlorine that can be obtained is also influenced by the number of swimmers daily.

Complaints of eye irritation other than residual chlorine can occur due to water pH, algae, viruses, bacteria, etc. Among the ocular signs are decreased height of the tear film meniscus, presence of flakes in the tear film, hyperemia of the conjunctiva, frothy discharge at the edge of the eyelids and canthi, frequent blinking, lack of luster on the conjunctiva, cornea or both surfaces seem to be signs. Important. Points to a diagnosis of dry eye [21]. Water that has been contaminated and comes into contact with the lining of the eye can cause complaints such as itchy eyes which are the most common complaint. The tear layer functions as a natural protection for the eyes. If the tear layer is damaged, it causes the salt concentration in the eyes increases and causes itching, burning, and blurred vision after a day of swimming [22].

This research aligns with Bayu Wicaksono, who states that the residual chlorine level factor does not have a significant relationship with the incidence of eye irritation in swimming pool users in the Semarang City area [23]. Residual chlorine does not affect the occurrence of eye problems, but it can be caused by other factors, namely the pH of a swimming pool that is too low, which tends to be

acidic, thereby changing the tissue proteins in the eyes of swimmers who do not wear swimming goggles. According to Masitoh, residual chlorine results do not meet the requirements and are not a risk factor for dry eye syndrome [5]. This research is not in line with Rahmawati's theory that there is a relationship between residual chlorine and swimmers' complaints of eye irritation [2]. According to Talita, Low residual chlorine can cause ineffectiveness during disinfection. This ineffectiveness means that pathogenic germs in swimming pools can still live, develop, and infect other swimmers [24]. Complaints of eye irritation due to exposure to chlorine in swimming pool water should not be taken lightly because this is an early symptom of eye disease [11].

The next researcher can determine which club members are experiencing eye irritation through medical diagnosis so that these complaints are clearly eye irritation or other eye diseases. The medical diagnosis results can help researchers find out what variables are related to the causes of different diseases so that the parties involved will be wiser in managing swimming pools. One way to reduce the formation of chloramines, which can irritate the eyes, is to improve filtration technology in swimming pools. More advanced filtration technology can reduce the organic material content in water, thereby reducing interactions with chlorine and the formation of chloramine compounds. Using a more efficient filtration system can maintain pool water quality and reduce the possibility of irritation for visitors.

Conclusions

The results of measuring water chemical parameters including residual chlorine, pH and Alkalinity need to meet the quality standards of Minister of Health Regulation No. 2 of 2023. The result is that there is no residual chlorine in the water, and the pH in the morning meets the requirements, but in the afternoon, it decreases, and the Alkalinity is below the quality standard. The pH value and Alkalinity of water are protective factors in the residual chlorine content of swimming pool water. Among the club members some members experience complaints of eye irritation. Based on the results of the Spearman correlation test, it was found that residual chlorine content had no influence on complaints of eye irritation among swimming club members.

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Informed Consent Statemen
Informed consent was obtained from all subject involved in the study.

Conflicts of Interest
The authors declare no conflict of interest.

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