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Effect of Different Silica Compositions on Water Filter Application using the Slip Casting Method

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Abstract: Water pollution problems have been a serious issue due to changes in the natural ecosystems. Researchers are working together to solve the water crisis by producing environmental-friendly water filters that are easily available in the marketplace at a low price. However, silica as the main material can pollute the environment and needs to be handled properly. The water filter process uses the casting method where it starts with the formation of a master mould according to the original water filter design. A Plaster of Paris (POP) mould is produced using a master mould. The POP mould is produced with a ratio of 75: 100 which is the weight of water and the weight of Paris powder respectively. Once the POP mould is ready, a slurry mixture consisting of water, silica and filler material will be poured into it. To produce the difference in silica composition of water filters, the slurry mixture is adjusted to 50wt%, 60wt and 70%wt. Samples of water filters are dried before undergoing a sintering process. SEM analysis results show that the sample of 70wt% silica composition had a significant pore surface. This is due to excessive water consumption which reduces the silica content. In conclusion, the different silica composition and temperature used greatly influence the rate of porosity, density and water absorption of water filtration.

Keywords: Slip Casting Method, Difference Silica Composition, Physical Characteristics

1. Introduction

Environmental problems which include different kinds of pollution such as water pollution and air pollution have led to a global crisis that needs to be dealt with in the right way. A water crisis is one of the consequences of environmental pollution where the water contains chemical substances or impurities that can be harmful to the community. This is due to the rapidly evolving influence of industrial activities. This industrial activity factor alters the natural ecosystem and can cause water pollution, endangering the health of those who live nearby [1]. Water pollution allows the contamination of water to spread through the community and the clean water resources are used in

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a limited way at particular locations. To accomplish the Sustainable Development Goals (SDGs), water resources management is crucial in handling this pollution issue. The pollution issues also can be overcome by improving the cleanliness of water sources using the water filters. Sand, quartz, and glass are common sources of this silica [2]. Chemical compound Silicate which known as Silica-Oxygen tetrahedral (SiO_4) produces this silica or Silica Oxide (SiO_2) [3]. The crystalline or amorphous nature of this silica may be determined with the application of a combustion temperature. The amorphous silica characteristics produce contain high purity at 500 degrees Celsius [4]. A regulated temperature of 800 degrees Celsius is used to make it crystalline [5]. High hardness, temperature range, and inertness make crystalline silica a useful material for water filtration system. This crystalline silica characteristic may be studied using many different instruments and technologies such as the Scanning Electron Microscope (SEM), X-Ray Diffraction (XRD) and Transmission Electron Microscopy (TEM) [6]. The silica content at the crystalline phase was produced 88.44 percent for rice husk silica, 96.05 percent for silica fumed and 96.80 percent for quartz, respectively. This crystalline silica composition makes this material appropriate for use as a water-filtration application.

Slip casting is often employed as the primary casting process for silica materials due to its ease of drying and low cost. Water filter production is becoming simpler and can be produced in a short period of time by applying this slip casting approach since no special equipment is required. However, the content of the silica material produces environmental pollution. According to previous studies [7], silica composition performance is dependent on pore size and water turbidity resistance. The strength qualities of silica may be increased or decreased depending on the silica composition. If the temperature setting is incorrect, the silica composition will lose its strength and function as an efficient water filter. Thus, the mechanical and physical characteristics of silica may be altered by the silica composition which has temperature issues. The suitable selection of different silica compositions on water filter applications by using the casting method must be choosing well to reduce the disfunction of water filter.

2. Materials and Methods

The materials and methods section describes in detail the flow of the water filter manufacturing process, the type of equipment being used, as well as the testing and analysis methods applied to the water filter with different silica compositions. This section also talks about the steps that need to be taken during the making of this study in order to achieve its stated objectives.

2.1 Materials Preparation

In this research project, the production of silica-based water filters made use of raw materials such as crude silica and other materials. Some of the fundamental materials that were utilized in this project will be discussed in further detail in this subsection. Silica is one of the primary materials in this water filter production process. This silica may be found in crystalline form and its percentage of silica content is approximately 96.99%. The silica was separated into a few different samples based on the silica composition, which consists of 50 weight percent of silica, 60 weight percent of silica, and 70 weight percent of silica, respectively. Next, the water also is a main material for water filter fabrication and acts as a liquid that combines the composition of silica as well as fillers to produce a slurry. The amount of water used has been set in a range of 160g to 340g according to the silica composition in the slurry. The filler material which is bentonite clay also being used to strengthen and incorporate silica particles according to the prescribed silica composition. Normally, the bentonite clay is present in a small percentage, which contributes about 3 or 4 percent of the material content of the slurry mixture.

There are a few pieces of apparatus and equipment listed with their own functions. This apparatus is used throughout this project and can be found in the laboratory or workshop. One of the apparatus and equipment is a sieve, which is to sieve insoluble material in the slurry so that the sample produced in this slip casting process has an ideal surface and shape. Next, the furnace also has its own purpose where it is used to sinter the water filter sample at a high temperature of 1000 °C for the sintering process. This is done to make sure that the material on the surface of the sample gets harder and does not break easily. Vernier calliper is also used as a measuring tool to measure the thickness, height, and diameter of a circle. The beaker is also a container to mix the slurry mixture according to the material composition that has been fixed. Lastly, the weighting scale is used to measure the silica composition weight, water weight, bentonite clay weight, and slurry weight to obtain the perfect volume of water filter sample.

2.2 Water Filter Fabrication Method

The production process of this water filter uses the slip casting technique to create a sample of the water filter. The production process started with the fabrication of POP mould. This mould fabrication starts with Paris plaster powder being mixed with water with an ideal ratio of 75:100, which is 75 percent of water and 100 percent of Paris plaster powder. The second step is to break up lumps of POP with a spoon or use your hands. The weight of the mixture between the POP and the water is measured using a scale based on the calculation of the weight of the material. The third step is to stir the plaster mixed with water to obtain a medium thickness of slurry as well as reduce the chance of bubble formation on the surface of the mould. The next step is to pour the well-mixed slurry into the main mould to allow the mould shape of the water filter to be formed. Before pouring the slurry into the mould, soapy water is flattened on the surface of the mould to prevent the POP mould from sticking to the main mould surface. The POP mould that has formed is flattened using wood or flat rods to get rid of excess POP material while compressing the POP mould according to the shape of the main mold.

The slip casting is started by weighing the beaker first and then adding the silica in the beaker to determine the weight of silica that has been set. Once the beaker is weighed, silica is put into the beaker according to a predetermined weight to obtain the prescribed silica composition. Then, water is poured into a beaker filled with silica according to the specified weight and ratio. The bentonite filler also uses the same method as silica, which is to weigh the beaker, and the bentonite is poured into the beaker according to the prescribed ratio and weight. The water mixed with silica in the beaker is stirred until it is well blended to become a slurry. This slurry is poured into a POP mould. Bentonite was also incorporated into the slurry mixture to further strengthen the sample structure. The water content in the slurry is absorbed and removed through the pores of the POP mould. This is because the POP mould will form a layer of silica water filter on its surface according to the design of the cylindrical plaster mould. When the silica layer of the water filter reaches the thickness as planned, the excess slurry is completely removed from the mould to the proper shape of the water filter. The sintering process for the sample of silica water filter is carried out by the sintering method at a temperature of 1000 °C after this silica water filter is completely removed from the plaster mould.

2.3 Testing and Analysis

Several samples of different silica compositions that have been completed through the sintering process are tested and analysed to show the structural condition and properties of the silica water filter. The composition of this silica is also tested to meet the criteria as the main material for water filtration by touching on its mechanical and physical properties. The characterization of the silica composition in this water filter can be studied through several methods, which are Scanning Electron Microscope Analysis (SEM) for morphological analysis. The physical analysis will show the mechanical and physical properties of silica composition in more detail, including silica bond structure, silica pore size, silica density, and resistance of silica to impurity filtration. For density analysis will follow the ASTM C20-00 through the Archimedes Principle.

3. Results and Discussion

This section describes the water filter analysis data and relates it for the purpose of improving the quality of silica water filter products. All results or data need to be observed more carefully to ensure that the water filter data produced is an authentic and reliable source for further study in the future. This is because the results and analysis data that have errors may cause problems in improving the level of quality and productivity to be studied later.

3.1 Microstructure of Water Filter Analysis

The Scanning Electron Microscope (SEM) is used to determine the particle size and image of the silica microstructure that can be obtained from this water filtration sample. Before this microstructural analysis process can be done, these samples of silica water filters need to be coated. This microstructural analysis started with a sample containing 50wt% silica. Based on the Figure 1 shows the microstructure sample of the water filter has irregular morphology with tiny pores visible. The lines on the sample structure are the result of notching during the sample transformation from a solid state to a powder.

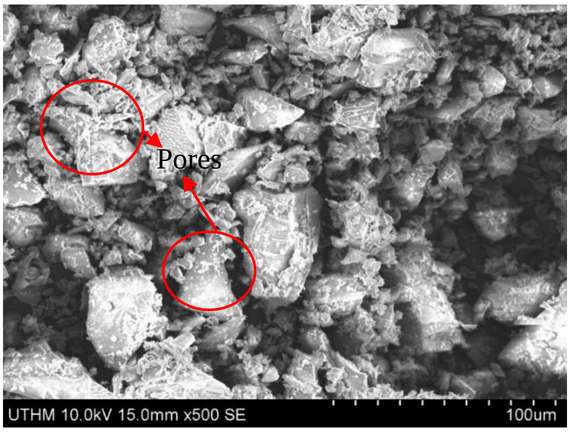

Figure 1: SEM images magnified at 500 for 50wt% silica sample

Figure 2 shows a water filter sample with 60% silica content has been sintered at a temperature of 1000°C while magnified by a factor of 500. In addition to the uneven morphological condition of this sample structure, there are tinier pores produced on the sample surface compared to 50wt% sample. The presence of this small pore size does not allow this water flow rate to flow easily through this sample.

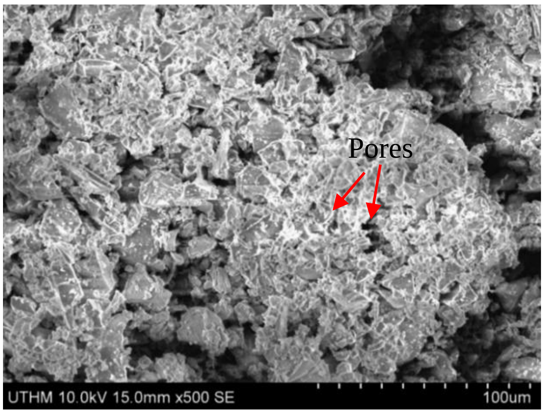

Figure 2: SEM images magnified at 500 for 60wt% silica sample

Figure 3 displays the magnification of the SEM image at 500× for a water filter sample of 70wt% silica composition. The structure of this sample exhibits an irregular morphology with the appearance of significant pores on the structure of this sample. This porous surface makes the water flow rate increase as well as the level of water filtration increase to produce a water filter. This is shown by the fact that this sample of a water filter made of 70% silica has a high porosity rate compared to other samples.

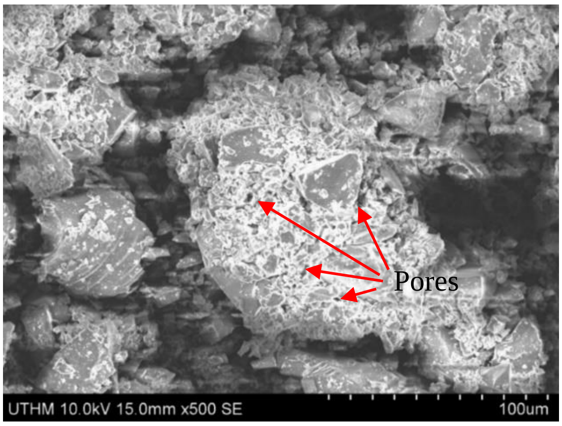

Figure 3: SEM images magnified at 500 for 70wt% silica sample

3.2 Water Absorption Analysis

Based on Figure 4, the bar chart shows the results for the percentage rate of water absorption on the type of water filter sample used. The highest water absorption percentage rate is sample for 50wt% silica composition, which is 0.399%, while the lowest water absorption percentage rate is sample for 60wt% silica composition, which contributes of 0.385%. The percentage rate for this water absorption analysis depends on the amount of significant porosity present in the silica water filter. The number of pores that fill the space on the sample surface of this water filter affects the percentage rate of water absorption.

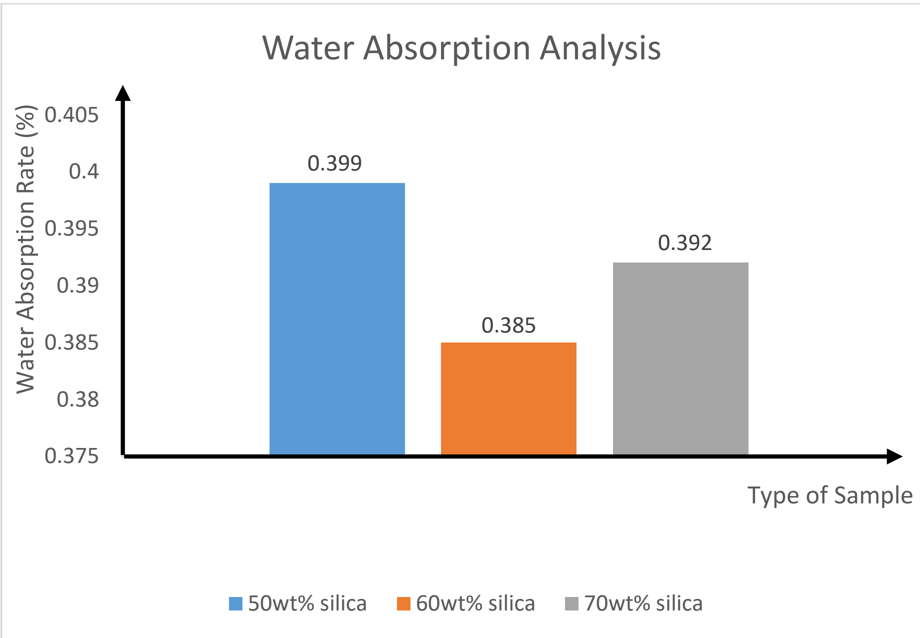

Figure 4: Percentage rate results for water absorption analysis after completion of testing for sample composed of 50wt% silica, sample composed of 60wt% silica and sample composed of 70% silica

4. Conclusion

In conclusion, this slip casting method is used as the main method in the production of silica water filters due to its ability to save time, manpower, and mould materials that are easily available on the market. This mould accelerates the formation of the water filter when this water filter can be obtained within a day. After that, this water filter will be exposed to the sun for a certain period of time for the drying process. The most complicated and difficult process in the production of these water filters is the sintering process. This is because this sintering process can cause cracking and brittleness on the water filter if the water content is not completely removed. This process is done entirely in a furnace located in a manufacturing laboratory. Then, the resulting water filter will be tested and analysed through some of the analysis methods that have been listed. This water filter is compared with the original water filter in terms of size and surface smoothness. The resulting water filter has a small size compared to standard water filters in terms of size because this silica water filter needs to follow the surface area of the furnace size for the sintering process. Although the size and surface area of the water filter is relatively small, this silica water filter is still able to filter water effectively as well as remove impurities contained in the water. This water filter has successfully achieved its goal which is to filter water from dirt and impurities even though there is a significantly porous surface compared to standard water filters.

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