

PRODUCTION OF CHLORINE GAS (Cl₂) AND SODIUM HYDROXIDE (NaOH) FROM THE PURIFICATION OF ACEH SALT: A Review Article

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ABSTRACT

Jangka salt contains NaCl, CaCl₂, MgCl₂, CaSO₄, MgSO₄, Na₂SO₄, H₂O, dust, soil, and fine sand, with NaCl content of less than 78%, categorizing it as low-quality salt. This salt can be refined to increase its NaCl content to 92%-100% through gradual physical and chemical purification processes, as well as using ion-exchange resin, resulting in high-quality salt. One of the advantages of high-quality salt is its use as a raw material for producing chlorine gas and sodium hydroxide through the electrolysis process. The results can be used in various industries for water treatment, soap production, plastics, paper manufacturing, and other chemical industries.

Keywords: Chlorine gas, sodium hydroxide, salt, purification, electrolysis.

1. INTRODUCTION

Most of Indonesia's territory consists of seas that contain sodium chloride (NaCl) at varying concentrations. However, this salt has not been optimally utilized for household consumption or industrial purposes. The demand for high-quality salt, with NaCl content between 92% and 100% for chemical industry raw materials, is still heavily dependent on imports.

Domestic salt industries, such as that of Jangka salt from the Jangka community in Aceh Utara, Nanggroe Aceh Darussalam (NAD), have bright prospects if developed into high-quality products, which could supply local needs and facilitate exports. High-quality salt resulting from the purification of Jangka salt can be used as raw materials for producing chlorine gas and sodium hydroxide. In various industries, chlorine gas and NaOH are essential for purposes such as pulp production, clean water treatment, cleaning

materials, soap manufacturing, margarine production, and pest control pharmaceuticals.

TYPES OF SALT AND THEIR USES

According to Prayitno (1999), salt products can be developed into various forms, including bulk salt, briquettes, table salt, food-grade industrial salt, oil drilling salt, and pharmaceutical and laboratory salt. High-quality salt, especially industrial-grade salt, is utilized as raw materials for producing chlorine gas (Cl₂), sodium hydroxide (NaOH), and calcium hypochlorite (NaOCl).

Local salt from the salt industry in Madura, East Java, has long been used by PT. Kertas Leces as a raw material for the chlor-alkali process. Before use, this salt undergoes physical, chemical purification, and ion exchange processes, and its specifications can be displayed in Tables 1 and 2.

Table 1. Specification of industrial salt solution for electrolysis process

No	Component Name	Chemical Formula	Content (%)	Remarks
1.	Sodium Chloride	NaCl	≅ 100	About
2.	Calcium Content	Ca ⁺⁺	< 0.20 ppm	Maximum
3.	Magnesium Content	Mg ⁺⁺	< 0.20 ppm	Maximum
4.	Sulfate Content	SO ₄ ⁻	0.00	Nil
5.	Insoluble Substances	CaCl ₂	0.00	NI

Source: Chlor Alkali Plant Unit PT. Kertas Leces, 1997

Tabel 2. Specification of of industrial salt solution for electrolysis process

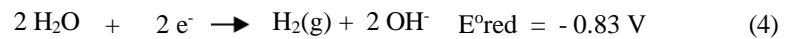
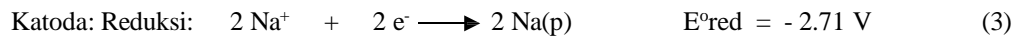
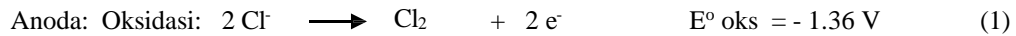
No	Component Name	Chemical Formula	Content (%)	Remarks
1.	Sodium Chloride	NaCl	> 98.50	Minimum
2.	Calcium Content	Ca ⁺⁺	< 4.00	Maximum
3.	Magnesium Content	Mg ⁺⁺	< 0.10	Maximum
4.	Sulfate Content	SO ₄ ⁼	< 0.06	Maximum
5.	Insoluble Substances	CaCl ₂	< 0.20	Maximum

Sources: Prayitno, 1999, Spesifikasi pada SII atau SNI no. 139 – 76

Electrolysis Reaction

Salt that has undergone a purification process can be decomposed by electrolysis process to produce Cl₂ and NaOH gases. The electrolysis

reaction takes place by utilizing electrical energy through electrodes decomposing sodium chloride by reaction:



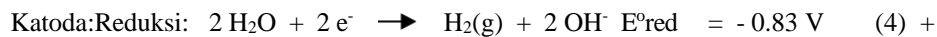
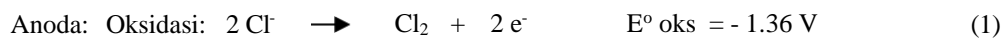
The electrode potential for half reaction (1) and (2) is equally large. The exact price depends on the concentration of Cl⁻ in one equation and the concentration of H⁺ in the other. When the NaCl solution is concentrated, a half-reaction tends to occur (1); If it is very diluted, a reaction occurs (2). As far as half-reduction reactions are concerned, water reduction occurs more likely than Na⁺ and generally only half-reactions (4) occur.

through the electrolysis process. According to Eni (1989), the conduction of electric current into an electrochemical cell containing an electrolyte solution will undergo a chemical reaction, the NaCl salt solution will undergo electrolysis to produce chlorine gas (Cl₂) and soda (NaOH). Electrochemical reactions require a pair of electrodes, an anode and a cathode. The electrodes are separated by a separator membrane or membrane.

Production of Cl₂ and NaOH Gases

The pure NaCl salt solution sourced from Lam Cok salt or Jangka salt (close to 100%) is used as raw materials for the manufacture of chlorine gas (Cl₂) and sodium hydroxide (NaOH)

The production of chlorine-alkali gas from NaCl solution, is an electrolysis process using a concentrated NaCl solution and according to Hiskia Ahmad (2001) the reaction occurs as follows:



The source of chloride ions is NaCl, the result of reactions other than hydrogen gas (H₂) is chlorine gas (Cl₂) and NaOH alkali. The process that produces this product is called the chlorine-alkali process, more details can be seen in Figure 1.

between Cl₂ and NaOH(aq) should also be prevented. This prevention is overcome by a barrier or barrier called the diaphragm. When Cl₂ and NaOH(aq) gases mix, they form NaOCl and NaClO₃ compounds.

According to Petrucci and Suminar (1989), one of the alkaline chlorine electrolysis cells is the diaphragm cell. The cell consists of an anode chamber, where chlorine gas (Cl₂) is produced, and a cathode chamber where hydrogen (H₂) and NaOH(aq) gases are produced. Chlorine and hydrogen gases must be separated, because the two gases when mixed can explode. Contact

The difference in the surface of the solution is maintained in such a way that the sodium chloride NaCl(aq) flows slowly from the anode chamber to the cathode. This reduces the backflow of sodium hydroxide NaOH(aq) into the anode chamber. The solution from the cathode chamber should be concentrated by water evaporation and purification by NaCl(p)

crystallization. The final result in the chlorine-alkali process is soda liquid with a content of 50% NaOH(aq) and chlorine gas (Cl₂) with about 1% NaCl in the form of residues.

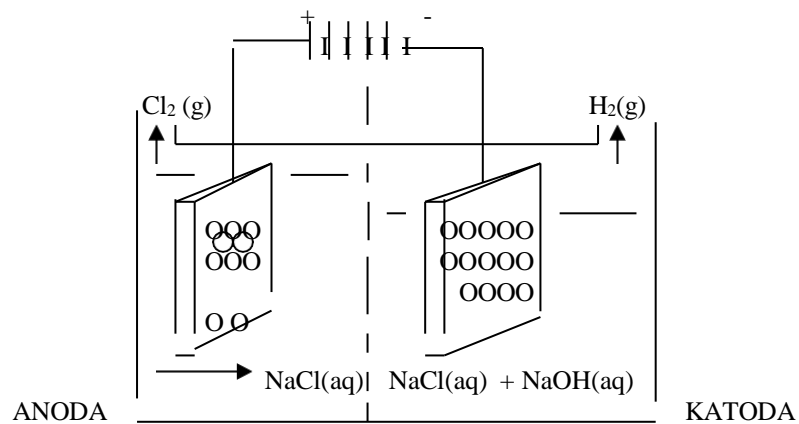


Figure 1. Sketch of alkaline chlorine electrolytic cell

SALT PURIFICATION

Termite salt is not yet suitable for consumption as a raw material for the chemical industry, so it must first be purified through various stages of the process by chemical reaction and physical separation because it still contains ingredients other than NaCl such as Ca salt, Mg. In the electrolysis soda process, the raw material contains NaCl 92 – 98%.

Physical Salt Purification Termite salts that are classified as high in impurities are purified by filtering the salt solution, which is retained in the sieve as impurities, while those that pass the sieve are recrystallized to obtain purer salt. This method cannot separate the salt components that do not mix with each other physically. The chemical components of salts that are mixed inseparable such as Ca⁺⁺, Mg⁺⁺, and SO₄⁼ still remain in the crystals or salt solution. According to Syafruddin, et al. (2002), local salt in Lam

Chok and Jangka Aceh North Aceh that is purified by filtration (physics) can produce NaCl salt levels of around 94 to 98%. Comparison of the quality of Lam Cok salt and Jangka salt with local salt from Madura with the specifications used by PT. Leces paper can be seen in Table 3 and Table 4. Table 3. Specification of local salt (Madura) for PT. Leces Paper

No	Component Name	Chemical Formula	Content (%)	Remarks
1.	Sodium klorida	NaCl	>92,00	At least
2.	Water	H ₂ O	<5,00	Maximum
3.	Calcium	Ca ⁺⁺	<0,15	Maximum
4.	Magnesium	Mg ⁺⁺	<0,10	Maximum
5.	Sulfate	SO ₄ ⁼	<2,00	Maximum
6.	content Insoluble substances	-	<0,50	Maximum

Sources: Unit CAP PT. Leces Paper, 1997.

Tabel 4. Specification of local salt (Madura) for PT. Leces Paper

No	Component Name	Chemical Formula	Content (%)	Remarks
1.	Sodium klorida	NaCl	> 92.00	At least
2.	Magnesium chloride	MgCl ₂	< 1.85	Maximum
3.	Magnesium sulfat	MgSO ₄	< 0.51	Maximum
4.	Calcium sulfat	CaSO ₄	< 0.41	Maximum
5.	Sodium sulfat	Na ₂ SO ₄	< 2.01	Maximum
6.	Calcium chloride	CaCl ₂	< 0.22	Maximum
7.	Insoluble substances	-	< 3.00	Maximum

Sources: Report of PKL TK-UGM PT. Leces Paper, 1997.

Chemical Salt Purification

Salt solutions other than NaCl such as Ca⁺⁺, Mg⁺⁺, and SO₄⁼ are minimized or precipitated by the addition of certain chemical compounds, such as Na₂CO₃, and BaCl₂. The deposition reaction is a valuable way to separate a sample into its component parts. The material that is held

in filtration is the substance that will be separated to be used to make a new phase, namely solid deposits, while the filtrate is a sodium chloride salt solution that has undergone a primary purification process. (Day and Underwood: 1990).

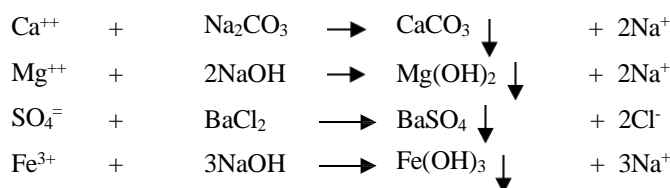
Table 5. Solubility and solubility product of some salts

Salt Components	Process Compound	Ksp	Solubility at 18oC (gram/100 ml of water)	Process Results
Na ⁺	NaCl	-	35.86	NaCl (Brine)
Ca ⁺⁺	CaCO ₃	5x10 ⁻⁹	0.0013	Mengendap
Mg ⁺⁺	Mg(OH) ₂	1x10 ⁻¹¹	0.001	Mengendap
SO ₄ ⁼	BaSO ₄	1x10 ⁻¹⁰	2.3 x 10 ⁻⁴	Mengendap
Fe ³⁺	Fe(OH) ₃	1x10 ⁻³⁶	5.1 x 10 ⁻¹¹	Mengendap

Sources: Vogel , 1985, dan Day and Underwood, 1990

According to Vogel, 1985, there is a precipitation reaction of salt component ions in

the form of a solution in a deposition vessel (reactor) as follows:



These salts can precipitate because of the solubility product (Ksp) and the solubility is very small compared to NaCl salts which have a much greater solubility, so NaCl salts can be purified.

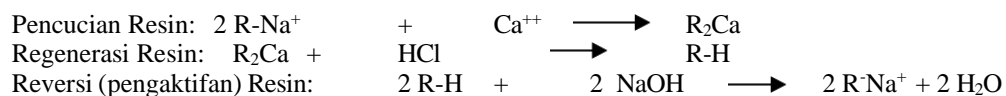
The salt solution that comes out of the *ion exchanger* with Ca⁺⁺ and Mg⁺⁺ content must be less than 0.2 ppm respectively. If it exceeds this number, the resin is immediately washed. To activate the resin, it is necessary to drain the demineralized water from the bottom of the resin column, 4% HCl is drained from the top of the resin column then drained until it runs out, the demineralized water is drained until it runs out, washed with 5% NaOH, then the demineralized water is drained again and rinsed once again with demineralized water.

All the compounds that form such as calcium carbonate, magnesium hydroxide, barium sulfate, and iron hydroxide precipitate, so the levels of these ions are reduced. To further maximize the deposition of impurities ions , excess precipitate is added, excess NaOH 0.5 –1.0 grams/liter, excess Na₂CO₃ 0.5 –1.0 grams/liter.

Salt Purification with Ion Exchange Resin

Further purification is carried out on the ion exchanger resin column. Resin is needed to bind unwanted ions that are still left in the primary

The ion exchange reaction is carried out until the requirements of Ca⁺⁺ and Mg⁺⁺ content are met, each must be less than 0.2 ppm and the reaction that occurs during washing is as follows:



4. RESULT AND DISCUSSION

The purification of local salt sourced from Lam Cok and Jangka can only physically separate salt impurity components such as dust, soil, and sand can produce NaCl with a level of 94% - 98%. This is better than salt from Madura

with a NaCl content of only 92%. With this method, chemical components that are still mixed with NaCl such as salts CaCl₂, MgCl₂, CaSO₄, MgSO₄, and Na₂SO₄, cannot be separated and are still combined with NaCl.

The salts CaCl₂, MgCl₂, CaSO₄, MgSO₄, and Na₂SO₄ contained in the Jangka salt

solution can be chemically separated through a precipitation process. Sedimentation is done by adding the appropriate settling chemicals for each salt to be separated. Separation results in NaCl levels above 99%.

To reduce the impurity chemicals that are still contained in the salt solution with NaCl levels above 99%, it can be done by an ion exchange process on the resin column. In this process, the remaining impurity levels in the form of Ca and Mg metals can be reduced until the level remains in the solution below 0.2 ppm.

NaCl salt solution with Ca and Mg levels of 0.2 ppm that has been purified with an impurity content below 0.2 ppm can then be used as raw materials for the manufacture of chlorine gas (Cl₂) and sodium hydroxide (NaOH) through the electrolysis process.

The production of chlorine and NaOH gas from a NaCl salt solution with Ca and Mg levels below 0.2 ppm with an electrolysis cell will take place continuously with the restriction or separation of products that occur between chlorine gas and NaOH must not be in direct contact with each other. In the event of direct contact with chlorine gas and NaOH, it can cause a powerful explosion, because it can form oxidizer materials such as NaOCl and NaOCl₃. The final result of the alkaline chlorine process produces a NaOH level of 50% and chlorine gas and the remaining NaCl salt solution of 1%.

North Aceh Jangka Salt with a salt content of 94% - 98% economically is not inferior in quality compared to local salt from Madura with a salt content of around 92%. However, the possibility of the obstacle lies in the low quantity of production compared to the salt produced in Madura. However, for the development of domestic industries, it is appropriate to develop industries based on local raw materials.

CONCLUSION

1. The production of chlorine gas (Cl₂) and sodium hydroxide (NaOH) from local industrial salt from the recrystallization

process can be done after the salt has been purified primary and secondary, so that NaCl is produced at a level of 100%.

2. The production of chlorine gas (Cl₂) and sodium hydroxide from people's salt raw materials from local industries (Jangka and Lam Cok) can be done by electrolysis process.
3. The electrolysis process of NaCl salt solution with a content of 100% produces a solution of 50% NaOH and chlorine gas (Cl₂), as well as 1% residual NaCl salt solution.

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