A PROPOSED TECHNIQUE FOR PRODUCING GREEN HYDROGEN, IN A SUGGESTED HYDROGEN SUPPLY CENTER AT AL-SOKHNA, GULF OF SUEZ

Ayman El Naharawy [(1)], **Mohamed Safwat Mohamed Tawfik** [(2)]

(1) Head of ports & Logistics Dep., Port Training Institute, Arab Academy for Science, Technology and Maritime Transport, Alexandria, Egypt. (Expert.ayman1000@gmail.com)

(2) Associate Professor Dr. in Radiochemistry, Egyptian Atomic Energy Authority, Cairo, Egypt. (m_tawfik7@hotmail.com)

1- Key words:

Green Hydrogen, Al-Sokhna, RO, Alkaline Electrolysis, Corrosion, Economic Tools.

2- Abstract:

The International Maritime Organization (IMO) is encouraging global shipping sectors, and seaports to reduce their global warming impacts, by using green fuels, instead of using conventional fossil fuel.

This research suggests new green ecological system for generating green hydrogen from seawater, the research aims to using a Reverse Osmosis (RO) desalinated plant at Al-Sokhna area, combining with a suggested Alkaline electrolysis system, to generate green hydrogen from seawater, where ALK electrolysis is one of the most efficient hydrogen generating tools.

The research methodology used different corrosion indexes to evaluate the suitability of Al-Sokhna seawater region for using as a source of regenerating hydrogen, to avoid any corrosive impacts on both RO and Alkaline electrolysis units.

The research results showed an increase in the calculated corrosion indexed values, which mean that there will be some corrosive impacts on the suggested RO and Alkaline electrolysis systems.

The research recommended using of debris filter combined with the injection of different anticorrosion chemical agents (polyphosphates) before the inlet of the suggested RO and alkaline electrolysis units, to avoid any fouling and corrosive impacts may be occurring. It also recommended applying different economic evaluation techniques, used for the proposed RO and Alkaline electrolysis units.

3- Introduction:

It became very urgent to rely on renewable green energy such as green hydrogen, as a clean source for energy. On the other hand, Egypt is aiming to implement many sustainable energy projects. It shall expand the use of green hydrogen energy sources, increase electricity supplies generated by hydrogen energy sources.

The aim of the research is to suggest a new green ecological and economical system for generating green hydrogen from seawater, by using a Reverse Osmosis (RO) desalinated plant at Al-Sokhna region, where this plant will be followed by a suggested Alkaline electrolysis system, in order to generate green hydrogen.

The research showed that using the suitable site for desalination plant with lowest corrosion impacts would lead to generate hydrogen, as each one megawatt of the suggested system will produce 18.7 Kg/h hydrogen.

4- Literature Review:

Many studies showed that water scarcity caused due the negative impacts of the climatic change and the increasing of the population growth rate. These negative impacts factors will affect the Egyptian annual water supply. On the other hand, Egypt has very large coastlines distances on both the Red Sea and the Mediterranean, as a result desalination became the suitable solution to provide Egypt with its needs of fresh water (**Yasser Elsie, et al., 2023)**.

Most of the desalination processes classified into two main categories, Thermal and Membrane. Where thermal desalination tools are the most distributed tools all over the world, for example the using the Multistage Flash Distillation (MSF) process as one of the most distributed thermal tools , where seawater is heated in a vessel called the brine heater. Another thermal type as Multi-Effect Distillation (ME), where there are different multi-effect evaporators (MED), leading to form vapor which being condense and the heat from its condensation being used to boil the saltwater in the latter desalting device (**AminI, et al, 2020)**.

Another desalination tool is the use of membranes which very effective tool, there are different types of desalination membranes such as; Electro-dialysis (ED) and Reverse Osmosis (RO). Where Electro dialysis is a membrane process uses an electrical potential to move salts through a membrane, leaving water behind.

The reverse osmosis considered one of the most efficient membrane tools, where is made up of the following parts: Pre-treatment, High pressure pumps, Membrane assembly and Post treatment.

These above mentioned parts are very important in the continuous improvements in the efficiency of the membranes, energy recovery, energy reduction, membrane life control of operations and operational experiences **(Abdin Z.، et al, 2020)**.

Reports showed that the alkaline water electrolysis technology used in different countries over the years in varying scale, which characterized by its relatively low purity of the H_2 gas **(Simonies et al, 2017, En App Sys, et al, 2019, Wach G, et al, 2020)**.

There are several advantages with ALK electrolysis technology. ALK uses Nickel and Copper as anode and cathode, which makes it one of the cheapest hydrogen generating technologies. ALK technology was considered as the most mature and commercialized technology. One of the larger disadvantages of the technology is the alkaline environment of operation. Solving this problem occurred by using the electrodes submerged in a KOH solution (**Schmidto, et al, 2017, Moller KT, et al, 2017**).

Proton exchange membrane (PEM) process is another type of hydrogen generating tools where water is typically fed with 80 degree C and its operational pressure in the cathode, set to around 30 bar, since the operation of the PEM with a high concentration of H+ ions create an acidic nature, the materials for the anode and cathode must be corrosion-resistant. Where typical materials used are platinum and iridium, which increases the cost of PEM (**Abe. JO, et al, 2019, Cosnell A et al, 2017, Shiva Kumer, et al, 2019)**.

5- Research contribution:

This research suggests a method for producing green hydrogen from Al-Sokhna sea water by suggesting an debris filter unit which is very necessary for preventing the fouling (accumulation of different marine debris such as snails and algae) of reverse osmosis unit which is responsible for desalination process, where the RO is connecting with Alkaline electrolysis unit responsible for generating hydrogen.

This proposal based on the evaluation of the suitability of inlet seawater at the site being selected for the hydrogen generation process, as shown in Fig (1)., three corrosion indexes used as helpful tools, in order to take the good environmental decision.

Table (1) showed four indices used to predict the corrosion and scale impacts on the hydrogen generating tool which was being suggested (Roger B. et al, 2020).

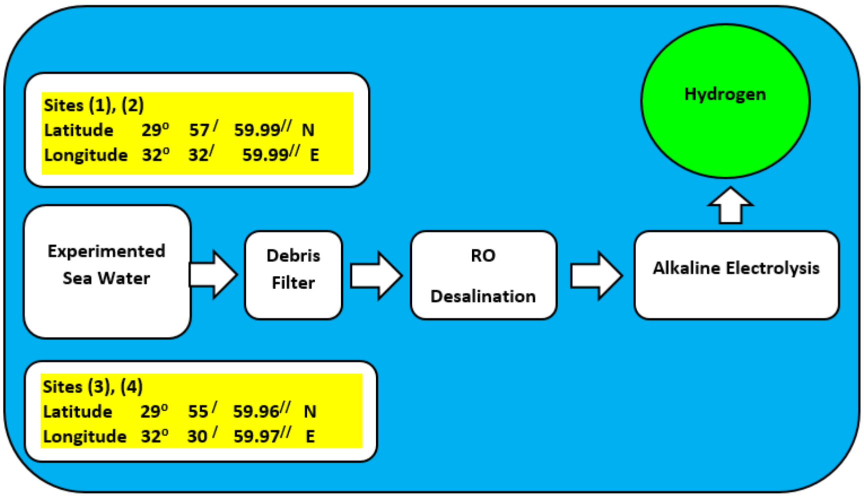

Figure (1) Suggested flow diagram showing the hydrogen generation process at the selected Al-Sokhna sites Using Saturation indexes

Table (1) Different corrosion and scale equations indices (Roger B. et al, 2020).

Index	Used Formula	Explanation
Langelier saturation index (LSI)	LSI= pH-pHs pHs=A+B-log[Ca]-log[Alkalinity]	LSI < -0.5 → Corrosion -0.5 < LSI<0.5 → Equilibrium LSI > 0.5 → Scale deposits If LI<-0.5 → indicates corrosiveness
Ryznar Stability index (RSI)	RSI= 2pHs - pH	If RSI value <5.5 heavy scales will be deposits If RSI value is 5.5<RI<6.2 the scale deposit will be formed If RSI value is 6.2<RI<6.8 there will be no difficulties If RSI value is 6.8<RI<8.5 water will have an aggressive property If RSI value is >8.5 water will be very aggressive
Stiff-Davis Index (SDI)	LSI = pH – pHs	LSI = pH - pHs (TDS <10,000 mg/l) S&DSI = pH - pHs (TDS >10,000 mg/l

6- Discussion:

Determintion of scale formation and corrosion impacts

Presence of other salts often exerts a strong influence the scale formation which finally leading to corrosion in different hydrogen generating tools, it was reported that, 1mm, 1.5mm and 7mm thick scales can increase cost by 7.5%, 15% and 70%, respectively. Six kg per cubic meter of hardness (expressed as calcium carbonate) require softening chemicals of almost the same order.

Table 2 showed that total dissolved solids ranged from 40200 mg/l in site 3 to 41900 mille gram/liter in location(1) while Table 2, showed that the chlorides concentration ranged from 20800 mille gram/liter in location (2) to 21400 mille gram/liter in location (1).

The increment of chlorides and sulfates concentrations in the studied desalination units of hydrogen generating tool (ALK), will lead to the probability of scale formation inside the recommended RO desalination unit, which leading to consume large amount of anti-scale formation chemicals, finally the cost of consumed megawatt for the desalination and hydrogen production will be increased due to that.

Table. (3) showed that the lowest Razynar stabilty index value 2.210**,** which showed the lowest degree of scale formation than other Ryzanar stability indexes of all the selected four Al-Sokhna water locations, while Table (3), also showed that location 2, have the lowest langerier and Stiff davis sturation indices than the other selected sites indices.

As the result location 2, is considerd suitable for the suggested desalinated and Alkline electrolysis units, because of their low tendency for corrosion and scale formation impacts.

Table (2) The measured concentrations of different physicochemical paramters in four sites proposed for generating hydrogen at Al-Sokhna portal site (M. S. Tawfik.et, 2024)

Sites	Major Average mean of Anions					
	pH	Temperature ºC	Total Dissolved Solids (mille gram/liter)	Carbonates (mille gram/liter)	Sulfates (mille gram/liter)	Chlorides mille gram/liter
Location (1)	8.1	28	41900	190	5100	21400
Location (2)	7.6	29	40700	215	5400	20800
Location (3)	8.3	27	40200	217	5560	21600
Location (4)	8.6	26	40700	210	5200	20880

Table (3) Determintion of corrosion and scale saturation indexes values at the different selected sites in Al-Sokhna

Proposed Al-Sokhna sites for hydrogen genation	Langlier saturation Index	Stiff davis stability index	Ryzner Sability Index
Location (1)	2.310	1.504	3.112
Location (2)	1.444	0.511	2.210
Location (3)	2.519	1.522	3.111
Location (4)	2.311	1.634	2.56 1

Using hydrogen production unit

As showed in Table 4, it was observed that each one megawatt system will produce 18.65 Kilogram /hour hydrogen so that for in case of using five operational hours per day, the hydrogen generator will produce 34.120 Kg of hydrogen per year,

It was reported that the hydrogen being produced by electrolysis is 99.999% pure and can be directly used in different applications such as combustion systems, fuel cells and chemical feed stock. (**Dominis Burrin et al, 2021, Anton Ottoson et al, 2021**).

It was observed that the three most common studied hydrogen-generating technologies are summarized in Tables (4) & (5).

Table (4) hydrogen production for 1 MW system (Anton Ottoson et al, 2021)

Operating of 1 MW hydrogen generating unit	
Hydrogen production in Kilogram /hour	18.65
Oxygen production in Kilogram/hour	137.27
Heat extracted in cooling circuit in Kilo Watt	310

Table (5) Comparison between hydrogen electrolyzes systems (Anton Ottoson et al, 2021)

	ALK	PEM	SOEC
Maturity level	Commercial	Commercial	Developing
Can be used as fuel cell	No	Yes	Yes
Price €/Kg	< 1000	< 1600	> 2000
System life time	20+	10+	>1
Maintenance cost	High	Low	High
Startup time	< 1 hour	< 15 min	< 1 hour
Load response time	Seconds	Milliseconds	Seconds
Operational temperature ^0C	~ 70-80	~ 70-90	~ 700-800
Purity level of produced H_2 gas:(% H_2)	~99.5	≤ 99.99	~99.9
Operating pressure (Bar)	<30	<100	<20
Stack life time hours	<70000	~ 70000	<20000

The study selected the using of ALK as a hydrogen production unit in Al-Sokhna where followed the RO desalination unit, as there are several advantages with the using of the ALK electrolysis technology as being showed in Table 4 compared with the other three hydrogen electrolysis units.

One of the larger disadvantages of the ALK technology is the alkaline environment it is operating in. This environment will cause some of the equipment, such as cathode and anode, to degrade over time, which will increase maintenance costs. By having the electrodes submerged in a KOH solution, traces of the electrolyte will be present in the H_2 flow, lowering the purity **(Anton Ottoson et al, 2021)**

7- Experimental Results:

Different physicochemical analysis were done for the four studied coastal sampling sites in the subsurface area of Alsokna Red Sea, where different parameters were determined at these sites such as; total dissolved solids, carbonates, sulfates and chlorides in milligram per litter, using the volumetric analytical technique

The results showed that the Location 2 has the lowest degree of scale formation than other saturation indexes of the all selected four Seuz sites.

Selecting these sites (1,3 and 4) would lead to the increasing of probabilty of corrosion riskes on the suggesed desalintion and hydrogen production units of Suez port region, leading to the consuming of large amount of anti-scale formation agents (polyphosphates) and anti corrosive chemicals (hydrazine), which means an increament in the cost of the chemical treatment in the suggeste RO desalination unit.

The research suggests using of debris filter before the entrance of the proposed RO Desalination unit.

The study showed that each one-megawatt system would produce 18.7 Kg/h hydrogen, so that for standard case of 5 operational hours per day, the hydrogen generator will produce 34.120 Kg of hydrogen per year. As the hydrogen, which produced by ALK, electrolysis is 99.999% pure, as the result the studied proposal results support the using of alkaline water electrolysis ALK as a suitable generating tool in Al-Sokhna region.

8- Green Hydrogen prospects in Shipping Industry:

Global shipping accounts for approximately 25% of world transport emissions, estimated to be one billion tons of CO2 per year. As the International Energy Agency (IEA) points out, green hydrogen would save 830 million tons of CO2 emitted annually using fossil fuels.

Green hydrogen as a fuel has several advantages, as it does not emit polluting gases during combustion or production; as it is easy to be stored, transformed into synthetic gas. Green Hydrogen stands out for its zero-emission operation at the point of use. Its high energy density makes it suitable for long-distance voyages, overcoming the limitation of battery technology.

One of the advantages of hydrogen is its relative ease of retrofitting the existing world fleet ships with hydrogen fuel cells. Due to this advantage in ship fuel engineering, predictions state that global green hydrogen market expected to reach $1.4 trillion by 2050.

Currently, the world is producing 70 million metric tons of hydrogen annually for industrial use. Countries pursue projects to expand production, Germany, as a G7 country example, is aiming to generate 10 gigawatts of its electrolysis capacity depending on green hydrogen in the next 15 years.

A Global Oil Companies as Royal Dutch Shell has already invested in several hydrogen production projects in Europe and China, realizing the potential of green hydrogen as a zero-emission fuel. International Maritime Organization (IMO) pledged shipping companies to quest reducing its fossil fuel gas emissions by 40% by 2030, while aiming for 70% by 2050 relative to the 2008 emission level.

Worldwide producers of Green hydrogen have plans to produce 11 million tons annually for the global shipping sector by 2030. On government side, 45 governments agreed to set ambitious green hydrogen projects within its power generating strategies.

9- Towards establishing a Green Hydrogen Supply Center in Egypt:

Green shipping offers many opportunities for Egypt due to its location on the Suez Canal where 15% of world seaborne trade annually transit the Canal. Accordingly, Egypt is well suited to become a global Hydrogen Supply Center on the route from Europe to Asia.

Green Bunkering in Egypt has a cost advantage as ships could get its fuel during their waiting time before entering the Suez Canal; the ship's bunkering stop would not require additional time and costs. On the other hand, this green fuel would be exported to large ports in Europe or Asia.

Suez Canal with its unique geographic location; works as an artery for global East – West trade, accordingly about 24000 ships of all types are transiting Suez Canal each year, including Oil Tankers, Liquefied Petroleum Gas Tankers, Liquefied Natural Gas Tankers, Container Ships, General Cargo Ships, Multipurpose ships, Dry Bulk Cargo Ships, .etc.

Suez Canal Ship Transit system includes two convoys: South bound convoy from Port Said to Suez, starts at 0330- direct transit. Northbound convoy from Suez to Port Said starts at 0400- direct transit. The Coeur concept of establishing a Green Hydrogen Supply Center in Al-Sokhna, is to provide ships anchoring in the Gulf of Suez waiting area with Hydrogen, while it's waiting time. This is the major marketing objective for the suggested Green Hydrogen Supply Center; it is because these ships can make the best use of their waiting time for Suez Canal transit.

On the other hand, these ships would not make any diversion from the main shipping route to Suez Canal to get its needs from Hydrogen; on the contrary, extra diversion distance sailing is required if it resorts to any port on the Red Sea Coast.

The suggested project location in Al-Sokhna region, as the port is close to the main shipping lanes for Asia Europe trade transiting Suez Canal, That region is having an existing industrial cluster that could potentially develop into a large consumer of green hydrogen. Producing green hydrogen close to its consumption will have a favorable cost impact on the product marketing.

In addition, Al-Sokhna Industrial Zone with its 210 Km area has several types of industries, light, medium and heavy manufacturing activities, as well as commercial, business and logistics activities. Industries at Al-Sokhna Industrial Zone include Energy Components Manufacturing, Refinery products, Construction & Building Materials, Chemicals & Petrochemicals, Heavy Industries, Textiles & Ready-made Garments, Fertilizer industries, Home Appliances & Electronics, Pharmaceuticals, Logistics activities & Courier services, Automobile Assembly & Parts, Food Processing, SME Cluster Park Development.

Egyptian government has signed development agreements with 20 industrial developers at Al-Sokhna industrial zone. By the end of 2024, more than 240 projects established there, and over 30 thousand direct and indirect jobs created in the area. On the other hand, Egyptian government is currently collaborating with global shipping companies working on Asia – Europe trade route to position the suggested Hydrogen Supply Center as a regional center for green shipping industry.

10- Conclusions & Recommendations:

1- Egypt has a great potential to produce green hydrogen and export it as green fuel to ships transiting Suez Canal, accordingly we recommend establishing a Green Hydrogen Plant and Supply Center in Al-Sokhna region, close to Suez Canal ship waiting Area close to Al-Sokhna region.

2- It is recommended to establish the Green Hydrogen Plant and Supply Center Site at Al-Sokhna region, due to area availability and the expected backward and forward vertical integration with industries in that area.

3- To obtain a significant financial and environmental cost reduction, it is recommended that the new hydrogen plant use renewable energy, such as wind energy, as Egypt has high, consistent wind speeds, which enable an efficient use of wind, especially in the Gulf of Suez Region.

4- Egyptian government should create synergies with existing industrial clusters and production facilities that could potentially use excess hydrogen capacity in times of high production and/or low demand.

5- It is essential for Egypt to launch a strategic marketing plan for its Green Hydrogen Supply Center, aimed towards global shipping lines and major shipping companies.

6- It is important that Egypt start setting up a legislative framework for green hydrogen industry, concerning investment, taxation and bureaucratic issues.

7- Egypt should work on fostering cross- sectoral collaboration and knowledge transfer in the field of green fuel technology.

8- it is recommended that Egypt work on combining industrial activities in Al-Sokhna, with renewable energy generation and green hydrogen investments.

9- Egypt should concentrate on reforming the regulations that could ease the participation and cooperation between all the stakeholders in Green Hydrogen Industry.

10- Egypt should take into consideration the competitive situation with similar projects in the Red Sea and the Mediterranean, which target having a share from that green energy market.

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