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Environmental Impacts of Glass Manufacturing Industry

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Abstract: Glass is a (usually) transparent, non-crystalline amorphous solid with many vital applications in various industries worldwide. However, like every other industry, waste is released into the environment in glass manufacturing. These are obstacles to maintaining the proper composition of the atmosphere. So this article will give you information about the present glass manufacturing industry in the world & manufacturing process steps, the ability to understand the waste that comes out during glass production also you can get details about Control techniques to reduce environmental pollution.

Index Terms: Glass manufacturing process, Emissions to Air, Pollution, Environmental Impact, Waste disposal.

1 INTRODUCTION

Glass production dates back to at least 7000 B.C., thousands of years ago. The Egyptians, who invented Glass first, regarded it as a priceless substance on par with jewels. (32135). The size of the worldwide Glass manufacturing market was estimated at USD 106.44 billion in 2021, and it is anticipated to increase at a CAGR of 5.2% from 2022 to 2030. During the projected period, it is anticipated that rising construction spending on homes and businesses, as well as increased use of recyclable materials in packaging, will fuel market expansion [1]. Glass attributes can be changed and controlled by altering composition and/or production methods since they are specific to the chemical makeup of the Glass. However, altering one glass attribute typically has an impact on the others. The mix of mechanical, chemical, thermal, optical, and other qualities is crucial when choosing a certain glass for a product. The choice of the best set of qualities for the application is at the heart of the science of glass making. Glass has a special set of qualities that make it cost-effective and have contributed to its widespread usage in construction, transportation, containers, and scientific items. The potential for producing a variety of materials and goods from Glass, according to many experts, has hardly been realized. Glass has also discovered new uses in the communications and electronics industries [2]. Atmospheric emissions from melting activities are what have glass production's biggest negative environmental impact. Water contamination, the exploitation of non-renewable natural resources, including sand and minerals, the generation of solid waste, and the emission of volatile organic compounds are further environmental problems (used in the production of mirrors and coatings) [3].

2 PROCESS DESCRIPTION

The glass business manufactures a vast range of goods, the bulk of which are supplied to other sectors of the economy, such as the construction, automotive, and food packaging sectors. There are, nevertheless, a few specialized, low-volume industries that produce expensive technical or specialized glass goods. At extremely high temperatures, various minerals are melted together to create Glass. The main component is silica in the form of sand, which is mixed with soda ash and limestone and melted at 1,700° C in a furnace. To create different hues or qualities, other materials can be used. Additionally, Glass can be coated, heated, etched, or embellished. Glass may be formed into packaging, automobile windscreens, glazing, and a variety of other things while it is still molten. The Glass's composition and pace of cooling will change depending on the final use. The six key product categories covered by this recommendation are as follows: (glass frit, water glass and stone wool are excluded):

- Container glass: Automated equipment press and/or blow molten glass into the desired shape. The final product is coated with surface coatings and colouring chemicals;
- Domestic: processes are similar to container glass. The products are finished through polishing, etching, engraving, enamelled etc.
- Flat glass: comprising float glass and rolled glass:
  - Float glass: molten glass is poured onto a bath of molten tin. The glass ribbon is caught by rollers and drawn in length and width. The product then passes through a temperature controlled tunnel for annealing (i.e. heat treatment to change glass properties). Glass is then cut and surface coatings added as required;
  - Rolled glass: molten glass is squeezed through water-cooled double steel rollers prior to annealing
- Special: a variety of chemical compositions and forming techniques are used, e.g. pressing, blowing, moulding, spinning, etc.;
- Continuous filament glass fibre: molten glass is drawn through bushings which contain over 1,600 calibrated holes at a constant speed of several thousand metres per minute. This is normally an aluminoborosilicate glass with very low sodium oxide content. The product is used to strengthen and stiffen thermosetting plastics, thermoplastics, nylon and polypropylene;
- Glass wool: molten glass flows into a rapidly- rotating alloy steel dish (crown) which has several hundred fine holes round the edge through which it is thrown out to form filaments. These are then extended into fine fibres by a high velocity blast of hot gas. The fibres are sprayed with a bonding agent, drawn by suction onto a conveyor and carried through an oven which cures the bonding agent, then to trimmers and guillotines which cut the product to size [4].

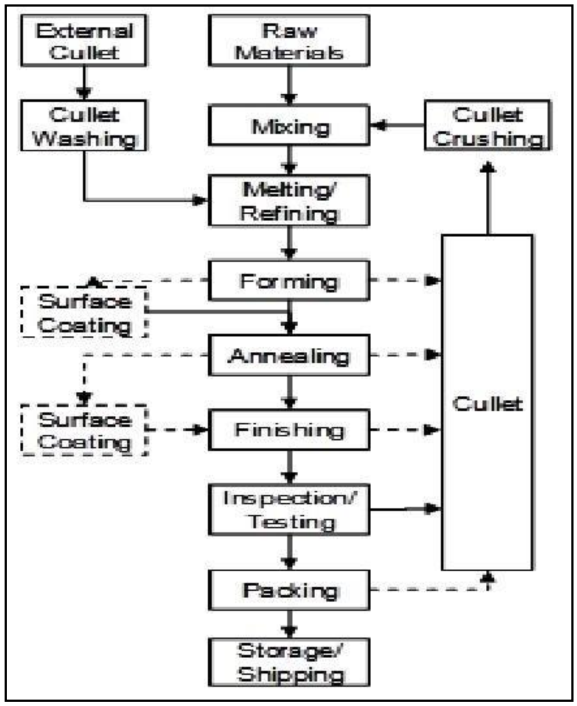

Fig.1. Glass Manufacturing – Typical Flow diagram [4]

3 MAJOR INGREDIENTS

The prime ingredient in passive solar building is the glass. Now let us put limelight to the major ingredients of glass. These ingredients required to manufacture glass include. The composition of glass is representing in Fig.2.

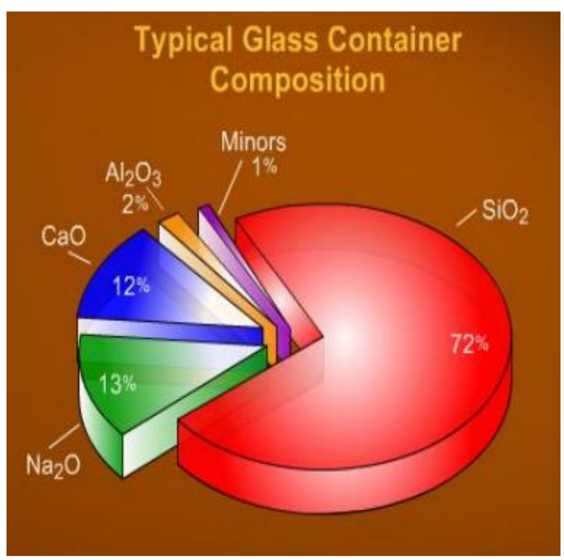

Fig.2. Composition of glass [6]

There are various types of glass manufactured using various techniques, with the aid of minor changes to their composition and occasionally with the addition of additional materials and and limestone are the most common sources of low-iron glass. Furnaces are designed to handle higher smelting and refining temperatures in order to produce low-iron glass. Thin layers of coating are typically applied to one side of the glass to demonstrate the purpose of anti-reflection, improved conductivity, or self-cleaning [6].

4. WASTE GENERATION

When deciding on a probable technique to generate garbage, it is particularly important to improve the design of the waste handling and gathering equipment to assess the waste's physical, chemical, and thermal characteristics and to preserve compliance with regional and national legislation. To comprehend the level of waste production. It is crucial to do research on waste characterization using methods that have received international recognition. The kind (composition) and amounts (created or produced) of pollutants in a waste stream must be described. [7]

Environmental issues in glass manufacturing primarily include the following:

- Emissions to air
- Wastewater
- Solid waste

Emissions to Air

Despite the fact that the finished product, glass, is entirely recyclable and can be used to make new glass, some environmental organizations and laws, such as the federal Clean Air Act, are not happy with the process. Air-polluting substances like nitrogen oxides, sulfur dioxide, and particulates have all been proven to be emitted during the glass manufacturing process. These pose a serious health risk since the metal, chemical, acid, and dust particles are so minute (10 micrometers or even smaller) that they can pass through the nose and throat and into the lungs, where they can cause harm to the body. [8]

Sulfur dioxide, carbon dioxide, and nitrogen oxides are released during the high-temperature, energy-intensive process of making glass, which also causes the oxidation of atmospheric nitrogen. Additionally, particulate matter (PM) and possibly trace amounts of metals are present in furnace emissions. Between 80 and 90 percent of all air pollution emissions from a glass manufacturing facility are caused by melting furnaces. The many types of glass production processes are associated with emissions from the forming and finishing phases. The majority of emissions are produced by container press and blow machines as a result of molten glass (the "gob") contacting the lubricants on the machinery. In the annealing process, when the glass product is held at 500-550°C in a regulated cooling process in the "lehr," emissions related to combustion are also produced during the manufacturing of flat glass, container glass, tableware, and artistic glass (annealing oven). In order to increase the number of products that can be made from a certain weight of molten glass, manufacturers should take into account product light weighting in containers and tableware.

Particulate Matter

A main contaminant released by glass production operations is particulates. All segments of the glass manufacturing business employ raw materials that are dusty, granular, or powdered. All glass industry sub-sectors share the similar practices of storing and combining raw materials. The transportation, handling, storage, and mixing of raw materials will always result in dust emissions. Although the dust produced by these processes is often coarser than the hot processes' particulates, which have diameters below 1 m, the smaller particles easily coalesce into bigger particles. PM produced by the hot operations in the batch plant is a potential environmental issue, but dust emitted from handling activities is primarily an occupational health and safety (OHS) issue. . The combination of volatile ingredients from the batch that melt with sulfur oxides to produce compounds that condense in furnace waste gases, the carryover of fine materials in the batch, and the combustion of some fossil fuels are the main sources of fine PM emissions to the atmosphere from the melting process.

Nitrogen Oxides

The homogenous gas-phase reaction of oxygen and nitrogen present in the combustion gas, at the high temperatures typical to this process, produces NOx emissions in the melting furnace in glass facilities. With very little NO2, such "thermal NO" is practically all in the form of NO. Since practically all glass furnaces burn natural gas as their primary fuel, fuel-bound nitrogen makes up a small portion of NOx emissions. However, some raw materials for making glass contain nitrates, or "niter," which when heated may release NO2.

The main process variables that affect uncontrolled NOx emissions are the fuel fire rate, furnace geometry, fuels used, and raw materials. NOx emissions can vary greatly from one location to another and from one furnace to another. Thermal NO emissions that aren't under control weigh 8 to 10 pounds each ton of glass produced. This range pertains to regenerative container glass furnaces and will differ significantly from site to site, even for apparently comparable furnaces, depending on the age of the furnace, the electric boost, the batch/cullet ratio, and other factors. These emissions would be equivalent to 1.3 to 1.7 lb NO/MM Btu, assuming a heat requirement of 6 MM Btu/ton glass. In general, smaller pressed/blown furnaces would have more NOx emissions than large flat glass furnaces.NO_2 from nitrates is of the order of 0.36 lb NOx per lb nitre (as NaNO3) in the batch formulation.[9]

Sulfur Oxides

The presence of sulfur oxides (SOX) in waste gases from glass furnaces depends on the sulfur content in the fuel and the sulfite / sulfate / sulfide content in raw materials , particularly the addition of sodium or calcium sulfate for glass oxidation. [10]

It has been determined that the fining agent Na2SO4, which is applied to batches of silicate glass, is a source of SOx and a contributing emission. The way that Na2SO4 decomposes in batches of silicate glass depends on how it interacts with the carbon. Inert and O2-rich atmospheres are used for the decomposition tests with Na2SO4 and Na2SO4 + C. Na2SO4 alone is shown to begin decomposing at around 1100° C. Due to the occurrence of lower-temperature breakdown areas at 500° C in O2 and 850° C in N2, carbon stimulates decomposition at lower temperatures. At temperatures as low as 500° C, SOx is released in O2. The byproducts of O2's breakdown are SO(g) and SO2(g). The solitary breakdown product in N2 is SO2(g). At 500 ° C, the concentration of SO(g) for Na2SO4 + C in O2 is 230 ppmV, and the SO/SO2 peak ratio is 1.23. A surface reaction that results in the formation of SOx by rearranging active S-O complexes on the melt surface of Na2SO4 can be used to explain how Na2SO4 decomposes. Na2SO4 + C in N2 demonstrates significant mass loss during the heating-up phase and a zone of increased decomposition rate at shorter durations during isothermal decomposition at 1200 ° C. The rate of decomposition is comparable to that of Na2SO4 alone over longer periods of time. [11]

Chlorides and Fluorides

These pollutants are produced in small quantities in glass melting furnaces as waste gases from impurities in the raw materials. The two main exceptions are the production of opaque materials like opal and continuous fiber glass, where the amount of fluoride / HF before mitigation can reach 1,000 mg/Nm3 or higher by adding fluorspar to the batch. Treatment of HF emissions typically involves the use of dry and semi-dry scrubbing procedures. Electric furnaces are thought to be the best option when the glass is very aggressive (such as opal because of the presence of fluorine). The causes of HCl and HF emissions, with the exception of when creating specific glasses, are typically connected to contaminants contained in the raw materials. (e.g. sodium or calcium chloride), and, less often, to the presence of small amount of calcium fluoride (CaF_2) in the batch. Both HF and HCl emissions may be controlled using the abatement techniques described above for abatement of SO_2 emissions.[12]

Wastewater

Industrial Process Wastewater

The cooling and cullet cleaning processes consume the most water. Surface water runoff, cleaning solutions, and contact cooling water system purges will all constitute aqueous emissions. To reduce losses, closed-water process systems ought to be adopted. Liquid effluent discharge from the glass industry is minimal compared to other industrial sectors and is only associated with specific operations (e.g. hot gob quenching and water-cooled shears). Glass solids, some soluble glass-making components (such as sodium sulfate), some organic compounds brought on by lubrication oil used in the cutting process, and treatment chemicals for the cooling-water system can all have an impact on discharges. [12]

Wastewater is discharged from the glass production process. There are potential pollution issues arising from:

- Use of coating materials during coating preparation, handling, throw off from winding etc.;
- Use of toxic compounds in lead crystal glass and special glass manufacture;
- Organic compounds from the lubricants used in cutting;
- Water treatment chemicals;
- Run-off from contaminated or dirty cullet2 , external stores and spillages.

[13]

Solid waste

The actual manufacture of glass generates very little waste. Waste is restricted to packaging waste, maintenance waste, and occasionally off-spec raw materials that cannot be combined. Other solid wastes include replacement refractory materials from furnace maintenance, acidic coating residues, and dust from abatement equipment.[13]

5. WHAT ARE THE METHODS TO MANAGE WASTE IN GLASS MANUFACTURING INDUSTRY

Control techniques to reduce dust emissions, NOx & Sox emissions

- Install/upgrade and maintain abatement technology to minimize exposure to toxic raw materials and products and to control the release of dust emissions, e.g. enclosure of equipment, installation of appropriate ventilation with filters, gas balancing systems, etc.;
- Ensure that regular maintenance and monitoring of fuel-burning equipment is undertaken;
- Reduce the number of fine particles in the batch by humidification with water or with alkali solutions (for example, sodium hydroxide, [NaOH], sodium carbonate [Na_2CO_3]) or by presenting, briquetting or palletizing
- Optimization of furnace design and geometry to permit a reduction in furnace temperature;
- It is important to minimize combustion air supply to furnaces, in order to enhance energy efficiency and restrict NOx formation. It is generally recommended to maintain 0.7–1 percent O_2 in unit melters and 1– 2 percent O_2 in end-port furnaces, measured at the combustion chamber exit, and to monitor the carbon monoxide (CO) level, which should be kept as low as possible (200–300 ppm to 1,000 ppm CO maximum).

- End-of-pipe (secondary) pollution-control techniques for reduction of NOX emissions in glass manufacturing include the following, which should be implemented in cases where primary measures do not achieve necessary NOX levels: · Chemical reduction by fuel (e.g. the 3R process); · Use of Selective Catalytic Reduction (SCR). The use of Selective Non-catalytic Reduction (SNCR) is not a widely adopted practice in the glass industry.
- The type of combustion fuel used affects the number of sulfur oxides and nitrogen oxides emitted. Use of natural gas results in negligible sulfur dioxide emissions from the fuel compared with high-sulfur fuel oils. Fuel oil with a low sulfur content is preferable to fuel oil with a high sulfur content if natural gas is not available. [14]
- The number of heavy metals used as refining and coloring or decoloring agents, as well as use of potassium nitrate, should be minimized to the extent possible. [14]
- Use of fuels with low sulfur content and, in particular, natural gas;
- Reduction in the amounts of sodium or calcium sulfate in the batch materials.

Control techniques to reduce water pollution

- Install grids to reduce or avoid the introduction of solid materials into the waste water drainage system;
- Adopt equipment cleaning-in-place (CIP)3 methodologies to reduce chemical, water and energy consumption.
- Monitor effluent to ensure compliance with wastewater discharge standards
- Use a closed process water system (to minimize uses and losses)
- Install (or upgrade) on-site wastewater treatment plant WWTP treatment plant to meet permitted effluent discharge standards;

Control techniques to reduce solid waste

- All trimmed glass should be recycled back into the melting process;
- Store solid wastes in adequate containers and segregate them where possible to encourage recycling;
- Where possible and safe to do so, recycle or reuse benign waste products; maintain an inventory of wastes generated and minimize where possible;
- Glass that cannot be remelted on site can be sent for recycling.

6. CONCLUSION

In this article, We talked about what is glass manufacturing industry, the process step & what are the major ingredients in this industry, what type of waste is generated and there are few suggestions to prevent environmental pollution. As well as it makes an opportunity to develop the glass industry by considering the manufacturing process and waste management. So by considering these factors, if these industries are subjected to the above suggestions it will be a great opportunity to save thousands of lives living things on earth.

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