



Wolkite University
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COLLEGE of ENGINEERING and TECHNOLOGY

DEPARTMENT of CHEMICAL ENGINEERING

TITLE: PRODUCTION of SILICA POWDER from CORN COB

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Declaration

We declare that this project entitled “silica production from corn cobs” is the result of our own project except as cited in the references.

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List of acronyms

CCA: Corn cob ash

FT-IR: Fourier transform infrared

Hrs: Hours

ICDD: International centre diffraction data

NaOH: Sodium hydroxide

PVC: Poly Vinyl chloride

SEM: Scanning electron microscopy

SiO₂: Silicon dioxide

UL: Fluid velocity at bulk temperature

UV: Ultra violet

XRD: X-ray diffraction

XRF: X-ray fluorescent

Abstract

Extraction of silica powder from Corn cob ash (CCA) will carry out in this study. Silica (SiO₂) is one of the valuable inorganic multipurpose chemical compounds. It can exist single, crystalline and amorphous forms and in the powder forms. Manufacture of pure silica is energy intensive. A simple chemical process will describe which uses a non-conventional raw material corn cob ash for extraction of silica. Corn cob ash is one of the most silica rich raw materials containing about greater than 60% silica (after complete combustion) among the family of other agro-wastes. Corn cob is a popular boiler fuel and the ash generate usually creates disposal problems. The main objective of this is to produce silica powder from corn cob. The main raw material for the production silica will be corn cob and some chemicals/ingredients will use (NaOH, Distilled water; Silica powder will produce). Silica production through biochemical process for Corn Cob was possibly produced by soaking corn cobs in organic acids like citric acid and burning of the powder by different temperature to get desired product followed by neutralization of the solution. Silica aerogel will produce by dissolving CCA with alkali solution to form sodium silicate solution and lowering the pH to 7.0 by adding hydrochloric acid to form silica aqua gel separated by centrifugation next drying by oven at 80°C and 10-gram powder of silica was produced. In Advantage of using corn cob as raw material for precipitate silica are superior and cost effective compare to present technology of producing Silica from quartz. Silica use full for elastomeric products like shoe soles, silicone rubber, compounds for cables, clarify of juices.

Key words: *citric acid, agricultural waste, corn cob ash, Na₂SiO₃, silica powder.*

CHAPTER ONE

1. Introduction

1.1 Background

Corn is one of the main agricultural products in Ethiopia. The word “corn” has various meanings depending upon different geographical regions. It stands for any local grains that are safe to eat and harvested in large areas. In many countries, and also in this research corn is the name given to Maize which are one and the same, and is meant for the plant that produces kernels used for cooking.

Maize arrived in Ethiopia slightly later, around the late 17th century and was mainly grown as a subsistence crop in the mid-altitudes (1500–2000m above sea level) in southern, south-central, and south western parts of the country (Huffnagel 1961). Maize is the second most widely cultivated crop in Ethiopia and is grown under diverse agro-ecologies and socio-economic conditions typically under rain-fed production. The maize kagro-ecologies in Ethiopia can be broadly divided into six major categories (MOA, 2005).

Silica (SiO_2) is one of the valuable inorganic multipurpose chemical compounds. It can exist in gel, crystalline and amorphous forms and in the powder forms. It is the most abundant material on the earth's crust. However, manufacture of pure silica is energy intensive. A variety of industrial process, involving conventional raw materials require high furnace temperatures (more than 550 degree C). In this thesis, a simple chemical process is described which uses a non-conventional raw material corn cob ash for extraction of silica. Corn cob ash is one of the most silica rich raw materials containing about greater than 60% silica (after complete combustion) among the family of other agro-wastes. Corn cob is a popular boiler fuel and the ash generated usually creates disposal problems. The chemical process discussed not only provides a solution for waste disposal but also recovers a valuable silica product, together with certain useful associate recoveries. The other associate recovery is sodium silicate. Effluent wash water obtained after washing precipitated silica (wet impure silica) contains sodium silicate.

By evaporation of water in multiple effect evaporators, followed by crystallization, filtration and drying, crystals of sodium silicate are obtained. The residue ash in sodium silica production can be utilized for making good quality bricks. Retained sodium silicate in residue ash acts as a binder and with incorporation of suitable ingredients high quality bricks can be manufactured. From rough estimation the production of corn in the country about twenty five million tons of corn cob is obtained from corn mills. Using corn cob as the raw material two million tons of pure high grade silica can be produced to meet the high demand of various industries that are using it. The main states with large number of corn mills are Canada, India, Nadu, Karnataka, and Kerala etc. The conventional process of manufacturing silica is the reaction of sand with soda ash at about 1500°C. In this project, a new method of manufacturing silica by reacting corn cob ash with caustic soda is developed.

1.2. Statement of the problem

Most of the time silica produced from rice husk ash and sand or quartzes. But rice grown in limited area or agro-ecological and in addition that it is seasonal. Because of this there is a lack of silica for the matter of insufficient availability of raw materials. At present excess corn is produced especially low land area in Ethiopia. Averagely the product is required for only home consumption and not used for industrial process. So this brings the falling down the market of the farmers. Due to this reason, the studies is depending on the production of silica from corn cob ash in laboratory and improve the application of corn cob ash in silica industry to encourage the knowledge for the advantage of this corn cob ash source to silica industry. The price of silica is increased from year to year and low production of silica due to environmental factors and which causes negative consequences for Ethiopian silica industries. Additionally, the most parts in Ethiopian the weather condition is cold and corn growth in lowlands. Therefore, this study deals with need to corn cob ash as the substitute for rice husk ash and increasing the market demand of corn cob ash. But Ethiopia has a good agro-ecological for corn cob production for year round. Therefore, additional feedstock is needed to produce silica throughout the year, so corn cob ash is the one which can fill this gap.

1.3. Objectives

1.3.1. General objective

The objective of this work is to prepare silica powder from corn cobs.

1.3.2. Specific objectives

- Raw material preparation (corn cob ash, equipment's and requirement chemicals).
- Sizing of major equipment.
- Cost estimation.
- To determine moisture content.

1.4. Significance of the study

In Advantage of using corn cob as raw material for precipitated silica are superior and cost effective compared to present technology of producing Silica from quartz Starts from a raw material of little or no cost and value, which otherwise would cause environmental pollution. Process is energy efficient and also consumes much lower energy compared to an alternative process involving fusion of selected quality of sand.

Some uses are as listed below

- Reinforcement of silicone rubber.
- Reinforcing material in tires.
- To improve mechanical properties of PVC flooring.
- As adsorbent.
- Purification and stabilization of beer.
- Analysis of blood.
- Cosmetics.
- Food industry as an anti-caking agent.

1.5. Scope of the study

The study of this research conducted at Wolkite University and the scope of this research paper focus only production of silica from agricultural waste, which is corn cob.

CHAPTER TWO

2. Literature review

2.1 What is Silica

Silica is another name for the chemical compound silicon dioxide. Each unit of silica includes one atom of silicon and two atoms of oxygen. Silicon and silica are two terms often used in inorganic. Silicon is the second most abundant element on the earth, second only to oxygen. Thus, it is very important to know the difference between silicon and silica. The main difference between silicon and silica is that silicon is an element whereas silica is a compound.

Silica makes up the mineral called quartz, and it is the most abundant mineral in the earth's crust. It is the main component of most sand and the primary ingredient in glass. Every time we probably come into contact with it, we every day pick up a glass to take a drink, we are using silica. Silica has been known to humans since ancient times, long before we knew it was made of silicon and oxygen. The art of making glass objects with silica dates back centuries.

Today, there are many industrial uses for silica. These include abrasives, building materials, fillers, electronics, and water filtration (C.P. Faizul, C. Abdullah & B. Fazlul ,2013) .Silica is occurring naturally as quartz, sand or flint. It can exist in gel, crystalline and amorphous forms. It is the most abundant material on the earth's crust. Nowadays, most silica was produced from quartz or sand by the extraction process. Silica also can be found in agricultural wastes such as palm ash, wheat straw, corn cob, corn stalk and rice husk. These wastes are needed to be disposed properly; otherwise it may cause a major environmental sustainable issue. The large amount of this waste can be a new source of silica production. Even though the production of silica from the agricultural wastes are not much compared to the production from quartz or sand, it is still can be used to fulfill the industrial demands (C.P. Faizul, C. Abdullah & B. Fazlul ,2013). Maize arrived in Ethiopia slightly later, around the late 17th century and was mainly grown as a subsistence crop in the mid altitudes (1500–2000 m above sea level) in southern, south-central, and south western parts of the country (Huffnagel 1961).

Maize is the second most widely cultivated crop in Ethiopia and is grown under diverse agro-ecologies and socio-economic conditions typically under rain-fed production.

The maize agro-ecologies in Ethiopia can be broadly divided into six major categories (MOA, 2005).

2.2. Properties of silica

The properties of silica include both chemical and physical properties such as hardness, colour, melting and boiling point, and reactivity (study.com, 2016). It is relatively hard, rating a 7 on the Mohs scale, a scale used to measure the hardness of minerals relative to each other. The hardest mineral, diamond, rates 10 on the scale. Pure silica is colourless, but if contaminants are present in a sample of quartz, it may be colored. For instance, rose quartz is silica with trace amounts of iron. This gives it a pinkish hue. Milky quartz is simply silica with air bubbles or inclusions of liquid that make the mineral appear white (www.study.com, 2016).

2.3 .Agricultural wastes as a source of silica material

Agricultural waste is defined as unwanted waste produced as a result of agricultural activities (i.e., manure, oil, silage plastics, fertilizer, pesticides and herbicides; wastes from farms, poultry houses and slaughterhouses; veterinary medicines, or horticultural plastics) (García, 2019). Agricultural waste such as rice husks, rice straw, corn cob, corn stalk, and bagasse can be used as a source of silica. Researchers in this field reviewed that several methods for extracting several materials, such as silica (Fadhulloh et al., 2014), titania (Rahman et al., 2014), carbon (Rahman et al., 2015), nanoselulosa (Effendi et al., 2015).

Isolation method used for extraction of silica in the agricultural waste is a chemical treatment, thermal treatment, and microbial treatment. The results showed that the agricultural waste can be used as an alternative silica source. However, this type of silica source will give advantages, not only as an inexpensive raw material but also as a problem solving to minimize the waste ([Http://ejournal.upi.edu/index.php/ijost/](http://ejournal.upi.edu/index.php/ijost/) a). Corn cobs as a source of silica Corn cob is an agricultural waste obtained from corn. Corn cobs contain more than 60 % silica with small amounts of metal (Adesanya & Raheem, 2009).

Corn cobs can be used as an economical raw material in the production of silica. Ash corn cob is obtained in the form of a fine powder after combustion so that it does not require further grinding, and corn cob ash is the most economical source of silica (Velmurugan et al., 2015).

2.4. Sources of silicon as raw materials

The two main sources of silicon as raw materials that is economically useful for the synthesis of low cost silicon for photovoltaic applications. The primary source of silicon is silicon dioxide which has the chemical formula of (SiO_2) and commonly known as silica. Among the known polymorphs of silica, quartz and quartzite rocks are the most stable and relatively pure form that can be found in almost all mineralogical rocks (Saraswathy, 2003).

Silicon precursors or volatile compounds of silicon represent the secondary source of silicon that is widely used in technological processing industries. Notably, the halides of silicon and flousilicic acids- a waste by-product of the phosphate fertilizer industry receive continuous attention for the synthesis of low cost silicon due to their ease of purification by fractional distillation. Lately, the sources of silica and silicon in biomass resources such as corn husk are being researched intensively for several industrial applications (A. Kumar and K. N. Rai. 2017). Most biomass resources are waste by-products whose disposal cause environmental nuisance hence developing uses for these waste resources are in common agreement with the global paradigm shift towards sustainable development.

Corn is Ethiopia's largest cereal crop in terms of total production, area planted, and number of farm holdings. Corn accounts for 22 percent of the total area covered by cereal and around 30 percent of the total cereal production. Corn is also the single most important crop in terms of number of farmers engaged in cultivation. During this reporting period, more than eight million small landholder farmers were involved in corn production. Subsistence and small landholder farmers produce 95 percent of total corn production and commercial farms produce only around 5percent.

2.5. Characteristics of amorphous silica

The characterization methods used in the analysis of chemical structure, microstructure and morphology, as well as the physical properties, of the silica nanoparticle are varied. To fully understand structure property relationships, several characterization techniques are often employed. The properties of the nanoparticle depend on their composition, the size of particles interfacial interaction. Defines amorphous silica as a naturally occurring or synthetically produced oxide of silicon characterized by the absence of a pronounced crystalline structure and whose X-ray diffraction (XRD) patterns have no sharp peaks. This type of silica may be anhydrous or have a significant water of hydration in its structure.

The desirable physio-chemical and mechanical properties of amorphous silica, notably their high reactivity, excellent binding properties, relatively high purity and excellent mechanical strength makes this material useful in a wide range of technologies. Although hosts of synthetic Silica are produced commercially, the ones produced from plant origins such as corn husks have been noted to have some significant advantages over those from mineral and synthetic origins. In particular, the processing steps are relatively simple and require no elaborate infrastructure or consumption of costly reagents as in the case of the synthetic processes. In addition the final silica powder produced from plant sources contains a narrow range of metal oxide impurities, which makes them exceptionally desirable in applications where high purity silica at modest cost is a necessary pre requisite.

As-prepared silica powder was characterized by using XRF (X-ray fluorescence), FT-IR (Fourier transform infrared spectroscopy), XRD (X-ray diffraction), and SEM (Scanning electron microscopy) techniques.

X-ray diffraction analysis

X-ray diffraction analysis was done on samples sintered in the temperature range of 1000 °C – 1400°C. X-ray mini diffract meter model MD-10 with $\text{CuK}\alpha$ radiation of wavelength 1.5406nm was used for the analysis. The samples were exposed to X-ray generator running at 25kv. The 2θ angle for the machine ranges from $(16-72)^\circ$. The unknown samples were search matched with the known samples from the database available at

International Centre for Diffraction data (ICDD). The production of Na_2SiO_3 basically comprises four main stages according to Banerjee, H. D. (2016).

- Calcinations of a mixture of Na_2CO_3 and natural Quartz or sand (SiO_2) in furnace at 1400°C - 1500°C to produce a solid glass;
- Dissolution of the produced solid glass in
- 1a reaction vessel under high pressure and temperature to produce Na_2SiO_3 solution and impurities (not reacted silica);
- Optimal filtration depending on the purity desired and
- Evaporation of H_2O from the silicate solution for the production of solid sodium silicate.

Based on the energy consumption with burning fuel to reach high temperature of calcinations, This process is considered as being expensive besides production of air pollutants such as dust, Nitrogen and SiO_2 Banerjee, H. D. (2016).

Thermal conductivity test

The thermal conductivity test was carried out using the hot flux method based on unidirectional heat transfer at steady state for a system of sandwich-like. A heat source was used to feed the system. Thermal conductivity was calculated using Fourier's equation for steady state heat conduction

$$K = \frac{Q\Delta X}{A\Delta T} \dots \dots \dots (1)$$

Apparent density test

The test to determine apparent density of CHA refractory was carried out in the following steps.

1. The refractory were weighed in air using a balance (m_o) gram.
2. The refractory were suspended in water and the weight recorded as (m_1) gram.
3. The refractory were again suspended in water and allowed to saturate with water.

Then they were removed and weight recorded as (m_2) gram.

$$\text{Volume of water displaced} = \frac{\text{density of water}}{(\text{Mass of water displaced})} = \frac{pw}{(m_2 - m_1)} \dots \dots \dots (2)$$

$$\text{apparent density} = \frac{\text{density of water}}{(\text{total volume including volume of voids (pores)})}$$

$$\text{apparent density} = \frac{m_2 - m_1}{m_2 - m_1} \dots \dots \dots (3)$$

The density of water (ρ_w) is 1gcm^{-3} .

Porosity test

The refractory were first weighed and recorded as W_0 . The refractory were then immersed in water at room temperature and removed; the weight recorded as w_1 . They were then allowed to absorb water to saturation; the weight recorded as w_2 .

Volume of pore spaces available= $W_2 - W_0$

Volume of test pieces= $W_2 - W_1$

$$\text{Porosity} = \left[\frac{(w_2 - w_1)}{w_2 - w_1 \times \rho_w} \right] \times 100 \dots \dots \dots (4)$$

Where ρ_w is the density of water (1gcm^{-3})

Table 1. Elemental Composition of Corn Cob

Serial No	Element	Weight (%)	Serial No	Element	Weight (%)
1	C	32.75	7	Al	0.052
2	O	45.89	8	Mn	0.031
3	H	6.36	9	Fe	0.025
4	K	0.46	10	N	1.38
5	Ca	0.022	11	P	0.064
6	Si	13.133	12	Mg	0.11

Generally silica is not only produced from corn cob but also produced from sand. The basic difference between based on parameter is shown by the following table.

Table 2. General comparison between silica produced from corn cob & sand.

Parameter	Silica produced from corn cob ash	Silica produced from sand
Temperature	550 ^o c-600 °C	1400 ^o c-1500 ^o c
Time	6hr	12 hr.
Atmospheric pressure	Standard atmospheric condition	Greater than standard atmospheric condition
Labour requirement for work including resource	Medium	Large

Chemical property

Silicon dioxide has covalent bonding and forms a network structure. SiO_2 is formed when silicon is exposed to oxygen. A very thin layer approximately 1nm of so called native oxide is formed on the surface when silicon is exposed to air under ambient conditions. Higher temperature and alternative environments are used to grow well controlled layers of silicon dioxide on silicon. The amount of atoms residing on the surface increases with the decrease in particle size. For silica nanoparticles smaller than 5nm, more than half of the Si atoms are presents on the surfaces. Thus, the surface should have one or more silanol group (Si-OH).here fore, the extent of chemical modification of silica such as grafting of organ function groups and incorporation of metal ions highly depend on the concentration of silanol groups per grams of silica. The number of silanol groups per unit area of silica provides information regarding the distribution of silanol groups on the silica surface. The concentration of silanol groups increase with the decrease in the particle size which is interrelated to the specific surface area. However, the silanol number decrease with the decrease in the particle size suggests that these nanoparticles could be chemically reactive, therefore suitable for catalyst applications.

Physical properties

Silica generally behaves as an insulator it does not show electrically conductivity due to large band gap energy. There are not any delocalized electrons. All the electrons are held tightly between the atoms, and are not free to move. It possess very high melting point about 1700°C shows very high refractive index and optical absorbance at high temperature. At high temperature, it exists in various crystalline forms as tridymite, coesite and cristobalite. It has very high dielectric constant and physical properties. It has high melting point varying depending on what the particular structure is around 1700°C. Very strong silicon oxygen covalent bonds have to be broken throughout the structure before melting occurs. It is hard this due to the need to break the very strong covalent bonds. It is insoluble in water and organic solvent molecules and the silicon or oxygen atoms which overcome the covalent bonds in the giant structure. Silicon dioxide, a brittle, weak material, has a high melting point varying depending on what the particular structure before melting occurs. It is hard, this is due to the need to break the very strong covalent bonds it is insoluble in water and organic solvents. There are no possible attractions which could occur between solvent molecules and the silicon or oxygen atoms which could overcome the covalent bonds in the giant structure. Silicon dioxide, a brittle, weak material, has melting point of 1728 degrees Celsius. It possesses low thermal conductivity and is therefore a natural thermal insulator.

Mechanical property

There are various ways of obtaining mechanical properties data, but the most direct and the least ambiguous in interoperation is testing under uniaxial loading. The determination of the mechanical properties of SiO_2 thin films at typical oxidation temperature and stressed. There is little doubt that time dependent inelastic deformation plays a significant role in SiO_2 films. The study of mechanical behaviour of the Nano rod entails the proper description of inter atomic interactions. To developing quantum mechanical methods for treating the inter atomic forces, and will apply them not only to Nano rod, but also to the effects of water on the strength and deformation of the Nano rod.

Among the Nanoparticles, Nano silica was used to improve the properties of cement based materials due to its pozzolanic activity. The excellent mechanical properties and micro structure of cement composite with Nano SiO_2 were also reported. Nano SiO_2 increases the compressive and flexural strength of concrete and mortar. Silicon dioxide possesses very strong covalent bonding structure and Vander walls force of attraction and so this oxide is very strong crack free.

Thermal property

In many cases of interest to the thermal management of semiconductors, SiO_2 is used in the form of a thin layer. Unfortunately the thermal conductivity of SiO_2 is about two orders of magnitude less than that of Si. Hence, even the influence of a very thin layer can be significant. For example, in the case of silicon insulator, thicker oxide layer result in faster devices, but at the cost of decrease in reliability due to higher temperature. Since the thermal properties of thin films may differ significantly from the bulk value, it is a must to repeat the measurements. A major reason is that the effective TC depends on the way the layer is created and its thickness. Another paper on the thermal SiO_2 showed a clear dependence of the effective TC on the oxide thickness, attributed to an increase in the contribution of the interface. Obviously a distinction should be made between intrinsic values and values that include the interfacial resistance between layer and substrate.

Optical properties

The inter band optical properties of crystalline quartz and amorphous SiO_2 vacuum in the ultraviolet UV region have been investigated using combined spectroscopic ellipsometry and UV spectroscopy. Over the range of 1.5-4.2 eV, the optical properties exhibit similar excitation and inter band transitions, with crystalline SiO_2 has more sharp features in the inter band transition strength spectrum than amorphous SiO_2 the energy of the absorption edge for crystalline SiO_2 is about 1 eV higher than that for amorphous SiO_2 . In SiO_2 , the Si-O-Si bond lengths vary from 1.55 to 1.65 Å while the bond angles vary from 136° to 180° and these changes are found to correlate to changes in the band gap energy from 8.4 to 11 eV. Optical properties of crystalline and amorphous SiO_2 crystals and glasses are

important optical materials, being the basis for optical elements, optical fiber telecommunications, and photolithographic.

Electric properties

Silicon oxide is an electrically insulating material. Silicon dioxide possess very high band gap energy i.e. The distance between the conduction band and valance band be very large so there be no possibility for the recommendation of electrons and hence silicon dioxide cannot shows conduction properties so electrically neutral. An electrical property of the bulk silicon oxide and the SiO_2/Si interface by TEOS/ O_3 was investigated using current voltage (I-V) and capacitance voltage (C-V) characteristic were measured by making a metal oxide semiconductor structure with the deposited silicon oxide film. From I-V measurements, it was observed that the deposition temperature affected the electrical properties of the bulk oxide, but the TEOS/ O_3 ratio did not have a strong influence. The break down strength was 2.5 and 5MV/cm at 240 and 380°C respectively.

2.6. The uses of agricultural waste to the environment

Agricultural wastes have become an increasing concern in recent years, as they may cause significant environmental problems; however, they may also be used for several beneficial purposes, as feed stock for energy production.(Zhenyuan et al., 2014).The use of agro industrial wastes as raw materials can help to reduce the production cost and also reduce the pollution load from the environment. The use of agricultural and agro-based industry wastes as raw materials can help to reduce the production cost and contributed in recycling of waste as well to make the environment eco-friendly. Agricultural waste is one of the cheapest sources for silica production. The reasons which are responsible for agricultural waste to be considered as good silica source and have potential for the large scale production are (V. Vaibhav, et,al. 2014). (S. Danewalia1,et,al.2016)

1. Low cost of the raw material
2. High silica content in agricultural waste
3. Comparable silica quality
4. High energy content
5. Fine sized amorphous material

2.7. The uses of corn cob as an agricultural waste

Usually, corncob has been treated as an agricultural waste. Finding practical applications of this waste in product manufacturing may preserve the environment and may also allow using more green technologies. Therefore, a corncob particleboard, a lightweight concrete for non-structural purposes, and a lightweight concrete masonry unit (CMU) are the granulated corn cob-based products. Modern industrial products made from corn cobs include absorbents for oil and hazardous waste, insecticides, fertilizer.

2.8. Uses of silica

- In Glass, Ceramic, and Fine China Manufacturing
- Crystalline silica is as a raw material for glass manufacture.
- In Construction Building materials, such as concrete and dimension stone (sandstone, granite, and limestone are examples) contain crystalline silica in the form of quartz.
- In Heavy Industry
- High-Tech Applications
- Historically, crystalline silica, as quartz, has been a material of strategic importance. During World War II, communications components in telephones and mobile military radios were made from quartz.

2.9. Basic parameters in the production of silica

1. Temperature: the main parameter in the production of silica is temperature. It has their own effect beyond the limit but recommended for silica preparation in the range (550-600) °C. It has direct relation between the silica quality and temperature up to its limit.
2. Retention time: in different unit operation require different time beyond that there is an effect on the production of silica both quality and quantity.
3. Pressure: is also one of the parameter properly arranged in each unit operation to produce a good quality and quantity of silica.

2.10. Types of amorphous silica

Synthetic amorphous silica can be classified in to four general classes. These are colloidal silica (silica sols), precipitated silica, silica gel and fumed silica. There are

two silica processes. The first one is wet process. Silica sols, precipitated silica and silica gel are prepared by wet process. The second one is thermal process. Fumed silica is processed by using volatilized reactants. Colloidal silica is called the primary particle because it is the basic building units of silica gels and precipitated silica. The polymerization of silica has three stages: Polymerization of monomers to form small primary particles, Growth of primary particles, Aggregation or agglutination of the particles to form a gel or a precipitate. Stage two and three highly depends on the pH and the electrolyte content of the silicic acid solution (C. Setzer 2002). When the pH is above 7 in the absence of salts the growth of colloidal particles occurs but their number decreases. This process results in the formation of silica sols. When the solution is acidic (in the presence of electrolytes) the colloidal particles form gels by aggregation. The final silica gel property highly depends on the post- treatment steps which are washing, aging and drying. If the silica solution is neutral or alkali a precipitate is formed.

The properties of precipitated silica is highly affected by pH, temperature, solid concentration and process conditions such as addition rate of raw materials, shearing action application (C. Setzer 2002). Fumed silica (pyrogenic silica) occurs in the gas phase at high temperature using flame. The common process nowadays is the flame-hydrolysis process. In this process the raw material which is silicon tetrachloride is mixed with dry air and hydrogen fed to burner and then hydrolysed. The characteristics of fumed silica are affected by reagent concentration, flame temperature and residence time in the combustion chamber (C. Setzer 2002).

A) Colloidal

Silica is a suspension of fine-sized silica particles in a liquid phase. Stable suspension is prepared at concentration particles exceeding 50% solids. The particle size of suspension is approximately Colloidal from 5-150 nm in diameter. Particles significantly smaller than 5 nm are difficult to stabilize at high concentration, while particles much greater than 150 nm are subject to gravitational sedimentation.

Silica sols do not gel or settle out of solution for at least several years of storage (C. Setzer 2002). Colloidal silica is processed when alkali silicate solution is partially neutralized by acidification and the reactive silicate species allowed growing on to silica nuclei. Then the resulting suspension is concentrated and stabilized. The stability of silica sols depends on several factors. The pH value should be >7 to maintain enough negative charge on the silica particle surface to prevent aggregation (C. Setzer 2002).

B) Precipitated silica

Precipitated silica is made by acidification of sodium silicate in which the primary particles formed are coagulated in to clusters. For the reaction sulphuric acid is usually used also some other acids such as hydrochloric acid, organohalosilanes and carbon dioxide. Precipitation is carried out under alkali conditions. The choice of agitation, duration of precipitation, temperature, concentration, and ph vary the properties of the silica. Precipitated silica differs from silica gel on the basis of pore structure. Precipitated silica has macro porous pore structure whereas gels have micro porous structure. Silica is precipitated by adding acid to sodium silicate to reduce the pH value of the hot suspension to a pH value of 9-10. Precipitated silica is used as extenders for detergents and cleaners, reinforcement, in paper processing and others (C. Setzer 2002).

C) Silica gel

Silica gel, a porous solid amorphous form of hydrous silicon dioxide, has the nominal chemical formula of $\text{SiO}_2 \cdot x\text{H}_2\text{O}$. It is constituted by randomly linked spheroidal polymerized silicate particles, the primary particles. The sol-gel process is the most studied and most documented route for preparing amorphous silica (C. Setzer,2002).

CHAPTER THREE

3. Material and methods

3.1. Materials and equipment used

- **Corn cobs:** were collected from rural area.
- **Plastic bags:** to collect and transport samples to the laboratory.
- **Oven dryer:** to dry the sample.
- **Mortar and pestle:** to crush the dried corn cob sample.
- **Balances:** to weigh samples.
- **Digital pH meter:** to measure the pH of silica after filtration.
- **Conical flask:** to hold samples and additives for filtration and pre-treatment.
- **Centrifuge:** to separate the liquid and solid part of the solution.
- **Mesh sieve:** to separate oversized and under sized corn cobs.
- **Filter paper:** used to separate impurities from silicate solution.
- **Thermo meter:** is an instrument used to measure temperature of the solution.
- **Muffle furnace:** is equipment used to ignite the corn cob in a carefully weighed Crucible.
- **Magnetic stirrer:** used to stirrer the solution.
- **Heater:** used to boil ash and sodium hydroxide aqueous.
- **Incubator:** is used to gel formation.
- **Beaker, petri dish, test tube:** used to holding sample.
- **Measuring cylinder:** used to measure volume.

3.2. Chemicals

- Distilled water
- NaOH
- HCl
- Citric acid

3.3. Methods to prepare silica from corn cob

The basic method to prepare silica from corn cob was soaking with organic acid for one day. The basic unit operations were listed below.

A) Grinding of corn cobs: grinding is one of the basic unit operation used to reduce larger size particles in to fine or powdered form. Therefore the collected corn cob was firstly removed the impurities and grinded by grinder with in its essential size.

B) Screening: is basic unit operation to removed unwanted impurities by using with in Different mesh size. To separates the coarse particle from the fine or powdered particle depending on the size of the particle.

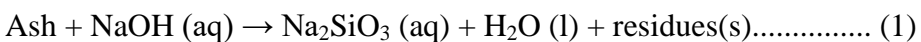
C) Washing and drying: is the major unit operation used to the corn cobs was washed by proper amount of distilled water to remove the earth dust particles. The washed corn cobs were dried by sun light within 24 hrs.

D) Soaking with in citric acid: the dried corn cobs was soaked by organic acid like citric acid to increase the quality of silica and remove impurities like organic molecules by soaked within 24 hrs.

E) Washing and drying: after soaked the corn cob by organic acid i.e. Citric acid washed by distilled water and dried using sun light.

F) Combustion: The beneficiated corn cobs were then placed inside a perforated metal basin for open air combustion to change the corn cobs into ash. The obtained corn cob ash was then subjected to thermal treatment at (550 -600)°C temperatures, within (3-2) hr and atmospheric condition. The purpose of this step is to enhance the relative amount of SiO₂ through reduction of the carbonaceous content present in the corn cob ash and some unwanted components. Increase in the relative amount of SiO₂ content present in the corn cob ash (CCA) as the temperature increases with increase in time.

G) Mixing of ash and NaOH (aq): By dissolving 1N NaOH Solution within 20 grams of ash to form Na₂SiO₃ stirred by magnetic stirrer within 3hr and a constant temperature of 80 °C. The chemical reactions was shown below between corn cob ash and sodium hydroxide.



H) Filtration: is one of the basic unit operations to separate impurities from the silicate solution after formation of sodium silicate. That was, the residues were K₂O, P₂O₅, CaO, etc.

I) **Neutralization with in HCl:** the purpose of this unit operation will for neutralization process and to produce sodium chloride and silica with water

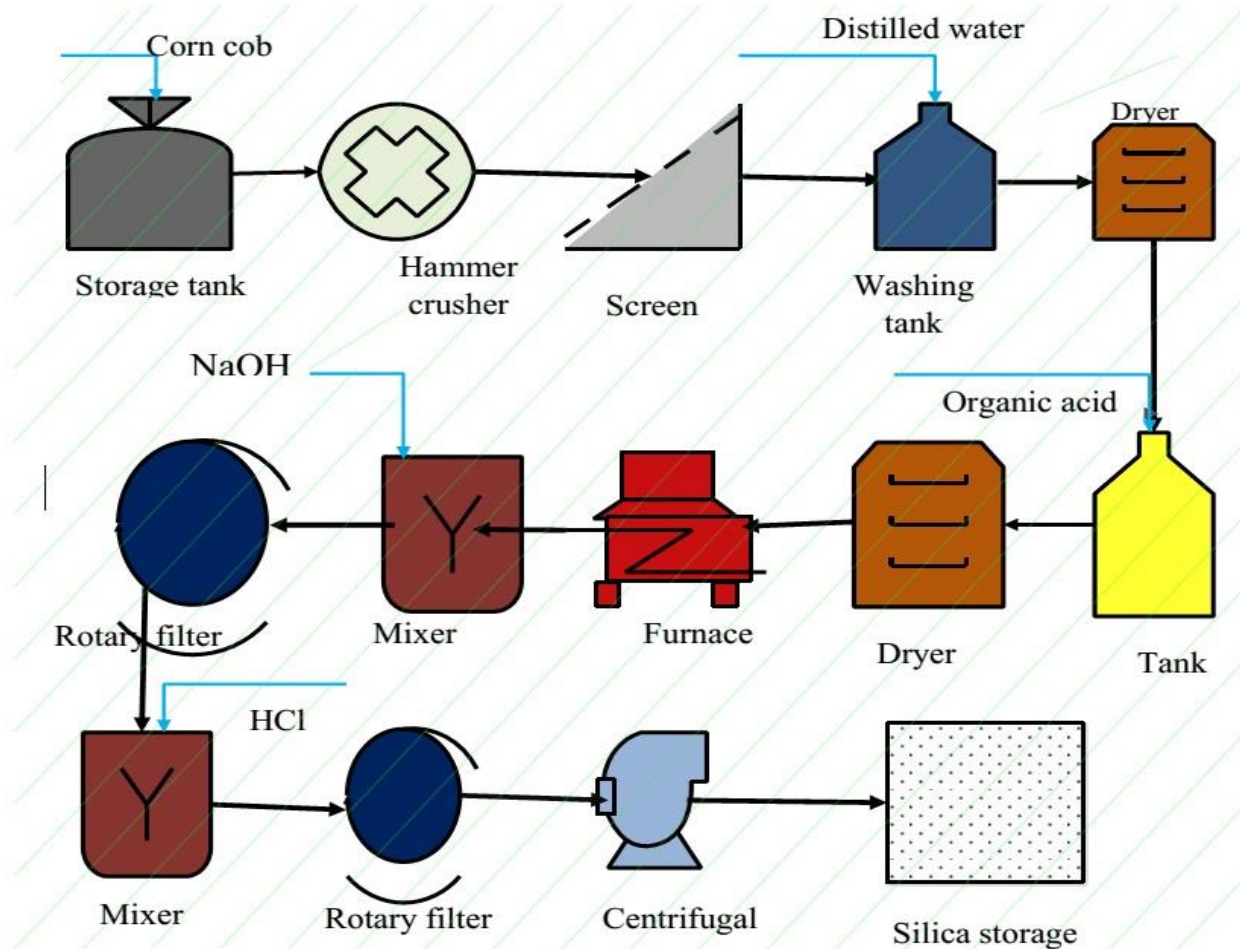
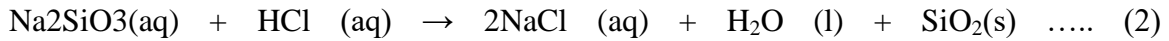


Figure 1; Process flow diagram of Silica Powder Production from Corn

3.4. Experimental procedure

The followings basic steps were used for the production of silica. These steps were:

Step1. Sample collection from rural area



Step 2. Size reduction of corn cob easy for grinding process and washing process.



Step 3. Washed and dried the grind corn cob by using sun light



Step 4. Soaked the corn cob by organic acid (acetic acid).



Step 5. Washed and dried the soaked corn cob by using distilled water and sun light respectively.



Step 6. Grind the corn cob with mesh size of 0.5mm.



Step 7. Measured the corn cob powder, put in to the crucible and burned to obtained ash by using furnace at 550°C .





Step 8. Mixture of 1 N of 120 ml sodium hydroxide (aq) and 20 gram of ash



Step 9. put the mixture to the heater for 3 hr. at 80°C to dissolve sodium silicate solution within magnetic stirrer constantly.



Step 10. Filtration of the solution to remove the undesired product.



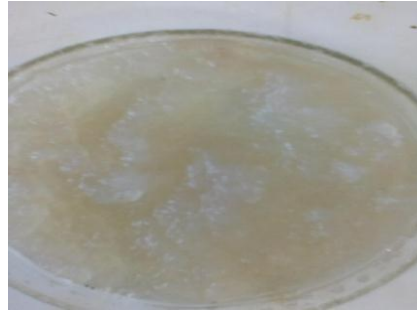
Step 11. Mixture of sodium silicate and 1 N hydrochloric acid for neutralization.



Step 12. Put the neutralized solution in to the incubator at 45 °C 6 hr.



Step 13. Separation technique by centrifuge at 4000 rpm for 30 min to separate solid and liquid.



Step 14. put viscous silica in to the oven drier at 80 °C for 5 hr then obtained the result



Preparation of 1M NaOH

The preparation of 1M NaOH was carried out by firstly calculating the molarity of the sodium hydroxide pellet using the formula below.

$$\text{Molarity} = \frac{\text{mass}}{\text{molar mass} \times \text{volume}}$$

Molar mass of NaOH = 23+16+1 = 40.

To prepare 0.12 liter, 1 M = mass/40 x1/ 0.12

Mass = 1 x40x0.12 = 4.8g.

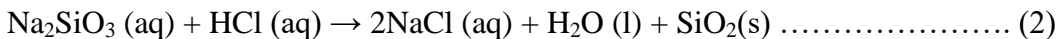
This means 4.8 g of NaOH Pellets will be dissolved in 120 ml of Distilled water.

The solution was achieved by dissolving the NaOH pellets inside a 500ml conical flask containing distilled water using stirring rod to stir it until the pellets dissolve totally.

Preparation of silica powder

Silica powder was achieved by adapting the purifying method of selected CCA powder burned at 550°C .20 g of CCA powder was stirred in 120 ml of a 1 N NaOH aqueous solution. The solution was stirred in a covered beaker for 3 hr with a constant heating at 80 °C to dissolve silica and produce a sodium silicate (Na₂SiO₃) solution.

After that, residues of K_2O , P_2O_5 , CaO , etc were separated from Na_2SiO_3 solution by filtering through filter paper, assisted with a pump inlet.



In general, insoluble ionic compounds have higher lattice energy than hydration energy. The energy provided by hydration of dissolved ions is inadequate to break down the ionic lattice, thus the ionic compounds remain mostly undissolved Chakraverty, A. (2014).

In order to remove residues, sodium silicate solution was washed with hot water several times until the solution was clear. The clear solution was allowed to cool to room temperature. pH of the solution was adjusted to 7.0 by using 1N HCl at a constant stirring and then incubated to encourage gel formation for 6 hrs. (as expressed in reaction (2)). This step was followed by several washings and centrifugation at 4000 rpm for 30 min. After that, the supernatant was removed. Next, the acquired gel was dried at 80 °C for 5 hrs. Finally, dried gel was washed with deionized water at least 3 times and then dried at 80 °C to produce 10g of silica powder.

3.5. Limitation of the project

The problem that we encountered is that, there was no enough lab equipment's for measuring the characterization of silica, budgets and chemicals.

CHAPTER FOUR

4. Result and Discussion

4.1 Result

During the experimental silica production process, the physical characteristic of raw material was determined, and the results are analysed as follows. It was observed that corn cob ash powder obtained from burning corn cob at 550 °C appeared as dark-gray powder due to existing of carbon residue (remaining from the decomposing of cellulose and lignin), whereas Corn cob ash powder from burning corn cob at 600 °C appeared as milky white powder. At high burning temperature, carbon was oxidized and burned off, thus the presence of unburned black carbon decreased. Corn cob ash obtained from burning at 550 °C is the optimum condition for 3 hr. Because it contained higher amount of silica than corn cob ash obtained from burning at 600°C. Moreover, burning at 550°C led to higher ash yield compared to corn cob ash obtained from burning at 600°C .

Determination of Moisture content of corn cobs

The washed corn cob (1000 g) was initially weighed and was kept in an oven at 115°C for 3 hrs. Then dried cob was removed and re-weighed to determine moisture content and its value was 400 g.

$$\text{Moisture content (\%)} = \frac{m_1 - m_2}{m_1} \times 100 \%$$

Where (m1) = Mass of corn cob before drying

(m2) = Mass of corn cob after drying

$$\text{Moisture content (\%)} = (1000 - 400) / 1000 \times 100 = 60\%$$

To determine moisture removed from sample weight use the following formula:

$$\text{Moisture removed (\% wt. / wt.)} = \text{initial mass (M1)} - \text{final mas (M2)}$$

$$\text{Moisture removed (\% wt. / wt.)} = 1000\text{g} - 400 \text{g} = 600 \text{g}$$

The 200g dried corn cob was entered in to furnace burned with 550°C for 3 hrs. And released after condensed and measured its weight was obtained 60 gram ash.

$$\% \text{ ash yield} = \frac{m_1 - m_2}{m_1} \times 100 \%$$

Where m_1 = weight of dried corn cob before furnace combustion = 200 g

m_2 = weight of corn cob after burned measured = 60 g

By measuring the following two parameters determined the ash yield from 200 gram.

Table 3. Temperature and time variation for ash preparation

Temperature in °C	600	550
Time in hr.	2	3
Ash yield in gram	24.23	60

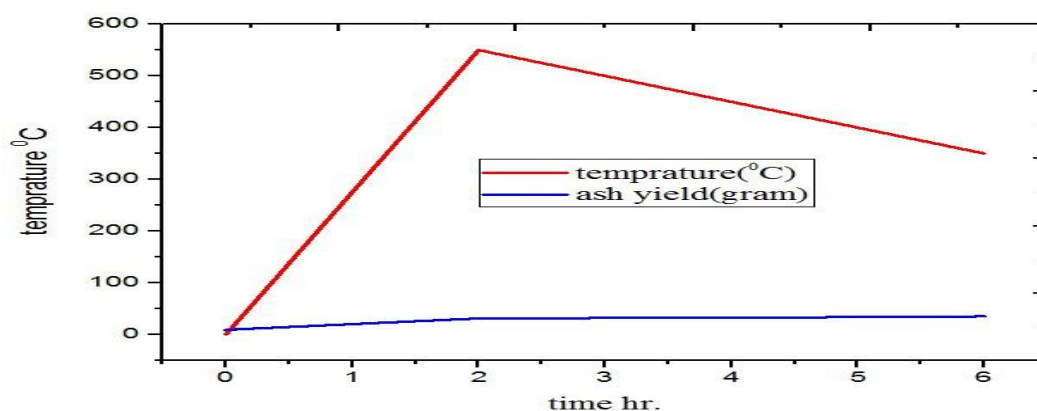


Figure 2; Ash yields with in different temperature and time from 200 gram

When 20 grams of ash dissolved in 120 ml of NaOH (aq) solution continuously stirred by magnetic stirrers with in a covered beaker heated at 80°C for 3 hrs. Obtained sodium silicate solution measured its pH is 13.3 by using pH meter but to adjust its pH by using 1N HCl its pH becomes 7. After that the solution was incubated at 45 °C for 6 hrs. it forms a good viscous then by using test tube the viscous was separated by centrifuge at 4000 rpm for 30 minute and dried for 5hrs obtained 10 grams of silica.

4.2. Discussion

Corn cobs have moisture content of 40-60% during harvesting time. The result shows that its moisture content is 60% which is within in the range. Storage mechanism of corncob is the big factor in varying moisture content.

These variations indirectly affect pre-treatment process of silica production. Before pre-treatment process the surface area of corn cobs increase in order to get the desired amount of size. As the size of particle decrease the surface area will be increase. This sample size and moisture content are factors affecting the pre-treatment process.

After necessary sized particles are getting, the result was treated in water .In pre-treatment process, cellulose is separate from lignin component through steam treatment. The dried the slurry of corn cobs in oven dried at temperature of 115°C for a few time rather than steam. In this process sized cobs are added into water and then cooked for few time. Due to the size of corn cobs, storage of corn cob powder and temperature the desired amount of corn cob powder is not properly extracted. During soaking process there was used citric acid in the laboratory to increase purity of silica.

CHAPTER FIVE

5. Material and Energy Balance

The amount of Materials that pass through processing operations can be described by material balances. Such balances are statements on the conservation of mass. Similarly, energy quantities can be described by energy balances, which are statements on the conservation of energy. Material and energy balances are very important in an industry. Material balances are fundamental to the control of processing, particularly in the control of yields of the products. Energy balance used to determine the amount of energy required for plant.

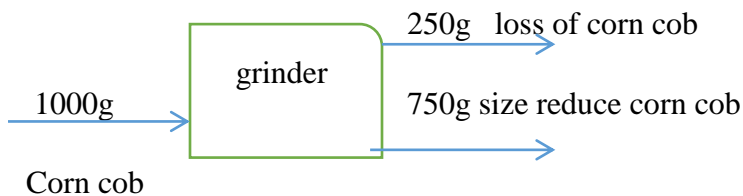
5.1. Material Balance

General assumption

- Total mass is conserved quantity
- At steady state with a chemical reaction

5.1.1. Material balance on laboratory level

1. Material balance on Grinder machine



General mass balance equation

In put + generation = consumption+ output+ accumulation

Assume the process is steady state and there is no generation and consumption.

During grinder there are 25% losses from the total corn cob.

Losses of corn cob $= (25 * 1000) / 100 = 250 \text{ gm}$

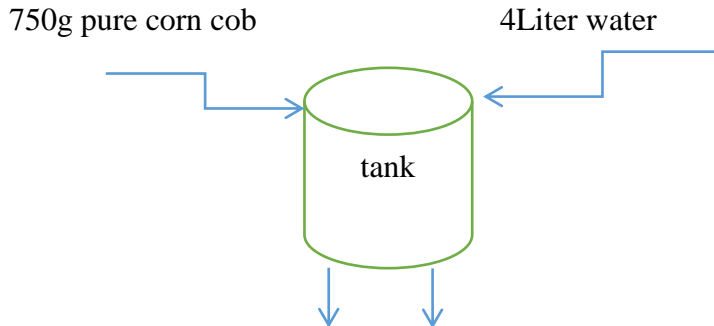
Input corn cob $= 1000 \text{ gm}$

Losses of corn cob $= 250 \text{ gm}$

Mass of size reduction corn cob $= \text{input corn cob} - \text{losses of corn cob}$

$= 1000 \text{ g} - 250 \text{ g} = 750 \text{ g}$

2. Material balance on washing tank



Impurities treated

wet corn cob powder=1020g

By water

In washing tank, the weight of corn cob powder increased by 10% of pure corn cob powder. The rest is removed as a waste within water.

Wet corn cob powder in year increasing = $(10 \times 750) / 100 = 75\text{g}$

Total wet corn cob powder = pure corn cob powder + wet corn cob powder increased in year.
 $= 750\text{g} + 75\text{g} = 825\text{g}$

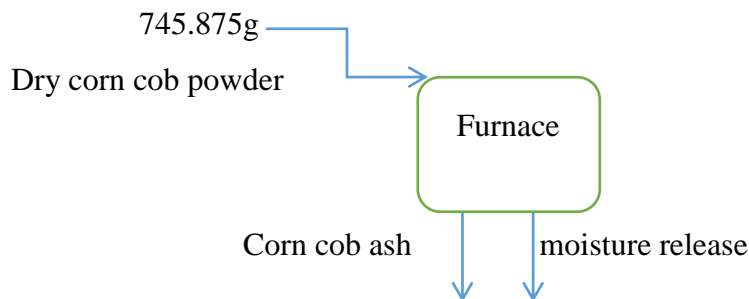
3. Material balance on dryer (oven)



When the witted corn cob is dryer the amount is reduced by half present from the pure corn cob powder. Therefore, the dry corn cob powder = $0.005 \times 825\text{g} = 4.125\text{g}$

Dry corn cob powder = pure corn cob powder – reduced corn cob powder
 $= [750\text{g} - 4.125\text{g}] \text{ tones / year} = 745.875\text{g}$

4. Material balance on furnace for composition

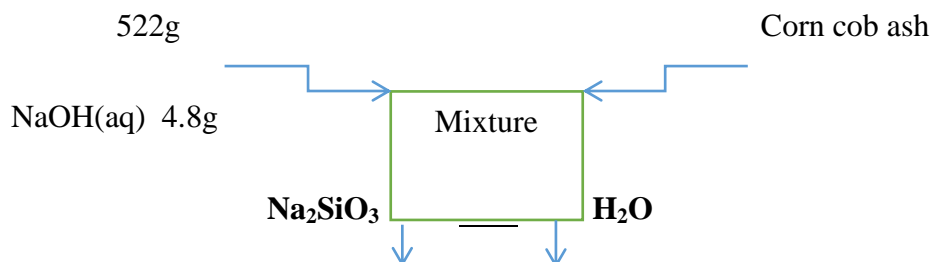


When the dry corn cob powder is burned at 550 °C there are 30 % losses from dry corn cob powder as moisture release.

$$\text{Moisture release} = 0.3 \times 745.875 \text{g} = 223.7625 \text{g}$$

$$\begin{aligned} \text{Corn cob ash} &= \text{dry corn cob powder} - \text{moisture release} = [745.875 \text{g} - 223.7625 \text{g}] \\ &= 522 \text{g} \end{aligned}$$

5. Material balance on mixture



For every 20g of CCA, you react with 120ml of NaOH. To calculate mass of sodium hydroxide uses the following equation.

$$\text{Molarity} = \frac{\text{given mass}}{\text{molar mass} \times \text{volume}}$$

$$\text{Given } V = [120 \text{ ml} \times 1 \text{ L}] / 1000 \text{ ml} = 0.12 \text{ L}$$

$$\text{Molar mass of NaOH} = 40 \text{ gram per mole}$$

$$\text{Molarity} = 1 \text{ mole/L}$$

Mass of NaOH = $1 \times 0.12 \times 40 = 4.8$ gram and from this relation the amount of NaOH required is 48 percent of the corn cob ash.

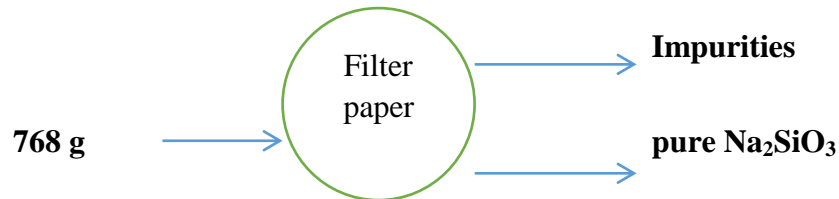
$$\text{Amount of NaOH} = 0.48 \times 522 \text{g} = 250.56 \text{g}$$

The amount of water can be removed by evaporator is 0.7% from corn cob ash.

$$\text{H}_2\text{O removed} = 0.007 \times 522 \text{ g tones/ year} = 3.654$$

$$\begin{aligned} \text{Amount of Na}_2\text{SiO}_3 &= [\text{Corn cob ash} + \text{NaOH (aq)}] - \text{H}_2\text{O removed} \\ &= ([522 + 250.56] - 3.654) \\ &= 768 \text{ g} \end{aligned}$$

6. Material balance on filtration tank

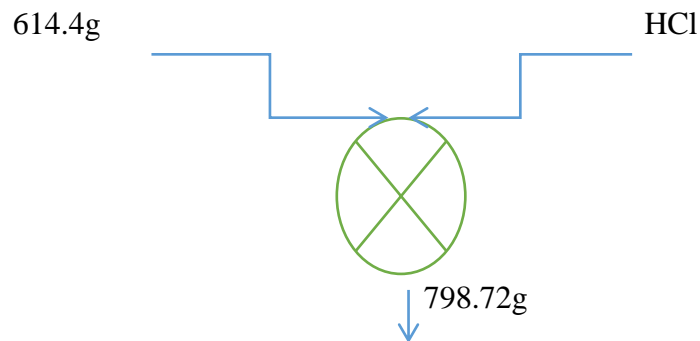


20% of impurities are removed from Na_2SiO_3 .

$$\text{Amount of impurities} = 0.2 \times 768 = 153.6 \text{ g}$$

$$\begin{aligned} \text{Amount of Pure Na}_2\text{SiO}_3 &= \text{Na}_2\text{SiO}_3 - \text{amount of impurities.} = [768 - 153.6] \text{ g} \\ &= 614.4 \text{ g} \end{aligned}$$

7. Material balance on mixture of Pure Na_2SiO_3 and HCl

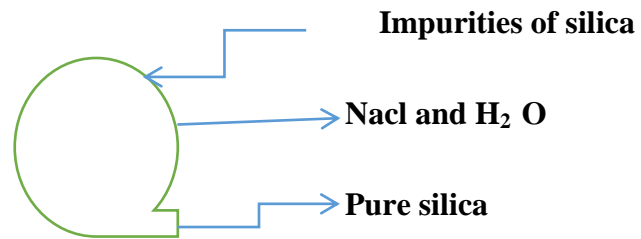


The amount of HCl required for neutralization of silicate is 30% of Na_2SiO_3

$$\text{Amount of HCl} = (30 \times 614.4) / 100 = 184.32 \text{ g}$$

$$\text{Impurities of silica} = [184.32 + 614.4] \text{ g} = 798.72 \text{ g}$$

8. Material balance on centrifuge for separation of solid and liquid



Assumption the removal of water from centrifuge is 50 % of impurities of silica.

$$\text{Amount of H}_2\text{O} = 0.5 \times 798.72\text{g} = 399.36\text{g}$$

The removal of Nacl with different impurities is 48.7 % of impurities of silica.

$$\text{Amount of Nacl} = 0.487 \times 798.72\text{g} = 389.36\text{g}$$

$$\text{Amount of pure silica} = \text{impurities of silica} - [\text{H}_2\text{O} + \text{Nacl}]$$

$$\text{Amount of pure silica} = 798.72\text{g} - [399.36\text{g} + 389.36\text{g}]$$

$$= 10\text{g}$$

5.1.2. Material balance on industrial level

General assumption

- Total mass is conserved quantity
- At steady state with a chemical reaction

Assume basis of the raw material of corn cob is 4,000,000 tons /year in industrial way.

From experimental analysis material and energy balance changed to in industrial way by considered the correct relation.

1. Material balance on Grinder machine

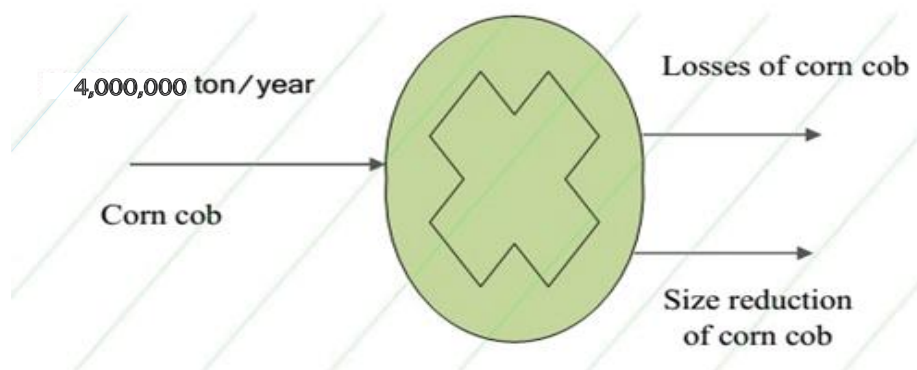


Figure3; Hammer Crusher for Reducing Raw Material

General mass balance equation

In put + generation = consumption+ output+ accumulation

Assume the process is steady state and there is no generation and consumption.

Therefore, the above equation is reduced in to the following way.

Input =out use for all calculation.

During grinder there are 10% losses from the total corn cob.

$$\text{Losses of corn cob} = \frac{10 \times 4,000,000}{100} = 400,000 \text{ ton/year}$$

Mass of size reduction corn cob=input corn cob –losses of corn cob

$$\begin{aligned} &= 4,000,000 \text{ tones/year}-400,000 \text{ tones /year} \\ &= 3,600,000 \text{ tones/year} \end{aligned}$$

2. Material balance on screening

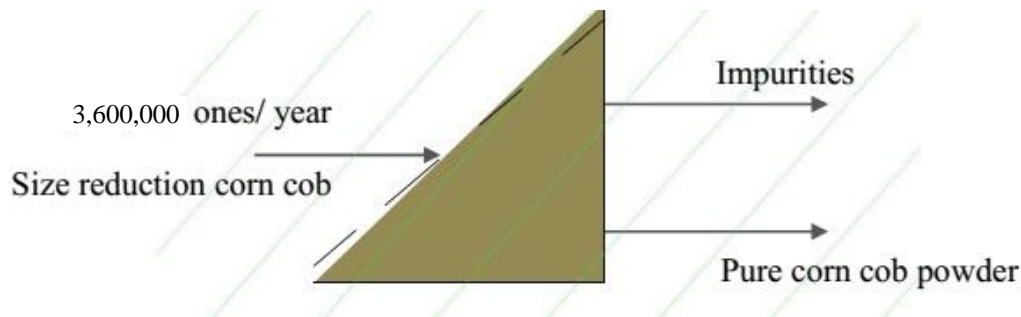


Figure 4Screening of Over Sized Material

In screening machine there are 6% losses of impurities from the size reduction of corn cob.

$$\text{Loss Impurities} = \frac{6 \times 3,600,000}{100} = 216,000 \text{ ton/year}$$

The mass of pure corn cob powder=size reduction of corn cob – impurities.

$$\begin{aligned} &= 3,600,000 \text{ tones/year} - 216,000 \text{ tones /year.} \\ &= \mathbf{3,384,000 \text{ tones/year}} \end{aligned}$$

3. Material balance on washing tank

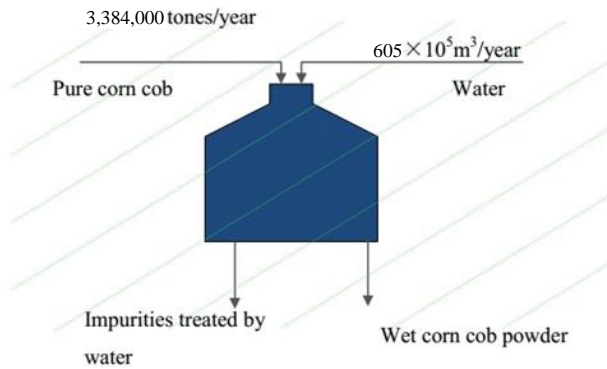


Figure 5; Washing Tank of Pure Raw Material

In washing tank, the weight of corn cob powder increased by 35 % of pure corn cob powder. The rest is removed as a waste within water.

$$\frac{35 \times 3,384,000}{100} = 1,184,400 \text{ ton/ year}$$

Wet corn cob powder in year increasing =

$$\begin{aligned} \text{Total wet corn cob powder} &= \text{pure corn cob powder} + \text{wet corn cob powder increased in year} \\ &= 3,384,000 \text{ tones/year} + 1,184,400 \text{ tones / year} \\ &= 4,568,400 \text{ tones / year.} \end{aligned}$$

$$\begin{aligned} \text{Impurities treated by water} &= [\text{water} + \text{pure corn cob powder}] - \text{wet corn cob powder} \\ &= ([605 \times 10^5 + 3,384,000] - 4,568,400) \text{ tones / year} \\ &= 59,315,600 \text{ tones/ year} \end{aligned}$$

4. Material balance on dryer

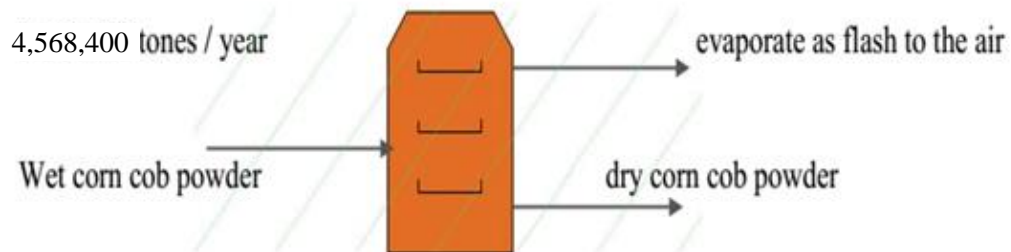


Figure 6. Dryer of Raw Material

When the witted corn cob is dryer the amount is reduced by half present from the pure corn cob powder. Therefore, the dry corn cob powder = $0.005 \times 3,384,000$ tones / year = 16,920 tones / year.

$$\begin{aligned} \text{Dry corn cob powder} &= \text{pure corn cob powder} - \text{reduced corn cob powder} \\ &= [3,384,000 - 16,920] \text{ tones/year} \\ &= 3,367,080 \text{ tones / year} \end{aligned}$$

evaporate as flash to the air = wet corn cob powder – dry corn cob powder.

$$\begin{aligned} &= 3,384,000 \text{ tones / year} - 3,367,080 \text{ tones / year} \\ &= 16,920 \text{ tones / year} \end{aligned}$$

5. Material balance on furnace for composition

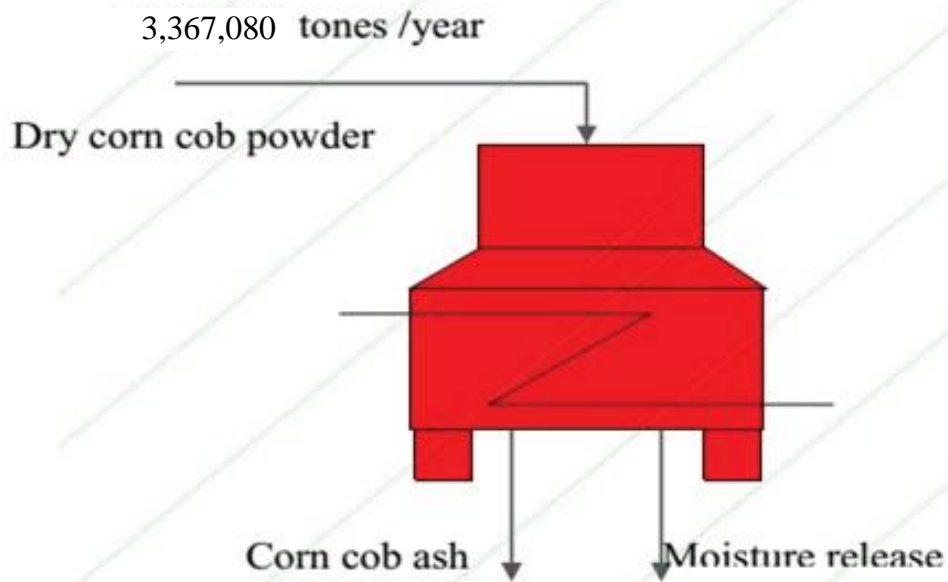


Figure 7. Muffle Furnace for Combustion

When the dry corn cob powder is burned at 550 °C there are 10 % losses from dry corn cob powder as moisture release. Moisture release = $0.1 \times 3,367,080$ tones/ year = 336,708 tones / year

$$\begin{aligned} \text{Corn cob ash} &= \text{dry corn cob powder} - \text{moisture release} \\ &= 3,367,080 - 336,708 \text{ tones/year} \end{aligned}$$

$$= 3,030,372 \text{ tones/year}$$

6. Material balance on mixture

For every 20g of CCA, you react with 120ml of NaOH. To calculate mass of sodium hydroxide uses the following equation.

$$\text{Molarity} = \frac{\text{given mass}}{\text{molar mass} \times \text{volume}}$$

$$\text{Given } V = [120 \text{ ml} \times 1 \text{ L}] / 1000 \text{ ml} = 0.12 \text{ L}$$

$$\text{Molar mass of NaOH} = 40 \text{ gram per mole}$$

$$\text{Molarity} = 1 \text{ mole/L}$$

Mass of NaOH = $1 \times 0.12 \times 40 = 4.8$ gram and from this relation the amount of NaOH required is 48 percent of the corn cob ash.

$$\text{Amount of NaOH} = 0.48 \times 3,031,000 \text{ tones / year} = 1,454,880 \text{ tones / year}$$

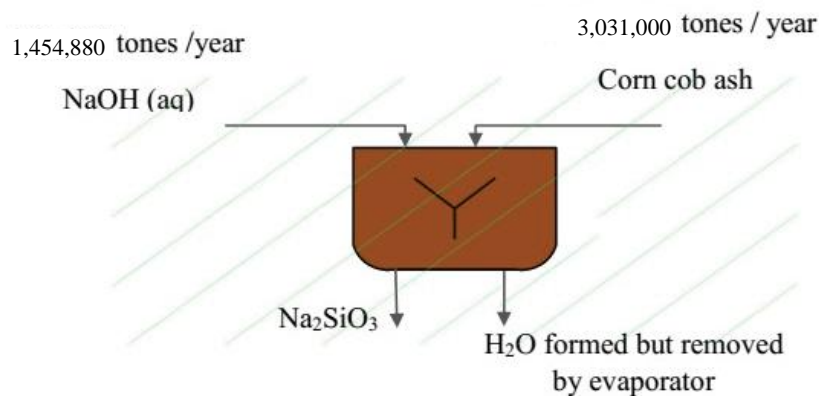


Figure 8. Mixer of a Different Solution

Assume the amount of water can be removed by evaporator is 0.2% from corn cob ash.

$$\text{H}_2\text{O removed} = 0.002 \times 3,031,000 \text{ tones/ year}$$

$$= 6,062 \text{ tones / year.}$$

$$\text{Amount of Na}_2\text{SiO}_3 = [\text{Corn cob ash} + \text{NaOH (aq)}] - \text{H}_2\text{O removed}$$

$$= ([3,031,000 + 1,454,880] - 6,062) \text{ tones / year}$$

$$= 4,479,818 \text{ tones / year.}$$

7. Material balance on filtration tank

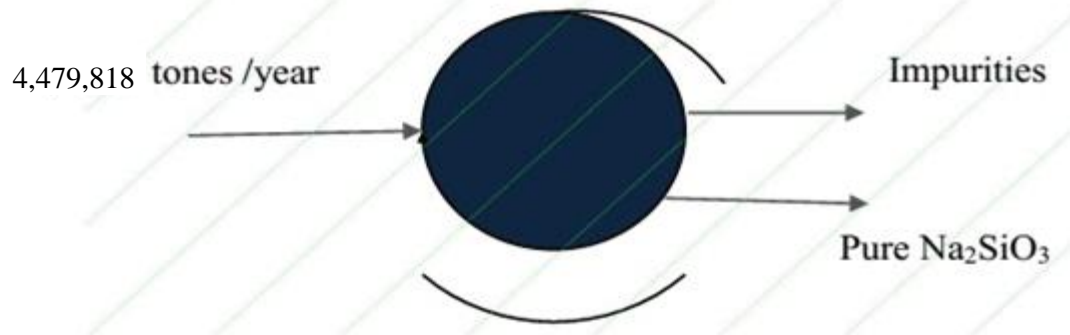


Figure 9; Filtration Tank

Assume four percent of impurities are removed from Na_2SiO_3 .

Amount of impurities = $0.04 \times 4,479,818 \text{ tones / year} = 179,193 \text{ tones / year}$

Amount of Pure Na_2SiO_3

= $\text{Na}_2\text{SiO}_3 - \text{amount of impurities.} = [4,479,818 - 179,193] \text{ tones / year}$

= $4,300,625 \text{ tones / year.}$

8. Material balance on mixture of Pure Na_2SiO_3 and hcl

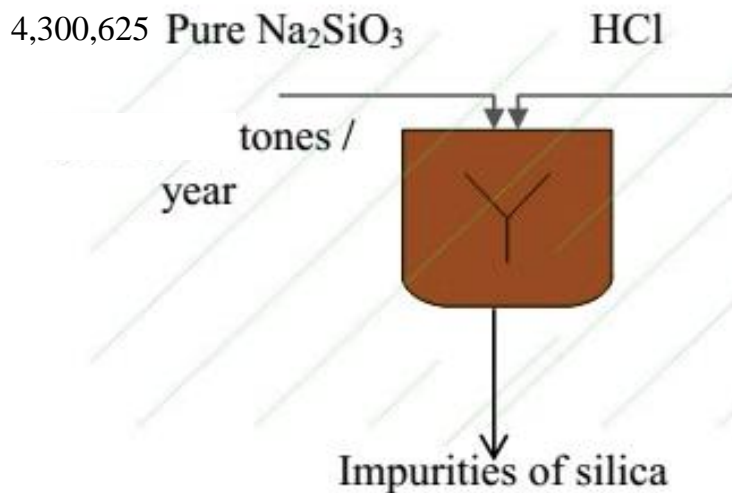


Figure 10. Mixer of Pure Na_2SiO_3 and hcl

The amount of Hcl required for neutralization of silicate is 35 % of Na_2SiO_3

$$\frac{35 \times 4,300,625}{100} = 1,505,218.78 \text{ ton/year}$$

Amount of Hcl =

Impurities of silica = $[1,505,218.78 + 4,300,625]$ tone/year = 5,805,844 tones/year

9. Material balance on centrifuge for separation of solid and liquid

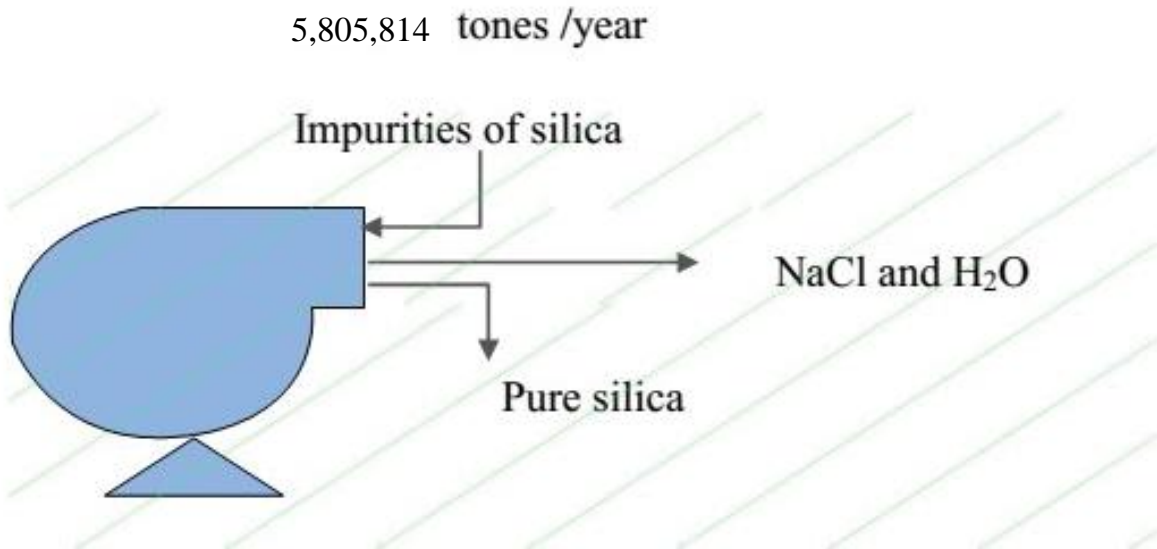


Figure 11. Separation of Solid and Liquid by Centrifugation

Assumption the removal of water from centrifuge is 30 % of impurities of silica.

Amount of $H_2O = 0.3 \times 5,805,844$ tones/year = 1,741,753 tones / year

The removal of NaCl with different impurities is 50 % of impurities of silica.

Amount of NaCl = $0.5 \times 5,805,844$ tones / year = 2,902,922 tones/year.

Amount of pure silica = impurities of silica - [H_2O + NaCl]

Amount of pure silica = $5,805,844 - [1,741,753 + 2,902,922] = 1,161,169$ tones/year

Table 4 .Generalization of material balance

Serial no,	Unit operation	Input	Out put
1	Grind machine	Corn cob	Size reduction of corn cob
2	Screening	Size reduction corn cob	Pure corn cob powder
3	Washing tank	Pure corn cob powder and water	Impurities treated by water and wet corn powder
4	Dryer	Wet corn cob powder	Evaporate and dry corn cob powder
5	Furnace	Dry corn cob powder	Moisture and corn cob ash

6	Mixer	Corn cob ash	H ₂ O formed and Na ₂ SiO ₃
7	Filtration	Na ₂ SiO ₃	Impurities and pure Na ₂ SiO ₃
8	Mixer	Hcl and pure Na ₂ SiO ₃	Impurities of silica
9	Centrifuge	Impurities of silica	Nacl , pure silica and H ₂ O

5.2. Energy Balance

The conservation of energy, however, differs from that of mass in that energy can be generated (or consumed) in a chemical process. Material can change form, new molecular species can be formed by chemical reaction, but the total mass flow into a process unit must be equal to the flow out at the steady state. The same is not true of energy. The total enthalpy of the outlet streams will not equal that of the inlet streams if energy is generated or consumed in the processes; such as that due to heat of reaction. Energy can exist in several forms: heat, mechanical energy, electrical energy, and it is the total energy that is conserved. In process design, energy balances are made to determine the energy requirements of the process: the heating, cooling and power required. In plant operation, an energy balance (energy audit) on the plant will show the pattern of energy usage, and suggest areas for conservation and savings. A general equation can be written for the conservation of energy.

Energy out = Energy in + generation - consumption – accumulation

This is a statement of the first law of thermodynamics and an energy balance can be written for any process step. Chemical reaction will evolve energy (exothermic) or consume energy (endothermic). For steady-state processes the accumulation of both mass and energy will be zero.

Calculation of specific enthalpy

Tabulated values of enthalpy are available only for the more common materials. In the absence of published data the following expressions can be used to estimate the specific enthalpy (enthalpy per unit mass). For pure materials, with no phase change.

$$H(T) = \int_{T_D}^T CPdT$$

Where H (T) = specific enthalpy at temperature T

C_p = specific heat capacity of the material, constant pressure

T_d = the datum temperature and but there is a phase change the equation would be

$$H(T) = \int_{T_d}^{T_p} C_{p1} dT + \int_{T_p}^T C_{p2} dT$$

Where T_p = phase transition temperature

C_{p1} = specific heat capacity first phase, below T_p

C_{p2} = specific heat capacity second phase, above T_p

The specific heat at constant pressure will vary with temperature and to use above equations values of C_p must be available as a function of temperature. For solids and gases C_p is usually expressed as an empirical power series equation.

$$C_p = a + bt + ct^2 + dt^3$$

$$C_p = a + bt + CT^{-1/2}$$

Absolute (K) or relative ($^{\circ}\text{C}$) temperature scales may be specified when the relationship is in the form given in equation for absolute temperatures must be used.

As no data are given on the exact variation of the C_p of the liquid with temperature, use an equation of the form $C_p = a + bt$

Calculating a and b from the data given; this will be accurate enough over the range of temperature needed. Estimate the specific enthalpy of Na_2SiO_3 at 1 bar and 200°C , taking the datum temperature as 0°C . Boiling point of NaSiO_3 at 1 bar = 78.4°C . C_p of na_2si_3 @ 0°C = 24.65 Cal/ mole $^{\circ}\text{C}$ @ 100°C = 37.96 Cal /mole $^{\circ}\text{C}$ The value of a is @ 0°C = 24.65 Cal/ mole $^{\circ}\text{C}$.

$$B = \frac{\Delta C_p}{\Delta T} = \frac{37.96 - 24.65}{100 - 0} = 0.133$$

$$H@200^{\circ}\text{C} = \int_0^{78.4} C_p dT$$

But $C_p = a + bt$

$$C_p = 24.65 + 37.96 T$$

$$H@200^{\circ}\text{C} = \int_0^{78.4} (24.65 + 37.96T) dT$$

$$H@200^{\circ}\text{C} = 118,594.3 \text{ Cal/mole} = 118,594.3 \times 4.2$$

$$= 495,724 \text{ joule/ mole} = 495.724 \text{ K J/ mole}$$

$$= \text{Molecular weight of } \text{na}_2\text{si}_3 = 99 \text{ Kg/ mole}$$

$$H @ 200^{\circ}\text{C} = \frac{495.724 \text{ kJ/mol}}{99 \text{ kg/mol}} = 5.01 \text{ kJ/kg}$$

Energy balance on dryer

The inlet temperature ranges of dryer (100-120) °C and The out let temperature range (35-25) °C. Assume the temperature inlet dryer is 110 °C and out let temperature is 30°C

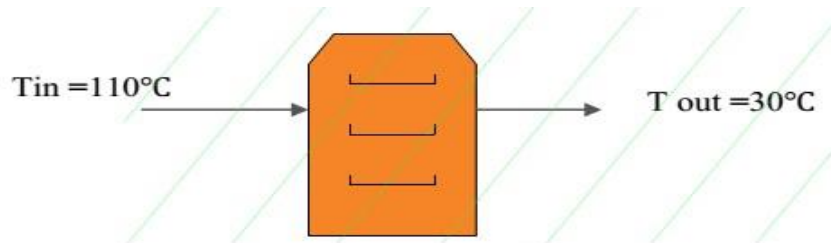


Figure 12; Final Product Dry by Dryer Operation

From energy equation

$$Q = mcp$$

$$(T_{\text{out}} - T_{\text{in}}) C_p \text{ water} = 2.69 \text{ KJ / Kg K and } C_p \text{ corn cob} = 2.54 \text{ KJ / Kg K}$$

Mass flow rate of corn cob in year = 3,367,080 tones / year = 384,369 Kg / hr.

$$Q = 384,369 \text{ Kg / hr.} \times (2.69 + 2.54) \text{ KJ / Kg K} \times 353 \text{ K}$$

$$Q = 927,062,589.1782 \text{ KJ / hr.}$$

CHAPTER SIX

6. Sizing of major plant equipment and cost estimation

6.1. Sizing of major plant

Safety factor: is a factor to represent the amount of our design that would be used to account for the changes in the operating performance with time. As a general;

Safety factor = (10-20) % capacity of equipment

Table 5. Physical properties of material

Serial no	Material	Property		
		Density (Kg /m3)	Melting point(°C)	Boiling point(°C)
1	Corn cob	719		
2	NaOH	2130	318	1388
3	Hcl	1.49	-114.2	-85.05
4	Acetic acid	1050	60.5	118.1
5	Citric acid	1660	153	310
6	Silica	2650	1710	2230

Equipment's are made from carbon steel and stillness steel based on different consideration.

Sizing of storage tank

Storage tanks are sized depended on daily requirement; they can store and assume 20% safety factor for the exothermic reaction was taken.

$$\text{Dried corn cob storage tank} = \frac{\text{mass flow rat of corn cob}}{\text{densty}}$$

Assumption mass flow rate of corn cob per a day is 4,000 tons per day.

$$Q = \frac{4,000 \text{ tonne/day}}{719 \text{ kg/m}^3} * \frac{1000 \text{ kg}}{1 \text{ ton}} * \frac{1 \text{ day}}{24 \text{ hr}} = \frac{231.8 \text{ m}^3}{\text{hr}}$$

Take safety factor =10 % of the capacity.

$$Q_S = 0.1 \times 231.8 = 23.18 \text{ m}^3/\text{hr}.$$

$$\text{Total capacity} = 231.8 + 23.18 = 254.98 \text{ m}^3/\text{hr}.$$

Storage tank for pre-treatment

Mixture of water and corn cob powder

$$\text{Density} = \frac{1000+719}{2} = \frac{859.5 \text{ kg}}{\text{hr}}$$

From the corn cob storage tank there is 10% loss due to size reduction of corn cob. Mass flow rate of mixture of water and corn cob is $4000 \text{ ton/day} \times 0.1 = 400 \text{ tons per day loss}$.

$$\text{Capacity} = \frac{\text{mass flow rat of corn cob and water}}{\text{densty}} = Q = \frac{3600 \frac{\text{ton}}{\text{day}} * \frac{1000 \text{ kg}}{1 \text{ ton}} * \frac{1 \text{ day}}{24 \text{ hr}}}{859.5 \frac{\text{kg}}{\text{m}^3}} = \frac{174.5 \text{ m}^3}{\text{hr}}$$

Take, safety factor = 10 % of the capacity.

$$Q_s = 0.1 \times 174.5 = 17.45 \text{ m}^3/\text{hr}.$$

$$\text{Total capacity} = 174.5 + 17.45 = 191.95 \text{ m}^3/\text{hr}.$$

Silica storage tank

Density of silica = 2650 Kg/m³

Mass flow rate of silica produced per day = 4860 ton per day.

$$\text{Capacity} = \frac{\text{mass flow rat of silica}}{\text{density}} = \frac{4860 \text{ ton/day} * \frac{1000 \text{ kg}}{1 \text{ ton}} * \frac{1 \text{ day}}{24 \text{ hr}}}{2650 \text{ kg/m}^3} = \frac{76.42 \text{ m}^3}{\text{hr}}$$

Take safety factor = 10 % of the capacity.

$$Q_s = 0.1 \times 76.42 = 7.642 \text{ m}^3/\text{hr}.$$

$$\text{Total capacity} = 7.642 + 76.42 = 84.062 \text{ m}^3/\text{hr}.$$

Storage tank for the mixing of acid and corn cob powder

Mixture of acid and corn cob powder of density is:

$$\text{Density} = 1050 \text{ kg/m}^3 \times 0.9 + 719 \text{ kg/m}^3 \times 0.1 = 971.9 \text{ kg/m}^3$$

Mass flow rate = 2560 ton/day

Capacity =

$$\frac{\text{mass flow rat of accid and corn cob}}{\text{density}} = \frac{2560 \frac{\text{ton}}{\text{day}} * \frac{1000 \text{ kg}}{1 \text{ ton}} * \frac{1 \text{ day}}{24 \text{ hr}}}{971.9 \frac{\text{kg}}{\text{m}^3}} = \frac{109.75 \text{ m}^3}{\text{hr}}$$

Take safety factor = 10 % of the capacity.

$$Q_s = 0.1 \times 109.75 = 10.975 \text{ m}^3/\text{hr}.$$

$$\text{Total capacity} = 10.975 + 109.75 = 120.725 \text{ m}^3/\text{hr}$$

Sizing of Pump

Table 6. Pump for delivering from storage tank

Slurry	To mix acid and water from corn cob
Head	4 m
Density	971.9 Kg/m ³
Capacity	109.75 m ³ / hr.

$$\text{Power} = D \times g \times h \times Q$$

$$= 971.9 \text{ kg/m}^3 \times 9.81 \text{ m/s}^2 \times 4 \text{ m} \times 109.75 \text{ m}^3/\text{hr.} \times 1 / 3600 \text{ second}$$

$$= 1162.66 \text{ W.}$$

Table 7. Pump for delivering from pre-treatment storage

Slurry	Mixture of water and corn cob
Head	4 m
Density	859.5 Kg/m ³
Capacity	184.2 m ³ / hr.

$$\text{Power} = \rho \times g \times h \times Q$$

$$= 859.5 \text{ kg/m}^3 \times 9.81 \text{ m/s}^2 \times 4 \text{ m} \times 184.2 \text{ m}^3/\text{hr.} \times 1 / 3600 \text{ second}$$

$$= 1725.69 \text{ W.}$$

Sizing on Drier

Mass flow rate of corn cob = 2500 ton/day

Density of corn cob = 719 Kg/m³

Volume of inlet per hour = [(2500 ton / day) / 719 kg / m³] × 1000 kg / ton

$$V = \frac{2500 \text{ ton}}{\text{day}} \times \frac{1000 \text{ kg}}{\text{ton}} \times \frac{1 \text{ day}}{24 \text{ hr}} \times \frac{1 \text{ m}^3}{719 \text{ kg}} = \frac{144.88 \text{ m}^3}{\text{hr}}$$

Assume residence time 2 hr. / batch,

$$V = \frac{144.88 \text{ m}^3}{\text{hr}} \times \frac{2 \text{ hr}}{\text{batch}} = 289.76 \text{ m}^3 / \text{batch}$$

Take safety factor = 10 % of the capacity.

$$Q_s = 0.1 \times 289.76 = 28.976 \text{ m}^3 / \text{batch.}$$

Total capacity = 28.976 + 289.76 = 318.736 m³/ batch.

Sizing on Mixer

Take safety factor of 15%

Mass of mixture = 3500 ton/day

Density of mixture = 971.9 kg/m³

Q = (Mass of mixture + safety of factory

$$= (3500 + 3500 \times 0.15) / 971.9 \text{ kg/m}^3 \times 1000 \text{ kg/ton} \times 1 \text{ day/24hr.}$$

$$= 172.56 \text{ m}^3/\text{hr.}$$

Take safety factor = 10 % of the capacity

$$Q_s = 0.1 \times 172.56 = 17.256 \text{ m}^3/\text{hr.}$$

Total capacity = 17.256 + 172.56 = 189.816 m³/ hr.

Sizing of hydrolyser

Mass flow rate of pre-treated mixture = 3800 ton/day

Mass flow rate of hydrochloric acid MHA = 300 ton/day

Density of mixture = 859.5 kg/m³

Density of sodium hydroxide = 2,130 kg/m³

Density of water = 1000 kg/m³

$$Q = \left[\frac{\text{mass flow rate of pretrated mixtur}}{\text{density of pretrated mixture}} + \frac{\text{mass flow rate of NaOH}}{\text{density of NaOH}} + \frac{\text{mass flow rate of HCL}}{\text{density of HCL}} \right] \frac{1000 \text{ kg}}{1 \text{ tone}}$$

$$Q = \left[\left(\frac{3800 \text{ ton/day}}{859.5 \text{ kg/m}^3} + \frac{2550 \text{ ton/day}}{2,130 \text{ kg/m}^3} + \frac{300 \text{ ton/day}}{1.49 \text{ kg/m}^3} \right) \right] * \frac{1000 \text{ kg}}{1 \text{ ton}} * \frac{1 \text{ day}}{24 \text{ hr}} = \frac{823.36 \text{ m}^3}{\text{hr}}$$

Take safety factor = 10 % of the capacity.

$$Q_s = 0.1 \times 823.36 = 82.336 \text{ m}^3/\text{hr.}$$

Total capacity = 82.336 + 823.36

$$= 905.696 \text{ m}^3/\text{hr.}$$

6.2. Cost estimation

6.2.1. Process of economics

Before attempting the design of a process and plant, it is the responsibility of the chemical engineer to make techno economic feasibility. It is essential that the chemical

engineer be aware of the many different types of costs involved in the design processes. Even if insufficient technical information is available to design a plant completely, we must still make techno economic feasibility to determine if it is economically and financially feasible. The ultimate purpose for developing such a detailed process design and cost estimate is to determine the economics of silica production from corn cob.

Cost Indexes

Are dimensionless numbers employed to updating capital cost required to erect a chemical plant from a past date to a later time.

Methods of cost indexes

- ❖ Marshall and Swift Equipment Cost Indexes
- ❖ Engineering News-Record Construction Cost Index
- ❖ Nelson-Farrar Refinery Construction Cost Index
- ❖ Chemical Engineering Plant Cost Index (CEPCI).

By using Equipment Cost Indexes 500 and 600 for the year 2014 and 2022 respectively

$$\text{Present cost} = \text{original cost} \left[\frac{\text{index value at present time}}{\text{index value at time original cost was obtained}} \right]$$

$$\text{Present cost} = \text{original cost} \left[\frac{\text{index value at present time (2017)}}{\text{index value at time original cost (2014)}} \right]$$

Table 8. Total present purchased equipment cost from calculation and match.com

No	Equipment name	Capacity	Quality	US dollar	Total cost (US dollar)
1.	Grinder machine	10 T/hr.	15	\$12,000	\$180000
2.	Screening(sieve)	32ft ²	3	\$18,700	\$56100
3.	Washing tank	800	1	\$30,000	\$30,000
4.	Boiler	10,000 lb./hr.	1	\$690,000	\$690,000
5.	Muffle furnace	240 L	2	\$1,000	\$2,000

6.	Thermocouple	(400-700) ^o c	2	\$10	\$20
7.	Beam balance	>500 kg	2	\$200	\$400
8.	Oven drier	200 ft ²	1	\$100,000	\$100,000
9.	Filtration tank	200ft ²	1	\$182,000	\$182,000
10.	Mixer	200ft ²	2	\$5,000	\$10,000
11.	Aging tank	200ft ²	2	\$10,000	\$20,000
12.	PH meter	-----	1	\$210	\$210
13.	Centrifugal separator	24 inch	2	\$14,300	\$28,600
14.	Conveyor belt	36 inch	3	\$30,000	\$90,000
	Total				\$13,389,330

Total Purchased equipment cost (TPEC) = \$ 13,389,330

But TPEC = 15 – 40% of FCI

Take the present between 15&40 let us take 30 %

$FCI = TPEC / 0.3 = \$ 44,631,100$

Methods for estimating capital investment

Various methods can be employed for estimated capital investment. The choice of any one method depends on the amount of available information and the accuracy desired.

Six methods are listed below:

- Detailed-itemestimate Method
- Unit-Cost Estimate Method.
- Percentage of Delivered Equipment Cost Method.
- Lang Factor for Approximation of Capital Investment Method.

- Power Factor Applied to Plant/Capacity Ratio Method.
- Investment Cost per Unit of Capacity Method

Direct cost estimation

Calculation of direct cost based on fixed capital investment (FCI)

- a) Purchase equipment installation including insulation and painting is (6 – 14) % of FCI
Take 12% and therefore, $0.12 \times \text{FCI} = \$5,355,732$
 - b) Instrumentation and control = (2 – 8) % FCI
Take 6%, therefore, $0.06 \times \text{FCI} = \$ 2,667,866$
 - c) Piping installed = (3 – 20) %
Take 10%, therefore, $0.1 \times \text{FCI} = \$4,463,110$
 - d) Electrical installed = (2 – 10) %
Take 9%, therefore, $0.09 \times \text{FCI} = \$4,016,799$
 - e) Building including service = (3 – 18) %
Take 10%, therefore, $0.1 \times \text{FCI} = \$4,463,110$
 - f) Yard improvement = (2 – 5) %
Take 4%, therefore, $0.04 \times \text{FCI} = \$1,785,244$
 - g) Service facility installed = (8 – 20) %
Take 18%, therefore, $0.18 \times \text{FCI} = \$8,033,598$
 - h) Land = (1 – 2) %
Take 1.5%, therefore, $0.015 \times \text{FCI} = \$669,466$
- Therefore, the total direct cost is = 4,992,586.75

Table 9 .Direct cost estimation

Direct cost	Factor % in (FCI)	Cost in dollar
Purchased equipment cost \$	0.12	\$5,355,732
Instrumentation and control	0.06	\$ 2,667,866
Piping (installed)	0.1	\$4,463,110
Electrical (installed)	0.09	\$ 4,016,799
Building including service	0.1	\$4,463,110

Service facility(installed)	0.18	\$8,033,598
Yard improvement	0.04	\$1,785,244
Land	0.015	\$669,466
TOTAL		\$31,454,925

Table 10. Indirect cost estimation

Indirect cost	Factor (%)	Cost in dollar
Engineering and supervision	0.11	\$764,131.5
Construction expense	0.1	\$ 694,665
Contractor fee	0.04	\$ 277,866
Contingent	0.1	\$ 694,665
Total		\$ 2,431,327.5

Generally fixed capital cost = (80 – 90)%TCI

Take 88%, therefore, $TCI = \frac{\text{fixed capital investment}}{0.85} = \frac{\$66,946,650}{0.85} = \$78,760,764.71$

Therefore, total capital investment (TCI) = \$50,717,159.1

$TCI = FCI + WC$

Worked capital investment (WC) = TCI - FCI

$$= \$50,717,159.1 - \$44,631,100$$

$$= \$6,086,059.1$$

The capital needed to supply the necessary manufacturing and plant facilities is called the fixed capital investment, while that necessary for the operation of the plant is termed the working capital. The sum of the fixed-capital investment and the working capital is known as the total capital investment. The fixed-capital portion may be further subdivided into manufacturing fixed-capital investment and nonmanufacturing fixed-capital investment. Fixed-Capital Investment can be classified in to the following ways:

Manufacturing fixed-capital investment: is the capital necessary for the installed process equipment with all auxiliaries that are needed for complete process operation.

Nonmanufacturing fixed-capital investment: Fixed capital required for construction overhead and for all plant components that are not directly related to the process operation.

6.2.2. Estimation of total production cost

Total production cost = manufacturing cost + general expense

Manufacturing cost = Direct production cost + Fixed charge + plant overhead cost.

A) Direct production cost

Table 11. Raw material cost

Raw material	Amount / year	Cost / unit	Cost / amount
Corn cob	600,000 Ton	\$100 / ton	\$60,000,000
Distilled water	4088000 L	\$0.3 / L	\$1226400
NaOH	600,000 Kg	\$47/ Kg	\$ 28,200,000
Hcl	1000 L	\$13 /L	\$13,000
Citric acid	5000 L	\$ 870/ L	\$ 4,350,000
Total			\$ 93789400/year

Raw material cost = (10- 50) % TPC. Take 25%, where TPC is total production cost.

$$\text{TPC} = \frac{\text{Raw material cost}}{0.25} = \frac{\$93789400}{0.25} = \$375,157,600$$

Operating labour cost = (10-20) % TPC

Take 15%

$$0.15 \times \$375,157,600 = \$56273640$$

Direct super vision 17% of operating labour cost

$$0.17 \times \$56273640 = \$9566518.8$$

Utilities cost 15% of TPC $0.15 \times \$375,157,600 = \56273640

Maintenance and repair cost 6 % of FCI

$$0.06 \times \$6,946,650 = \$416799$$

Operating supplies cost 15% of maintenance and repair cost

$$0.15 \times \$416799 = \$62519.85$$

Laboratory cost = 15% operating labor

$$0.15 \times \$56273640 = \$8441046$$

Patent and loyalty cost = 3% TPC

$$0.03 \times \$375,157,600 = \$ 11254728$$

Total direct production cost = \$ 142,288,891.65

B) Fixed Charge

Deprecations Cost =10% FCI

$$0.1 \times \$6,946,650 = \$6694665$$

Local taxes =2% FCI

$$0.02 \times \$6,946,650 = \$138933$$

Insurance = 0.07% FCI $0.07 \times \$6946650 = \486265.5

Rent =10 % (land + building cost)

Building cost = 0.1 $\times \$6946650 = \694665

Rent = 0.1 $\times (\$694665 + \$74199.75) = \$768864.75$

Total fixed charge = \$2,088,728.25

C) Plant overhead cost (POC)

Plant overhead cost = 60 % (operating labor cost + cost of supervision + cost of maintenance and repair).

$$0.6 \times (\$56273640 + \$416799 + \$9566518.8) = 0.6 \times 66256957.8 = \$ 39754174.68$$

$$\text{POC} = 0.6 \times 66256957$$

$$\text{POC} = \$39754174.68$$

Manufacturing cost = POC + TFC + TDPC

Manufacturing cost = \$184,131,794.58

General expense

General Expense = Administrative cost + distribution and sealing cost + research and development

Administrative cost = 15% operating labor

$$0.15 \times \$56273640 = \$84410446$$

Distribution and selling cost = 11% TPC

$$0.11 \times \$375,157,600 = \$41267336$$

Research and development = 5% TPC $0.05 \times \$375,157,600 = \$ 18757880$

Financing cost = 5% TCI $0.05 \times \$8,172,529.42 = \$ 408626.471$

General expense = \$ 144,844,288.471

TPC = General expense + Manufacturing cost then TPC

= \$ 328,976,083.051 /yr. E.

Depreciation: Assumption

- The useful life of all the machines is 15 years (that is after it exceeds its salvage value, but it is still useful and effective) and the salvage value is 15 % of FCI.

$$\text{Therefore, } V_s = \frac{FCI \times 15}{100} = \frac{\$66,946,650 \times 15}{100} = \$10,041,997.5$$

In general, depreciation accounting methods may be divided into two classes:

1). Arbitrary methods giving no consideration to interest costs,

- ❖ Straight-line,
- ❖ Declining-balance, and
- ❖ Sum-of-the-years-digits methods.

2) Methods taking into account interest on the investment.

- ☞ Sinking -fund, and
- ☞ Present -worth methods

From the above depreciation accounting methods, we use straight line method because it is simple for calculation analysis.

Straight-Line Method

It is assumed that the value of the property decreases linearly with time and equal amounts are charged for depreciation each year throughout the entire service life of the property. Thus, annual depreciation cost may be expressed;

$$D = \frac{v - v_s}{n}$$

Where d = annual depreciation, \$/year

V = original value of the property at start of the service-life period, completely installed and ready for use, dollars.

V_s = salvage value of property

n = service life, years

$$D = \frac{v - v_s}{n} = \frac{\$669,466,50 - \$10,041,997.5}{15} = \$3,793,643.5/\text{year}$$

6.2.3. Profitability Analysis

Profitability analysis are the measure of the amount of profit that can be obtained from a given situation function of the quantity of goods or services produced and the selling price and also affected by the economic efficiency of the operation and may be expressed on a before-tax or after tax basis.

Amount of silica produced = 4,860 ton /day

Operating day in a year =300 days

4860 ten-day \times 300 day/yr= 1,458,000 ton/yr

Sell of silica per ton= \$250

Total income=1,458,000 ton/yr. \times \$ 250/ton = \$ 364,500,000 /yr.

Gross-earnings cost

Gross earnings = total income - total product cost.

Gross earning == \$ 364,500,000 /yr. - \$ 328,976,083.051 /yr.

Gross earning = \$35,523,916.949/yr.

Income tax per year is 35% of gross earning.

Income tax = $0.35 \times \$35,523,916.949$ /yr.

Income tax= \$21,433,370.932 / yr.

Net profit= gross earning – income tax

Net profit = \$35,523,916.949/ yr. - \$21,433,370.932 / yr.

Net profit = \$14,090,546.017 /yr.

6.2.3.1. Mathematical Methods of Profitability Evaluation

- ❖ Rate of return on initial investment
- ❖ Minimum pay out period with no interest charge
- ❖ Discounted cash flow, Net present worth and Capitalized costs

But we use the following two methods due to calculation simplicity.

A) Rate of return on investment

Expressed on an annual percentage, then yearly profit divided by the total initial investment necessary represents the fractional return, and this fraction times 100 is the standard per cent return on investment.

$$\text{RORI before tax} = \frac{\$35,523,916.949/\text{year}}{\$78,760,764.71} \times 100\% = 45.86\%$$

$$\text{RORI after tax} = \frac{\text{net annual profit}}{\text{Total capital investment}} \times 100\%$$

$$\text{RORI after tax} = \frac{\$14,090,546.017}{\$78,760,764.71} \times 100\% = 17.89\%$$

B) Payback period (PBP)

$$\begin{aligned} \text{C) Payback period after tax} &= \frac{\text{FCI}}{\text{net profit} + \text{depreciation cost}} \\ &= \frac{\$66,946,650}{\$14,090,546.017 + 66,946,65} \\ &= 3.22 \text{ year} \approx 3 \text{ year} \end{aligned}$$

D) Break-even Analysis (BE)

The break-even point occurs when the total annual product cost equals the total annual sales

$$\text{BE} = \frac{\text{FCI}(\text{fixed capital investment})}{\text{TCI}(\text{total capital investment}) - \text{WC}(\text{working capital})} \times 100\%$$

$$\text{BE} = \frac{\$66,946.650}{\$78,760,764.71 - \$11,814,114.71} \times 100\% = 87.8\%$$

CHAPTER SEVEN

7. Conclusion and Recommendation

7.1. Conclusion

Generally, we Conclude that producing silica from agro waste such as Corn Cob get feasible product for pure corn cob powder when properly follow the basic unit operations, methods and measured different parameters and produced great help in reducing the large effects of environmental pollution by fossil fuel as well as increase the corn cob plants as sources of material for silica production .use 550°C in furnace at 3 hr and get 60 gram of Ash from combustion and for every 20g of Corn cob ash was mixed with 1N Sodium hydroxide solution to produce sodium silicate solution and filtered by filter paper then neutralization of sodium silicate solution by 1N of HCl(aq) and separated by centrifugation next drying by oven at 80°C and 10-gram powder of silica was produced.

7.2. Recommendation

In order to produce silica, the moisture content of raw material should be low. This was because of when moisture content increase sizing is difficult, and cellulose amount also reduce. The storage of corn cob has the big factor in increasing moisture content of corn cobs. We recommended for future the store of corn cob have ventilator house, using as rotary drum dryer in place of oven dryer and through silica production process generate by product which is use as composite and to make activated carbon should be treated correctly. After silica produced we recommended that should be analysing the parameter of desired product is true or not by related technology and elemental silicon will produce by using reduction process and use different unit operations directly start to application area of silica powder.

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Appendices

Conversion is a measure of the fraction of the reagent that reacts. To optimize reactor design and to minimize by-product formation, the conversion of a particular reagent is often less than 10 per cent. If more than one reactant is used, the reagent on which the conversion is based must be specified and Conversion is defined by the following expression:

$$\text{conversion} = \frac{\text{amount of reagent consumed}}{\text{amount of supply}} * 100$$

$$\text{Conversion} = \frac{\text{amount of feed stream} - \text{amount of in product stream}}{\text{amount in feed stream}} * 100\%$$

Yield is a measure of the performance of a reactor or plant.

$$\text{Yield} = \frac{\text{mole of product produced} * \text{stouchiomertic factor}}{\text{mole of reagent converted}}$$

Stoichiometric factor = stoichiometric mole of reagent required per mole of product produced

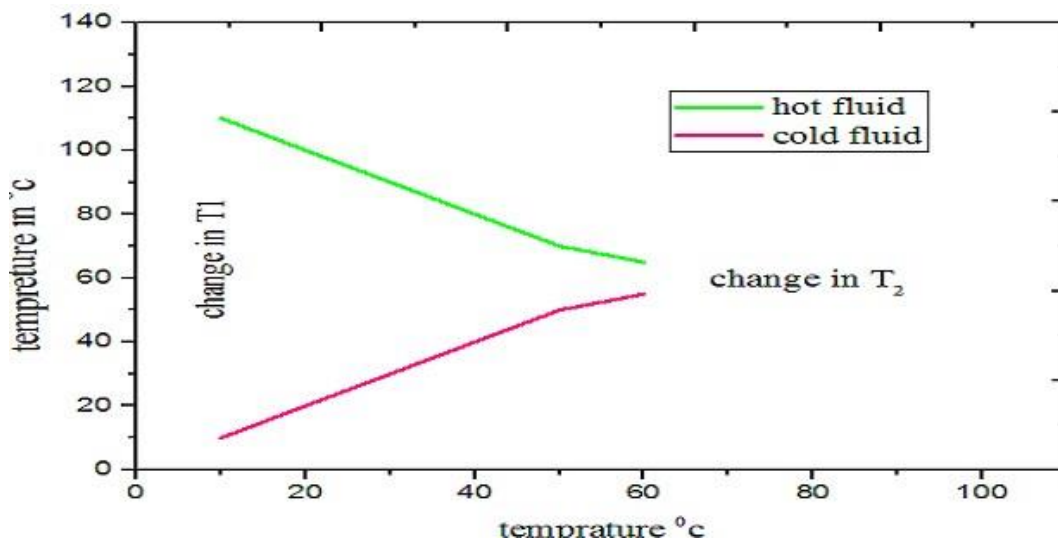


Figure 13 Concurrent Temperature flow between two bodies

In order to calculate log mean temperature from the above figure use the following formula

$$\Delta T_1 = 110^\circ\text{C} - 15^\circ\text{C} = 95^\circ\text{C}$$

$$\Delta T_2 = 65^\circ\text{C} - 55^\circ\text{C} = 10^\circ\text{C}$$

$$\Delta LTM = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)} = \frac{95 - 10}{\ln\left(\frac{95}{10}\right)} = 37.75^\circ\text{C}$$

Conversion factors for some common SI units and value

Volume

$$1 \text{ in}^3: 16.387 \text{ cm}^3$$

$$1 \text{ ft}^3: 0.02832 \text{ m}^3$$

$$1 \text{ yd}^3: 0.76453 \text{ m}^3$$

$$1 \text{ UK gal}: 4546.1 \text{ cm}^3$$

$$1 \text{ US gal}: 3785.4 \text{ cm}^3$$

Mass

$$1 \text{ lb.}: 0.45359237 \text{ kg}$$

$$1 \text{ ton}: 1016.06 \text{ kg}$$

Area

$$1 \text{ in}^2: 645.16 \text{ mm}^2$$

$$1 \text{ ft}^2: 0.092903 \text{ m}^2$$

$$1 \text{ yd}^2: 0.83613 \text{ m}^2$$

$$1 \text{ mile}^2: 2.590 \text{ km}^2$$