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Research Article

Development of Multifunctional Tablet Formulation for Use In Swimming Pools

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ABSTRACT

The pool waters pose certain risks to public health. Therefore, it is crucial for swimming pool water to meet the desired standards in terms of physical, chemical, and biological parameters, and to be regularly monitored to ensure the provision of healthy and safe swimming conditions. In our country, swimming pool water standards are determined in accordance with regulations set forth by the Ministry of Health. To maintain these standards, various pool chemicals are required, including pool water disinfectants, pH reducers, precipitators, brighteners, and algae inhibitors. The objective of our study is to develop a multifunctional tablet formulation, a technological innovation that combines the properties of these chemicals into a single product. To achieve this goal, we conducted physical and bactericidal tests on new formulations containing disinfectants such as calcium hypochlorite, trichloroisocyanuric acid, and sodium dichloroisocyanurate. The multifunctional tablet formulations developed provide an effective solution to meet and exceed the required standards for swimming pool water quality.

Keywords: *Disinfection, Formulation, Multifunctional Tablet, Swimming Pool*

Yüzme Havuzlarında Kullanıma Yönelik Çok Fonksiyonlu Tablet Formülasyonunun Geliştirilmesi

ÖZ

Havuz suları halk sağlığı açısından belirli riskler taşımaktadır. Bu nedenle yüzme havuzu suyunun fiziksel, kimyasal ve biyolojik parametreler açısından istenilen standartları karşılaması ve sağlıklı ve güvenli yüzme koşullarının sağlanması için düzenli olarak izlenmesi büyük önem taşımaktadır. Ülkemizde yüzme havuzu suyu standartları Sağlık Bakanlığı tarafından belirlenen yönetmeliklere göre belirlenmektedir. Bu standartları korumak için havuz suyu dezenfektanları, pH düşürücüler, çöktürücüler, parlatıcılar ve yosun inhibitörleri gibi çeşitli havuz kimyasallarına ihtiyaç duyulmaktadır. Çalışmamızın amacı, bu kimyasalların özelliklerini tek bir üründe birleştiren teknolojik bir yenilik olan multifonksiyonel bir tablet formülasyonu geliştirmektir. Bu hedefe ulaşmak için kalsiyum hipoklorit, trikloroizosiyanürik asit ve sodyum dikloroizosiyanürat gibi dezenfektanlar içeren yeni formülasyonlar üzerinde fiziksel ve bakterisidal testler yapılmıştır. Geliştirilen çok işlevli tablet formülasyonları, yüzme havuzu suyu kalitesi için gereken standartları karşılamak ve aşmak için etkili bir çözüm sunmaktadır.

Anahtar Kelimeler: *Dezenfeksiyon, Formülasyon, Çok İşlevli Tablet, Yüzme Havuzu*

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I. INTRODUCTION

Swimming pools are environments where many people come into direct contact with water [1]. This condition contributes to the emergence and spread of certain infectious diseases facilitated by water contact. Maintaining a healthy and safe environment in swimming pools has become increasingly important with the rise in the number of users [2]. The Ministry of Health has established standards on various issues such as hygiene and disinfection methods by publishing regulations in the official gazette, outlining the principles to which swimming pools must adhere [3]. Various pool chemicals are used to maintain these standards at the determined level. These include liquid chlorine for pool disinfection, anti-algae agents, clarifiers to improve water clarity, precipitators to settle suspended and contaminating particles, and pH regulators to adjust the pool's pH value. The variety of chemicals reflects the potential for conducting various studies to optimize pool water management. However, there is a gap in the literature in this area, with most studies focusing on by-products that are predominantly formed in swimming pools [4].

Chlorine is widely used to prevent contamination in pool waters [5]–[9]. This disinfection method provides a rapid and long-lasting bacteriological effect with the least possible potential for the formation of by-products in swimming pools [10].

Chlorine added to pool waters reacts primarily with water and turns into hydrochloric acid (HCl) and hypochlorous acid (HOCl) (Eqn.1) [11].

$$Cl_2 + H_2O \longrightarrow HCl + HOCl \tag{1}$$

It is hypochlorous acid that reacts with the pollutants in the pool and kills them. This acid is called free chlorine [9]. Free chlorine has the ability to neutralize microorganisms such as bacteria, viruses, algae, and react with organic matter [12]. With this feature, it ensures that the water is hygienic and safe. Before the chlorination process, the pH of the pool should be brought to the range of 7.2-7.8, which are the established standards. Otherwise, chlorine delivered at a high pH cannot be converted into hypochlorous acid sufficiently for the oxidation and disinfection of organic substances. Chlorine, which is given to water in this reaction, is very dangerous in gaseous form [11].

Table 1. *pH and free chlorine ratios of chlorine products.*

Type of Chlorine	**Free Chlorine Ratio, %**	**pH**	**The free chlorine rate when 1 kg is added to 100 Tons of water (mg/L, ppm)***
Sodium Hypochlorite (Liquid Chlorine)	10	14	1
Lithium Hypochlorite	35	11	3
Calcium Hypochlorite	65	12	7
Dichloroisocyanuric acid ($C_3Cl_2N_3NaO_3$)	56	6.5-7.5	6-9
Trichloroisocyanuric acid ($C_3Cl_3N_3O_3$) (TClCA)	90	6.5-7.5	6-9

*After 1 kg of product, free chlorine should be measured at least 4 hours later.

Chlorine in gas form (Cl_2) reacts with water 100%, sodium hypochlorite in liquid form (NaClO) reacts with water 10%, lithium hypochlorite in powder form (LiClO) 35%, calcium hypochlorite ($Ca(ClO)_2$) 65%, stabilized sodium dichloroisocyanuric acid ($C_3Cl_2N_3NaO_3$) 56%, stabilized trichloroisocyanuric acid ($C_3Cl_3N_3O_3$) provides 90% free chlorine (Table 1) [13]. The content of stabilized chlorins contains cyanuric acid, also known as a stabilizer. For this reason, free chlorine has anti-breakdown effects by sunlight [7]. It is used only in outdoor pools. According to the regulation published by the Ministry of

Health on the supervision of swimming pools, the amount of free chlorine should be in the range of 1-1.5 mg/L in indoor pools and 1-3 mg/L in outdoor pools (Table 2).
The preference for gas chlorine has decreased over the years due to the difficulties in application and toxic properties, while liquid chlorine has low chlorine content, transportation, and application problems. In recent years, chlorine products in powder or granular form have come to the fore. Solid chlorine products have many advantages such as ease of transportation, shelf life, stability, and easy application.

Table 2. *The chemical properties of chlorinated compounds (Attachment 1).*

Parameter	**Analysis Range**	**Unit**	**Limit Values**	
			Minimum	**Most**
Cyanuric acid(1)	Once a month	mg/L	-	100
Biguanid (2)			2	30
Hidrojen Peroksid (2)			40	80
pH (2)			6.5	7.8
Ammonium(2)				0.5
Nitrite				0.5
Nitrate				50
Copper				1
Aluminium				0.2
Total alkalinity (2) ($CaCO_3$)			30	180
Chlorine bound (3)				0.2
Indoor swimming pool water free chlorine (3)			1	1.5
Outdoor swimming pool water free chlorine (3)			1	3
Free chlorine (4)			0.3	0.6

(1) It is monitored in pools where chlorine compounds with stabilizers are used for water disinfection.
(2) If "hydrogen peroxide + biguanide" is used for water disinfection, hydrogen peroxide should be in the range of 40-80 ppm. In this case, a pH of 8.2, ammonium at 1.5 ppm, and total alkalinity up to a level of 220 ppm are considered appropriate. In these pools, free chlorine measurement is not conducted; instead, hydrogen peroxide and biguanide levels are measured.
(3) It is monitored in pools where chlorine and chlorinated compounds are used for water disinfection.
(4) It is the level to be monitored in pools where ozone, UV, chlorine dioxide, and other disinfection systems are used for water disinfection.

In Turkey, liquid chlorine is produced in liquid form and serves as a precipitant, algaecide, pH regulator, brightener, and disinfectant. However, chemicals in solid form that provide these properties are not produced. In the literature, sodium hypochlorite is commonly used for disinfection, polyaluminum chloride for precipitation, didecyldimethylammonium chloride as an algaecide, and polydadmac as a brightener. The primary market for pool chemicals in powder and tablet form is China.
The chemical, physical, and microbiological properties of pool water are indicators of water quality. Water temperature, turbidity, color, and odor are important factors (Table 3). Chemical properties include both organic and inorganic parameters as regulated (Table 2).

Table 3. *The physical properties of chlorinated compounds (Attachment 2).*

Parameter	**Analysis Range**	**Desired Value**		
Color	Once a month	10 units in Pt/Co		
Blur	Once a month	5 units in SiO_2 or Jackson units or 0.5 units in NTU or FNU		
Temperature [(1)]	Once a month		**Minimum**	**Most**
		Indoor pool	26 ºC	28 ºC
		Outdoor pool	26 ºC	38 ºC

(1) Temperature measurement is carried out at the pool area.

Microbiological quality assessment in pool water is based on indicators such as total colony count, total coliform bacteria count, presence of *P. aeruginosa, L. pneumophila, E. coli,* and *E. faecium* from *Enterococci*, as well as *S. aureus* from the Staphylococci family [14]. These bacteria are typically of human origin and can cause various diseases [13]. The total number of colonies is determined by counting the colonies formed at 36°C and 22°C. This helps to assess the pollution status of the water and whether the applied disinfectant dose is sufficient for pollution control. According to regulations, the total number of aerobic heterotrophic bacteria in pools should be $\leq$ 200 kob/mL (Table 4). The number of these bacteria may increase when there are a large number of swimmers in the pool or when there are deviations in water parameters such as chlorine, temperature, pH, alkalinity, conductivity, and total dissolved solids [11].

The coliform group consists of bacteria from the Enterobacteriaceae family. The total number of coliform bacteria is a reliable indicator of water quality. Coliform bacteria can be found in the human and animal intestines, as well as in the environment, and can indicate potential fecal contamination. This group of bacteria includes species from the genera *Escherichia, Citrobacter, Enterobacter, Klebsiella,* and *Serratia* [15].

The majority of *Enterococci* are of fecal origin, and their presence in water has long been central to water microbiology as an indicator of fecal contamination [16]-[19]. Among *Enterococci, E. coli* can cause clinical infections such as urinary tract infections and meningitis, and some studies have shown a direct correlation between gastrointestinal diseases and *E. coli* [20]. *E. coli* is an organism known to be very sensitive to free chlorine [21].

Table 4. *The microbiological properties of chlorinated compounds (Attachment 3).*

Parameter	**Recommended Method[(1)]**	**Analysis Range[(2)]**	**Limit Values**
Total number of colonies (germs)	TS EN ISO 6222	Once a month	200 CFU[(3)] /mL
Total coliform bacteria	TS EN ISO 9308-1		0/100 mL
Escherichia coli	TS EN ISO 9308-1		0/100 mL
Pseudomonas aeruginosa	TS EN ISO 16266		0/100 mL

(1) Laboratories may use another method other than the recommended method, provided that they show references.
(2) The analysis range should be twice a month during periods of intensive swimming pool use.
(3) CFU Colony Forming Unit.

It has also been observed that swimming-related illnesses are caused by waterborne pathogens such as *E. faecium* and *E. faecalis* [19]. *L. pneumophila* is the most pathogenic species among Legionella species and can cause upper respiratory tract infections that may result in death. As the temperature rises above 25°C and organic substances reduce the effectiveness of disinfection, Legionella bacteria have a higher

chance of survival in pool water and can easily enter the body through the respiratory tract during swimming [11]. A free chlorine level of 1.5-2.0 mg/L is sufficient to control this organism [13].
P. aeruginosa is the most resistant thermophilic bacterium among these bacteria and is more resistant to disinfectants. It causes various diseases, including urinary tract infections, pneumonia, otitis media, and gastrointestinal infections [4], [22]–[24]. According to a study of waterborne diseases conducted in the United States between 1999 and 2008, *P. aeruginosa* has been identified as the second most common pathogenic microorganism [22].
Another group of bacteria commonly found in swimming pools is Staphylococci. These bacteria are from the skin, oral cavity, and nasal passages of swimmers. The *S. aureus* bacterium can cause serious skin infections as well as respiratory tract infections. Relatively low levels of free chlorine (<1.0 mg/L) are sufficient to neutralize this group of bacteria [13].

In our study, the aim is to develop a multifunctional swimming pool water chemical in tablet form by combining disinfectants, flocculants, clarifiers, and pH balancers used separately in swimming pools into a single formula.

II. MATERIALS AND METHODS

Materials
The tablets have been pressed on a Prism Pharma Machinery branded PTCMD4-16 model machine.
Eleven types of chemicals were used for the developed tablet formulation. Palm oil, sodium dichloroisocyanurate ($C_3Cl_2N_3NaO_3$), trichloroisocyanuric acid (99%) ($C_3Cl_3N_3O_3$), sodium chloride (NaCl), sodium carbonate (Na_2CO_3), microcrystalline cellulose (MCC), alginic acid, calcium hypochlorite ($Ca(ClO)_2$), technical grade magnesium stereat ($Mg(C_{18}H_{35}O_2)_2$), sodium aluminate ($NaAlO_2$), sodium carboxymethyl cellulose (CMC) were obtained and used without purification.
In the subsequent experiments, a Tess brand digital balance was used to add raw materials in the quantities we determined, and an Emir brand grinding machine was used to mix and homogenize these raw materials.
Various preliminary analyses were carried out to determine the efficacy of the formulations obtained. Wtw pH meter, conductivity meter, temperature meter and Merck portable free chlorine meter were used in these analyses. The pH meter helped us determine the pH level that the formulation should have by measuring the acidic or basic properties of the solution. The conductivity meter evaluated the distribution of the components of the formulation in solution by measuring the electrical conductivity of the solution. The temperature meter allowed us to perform the experiments at a consistent temperature.
Finally, the amount of free chlorine in the formulation was determined using a portable free chlorine meter. These measurements helped us to verify the efficacy and assess the quality of the formulation.

Methods
Creation of Formulations
The formulations developed in our study are based on carefully defined criteria aimed at improving pool water quality and meeting hygiene standards. Among these criteria, the selection of chemicals that do not react with each other and the solid form of the chemical are prioritized, as well as the free chlorine content. Other disinfection materials mentioned in the literature were not utilized due to their low free chlorine content and the fact that most of them are in liquid form. Consequently, 9 formulations were developed in this direction.

1. **Formulation:** 80-85% $Ca(ClO)_2$, 7-10% $NaAlO_2$, 3-5% Na_2CO_3, 7-10% NaCl were taken and homogeneous powder form was obtained in a grinder at 1500 rpm.
2. **Formulation:** $Ca(ClO)_2$ in the range of 80-85%, $NaAlO_2$ in the range of 7-10%, Na_2CO_3 in the range of 2-4%, NaCl in the range of 6-8%, palm oil in the range of 1-3%, $Mg(C_{18}H_{35}O_2)_2$ in the range of 1-3% was taken and a homogeneous powder formula was obtained in the grinder at 1500 rpm.
3. **Formulation:** $Ca(ClO)_2$ in the range of 80-85%, $NaAlO_2$ in the range of 7-10%, Na_2CO_3 in the range of 1-3%, NaCl in the range of 2-4%, palm oil in the range of 1-3%, $Mg(C_{18}H_{35}O_2)_2$ in the

range of 1-3%, CMC in the range of 3-6% was taken and a homogeneous powder form was obtained in the grinder at 1500 rpm.

4. **Formulation:** $Ca(ClO)_2$ in the range of 80-85%, $NaAlO_2$ in the range of 7-10%, Na_2CO_3 in the range of 1-3%, NaCl in the range of 2-4%, palm oil in the range of 1-3%, $Mg(C_{18}H_{35}O_2)_2$ in the range of 1-3%, MCC in the range of 3-6% was taken and a homogeneous powder form was obtained in the grinder at 1500 rpm.
5. **Formulation:** $Ca(ClO)_2$ in the range of 80-85%, $NaAlO_2$ in the range of 7-10%, Na_2CO_3 in the range of 2-4%, NaCl in the range of 4-6%, palm oil in the range of 1-3%, $Mg(C_{18}H_{35}O_2)_2$ in the range of 1-3%, alginic acid in the range of 2-5% was taken and a homogeneous powder form was obtained in the grinder at 1500 rpm.
6. **Formulation:** $Ca(ClO)_2$ in the range of 80-85%, $NaAlO_2$ in the range of 7-10%, Na_2CO_3 in the range of 3-5%, NaCl in the range of 6-8%, palm oil in the range of 1-3% were taken and formed into homogeneous powder in the grinder at 1500 rpm. Was obtained.
7. **Formulation:** $Ca(ClO)_2$ in the range of 80-85%, $NaAlO_2$ in the range of 7-10%, Na_2CO_3 in the range of 3-5%, NaCl in the range of 6-8%, palm oil in the range of 1-3%, $Mg(C_{18}H_{35}O_2)_2$ in the range of 1-3% and a homogeneous powder form was obtained in the grinder at 1500 rpm.
8. **Formulation:** $C_3Cl_3N_3O_3$ in the range of 80-85%, $NaAlO_2$ in the range of 9-11%, Na_2CO_3 in the range of 3-5%, NaCl in the range of 6-8% were taken and a homogeneous powder form was obtained in the grinder at 1500 rpm.
9. **Formulation:** $C_3Cl_2N_3NaO_3$ in the range of 80-85%, $NaAlO_2$ in the range of 5-8%, Na_2CO_3 in the range of 3-5%, NaCl in the range of 6-8% were taken and a homogeneous powder form was obtained in the grinder at 1500 rpm.

The Production of Tablets

Through the main electric motor of the machine, the operating pressure has been set to 10 tons. The upper punch penetration has been adjusted to 6. The optimizations made are crucial stages for achieving the desired dimensions of the tablet. Tablet compressions were carried out with a formulation pulverized into powder at 1500 rpm through a force feeder motor with a power of 0.25 hp/0.18 kW, with tablet diameters of 25 mm and a filling depth of 20 mm (Figure 1).

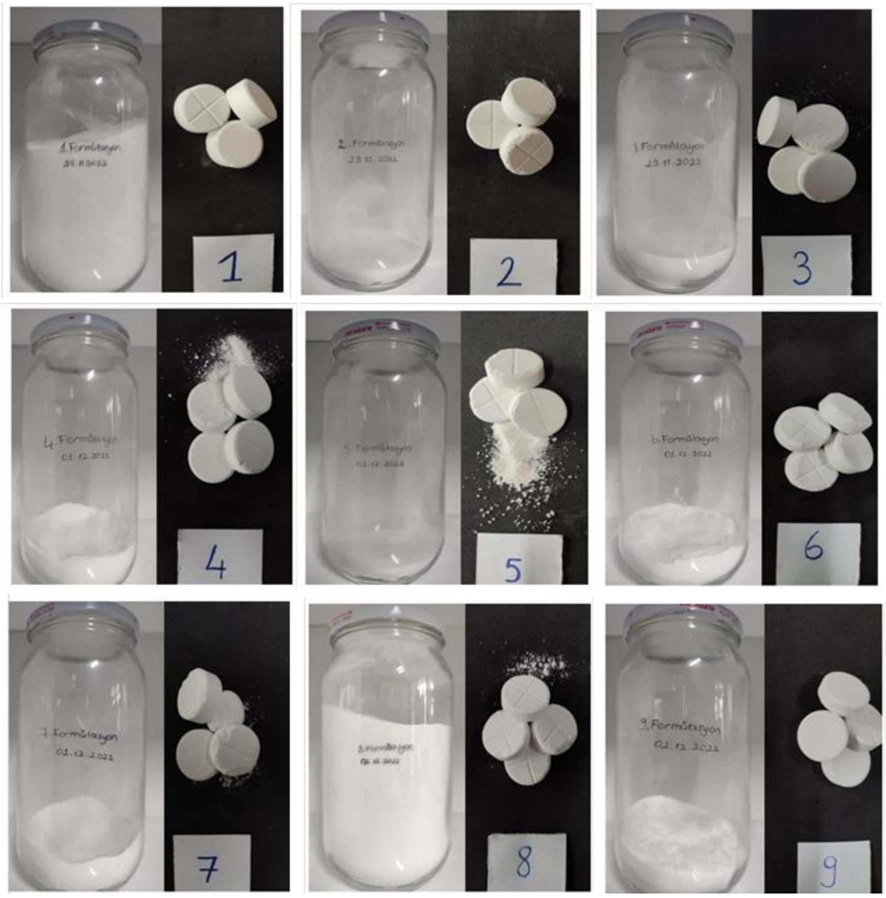

Fig. 1. Powder and tablet forms of multifunctional tablet formulations.

pH, Conductivity, Free Chlorine and Temperature Measurement

The formulations, prepared with free chlorine sources ranging from 80% to 85%, were dissolved in 2 liters of distilled water to theoretically provide free chlorine within the range of 1-2 ppm. pH, conductivity, free chlorine, and temperature measurements were conducted. For formulations 1-7, 0.005 gram of $Ca(ClO)_2$ was added to 2 liters of distilled water, while for the 8th formulation, 0.0041 gram of $C_3Cl_3N_3O_3$, and for the 9th formulation, 0.0066 gram of $C_3Cl_2N_3NaO_3$, were added.

Physical, Chemical and Microbiological Tests

All tests in Table 6 were conducted in an accredited laboratory with TURKAK accreditation. Sensory characteristics such as color, odor, and turbidity were assessed using organoleptic methods. Coliform enumeration was performed according to TS EN ISO 9308-1, enterococci enumeration according to TS EN ISO 7899-2, Escherichia coli enumeration according to TS EN ISO 9308-1, and sulfite-reducing anaerobic bacteria (Clostridia) enumeration according to TS 8020 EN 26461-2. Arsenic, iron, and aluminum analysis were conducted according to EPA 200.8.

Microbiological Analysis of Multifunctional Tablet Formulations

All tests in Table 7 were conducted in an accredited laboratory with IAS accreditation. Enterococcus faecium testing was performed according to ISO 7899, Pseudomonas aeruginosa testing according to ISO 22717, Legionella pneumophila testing according to ISO 11731, Staphylococcus aureus testing according to ISO 22718, and Escherichia coli testing according to ISO 21150.

III. RESULTS AND DISCUSSION

Our aim in this study is to introduce a multifunctional tablet formulation, a technological product offering numerous benefits to industries and consumers. The multifunctional tablet combines precipitating, brightening, pH-regulating, anti-algae, and decontamination properties. Through production modification, many advantages such as easy transportation, storage, packaging, long shelf life, and controlled active substance release can be achieved. The formulations were developed based on the chemicals and chemical ratios specified by the Ministry of Health for use in swimming pools. Calcium hypochlorite, trichloroisocyanuric acid, and sodium dichloroisocyanuric acid were separately used for disinfection, which also possess anti-algae properties. Sodium aluminate served as a precipitant and brightener, while sodium carbonate and sodium chloride acted as pH stabilizers. Additional components included palm oil for particle adhesion, magnesium stearate, alginic acid, and sodium carboxymethyl cellulose for tablet printing.

During formulation development, combinations of chemicals with desired properties that do not react with each other were preferred, considering the amount of chlorine released into the environment after dissolution in water. This is crucial for enhancing formulation stability and controlling interactions in pool water. The compatibility of selected chemicals and their desired properties ensure the long-term effectiveness of the formulations, minimizing unwanted reactions in pool water.

The formulations we have developed are based on the 200 grams tablet form of chlorine, which is widely used globally. This standard form facilitates practical, effective, and reliable use of chlorine tablets. Since tablets of this size are not produced in Turkey and are imported, our modified formulations have the potential to capture more market share in the sector due to the advantages they offer.

The physical, chemical, and biological quality of water in swimming pools is paramount for public health. Therefore, compliance with hygienic conditions and water quality standards is determined by the Ministry of Health through regulations such as the Regulation on the Health Principles to be Subject to Swimming Pools in our country (T.C. Official Gazette, Issue: 28143, December 15, 2011, Attachment 1-3) and the Regulation on the Working Procedures and Principles of Laboratories for Public Health Services (T.C. Official Gazette, Issue: 30709, March 9, 2019) [25].

Tests conducted in accredited laboratories for the formulations developed in this direction include physical, chemical, microbiological, bactericidal, virucidal, first-day analysis, antibacterial, and fungal analyses. These tests were carried out through service procurement. Prior to the accreditation process, preliminary analyses such as pH, conductivity, free chlorine, and temperature tests were performed in our own laboratory (Table 5).

Table 5. *Preliminary analysis results of multifunctional tablet formulations.*

Sample Name	**Measuring Range**	**pH**	**Conductivity (µS/cm)**	**Temperature (°C)**	**Free Chlorine (ppm)**
Pure Water	-	6.40	4.7	14.7	0
1.Formulation	0th hour	6.77	13.2	16	0.71
	1st hour	6.78	6.4	17.5	0.61
	2nd hour	6.85	14.7	18.5	0.42
	4th hour	6.81	15.2	18.9	0.35
2.Formulation	0th hour	6.94	11.4	16.1	1.64
	1st hour	7.03	12.2	17.5	1.49
	2nd hour	7.03	12.5	18.2	1.47
	4th hour	7.02	12.8	18.9	1.33

3.Formulation	0th hour	6.43	14.3	16.3	0.03
	1st hour	6.57	14.9	17.5	0.02
	2nd hour	6.63	17.4	18.2	0.06
	4th hour	6.66	16.7	18.8	0.04
4.Formulation	0th hour	6.44	8.1	19	0
	1st hour	6.47	8.7	18.8	0.06
	2nd hour	6.44	9.1	18.9	0.02
	4th hour	6.45	10	19.5	0.04
5.Formulation	0th hour	6.45	9.7	18.8	0.1
	1st hour	6.44	9.5	18.9	0.05
	2nd hour	6.48	9.7	19	0.04
	4th hour	6.51	9.9	19.2	0.04
6.Formulation	0th hour	6.39	10.5	19	0.03
	1st hour	6.46	10.6	19	0.06
	2nd hour	6.44	10.8	19	0.02
	4th hour	6.44	11.2	19.5	0.05
7.Formulation	0th hour	5.93	4.6	18.1	0.09
	1st hour	6	5.1	19	0.06
	2nd hour	6.01	5.2	19.7	0.04
	4th hour	6.27	6	20.1	0.04
8.Formulation	0th hour	6.28	11.7	18.5	2.23
	1st hour	6.3	12.1	19.2	2.18
	2nd hour	6.27	12.1	19.8	1.92
	4th hour	6.33	12.3	20	2.04
9.Formulation	0th hour	6.06	7.8	18.3	0.3
	1st hour	6.07	7.9	19.4	0.23
	2nd hour	6.04	8	19.9	0.13
	4th hour	5.99	8	20.2	0.11

The effectiveness of disinfection relies on several factors including the chlorine dosage, water temperature, contact time, and ambient pH. Therefore, physical and chemical parameters such as free chlorine, temperature, pH, and conductivity in pool water serve as indicators to determine the healthiness of pools. The pH value of water indicates its acidity or alkalinity [1], with the pH level in pool waters considered appropriate between 6.5 and 7.8. Conductivity in pool water measures the electrical conductivity of ions in solution, typically expressed in microsiemens per centimeter (µS/cm) [2].

Table 6. *Physical, chemical and microbiological tests.*

The parameters analyzed	**Unit**	**Formulation (1-9)**
Color	-	White
Smell	-	Characterization
Appearance	-	Solid
Blur	-	Detected
Coliform Census	kob/100 mL	0
Enterococcus Census	kob/100 mL	0
Escheria Coli Count	kob/100 mL	0
Sulfite-Reducing Anaerobic Bacteria (Clostridia) Count	kob/100 mL	0
Determination of Arsenic	µg/L	Not Detected

Determination of Iron	µg/L	Not Detected
Determination of Aluminum	µg/L	Not Detected

Tests for each formulation were conducted by adding the calculated sample amounts to 2 liters of distilled water. During the calculation, the required amount of free chlorine, ranging from 1 to 1.5 mg/L for indoor pools and 1 to 3 mg/L for outdoor pools per 100 m3 of water, was considered [25]. Measurements were taken initially in distilled water and then at subsequent intervals after adding the sample, specifically at the first, second, and fourth hours. Repeated measurements enabled the observation of any variations in the water. As shown in Table 5, it is evident that the ratio of free chlorine decreases as pH and temperature increase for the measured values of formulations 1-9, illustrating the impact of pH and temperature on free chlorine.

Table 6 presents the parameters common to the physical, chemical, and microbiological tests conducted in the accredited laboratory for the 9 formulations. According to the results, the active substance in all formulations is granular chlorine, with a white color and a distinct chlorine odor dominating the smell. The presence of iron in pool water can lead to water hardness and discoloration [4]. Arsenic is considered an undesirable heavy metal in pool water due to its toxic effects on human health. Aluminum ions form strong complex ions with organic matter, sulfate, and fluoride, contributing to water hardness and corrosion. Therefore, their presence in water is undesirable, and salts of aluminum are often used to address water color and turbidity [26]. Sodium aluminate, in salt form, was included in the formulation for its precipitating and brightening effects. The heavy metals arsenic, iron, and aluminum were not detected in the formulations, meeting the standards required by regulations. Arsenic, iron, and aluminum were analyzed by ICP-OES, and none were observed in any of the formulations.

Table 7. *Microbiological analysis of multifunctional tablet formulations*

Microorganisms	**Formulation**				
	1	**2**	**7**	**8**	**9**
Enterococcus faecium	*	*	*	*	*
Pseudomonas aeruginosa	*	*	*	*	*
Legionella pneumophila	*	*	*	*	*
Staphylococcus aureus	*	*	*	*	*
Escherichia coli	*	*	*	*	*
Streptococcus uberis	*	*	*	*	*
Enterococcus hirae	*	*	*	*	*

* Appropriate, the unit cfu/g was used.

The bacteria analyzed included *E. faecium, P. aeruginosa, L. pneumophila, S. aureus, E. coli, S. uberis,* and *E. hirae* (Table 7). In the first, second, and seventh formulations, the preliminary analysis results were very similar in terms of appearance and tablet durability. However, for the eighth and ninth formulations, bactericidal tests were preferred due to the use of different chlorine providers in these formulations. Therefore, these formulations were prioritized for bactericidal testing.

In order for formulations to be suitable for use in swimming pools, they should be free from *E. faecium, P. aeruginosa, L. pneumophila, S. aureus,* and *E. coli* bacteria. According to the results, these bacteria were not detected in the formulations. The suitability of these formulations for *E. coli, E. faecium,* and *P. aeruginosa* indicates their potential for use as bactericidal agents in drinking water disinfection. Similarly, the presence of *S. aureus, P. aeruginosa, E. coli, S. uberis,* and *E. hirae* bacteria suggests the potential use of these formulations as disinfectants in the veterinary field, as well as for surface disinfection and in food and feed areas. These formulations can be further modified for use in these specific areas.

IV. CONCLUSION

In our study, we developed a multifunctional tablet designed to serve as a comprehensive pool water chemical, combining disinfection, precipitant, polishing, and pH balancing properties. To achieve this, we formulated 9 different compositions using calcium hypochlorite, trichloroisocyanuric acid, and sodium dichloroisocyanurate compounds as the main ingredients. To assess the efficacy of these formulations, we conducted a series of physical, chemical, microbiological, and bactericidal analyses as required by the Ministry of Health.

For each formulation, we measured pH, conductivity, temperature, and free chlorine levels. Additionally, we conducted tests for color, odor, appearance, turbidity, coliform, enterococci, *Escherichia coli* count, sulfite-reducing anaerobic bacteria (Clostridia) count, as well as determinations for arsenic, iron, and aluminum. After converting all formulations into 17-gram tablet forms through procurement services, we examined their physical structures. Bactericidal tests were specifically conducted for Formulations 1, 2, 7, 8, and 9, considering both their physical characteristics and chemical compositions.

The results of our analyses indicated that all measurement outcomes fell within the legal limits stipulated by regulatory standards. This technological product offers a myriad of benefits for pool owners, operators, and users by providing an effective amalgamation of various chemicals. Furthermore, the formulations' compliance with the Ministry of Health standards enhances the product's marketability, establishing it as a reliable option within the industry.

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