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Innovative Approaches for Efficient Salt Handling in Chlor Alkali Industries

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Abstract

In this research article an industrial problem is discussed faced by chlor alkali industries lies in under-developed countries like Pakistan. In industry salt is used as a raw material for the production of caustic and chlorine. The salt is used in an estimated amount. The purpose of this project is to measure the accurate amount of salt that is needed for efficient and good production of caustic and chlorine. At a present condition, the amount of salt required for the production of caustic is calculated through back-calculation, in which load(current) is an important factor. In this report, some proposals such as Calibration, Bucket Loader Scale, weight Budget, Double-Down Salt Bucket, Conveyer and Weigh Hopper are proposed based on the current situation of salt handling. These technique and equipment are proposed in such a way that salt measuring system becomes easy, safe, and fast. Loading and unloading of salt with least human interference could also be achieved.

Keywords: Chlor-alkali industry, brine solution, salt measuring system, calibration

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1. Introduction

The Chlor alkali (CA) industry is dedicated for the manufacture of two chemicals (chlorine and an alkali) which are produced at the same time as a consequence of the ion-exchange membrane method of electrolysis of brine. For the production of brine solution usually Raw Salt is used which contains many impurities like Ca, Mg, Sulphate, and Insoluble matters. Insoluble matters contains sand and dust particles that are removed through sedimentation and do not require any chemical for their removal. Chlor alkali industries are considered among the basic chemical production industries. Despite the fact that this industry has set up with highest energy consumption and large pollutant emission, Products obtained from the industry have found usage in more than 50% of all industrial chemical processes. Chlor-alkali industry refers to the industrial production of sodium hydroxide (caustic soda), chlorine and hydrogen by electrolysis of saturated brine (Hou et al., 2018). Although great efforts have been made in recent decades to understand the fate and environmental impact of chlor-alkali industry (Wang et al., 2021; Wang, F. et al., 2019), there are still considerable concerns across the life cycle of resource efficiency (Del Valle et al., 2022; He et al., 2022; Shi et al., 2022). Lakshmanan, S., & Murugesan, T. (2014) reviewed the three processes used in chlor alkali industries and highlighted the areas for further improvements [1]. Karlsson, R. K., & Cornell, A. (2016) reviewed the energy consumption in electrolytic cell and selectivity between chlorine and oxygen evolution in chlorate and chlor-alkali production [2]. Zhang et al. (2021) discussed the co-production of hydrogen with chlor alkali reaction. With a special emphasis on the relationship between their structure and electrolytic properties. Simultaneously, the latest progress in the technology and engineering of the co-production process is also listed. Finally, the opportunities and the way forward for hydrogen and chlor-alkali co-production are also discussed [3]. Zhang et al. (2022) proposed that the resource efficiency, production and conversion rate of chlorine was significantly improved with the establishment and optimization of symbiosis scenarios, which also showed very positive environmental and economic benefits according to LCA-LCC analysis. DEA was performed to analyze the Chlorine's resource efficiency in its metabolism, and the results showed that the efficiency of Scenario 1, Scenario 2 and Scenario 3 were 0.8548, 0.9490 and 1, respectively. Especially, in Scenario 3, a new chemical technology, catalytic oxidation of hydrogen chloride, can convert the by-product hydrogen chloride into chlorine, which can be reused and finally made a closed-loop in this industrial symbiosis. The results of this study can provide a new way to optimize the resource recycle, pollutants discharge and carbon emissions of chlor-alkali industry [4].

2. Materials and Methods

The main processes involved in Chlor alkali industry are preparation of Primary Brine solution, Salt Storage system, Brine Purification system, De-chlorination utilities with chlorate, Electrolysis, Chlorine Treatment, Hypo manufacturing, Chlorine Liquefaction, Hydrogen Treatment, HCl synthesis, Caustic Evaporation, Storage tanks.

2.1. Preparation of brine solution

The salt is dissolved to make a brine solution and the depleted brine coming from the depleted storage tank is also used again. The concentration of brine is maintained within a range of 305-310 g/l at the outlet stream. Raw Salt with the help of bulldozer is added to the Salt Dissolver. Manual sampling is done by hygrometer to analyze the concentration of brine. Two Dissolvers A and B are used alternatively. From the top of the Salt Dissolver, crude brine solution flows by gravity to Crude Brine Receiver through a concrete channel.

2.2. Removing impurities in brine solution

2.2.1. Removal of Mg^{+2} Ions, Organic Impurities, and Insoluble Impurities

Saturated brine from the salt dissolver flows by gravity to a concrete channel (strainers to remove large undesired particles like the wood piece and plastic) towards the agitation tank. During passing through the concrete channel caustic soda (15%) and diluted hypochlorite (1%) are added into the brine solution. The excess quantity of caustic is controlled by a pH sensor. In the Agitation tank even reaction and anti-settlement are done.

$$MgCl_2 + 2\ NaOH \longrightarrow Mg\ (OH)_2 + 2NaCl$$

After that, the compressed air is mixed Crude brine is at a pressure of 3-5 bar. The air dissolved crude brine is fed to the clarifier underflow rate. $FeCl_3$ (2wt %) as a coagulating agent is added in the feeding pipeline of the clarifier to coagulation $Mg(OH)_2$. When brine is introduced in the clarifier suddenly the pressure is reduced to 1.01325 bar. As a consequence of which small air bubbles are released from the brine solution, these bubbles will stick to on the surface of Mg $(OH)_2$ particles, therefore, bulk density of Mg $(OH)_2$ will be reduced and they lift. The slurry of $Mg(OH)_2$ is removed from the top of the clarifier by strip out while the slurry of insoluble particles drains off from the bottom of the clarifier. Both slurries are collected in a slurry pit. The suspended solids in the clarified brine shall be less than 50 ppm.

2.2.2. Removal of Ca^{+2} and Residue Suspended Solid

Sodium Carbonate (15wt %) is fed into the reactor containing the certifier brine. After complete reaction, the brine with $CaCO_3$ slurry feeds to the membrane filter through a buffering tank. The membrane filters are cylindrical hollow membrane modules. These membranes filter brine while slurry will accumulate on the surface of the membrane.

$$CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3 + 2NaCl$$

The filtrated brine from the top of each membrane filters passes through the baffling mixer where Na_2SO_3 (10%) is added to kill the ClO^- ion which can cause trouble in another process. The membrane filters are periodically washed with dilute HCl (17wt %) to remove the solids plugged in the interior of the membrane. The suspended solids in the filtered brine at the outlet stream of a filter are less than 1ppm.

$$NaClO + Na_2SO_3 \rightarrow NaCl + Na_2SO_4$$

2.2.3. Removal of SO^{-4}

The de-chlorinated brine which is also called Depleted brine coming from the different source is fed into Baffle mixer (clarifier) where it is. From the top of the clarifier, clear brine flows by gravity to Depleted Brine Storage tank. BaSO4 slurry is purged at the bottom of Slurry Pit.

$$Na_2SO_4 + BaCl_2 \longrightarrow BaSO_4 + 2NaCl$$

2.3. Treatment of Slurries

The Slurry is produced in different processes of the primary brine purification process is collected in a pit. This slurry contains a precise amount of brine that is covered by filter press. The treatment utilizes two brackish water mud filter press both are utilized at the same time yet their cleaning cycle is interchanged, which means when one is working the other is on the cleaning cycle. The consequence brine from filter press is sent to Depleted Brine Storage Tank. The cake stores on the outside of filter fabric are disposed of and the same process will repeat for the coming.

2.3. Problem associated with the preparation of brine solution

It is observed that salt is dosed with the help of a loader mechanical bucket of loader machine. The capacity of a bucket is usually 3.5-3.7 tons according to the specification. The amount of salt load on the bucket every time is different because of the handling of a machine (payloader) and also the way salt is distributed in that area. This is one of the main reasons that the amount of salt every time is dose into the dissolver is different. Due to the change of bulk density of salt (refine and sea), the amount of salt in the bucket is also changed as shown in the graph. The Second thing that is observed is some of the amount of salt are waste while taking the salt from the salt yard to dissolver because of the heap of a bucket of payloader and non-uniform space from the salt yard to dissolver (30m). This loss of raw material is not economically acceptable at the industry level. Therefore, a proper salt measurement is required to measure salt accurately with efficiency. The amount of salt dose based on back-calculation by incorporating membrane efficiency, no of cells, load and faraday’s constant. Salt consumption can also be calculated by multiplying amount of required caustic soda with stoichiometric factor. In this back-calculation, the load (current) affects both the amount of salt and the production of caustic because the greater the load high amount of salt is utilized for the greater production of caustic Vies Versa. Thirdly the Concentration of brine is checked time to time by sending the sample (brine) to the lab. There is no online system of measuring the Conc. of brine.

3. Results and discussion

3.1. Analytical solution: calibration curve

In calibration curve (Figure 2), the amount of salt is measure by taking the density of brine sample using hydrometer and match the reading with the respected curve available at different temperatures and wt. of salt that is required to maintain the required Conc. i.e., 310g/l is evaluated.

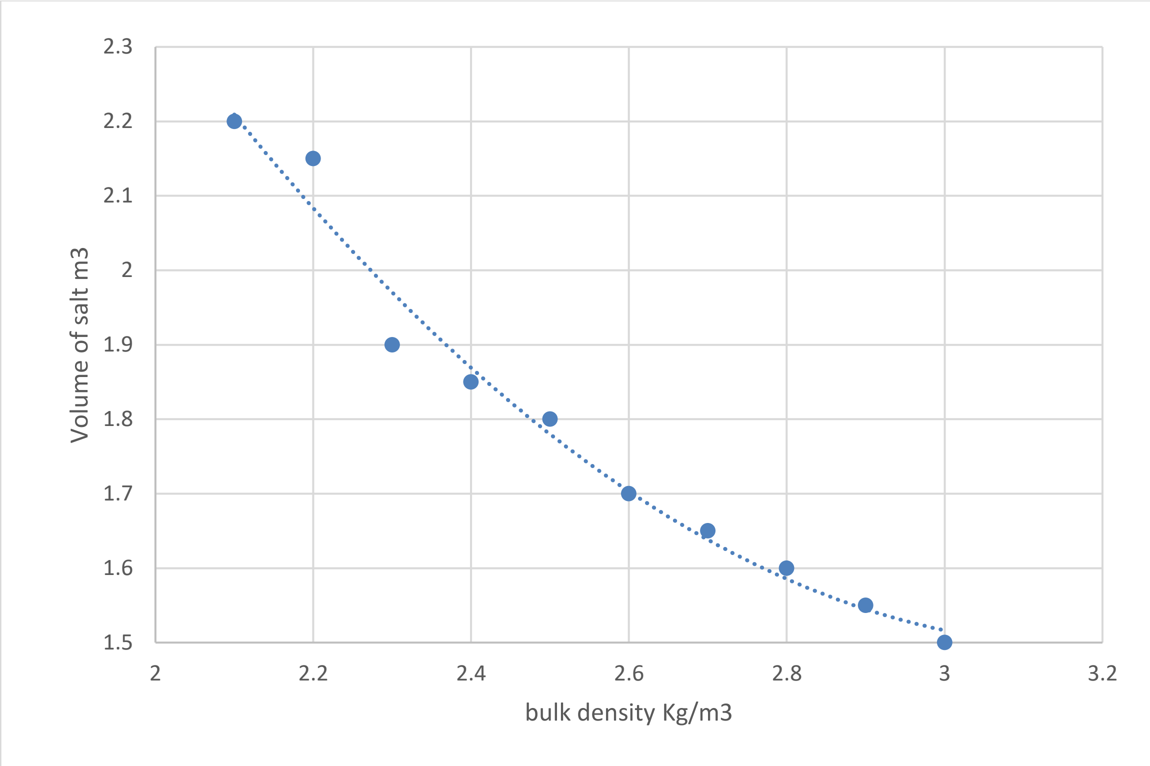

Figure 1. Graphical representation of the relationship between bulk density and volume of salt

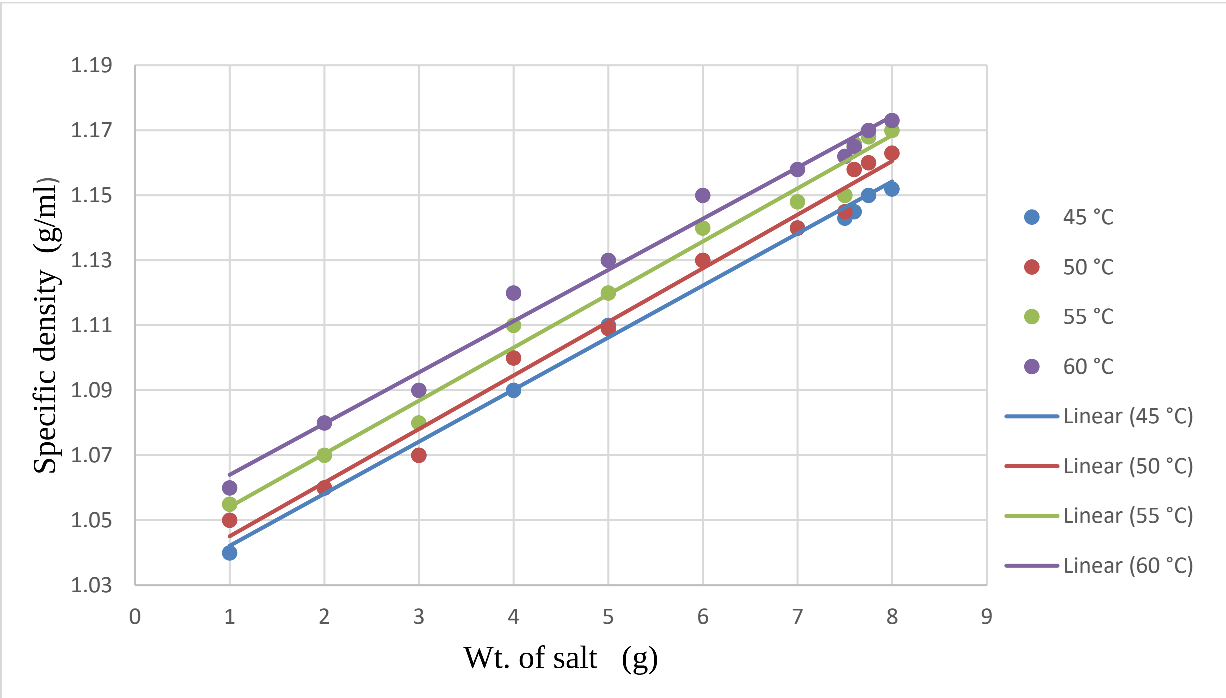

Figure 2: Calibration curves

Table 1: Weight of salt and specific density at different temperature

Weight of salt (g)	Specific density at 45ºC	Specific density at 50ºC	Specific density at 55ºC	Specific density at 60ºC
1	1.04	1.05	1.055	1.06
2	1.06	1.06	1.07	1.08
3	1.07	1.07	1.08	1.09
4	1.09	1.1	1.11	1.12
5	1.11	1.109	1.12	1.13
6	1.13	1.13	1.14	1.15
7	1.14	1.14	1.148	1.158
7.5	1.143	1.145	1.15	1.162
7.6	1.145	1.158	1.166	1.165
7.75	1.15	1.16	1.168	1.17
8	1.152	1.163	1.17	1.173

Table 2: DOUBLEDOWN SALT BUCKET™ Specifications [10]

width	112.5"
Height	60.7"
Length	51.5"
weight (empty)	1.509 tons
weight (loaded)	4.749 tons

Table 3: Technical parameter [12]

Hopper Capacity	10-60 tons
Transfer speed	20-30 tons/hrs
Conveying power	3kw
Mixing power	4kw
Size(mm)	6000×2360×2800

Table 4. The specification of Weigh Bridge [14]

Material	Mild Steel
Weight Capacity	Up to 100Tons
Accuracy	99%
Voltage	220-240V
Usage/Application1	Industrial
Color	Black
Type	Electronic

3.2. Mechanical Solutions

3.2.1. Hydraulic Wheel Loader Scale

It is also proposed to install hydraulic scale (loader bucket scale) that is user-friendly and easy to install, with a water-resistant corrosion-proof enclosure and stainless-steel adjustable stand/mount, and also suitable for use in harsh weather conditions including rain, wind, and sun. By this scale, the desired amount of material is calculated and it is also cost-effective because not too many people are required to install this scale and also no machinery is required for this scale [5-7]. It weighs in pounds or kilograms operator can view the weight of the load being lifted and the accuracy error is +/- 1-2% of the capacity of the lift. It works on the principle that attaches to the hydraulic lifting system by converting hydraulic pressures to a readable weight display. It contains three different parts Oil Pressure sensor, Position sensor and Indicator (Load Monitor). First one sense the hydraulic pressure means how much volume is available in the bucket, the greater the weight greater the hydraulic pressure and it also indicates a problem — such as a leak, or no oil pressure in the engine or low level of oil that the oil pressure sensor is reporting. The oil pressure sensor will usually be placed near the back and top of the engine section and bolted into the engine block, connected by an electrical clip to the wheel loader system. Second one is a position sensor is utilized for measuring the distance traveled by a body starting from its reference position. It measures linear or angular position about a fixed point or arbitrary reference. Third one is the Indicator (Load Monitor) unit gives the operator a secondary display showing weight information for easier loading to target values. The system can be set up to view the weight on the bucket as it goes up or view it going from the target weight setting down toward zero. The accumulated total can be viewed also.

Number of Runs of A Wheel Loader: Caustic Production=360 tons/day

Salt Consumption=550 tons/day
1 hr. $\longrightarrow$ 22.9 approx. 23 tons
Amount of salt in one bucket=3.2/run
23 tons $\longrightarrow$ 7.1 approx. 7run
Total number of runs required to transfer 23 tons per hr. is 14

Caustic Production=174tons/day

Salt Consumption=270tons/day
1 hr. $\longrightarrow$ 11.25 tons
Amount of salt in one bucket=3.2/run
11.25 tons $\longrightarrow$ 3.5runs
Total number of runs required to transfer 11.25 tons per hr. is 7

3.2.2. Double-down Salt Bucket

In this Proposal, the recommendation is to use the Double-Down Salt Bucket that is capable of spreading an 80ft path. The salt bucket loads salt with the machine and spreads the salt on the desired path with twin spinners and twin augers. The salt is spread equally in the left and right and no heap is form due to this the wastage of salt is minimize [8-9].

3.2.3. High-Efficiency Hopper Weighing Scales

The high-Efficiency hopper scale contains a hoper with a conveyor. The parameter of hopper and conveyer is given in the table. It is made of stainless material. It measures the material from a range of 10ton to 60 tons. With the help of the Payloader load, the salt is load into the hopper and the weigh sensor measure the amount of salt automatically. After weigh the hopper released the material onto the conveyer and with the specific speed of conveyer the salt is does in to the dissolver [11].

Running Time of Hopper: At full load the 550 tons salt is utilized for 360 Tons/day caustic productions

Hopper speed =20tons (1hr)
Salt consumption =23tons (1.15hr)
Hopper capacity is 60 tons so it can run for 2.6 hrs.

At min load the 270 tons salt is utilized for 174 Tons/day caustic production.

Hopper speed =20tons (1hr)
Salt consumption =11.25tons (0.56hr)
Hopper capacity is 60 tons so it can run for 5.3 hr.

3.2.4. Weighing bridge

A weighbridge is a scale which is utilized to weigh bulk mass. It is a set of scale which is mounted by the weighbridge’s manufacturer on a solid surface. It has an electronic or advance monitoring system that displays the weight of the material that the vehicle carries [13]. The proposal is to place the weighbridge near to the dissolver as the weighbridge contains load cell it measures both the loader and salt weight and by eliminating the loader weight the amount salt is easily being calculated.

4. Conclusions

Using any one of these different equipment and technique for measuring salt quantity for Chlor alkali plant of Engro Polymers and Chemicals Limited (EPCL) the required amount of salt will be calculated accurately and then no need to calculate the amount on the estimation basis i.e not convenient for this plant economically. This equipment and technique will be very helpful for measuring salt quantity per day and also helpful for the industry to properly utilize its raw material and save time and cost. For the future best recommendation is to install the hopper scale because it has large capacity and provides continuous flow & control of feeding raw material, require less time and space, reliable and durable and connect this hopper to the control room to look after the level of salt present in the hopper.

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