การพัฒนาเนื้อเซรามิกชนิดไฮ-อะลูมิน่า สำหรับอุตสาหกรรมไส้กรองน้ำ

DEVELOPMENT OF HIGH-ALUMINA CERAMICS FOR THE WATER FILTER INDUSTRY

นิวัตร พัฒนะ

Niwat Pattana

บทคัดย่อ

การวิจัยนี้มีจุดมุ่งหมายเพื่อ 1) เพื่อทดลองเนื้อเซรามิกชนิดไฮ-อะลูมินา ที่เหมาะสำหรับผลิตไส้กรองน้ำ 2) เพื่อทดลองผลิตไส้กรองน้ำจากเนื้อเซรามิกชนิดไฮ-อะลูมินาให้ได้ตามมาตรฐาน โดยมีวิธีดำเนินการวิจัย 2 ขั้นตอนได้แก่ ขั้นตอนที่ 1 ทดลองเนื้อเซรามิก กลุ่มตัวอย่างคือส่วนผสมของดินขาว อะลูมินา และโดโลไมท์ จำนวน 45 ตัวอย่าง เผาอุณหภูมิอุณหภูมิ 1200 1225 1250 1275 1300 องศาเซลเซียส ขั้นตอนที่ 2 ทดลองผลิตไส้กรองน้ำจากเนื้อเซรามิก จากส่วนผสมที่มีสมบัติเหมาะสม เผาที่ 1225 องศาเซลเซียส ผลการวิจัยพบว่า 1) ค่าร้อยละการดูดซึมน้ำหลังการเผา สูตรที่ 7 ที่อุณหภูมิ 1200 องศาเซลเซียส มีค่าการดูดซึมน้ำมากที่สุด คือ ร้อยละ 43.88 และสูตรที่ 29 ที่อุณหภูมิ 1300 องศาเซลเซียส มีค่าการดูดซึมน้ำน้อยที่สุด คือ ร้อยละ 20.47 การหดตัวหลังการเผา สูตรที่ 29 ที่อุณหภูมิ 1300 องศาเซลเซียส มีค่าการหดตัวมากที่สุด คือ ร้อยละ 8.25 และสูตรที่ 36 ที่อุณหภูมิ 1300 องศาเซลเซียส มีค่าการหดตัวน้อยที่สุด คือ ร้อยละ 0.12 ค่าความแข็งแรงหลังการเผา สูตรที่ 29 ที่อุณหภูมิ 1300 องศาเซลเซียส มีความแข็งแรงมากที่สุด 472.54 กิโลกรัมต่อตารางเซนติเมตรและสูตรที่ 36 ที่อุณหภูมิ 1200 องศาเซลเซียส มีความแข็งแรงน้อยที่สุด คือ 29.85 กิโลกรัมต่อตารางเซนติเมตร 2) การทดสอบประสิทธิภาพการกรองน้ำ พบว่าไส้กรองสามารถทนความดันน้ำที่ 70 กิโลกรัมต่อตารางเซนติเมตรโดยไม่เกิดความเสียหายใด ๆ อัตราการไหลของน้ำกรองที่ความดันน้ำ 30 กิโลกรัมต่อตารางเซนติเมตรค่าเฉลี่ย 31.52 ลิตรต่อชั่วโมง ส่วนเบี่ยงเบนมาตรฐาน 0.42 และการตรวจสอบคุณภาพน้ำพบว่า ค่าความเป็นกรดด่าง 8.73 ปริมาณของแข็งที่ละลายน้ำได้ทั้งหมด

คณะเทคโนโลยีอุตสาหกรรม มหาวิทยาลัยราชภัฏพิบูลสงคราม อำเภอเมือง จังหวัดพิษณุโลก 65000

Faculty of Industrial Technology, Pibulsongkram Rajabhat University, Muang District, Phitsanulok Province 65000

corresponding author e-mail: pattananiwat@gmail.com

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141.4 มิลลิกรัมต่อลิตร ความกระด้างทั้งหมดโดยการคำนวณเป็นแคลเซียมคาร์บอเนต 75.6 มิลลิกรัมต่อลิตร ปริมาณคลอไรด์โดยคำนวณเป็นคลอรีน 16.14 มิลลิกรัมต่อลิตร ปริมาณไนเตรท โดยคำนวณเป็นไนโตรเจน 0.12 มิลลิกรัมต่อลิตร ไม่พบเหล็ก พบตะกั่วน้อยกว่า 0.01 มิลลิกรัมต่อลิตร ปริมาณโคลิฟอร์มแบคทีเรีย พบมากกว่า 23 หน่วยต่อ 100 มิลลิลิตร ไม่พบ *E. coli* ไม่พบ *Salmonella spp* และไม่พบ *S. aureus* ในน้ำตัวอย่างที่ผ่านการกรองด้วยไส้กรองน้ำเซรามิกที่เตรียมได้

คำสำคัญ: ไส้กรองน้ำเซรามิก ไฮอะลูมินา การดูดซึมน้ำ

Abstract

The purposes of this study were 1) to test the high-alumina ceramics and 2) to test the production of water filter from ceramic high-alumina type to meet the standards. There are two methods of conducting research: Step 1: the test of high-alumina ceramics for suitable water filter using 45 mixture samples of kaolin, alumina and dolomite with the firing temperature of 1200, 1225, 1250, 1275 and 1300 degrees Celsius respectively. Analysis of properties for water absorption, shrinkage and strength. Step 2: test the production of ceramic water filter from the qualifying ingredients, the suitable formula is formula 16 fired at 1225 degrees Celsius. The results showed that 1) percentage of water absorption after firing formula 7 with 1200 degrees Celsius, it has the highest water absorption values at 43.88% and formula 29 with 1300 degrees Celsius, it has the lowest water absorption value at 20.47%. The shrinkage after firing of formula 29 with 1300 degrees Celsius, it has the highest shrinkage values at 8.25 %. The formula 36 with 1300 degrees Celsius, it has the highest shrinkage at 0.12%. The firing strength for formula 29 with 1300 degrees Celsius, it has the highest strengths at 472.54 kg/cm^2 and formula 36 with 1200 degrees Celsius, it has the lowest strength at 29.85 kg/cm^2 2) Water filtration test, it was found that the three-layer filter was resistant to water pressure at 70kg/cm^2 without any damage. The water flow rate at 30 kg/cm^2 has mean value of 31.52 l/h, and the pH value of filtered water was 8.73. Total dissolved solid content was 141.4 mg/l Total hardness was calculated as calcium carbonate 75.6 mg/l. Chloride was calculated as chlorine 16.14 mg /l. Nitrate was calculated as nitrogen 0.12 mg/l. No-iron was found. Lead was found less than 0.01 mg/l. Coliforms was found more than 23 per 100 ml. E. coli was not found. Salmonella spp and S.aureus were not found.

Keyword: Ceramic water filter, High-alumina, Water absorption

Introduction

Ceramic filters made from special kaolin fired for porosity, water absorption, white, easily fragile are mainly hollowed cylinders with various kinds and high prices. They are industrial products manufactured to filter liquid, water to flow; filter sediments, and make water clean. Currently, ceramic filters are popular but problematic in terms of strength property, some are easily broken and non-resistance to attrition since they were fired in the temperature at 950-1100 degrees Celsius (Phrompruk, 1980). Though they have been finely filtered, they still were pervious or the ceramic itself can be broken along with the water pressure which results in the problem of the filtered water. Therefore, the researcher is interested in developing to upgrade thequality of ceramic filter in terms of strength by using High alumina with the mixture in high quantity up to 80% which is mechanically stronger than other oxide ceramic products by firing with high temperature at 1200-1300 degrees Celsius. This will result in the good property aforementioned with a better effective filter or as standardized due to the fact that the range of temperature from 1000-1200 degrees Celsius, the spinel will change structure into mullite ($3Al_2O_3.2SiO_2$) and allow amorphous silica, crystal of mullite, occurs from the decompose of kaolin which is normally very tinny and it helps the ceramic become strong (Watthanasiriwet & Watthanasiriwet, 2009). The research aims at 1) testing the high-alumina ceramics and 2) testing the production of water filter from ceramic high-alumina type to meet the standards. It focuses on testing ceramic for industrial purposes. In addition, it can upgrade industrial market value for the water filter industry of Thailand to compete in the international market. Furthermore, this can be the vital alternative for ceramic industry of conventional SMEs which encounter competitive potential problem through the application of ceramic production experience via the marketable innovation. The research: therefore, is significant to create inspiration for the entrepreneurs to see the significance of innovative development potentially competitive and survival.

Methodology

1. Samples are 45 kaolin alumina mixture and dolomite as shown in Table 1.

Table 1 Samples from kaolin, alumina and dolomite.

Sample	Kaolin	Alumina	Dolomite	Sample	Kaolin	Alumina	Dolomite
1	15	50	45	24	25	60	15
2	10	50	40	25	20	65	15
3	5	55	40	26	15	70	15
4	15	50	35	27	10	75	15
5	10	55	35	28	5	80	15
6	5	60	35	29	40	50	10
7	20	50	30	30	35	55	10
8	15	55	30	31	30	60	10
9	10	60	30	32	25	65	10
10	5	65	30	33	20	70	10
11	25	50	25	34	15	75	10
12	20	55	25	35	10	80	10
13	15	60	25	36	5	85	10
14	10	65	25	37	45	50	5
15	5	70	25	38	40	55	5
16	30	50	20	39	35	60	5
17	25	55	20	40	30	65	5
18	20	60	20	41	25	70	5
19	15	65	20	42	20	75	5
20	10	70	20	43	15	80	5
21	5	75	20	44	10	85	5
22	35	50	15	45	5	90	5
23	30	55	15				

2. Test the mixture by molding into the testing bars, then fire them with different temperatures at 1200, 1225, 1250, 1275, 1300 degrees Celsius.

3. Analyze the data results by testing the testing bars after firing by calculating percentage of water absorption, percentage of shrinkage, and the strength of the bars. Then choose the one with special body for the water filter.

3.1 The calculating formula for Water Absorption (Andrew & Andrews, 1928)

$$A = \frac{W-D \times 100}{D}$$

When A = percentage of water absorption, W = weight of testing bar filled with water, D = weight of testing bar after firing

3.2 The calculating formular for Linear Firing Shrinkage:

$$a = \frac{Lp - Lf}{Lp} \times 100$$

When a = percentage of shrinkage after firing, Lp = the length when forming, Ld = the length after firing

3.3 The calculating formula for the strength

$$MOR = \frac{3PL}{2bd^2}$$

When MOR = strength value (MOR) (kg/cm^2) P = Pressing weight causing the break of the testing bars

L = the distance between two beams, b = the width of testing bars, d = the thickness of the testing bars

4. Select the special body with suitable property in producing the water filter products.

5. Testing of water filter quality comprises the following procedures:

5.1 Pressure resistance by assembling the sampled water filter within the prepared water filter equipment with the pressure resistance testing kits. Pump in the water through the water filter till the pressure in the water filter equipment reaches 70 kg/cm^2 allowing the water flow till the reading scale totally reads 200 liters and then reduce the pressure. Finally, check the sampled water filter.

5.2 The water filter flowing rate: It has been done by pumping the testing water flowing through the sampled water filter with the water pressure between 20- 40 kg/cm^2 till the filtered water accumulates equally of 500 liters. Then read the filtered water flow scale and calculates the mean of filtered water flow rate.

5.3 Water quality: it has been tested by Medical Science Center 2 Phitsanulok, Department of Medical Science, Ministry of Public Health by comparing the analytical water quality with the set standard. The tested water is from water supply within Pibulsongkram Rajabhat University water supply production.

Research results

1. It was found that some formula cannot be analyzed regarding the set variable physical properties such as formula 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 13, 14, 15, 20, 21 due to the lack of stable shape existence whereas the rests can be tested for physical properties which resulted in the research findings as follows:

1.1 The results of water absorption are shown in Table 2.

Table 2 Water absorption of fired specimens

Sample	Percentage of water absorption (%)				
	1200°C	1225°C	1250°C	1275°C	1300°C
7	43.88	40.93	43.09	41.43	38.29
11	39.68	39.07	39.12	39.10	39.46
12	39.70	38.99	39.97	39.11	35.03
16	37.84	37.30	36.72	36.98	36.93
17	37.22	36.29	36.54	36.33	36.22
18	36.10	31.16	35.23	34.69	32.47
19	36.34	35.66	35.56	34.60	29.32
22	36.55	35.49	3.05	34.68	32.81
23	35.43	35.69	34.82	34.51	32.81
24	35.11	33.68	34.45	34.25	33.69
25	33.98	33.12	32.92	32.95	32.31
26	33.27	33.06	32.40	31.91	27.57
27	32.03	32.31	32.58	29.91	26.12
28	33.26	32.50	33.31	31.44	29.84
29	35.05	33.04	32.28	26.92	20.47
30	33.32	34.36	33.36	29.52	26.26
31	33.79	33.16	32.51	31.11	29.76
32	32.85	32.61	32.71	32.55	31.63
33	33.34	33.65	27.48	32.17	32.72
34	32.01	31045	30.94	31.45	30.03
35	30.52	30.77	30.55	29.42	29.50
36	30.12	29.70	31.45	30.45	29.43
37	34.05	32.15	25.27	28.73	25.17

Table 2 Water absorption of fired specimens (cont.)

Sample	Percentage of water absorption (%)				
	1200°C	1225°C	1250°C	1275°C	1300°C
38	34.34	32.93	30.95	29.90	23.98
39	33.63	32.04	30.75	29.73	26.01
40	32.19	31.58	29.87	28.72	26.46
41	31.19	31.11	30.76	29.78	27.27
42	31.18	30.61	29.79	29.58	27.40
43	29.92	30.04	30.14	29.47	29.23
44	29.45	28.05	28.52	28.27	27.73
45	29.04	27.07	27.89	27.45	27.32

From the Table 2, it can be seen that the percentage of water absorption after the firing, formula 7 at the temperature of 1200 degrees Celsius has the most absorption value at 43.88% and formular 29 at the temperature of 1300 degrees Celsius has the lowest absorption value at 20.47%.

1.2 From the test of shrinkage after the firing at various temperatures as shown in Table 3.

Table 3 Firing shrinkage of fired specimens

Sample	Percentage of firing shrinkage (%)				
	1200°C	**1225**°C	**1250**°C	**1275**°C	**1300**°C
7	0.13	0.53	0.79	0.27	1.33
11	0.54	0.40	0.40	0.67	0.40
12	0.41	0.13	0.40	0.20	1.00
16	0.34	0.40	0.27	0.34	0.13
17	0.34	0.47	0.13	0.34	0.34
18	0.34	0.20	0.13	0.27	0.67
19	0.20	0.53	0.53	0.33	1.67
22	0.81	0.54	0.75	1.35	1.89
23	0.48	0.54	0.67	0.81	0.81
24	0.47	0.20	1.06	0.47	0.67
25	0.34	0.47	0.33	0.27	0.33
26	0.40	0.38	0.33	0.34	2.73
27	0.65	0.33	0.20	0.33	2.31

Table 3 Firing shrinkage of fired specimens (cont.)

Sample	Percentage of Firing shrinkage (%)				
	1200℃	**1225℃**	**1250℃**	**1275℃**	**1300℃**
28	0.52	0.39	0.85	0.39	0.46
29	1.01	1.74	2.34	5.21	8.05
30	0.53	1.26	1.27	3.06	5.64
31	0.53	0.27	0.60	1.34	2.73
32	0.40	0.53	0.53	0.53	1.20
33	0.13	0.40	0.13	0.26	0.53
34	0.33	0.20	0.33	1.32	0.33
35	0.13	0.26	0.20	0.39	2.26
36	0.51	0.38	0.38	0.38	0.12
37	1.96	2.35	4.49	3.69	5.92
38	0.86	1.06	1.86	2.79	5.43
39	0.66	1.18	1.12	2.58	4.60
40	0.46	0.72	1.71	2.54	3.87
41	0.46	0.58	0.85	1.56	2.20
42	0.26	0.39	0.46	2.31	1.95
43	0.58	0.58	0.26	0.13	0.89
44	0.20	0.32	0.39	0.78	0.26

From Table 3, it can be seen that the shrinkage after firing of formula 29 at the temperature of 1300 degrees Celsius has the most shrinkage value at 8.25% and formular 36 at 1300 degrees Celsius has the least water shrinkage value of 0.12%.

1.3 The test results of the strength after firing at different various temperatures as shown in Table 4.

Table 4 Strength after firing at different various temperatures

Sample	Strength after firing (kg/cm^2)				
	1200℃	**1225℃**	**1250℃**	**1275℃**	**1300° C**
7	33.32	38.57	49.92	52.52	62.45
11	57.66	80.85	85.91	104.12	138.67
12	21.61	39.03	32.96	41.59	73.17
16	66.04	71.04	95.75	120.29	134.88
17	57.45	71.62	104.36	124.58	131.56

Table 4 Strength after firing at different various temperatures (cont.)

Sample	Strength after firing (kg/cm^2)				
	1200℃	**1225**℃	**1250**℃	**1275**℃	**1300**℃
18	61.41	70.50	89.91	111.62	220.53
19	61.41	49.50	52.11	77.20	140.35
22	81.79	109.15	124.64	150.01	214032
23	86.57	92.25	120.66	138.19	177.39
24	51.61	91.58	110.44	116.77	157.65
25	59.24	79.82	104.28	115.09	144.34
26	53.80	62.27	90.01	118.85	310.37
27	58.62	73.44	66.42	168.00	301.59
28	32.88	80.87	46.01	116.34	126.94
29	104.94	129.90	156.23	302.59	472.54
30	80.12	112.67	124.42	232.38	347.71
31	80.41	106.14	114.33	180.53	292.19
32	64.00	86.88	93.59	100.65	176.91
33	46.51	24.60	108.58	79.18	110.98
34	39.12	63.26	77.48	59.03	100.47
35	47.81	59.64	47.23	67.55	96.96
36	35.84	44.21	58.84	46.94	84.65
37	79.13	125.64	251.81	200.82	421.38
38	64.80	95.32	165.40	191.13	345.61
39	71.30	112.57	123.45	196.35	173.67
40	65.42	90.19	162.91	213.35	275.48
41	66.21	102.10	103.75	147.74	289.26
42	42.54	68.62	73.91	119.23	274.49
43	34.16	51.75	59.67	74.86	131.81
44	30.26	44.64	51.12	53.62	78.17
45	29.85	41.34	34.46	43.24	60.04

From Table 4, it can be seen that the strength after firing for the formula 29 at the temperature of 1300 degrees Celsius has the most strength at 472.54 kg/cm^2 and formula 36 at the temperature of 1200 degrees Celsius has the least strength value of 29.85 kg/cm^2.

2. The results of water filter production after testing the physical properties as shown in the research result item 1 the selection of clay with high water absorption

with little shrinkage after firing and with high strength for making filter with slip casting and fired at 1200 degree Celcius, then the production of the water filters as ceramic production process and later assemble with the plastic set connecting with water system as shown in Figure 1 and then assemble with the water filter efficiency as shown in Figure 2. This research finding is from the data analysis of the water filter product quality testing. The analysis of water filter efficiency product is the water filter efficiency and water quality testing which has been filtered gained from the research outcome as the standardized industrial product 1420-2551 (Office of standardized industrial product, Ministry of Industry, 2008) as follows:

Figure 1 Ceramic filters

Figure 2 Water filter and water filter test kit

2.1 The result of forcing resistance when tested, the water filter can resist the forcing power of 70 kg/cm^2 and it was found that there is no damage ; therefore, it is standardized.

2.2 The testing result of water flowing rate at the water pressure of 30kg/cm^2 quantity of 500 liters as shown in Table 5.

Table 5 The results of the test of water flow rate through the filter

Filter water flow rate (Liters/hour)			average (Liters/hour)	S.D.	standard	result
1st time	2nd time	3rd time				
31.91	31.57	31.08	31.52	0.42	Not less than 10 liters / hour	Passed the criteria

From Table 5, it can be seen that the water flowing rate through the filter is as standardized that is the flow of the water through the filter is more than 10 liters per hour as the standard.

2.3 The water quality testing by Medical Science 2 Phitsanulok, Department of Medical Science, Ministry of Public Health, is the analysis of water quality compared with the set standardized criteria having the analytical outcomes as shown in Table 6.

Table 6 Water quality analysis results compared to standard values

Checklist	Analysis results before filtering	Analysis results after filtering	Standard	Result
1. Physical properties				
1.1 pH	7.86	8.73	6.50-8.50	Exceed the standard
2. Chemical properties (measured in milligrams per liter)				
2.1 The total amount of the substance	122.9	141.4	Not more than 500.0	According to the standard
2.2 Total hardness by calculating as Calcium carbonate	52.5	75.6	Not more than 100.0	According to the standard
2.3 Chloride, calculated in chlorine	10.19	16.14	Not more than 250.0	According to the standard
2.4 Nitrate is calculated as nitrogen.	0.25	0.12	Not more than 4.0	According to the standard
2.5 Iron	0.34	Not found	Not more than 0.30	According to the standard
2.6 Lead	Less than 0.01	Less than 0.01	Not more than 0.05	According to the standard
3. Biological properties				
3.1 MPN Coliforms/100 milliliter	Over 23	Over 23	Less than 10	Exceed the standard
3.2 *E. coli*/100 milliliter	Not found	Not found	Not found	According to the standard
4. Food poisoning pathogens				
4.1 *Salmonella spp*/100 milliliter	Not found	Not found	Not found	According to the standard
4.2 *S.aureus*/100 milliliter	Not found	Not found	Not found	According to the standard

From Table 6, it was found that the major quality fit the standardized criteria except for the pH value 8.7 and the value of coliforms/100 milliliter and it can filter all iron.

Discussions

1. From the research, it was found that some formula cannot be analyzed for physical properties as set for the variables due to the shape unstableness when fired; furthermore, it was found that there are some broken pieces after being fired. It can be seen that the formula with dolomite quantity at the range of 20-45% and the kaolin quantity at the range of 5-15% with the carbon dioxide quantity occurred from the firing of high quantity of dolomite as the mixture of special body in less quantity can cause the unstable shape.

2. The physical property of ceramics found in this research is that water absorption rather high at 20.47- 43.88% is near the White earthenware which is porous, white and lightweight. The whiteness occurs by mixing dolomite into the mixture around 20-30% called dolomite body because it contains the chemical compound- $CaMg(CO_3)_2$. When fired, the carbonate compound is broken into carbon dioxide (CO_2) with high amount around 47.9%; therefore, it results in the porosity and lightness after firing (Pattana, 2020) having the low shrinkage only 0.12-8.25% especially the mixture with high quantity of alumina, it will be low shrinkage and some mixture with enough strength in its use for the fact that this test is conducted with high temperature of firing at 1200-1300°C which is consistent with the research paper of Deutou (2018) which tested the porous ceramics from raw material generally found such as kaolin, aluminum, felspar and kyanite. It was found that the ceramic formula with porosity fired at different temperatures from 1200 to 1400° C and found that the seepage of water and mercury, porosity and total density in the range of 15.57% ± 1.56% to 42.73% ± 2.28%; it was found that the high porous quantity with high strength and stable heat will be suitable for the high pressure filter.

3. The test of water quality, it was found that its property mainly meets with standardized criteria except for the pH 8.7 and the value of Coliforms/100 milliliter and it can filter all iron; however, there is such interesting issue is when comparing with the water prior to the filter, the pH increases. It could be the compounds in the mixture

which contains magnesium oxide, and calcium oxide which are bases; therefore, it could result in the increasing of the pH from 7.86 to 8.73 which is still allowed as the standardized criteria for drinking water product industry with no exceed 9.2. The total substant quantity increases from 122.9 to 141.1 could occur from various compounds in ceramic mixture, all the hardness by calculating the calcium carbonate increases from 10.19 to 16.14 could be the compound of dolomite which has chemical components: calcium carbonate and magnesium carbonate ($CaCO_3.MgCO_3$). The percentage of calcium carbonate at 56 and magnesium carbonate at 44 (Pattana, 2006). Chloride by calculating into chlorine increases could be due to the quality of raw water. While coliforms is unlikely occurred from the ceremic mixture due to the firing process with higher temperature over 1,200 degree Celcius (Office of Food Quality and Safety, Department of Medical Science, Ministry of Public Health, 2019). This could occur from the water container contamination so the containers or bottles collected for bacteria test must be truly cleaned.

Conclusions

It was found that the piloted production of water filter ceramic after firing with the temperature at 1200 degrees Celsius has the most water absorption value of 43.88%; and after the firing with temperature at 1300 degrees Celsius, it has the most shrinkage value of 8.25% and the most strength at 472.54 kg/cm^2. Testing the filter efficiency, it was found that the filter can resist the water pressure at 70kg/cm^2 without having any damage. The filtered water flowing rate is at 30kg/cm^2 with the mean of 31.52 liters per hour and testing the filtered water quality, it was found that major quality is according to the standardized criteria except for the pH 8.7 and coliforms and it can filter all iron.

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