International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
Vol. 49 No. 1 February 2025, pp. 239-244

Experimental Study Of The Effect Of Chlorine In Drinking Water Flow On Astm A53 Black Steel Pipe Walls

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Abstract – This study investigates the corrosion rate of black steel pipes (ASTM A53) used in drinking water distribution systems when exposed to chlorinated water over varying immersion times. The research aimed to analyze the impact of chlorine on the corrosion behavior and mechanical properties of black steel pipes. The methodology involved preparing pipe specimens, which were cut, smoothed, and weighed before immersion in a chlorine solution (200 mg in 5 liters of distilled water) with controlled pH levels. The specimens were submerged for 24, 48, 72, 96, 120, and 144 hours, with flow rates maintained at 0.625 L/min. Corrosion rates were assessed based on weight loss measurements before and after exposure. The results showed a progressive decrease in specimen weight from 73.5873 grams to 64.4786 grams as immersion time increased, indicating significant material degradation. The pH of the solution also increased from 6 to 7–8, suggesting chemical reactions during corrosion. These findings highlight the role of chlorine concentration, flow capacity, and pH changes in accelerating corrosion, emphasizing the need for water quality management to enhance the durability of piping systems.

Keywords – Corrosion Rate, Black Steel Pipes, Chlorinated Water, Drinking Water Distribution.

I. INTRODUCTION

The development of piping systems has played a crucial role in human civilization, enabling the efficient transportation of fluids across various sectors. In drinking water distribution networks, black steel pipes (ASTM A53) are essential for ensuring the health and safety of urban and rural populations. These systems are designed and operated to provide clean water to consumers and prevent waterborne disease outbreaks (Waving, 2014). Piping systems are fundamental infrastructure components, as they facilitate the continuous flow of clean water to communities. Without pipelines, the distribution of water would be highly inefficient. Pipes are extensively used in households, small industries, and large-scale industrial applications, with varying diameters to accommodate different flow requirements. However, during their operation, energy losses frequently occur within the system. Understanding these energy losses, which are primarily due to fluid friction against the pipe walls, is essential for optimizing energy efficiency in fluid transport systems (Rochani, 2012).

Pipes are defined as hollow cylindrical structures with openings at both ends, designed to transport fluids—both liquids and gases—from one location to another. Historically, pipes were developed to address the challenges of transporting water over long distances, eliminating the need for manual water carriage. This innovation significantly improved the efficiency of water distribution systems (Aji, 2010). Black steel pipes used in drinking water installations are susceptible to corrosion due to the presence of chlorine compounds. Corrosion is a common degradation process in carbon steel materials, leading to structural damage, reduced mechanical integrity, and premature material failure. Factors influencing corrosion include the presence of ions, temperature variations, and dissolved gases (Pratama, 2016). According to the Indonesian Ministry of Health Regulation No. 472/Menkes/Per/V/1996, chlorine is classified as a chemical and biological substance that can pose health and environmental risks, either directly or indirectly. Chlorine exhibits toxic, carcinogenic, teratogenic, mutagenic, and corrosive properties (Meryalinda, 2014).

Given these concerns, this study aims to investigate the corrosion rate of black steel pipes (ASTM A53) when exposed to chlorinated water under varying immersion times. The purpose of this research is to analyze the effect of chlorine in drinking water on the corrosion behavior and mechanical properties of black steel pipes (ASTM A53), providing insights into the durability and performance of piping systems in drinking water networks.

II. Material and Method

The equipment and materials used in this study included sandpaper with grit numbers #400, 800, 1200, 1500, and 2000, which were utilized to smooth and clean the surface of the black steel. Beaker glasses were employed to measure the chlorine and water used for immersing the black steel specimens. Additionally, a handheld grinder was used to cut the black steel specimens to the required dimensions. Chlorine, a hazardous chemical compound commonly used for disinfection, was used in this study at a concentration of 200 mg. The specimens consisted of black steel pipes with a length of 30 cm, cut into five sections for testing purposes. The experimental design included multiple testing stages, as shown in Table 3.3. The tests involved exposing black steel pipe specimens to chlorine solutions with varying immersion times of 24, 48, 72, 96, 120, and 144 hours. The flow rate was maintained at 0.625 L/min, and parameters such as pH and specimen weight were measured before and after exposure.

The testing process began with the preparation of specimens, which were cut to a length of 20 mm and a width of 25 mm using a metal saw, resulting in pipe-shaped samples. These specimens were then smoothed using #240 sandpaper to ensure uniform surface conditions. Initial weight measurements of the specimens were recorded before exposure to the chlorine solution. The solution was prepared by mixing 5 liters of distilled water with 200 grams of chlorine, and the pH was measured using a pH meter to ensure consistency. After preparation, the specimens were immersed in the chlorine solution, and their weights were measured at specified intervals (24, 48, 72, 96, 120, and 144 hours) to assess the degree of corrosion. The steps involved in the testing procedure included preparing the necessary equipment, securing the specimens with a vise, cutting the specimens to the designated size, smoothing the inner surfaces with sandpaper, and recording the initial weights. The specimens were then immersed in the chlorine solution, and the pH was monitored. After the designated exposure times, the specimens were removed, dried, and their final weights were recorded to determine the extent of corrosion based on weight loss.

III. RESULTS and discussion

Based on the results of the flow capacity measurements listed in Table 1, the flow capacity values obtained ranged from 5.00 to 7.50 liters per minute with an average of 6.50 l/minute. The highest flow capacity value was achieved at a shorter measurement time (0.033 minutes), while the flow capacity decreased when the measurement time was longer (0.050 minutes). This shows that the flow rate is highly dependent on the duration of the measurement time, where the flow tends to be more stable at shorter times. This variation can be caused by pressure fluctuations or non-uniformity in the measurement process. Furthermore, the corrosion test data on carbon steel pipe specimens showed a decrease in specimen weight as the immersion time in chlorine solution increased. In the first test to the sixth test, there was a decrease in weight from 73.5873 grams to 64.4786 grams after 144 hours. This decrease in weight indicates a significant corrosion rate, which indicates that chlorine has an effect on the degradation of pipe material. The increase in pH from 6 to 7-8 also indicates a chemical reaction that affects the properties of the solution during the process.

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Table 1. Flow Capacity Measurement Results

Measurement to	Flow Volume (liters)	Measurement Time (minutes)	Flow Capacity (l/min)
1	0.25	0.033	7.50
2	0.25	0.033	7.50
3	0.25	0.033	7.50
4	0.25	0.050	5.00
5	0.25	0.050	5.00
	Average		6.50

The change in solution pH from the initial condition (pH 6) to the final condition (pH 7-8) shows that the corrosion process not only causes mass loss in the specimen, but also changes the chemical characteristics of the solution. This can be caused by the release of metal ions into the solution, which contributes to the change in pH. The increase in pH tends to occur due to the formation of hydroxide compounds as a result of the reaction between metal ions and water, which reduces the acidity of the solution. Overall, these results indicate that the corrosion rate of carbon steel pipes is quite significant in a chlorine-containing environment, especially with longer exposure times. Factors such as flow capacity, chlorine concentration, and changes in solution pH play an important role in determining the corrosion rate. These findings provide an illustration that water quality control, including regulating chlorine and pH levels, is very important to reduce the risk of pipe damage in drinking water distribution systems.

Table 2. Flow Capacity Test Result Data

Measurement to	Q/t (l/men)	Specimen	Solution		Time (hour)	pH of Solution		Specimen Weight	
			Klorin (mg)	Aquadest (lit)		Beginning	End	Beginning (gr)	End (gr)
1	6.5	Carbon Steel Pipe: Do = Di = t =	200	5	24	6	7	73.5873	73.45
2					48	6	7		71.43
3					72	6	7		68.99
4					96	6	7		65.92
5					120	6	8		65.59
6					144	6	8		64.48

Based on the data in Table 2, it can be seen that there is a decrease in the weight of the carbon steel pipe specimen as the immersion time in the chlorine solution increases. In the first 24 hours, the weight loss is still relatively small, which is 0.1376 grams. However, after 48 hours, there is a significant increase in weight loss to 2.163 grams. This indicates that the corrosion process begins to take place more actively after the initial period, possibly due to the formation of an oxide layer that begins to degrade, thus accelerating the corrosion rate.

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https://ijpsat.org/
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Table 2. Weight Loss With Time Variation

Time (Hours)	Time (Hours)	Time (Hours)	Time (Hours)
24 hours	73.5873 g	73.4497 g	0.1376 g
48 hours	73.5873 g	71.4243 g	2.163 g
72 hours	73.5873 g	68.9902 g	4.5971 g
96 hours	73.5873 g	65.9179 g	7.6694 g
120 hours	73.5873 g	65.5877 g	7.996 g
144 hours	73.5873 g	64.4786 g	9.1084 g

As time goes by, the rate of weight loss increases. At 72 hours, the weight loss reaches 4.5971 grams, indicating that the corrosion reaction is taking place more intensively. This phenomenon can be explained by the accumulation of corrosive ions around the pipe surface which accelerates the material degradation process. In addition, the corrosive nature of chlorine which is able to penetrate the protective oxide layer on carbon steel also accelerates the corrosion process, making the material more susceptible to weathering. However, in the period from 96 to 144 hours, although the weight loss continues to increase, the rate of increase appears to be slowing down.

Table 3. Pipe image and its changes based on time variation

time variation	pipe section before testing	pipe section after top test	pipe section after bottom test
24 hours			
48 hours			

72 hours			
96 hours			
120 hours			
144 hours			

The weight loss at 96 hours was 7.6694 grams, then to 7.996 grams at 120 hours, and finally 9.1084 grams at 144 hours. This decrease in corrosion rate could be caused by the formation of a passive corrosion layer (such as rust deposits) that prevents direct contact between the pipe surface and the corrosive solution. This layer, although fragile, can provide temporary protection against further attacks. Overall, these results indicate that corrosion of carbon steel pipes in chlorine solution is progressive with a high rate at the beginning of exposure, then tends to slow down after a longer immersion time. This phenomenon is important to consider in the management of drinking water distribution systems, especially in controlling chlorine levels and conducting regular monitoring of pipe conditions to prevent more severe damage.

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