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Batch Electrochemical Production of Sodium Hypochlorite : P^h Change and Influence of Alkalinity

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Abstract:- **The effect of using variable alkaline mediums; sodium carbonate , sodium hydroxide and ammonium hydroxide in different concentrations on on-site electrochemical production of sodium hypochlorite using a single batch electrolysis cell as studied by following up the rate of reaction and the p^H at specific time intervals. Generally the rate of production increase at 0.4 %w/v followed by 0.2 %w/v. Ammonia hydroxide was not suitable as alkaline medium because there was no significant increase in production rate at 0.2 %w/v0.4 %w/v , reaction was very slow and sodium hypochlorite did not firmed at higher concentration. The optimum P^H to get best production rate was between (8 -8.5)**

Keywords:- *Sodium Hypochlorite; Electrochemichal Production; Sodium Chloride.*

I. INTRODUCTION

Sodium hypochlorite is a pale yellow compound with the distinctive smell of chlorine. NaOCl is a powerful oxidant , strong antimicrobial against bacteria and bleaching agent. It's commonly used as disinfectant for drinking & waste water [1-3]. In the last three years with COVID-19 pandemic sodium hypochlorite has become one of most disinfectant required in the world. Because many safety precaution that are to be taken into consideration during storage and transporting large volumes of liquid chlorine ; the local hypochlorite electrochemical generation increased[4-6].

The chlor-alkaline industry produce many important compound by the electrolysis of brine .this method produce sodium hydroxide and chlorine gas which blended to produce sodium hypochlorite. The following equation illustrate the process at anode (loss of electrons):

$$2Cl^-_{(aq)} \longrightarrow Cl_{2(g)} + 2e^-$$

at cathode (gain of electrons):

$$2H_2O_{(l)} + 2e^- \longrightarrow H_{2(g)} + OH^-_{(aq)}$$

Because of the civil war in Yemen, we have a complex problem for two main reasons; stopping electricity generation and preventing the import of chlorine gas . Therefore, this work tries to contribute to finding an energy-saving solution that uses local resources to produce sodium hypochlorite[7-14].

The main raw material in our experiment was sodium chloride, which may be available from different sources such as rock salt or solar salt, which is obtained by solar evaporation of sea water[15].

II. MATERIALS AND METHOD

Table(1) lists materials, chemicals, and equipment used in electrochemical Production of Sodium Hypochlorite from brine water.

A plastic container filled with 3L of tap water. 360gm of sodium chloride salt dissolved in tap water to get a 12%w/v solution. Graphite rods was used as anode and zinc plate with 5*10 dimensional used as cathode .the distant between anode & cathode was 20 cm.

After connected zinc plate with negative pole and graphite with positive pole of DC supply power 5ml of reaction mixture Transferred to conical flask contain 5ml of KI has 6%w/v concentration and drops of starch as indicator every ten minutes from 10 up to 120 min . The solution mixture was titrated with a standard $Na_2S_2O_3$ solution. The P^H has been measured every 10 min since the beginning of the reaction. The previous steps are repeated by adding different concentrations of different alkaline solutions (Na_2CO_3,NaOH,NH_4OH)(0.2%, 0.4 %w/v ,0.6 %w/v, 0.8 %w/v ,1% w/v).

Table 1 Materials, Chemicals, and Equipment Used in the Present Study.

Material / chemical	Assay%	Source
Salt (NaCl)	Commercial grade	Local market
Tap water	-	Our lab
Distillated water	-	Our lab
Starch indicator	Analytical grade	BHD
Potassium iodide	99-100%	BHD
Sodium thiosulfate	90%	Labtech Chemicals
Sodium carbonate	99.5%	Chemical laborites
Sodium hydroxide	96.5%	ADWIC
Ammonia solution	25%	Chemical laborites

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III. RESULTS & DISCUSSION

The effect of adding different concentrations of Na_2CO_3 on the electrochemical kinetics (U) of NaOCl using graphite and zinc rods is presented in fig. (1,2,3,4,5).

When the concentration of Na_2CO_3 is increased from 0.2% w/v to 0.4% w/v, the slope value increases. It was also observed that slope value was strong and suddenly rose at 0.8 %w/v while slope value was low at 0.6 %w/v and 1%w/v.

Table (2) describe values of production rate with change of Na_2CO_3 concentration and P^H ranges. In addition to some statistical parameters, standard deviation (SD)and squared correlation coefficient (R2). The highest production rate was at 0.8 %w/v followed by 0.4 %w/v, while the rest concentration gave low production rate .

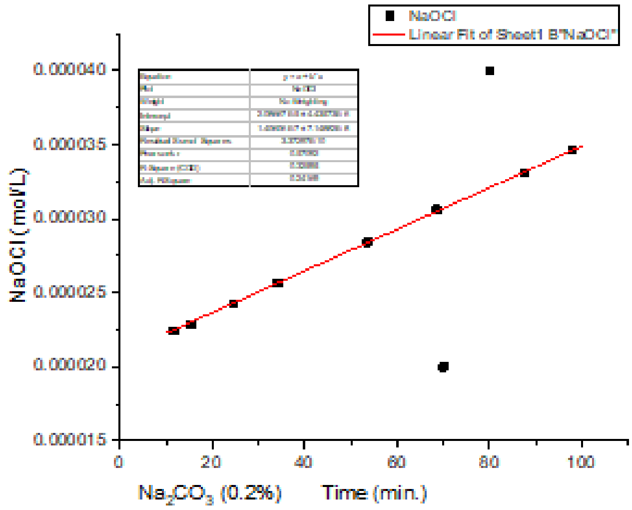

Fig 1 Effect of Added 0.2% W/V Na_2CO_3 on Electrochemical Kinetics of NaOCL

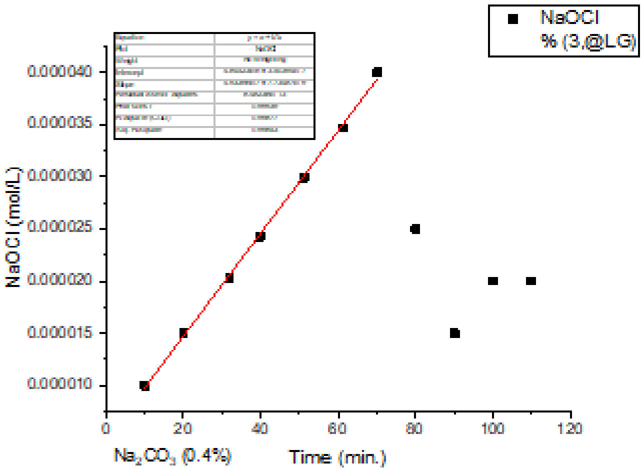

Fig 2 Effect of Added 04% w/v Na_2CO_3 on Electrochemical Kinetics of NaOCl

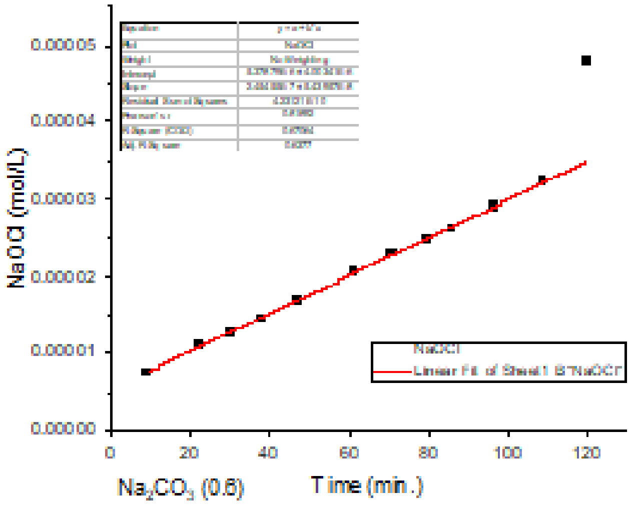

Fig 3 Effect of Added 06% w/v Na_2CO_3 on Electrochemical Kinetics of NaOCl

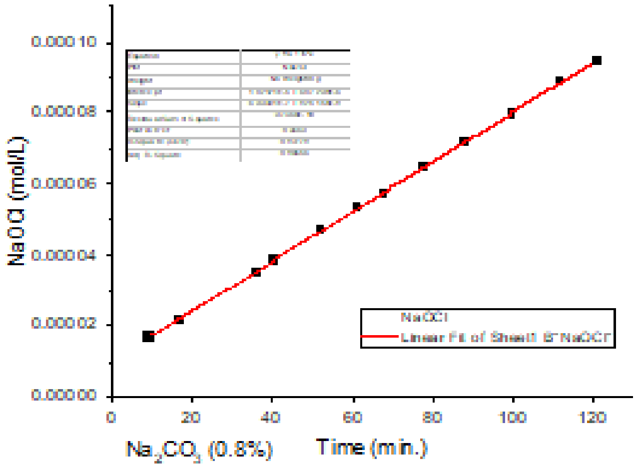

Fig 4 Effect of Added 08% w/v Na_2CO_3 on Electrochemical Kinetics of NaOCl

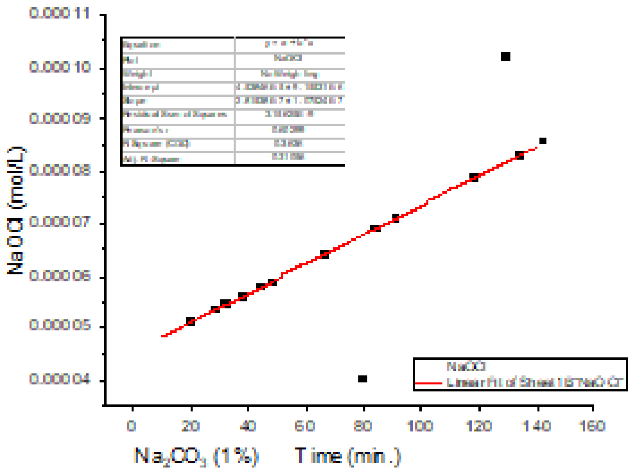

Fig 5 Effect of Added 1 % w/v Na_2CO_3 on Electrochemical Kinetics of NaOCl

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Table 2 Values of Production Rate with Change pof Na_2CO_3 Concentration and P^H Ranges Standard Deviation and Squared Correlation Coefficient.

W / V % Na_2CO_3	**P^H rang**	**U mol NaOCl s^{-1} cm^{-2}**	**R^2**	**SD**
0.2	9 – 10	$4.66*10^{-10}$	0.32595	$7.46*10^{-6}$
0.4	9 – 10	$1.60*10^{-9}$	0.84375	$9.32*10^{-6}$
0.6	9.7 – 10.2	$8.14*10^{-10}$	0.67064	$1.08*10^{-5}$
0.8	10.3 – 10.6	$2.32*10^{-9}$	0.87778	$2.69*10^{-5}$
1	10 – 10.7	$9.34*10^{-10}$	0.3636	$1.95*10^{-5}$

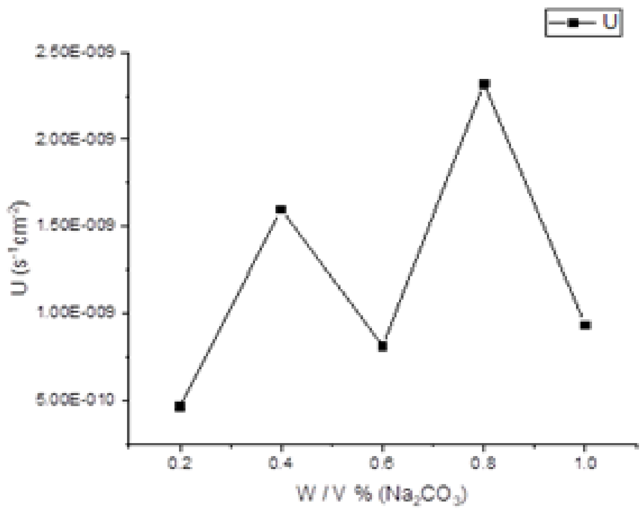

Fig 6 Relationship between Production Rate of NaOCl and Na_2CO_3 Concentration

When NaOH used as an alkaline medium the slope value was high at 0.4 %w/v , 0.6 %w/v compare with 0.2 %w/v. As shown in figure (7,8,,9) the highest production rate was at 0.4 %w/v as seen at figure (10) and table (3).

As clearly presented in figure (11,12) , when NH_4OH used as alkaline medium no change in the kinetics of NaOCl production was observed When concentration was raised from 0.2 %w/v to 0.4 %w/v . the hypochlorite was not formed at higher concentration . Table (4) and figure (13) illustrate no significant change in production rate of sodium hypochlorite. The NaOCl production rate in the previous alkaline medium in different concentration was compared . result obtained clearly tell the production rate was high for NaOH medium compared with sodium carbonate and ammonium hydroxide when concentration was 0.4 %w/v , 0.6 %w/v while production rate with NH_4OH was higher at 0.2 %w/v.

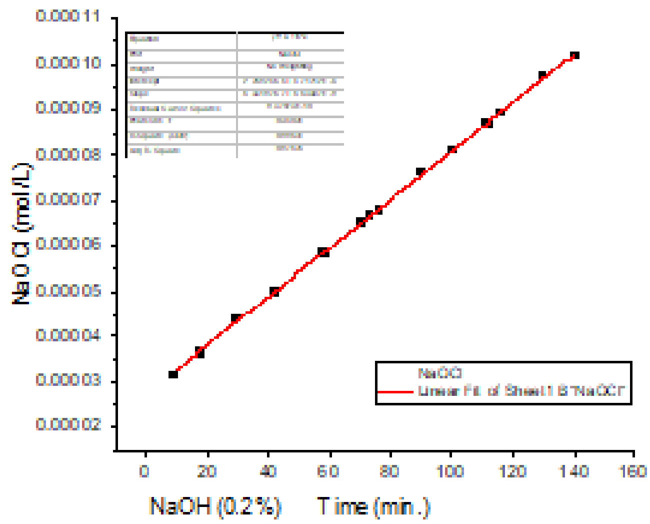

Fig 7 Effect of Added 0.2 % w/v NaOH on Electrochemical Kinetics of NaOCl

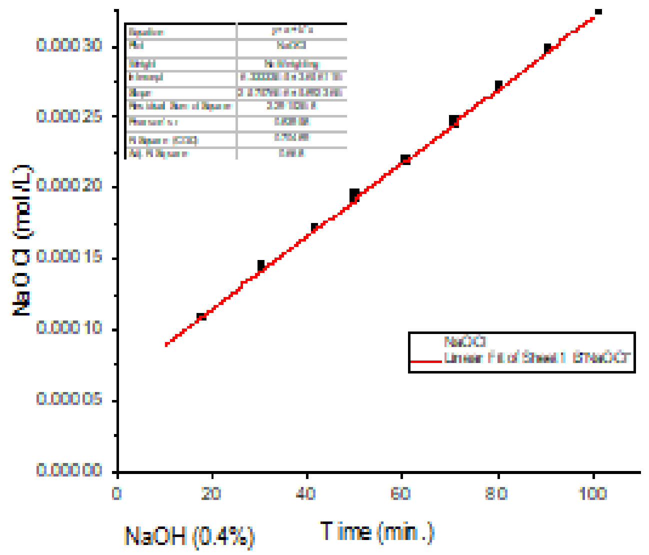

Fig 8 Effect of Added 0.4 % w/v NaOH on Electrochemical Kinetics of NaOCl

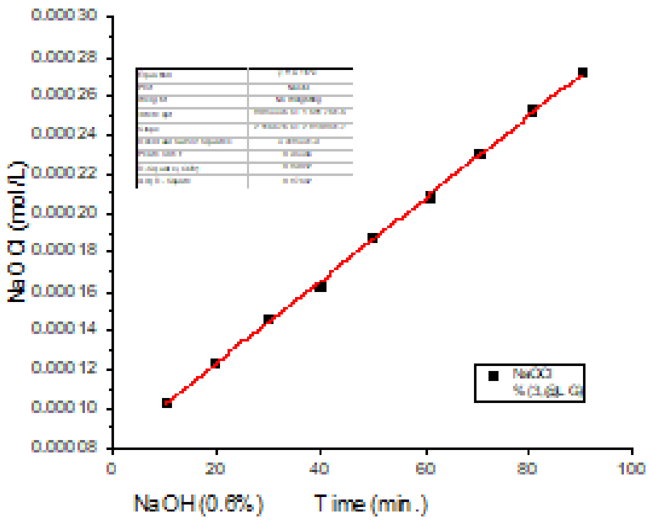

Fig 9 Effect of Added 0.6 % w/v NaOH on Electrochemical Kinetics of NaOCl

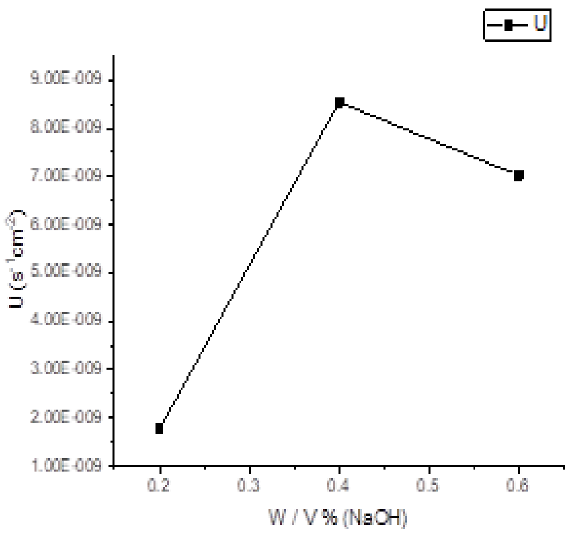

Fig 10 Relationship between Production Rate of NaOCl and NaOH Concentration

Table 3 Values of Production Rate with Change of NaOH Concentration and P^H Ranges Standard Deviation and Squared Correlation Coefficient

W / V % NaOH	**P^H rang**	**U mol NaOCl s^{-1} cm^{-2}**	**R^2**	**SD**
0.2	11.14 – 11.21	$1.77*10^{-9}$	0.88531	$2.37*10^{-5}$
0.4	11.40 – 11.93	$8.54*10^{-9}$	0.70489	$8.24*10^{-5}$
0.6	11.90 – 11.96	$7.02*10^{-9}$	0.89012	$6.14*10^{-5}$

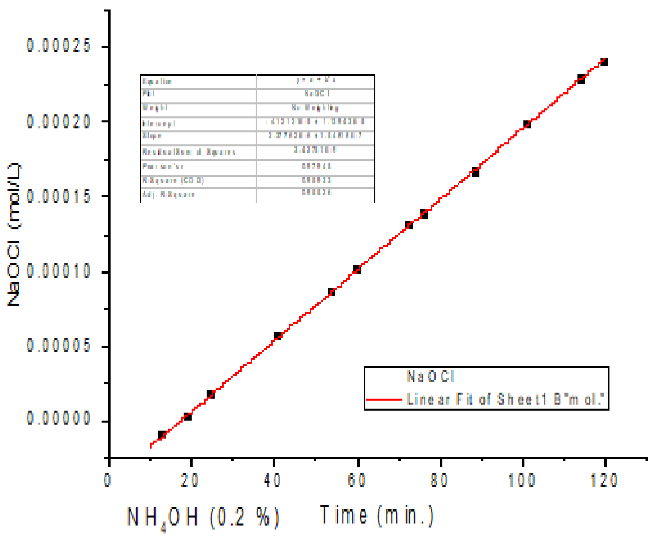

Fig 11 Effect of Added 0.2 % w/v NH_4OH on Electrochemical Kinetics of NaOCl

Table 4 Values of Production Rate with Change of NH_4OH Concentration and P^H Ranges Standard Deviation and Squared Correlation Coefficient

W / V % NH_4OH	**P^H rang**	**U mol NaOCl s^{-1} cm^{-2}**	**R^2**	**SD**
0.2	9 – 9.8	$7.89*10^{-9}$	0.95933	$8.75*10^{-5}$
0.4	9.9 – 10.24	$7.67*10^{-9}$	0.92181	$9.04*10^{-5}$

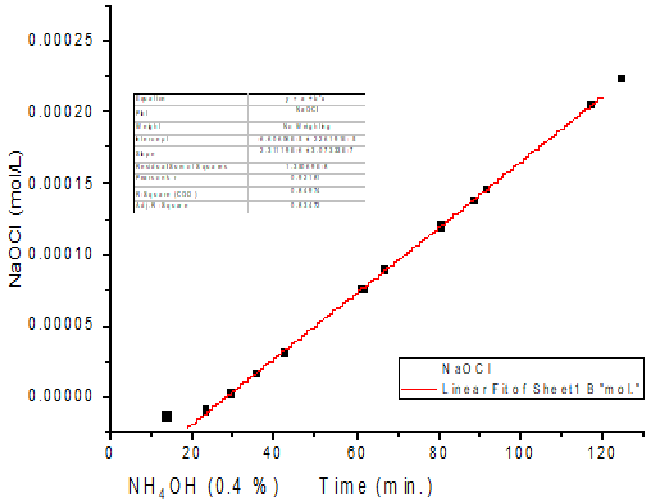

Fig 12 Effect of Added 0.4 % w/v NH_4OH on Electrochemical Kinetics of NaOCl

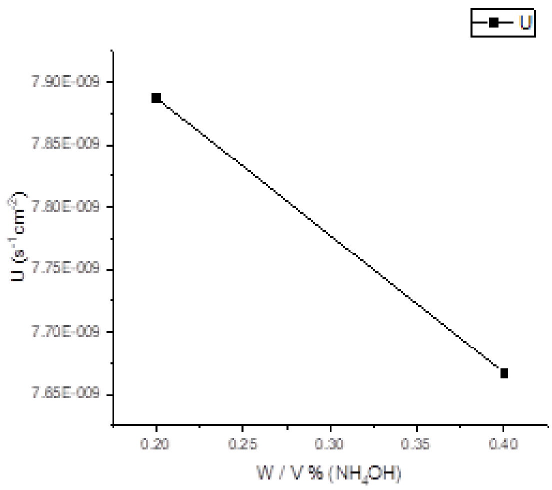

Fig 13 Relationship between Production Rate of NaOCl and NH_4OH Concentration

Figures from (14) to (23) illustrate the change of P^H during reaction with different alkaline medium in different concentrations.

Despite obtaining high slope value with NaOH at 0.4 %w/v and 0.6 %w/v ,but the used volume from the burette was very small. This means that the high PH value was unsuitable and inhibited the formation of NaOCl. Blue color did not appear at 0.8%w/v NaOH concentration even after 120 minutes because sodium hypochlorite was not formed.

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Also the yellow color did not appear when 5ml of KI added To make sure , experiment with only NaCl were carried out. Blue and yellow colors are noted clearly . Reaction was slow when NH_4OH used blue and yellow color did not show at early minutes of reaction.

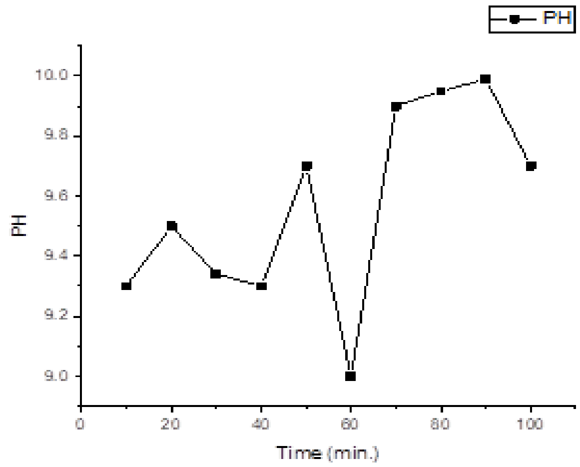

Fig 14 P^H Change at 0.2% w/v of Na_2CO_3

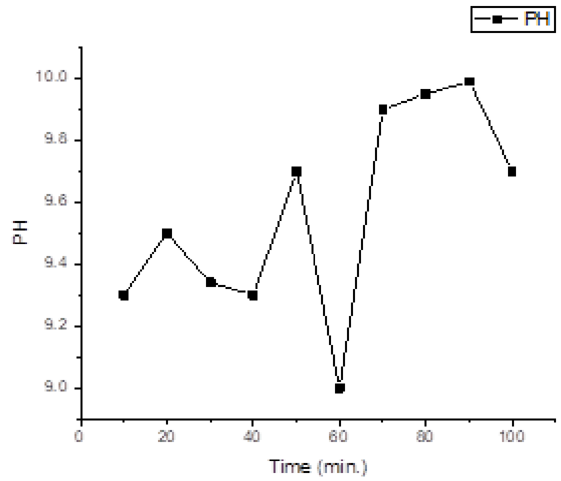

Fig 15 P^H Change at 0.4% w/v of Na_2CO_3

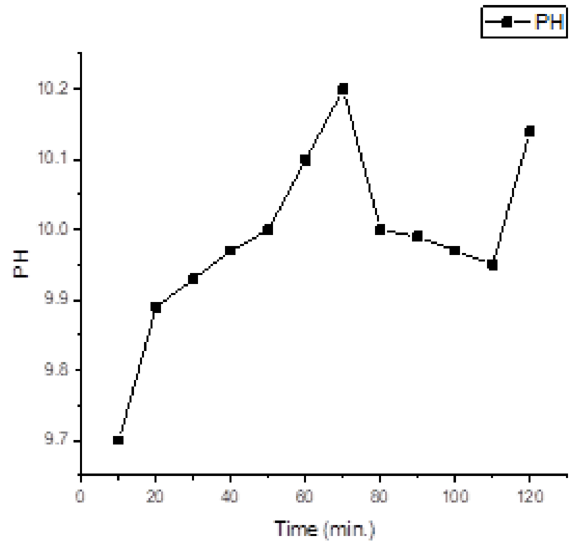

Fig 16 P^H Change at 0.6% w/v of Na_2CO_3

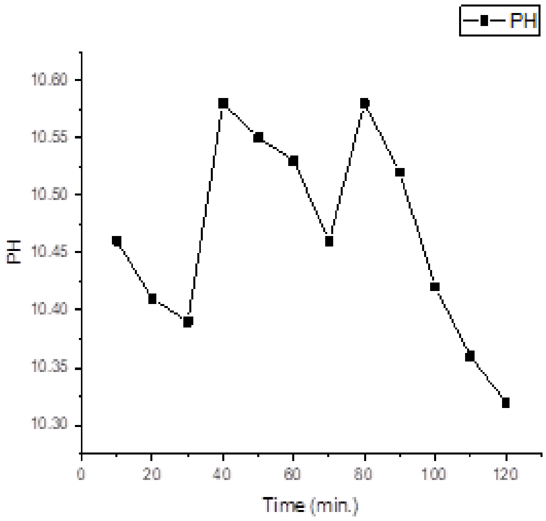

Fig 17 P^H Change at 0.8% w/v of Na_2CO_3

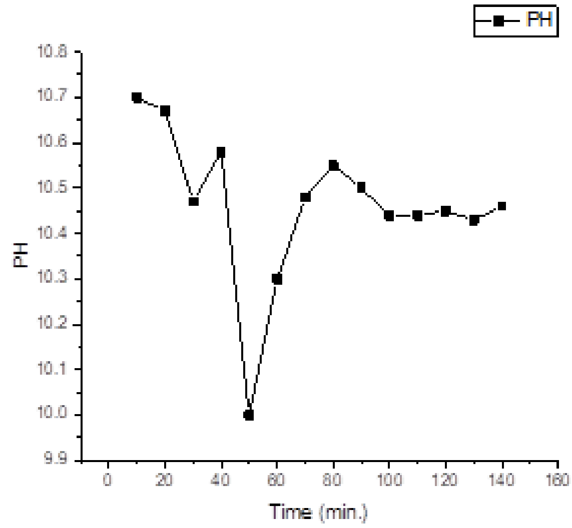

Fig 18 P^H Change at 1% w/v of Na_2CO_3

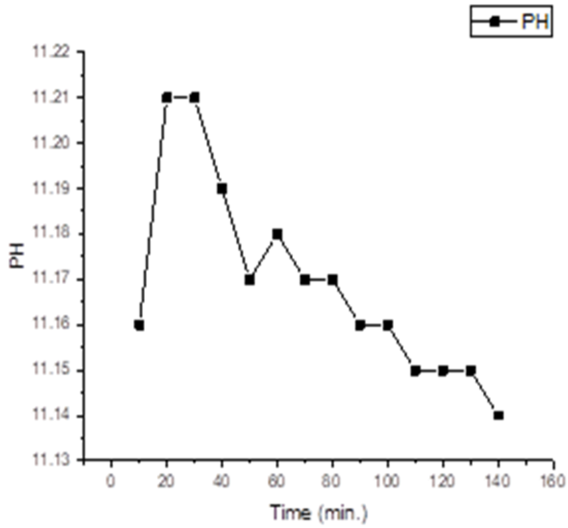

Fig 19 P^H Change at 0.2% w/v of NaOH

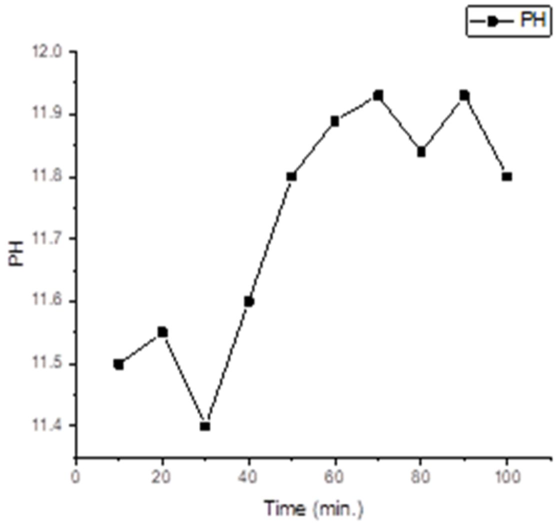

Fig 20 P^H Change at 0.4% w/v of NaOH

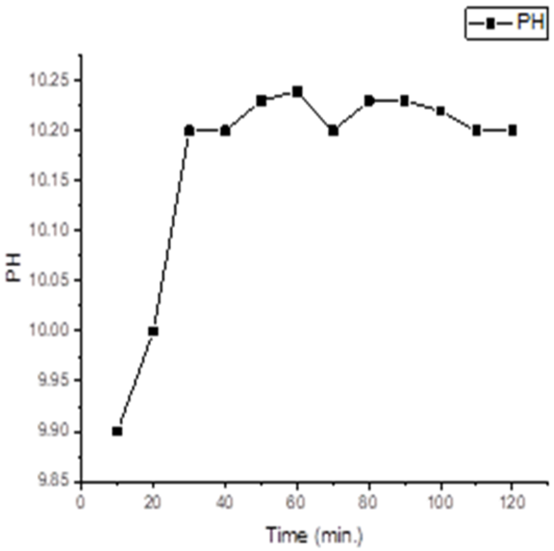

Fig 23 P^H Change at 0.4% w/v of NH_4OH

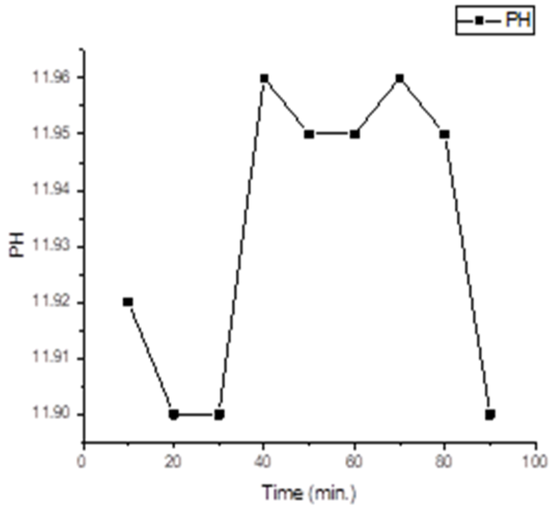

Fig 21 P^H Change at 0.6% w/v of NaOH

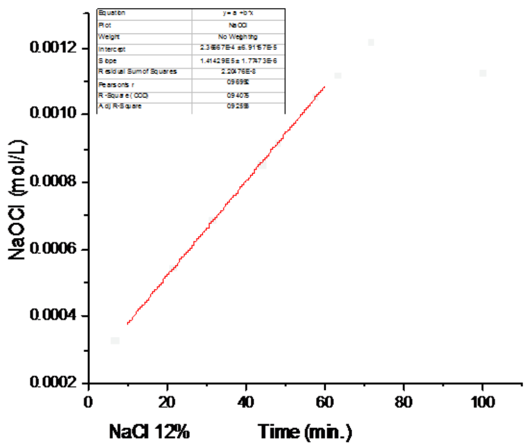

Fig 24 Electrochemical Kinetics of NaOCl without Alkali

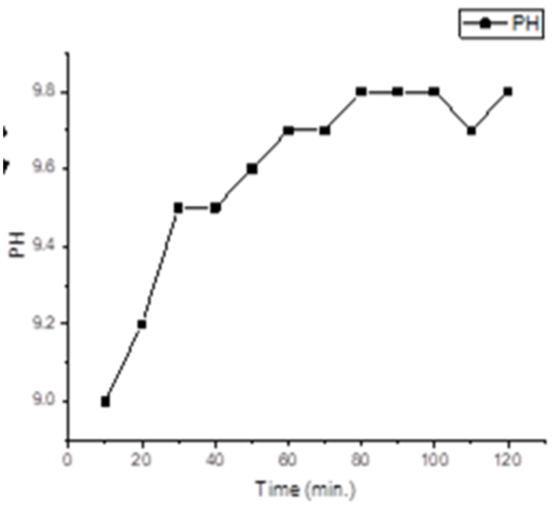

Fig 22 P^H Change at 0.2% w/v of NH_4OH

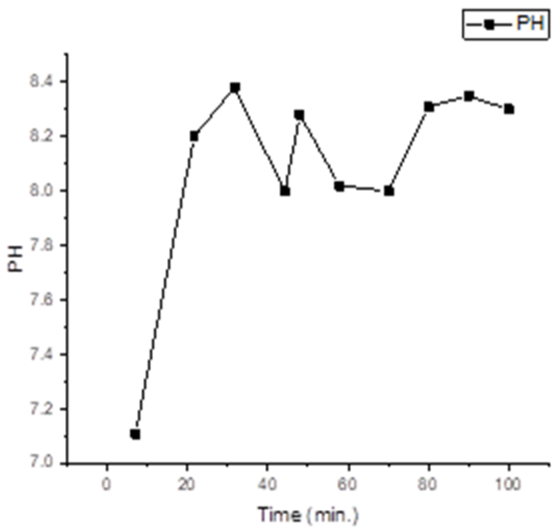

Fig 25 P^H Change without Alkali Medium

IV. CONCLUSION

The main objective of this research work was to study the effects of P^H change and the effect of adding variables type and concentration of alkaline medium on the electrochemical production of sodium hypochlorite.

The P^H range from 8 to 8.5 gave the best results at the on-site electrochemical production of sodium hypochlorite using zinc plate and graphite rods with a 20 cm distance between them. So the recommended concentration of alkaline medium is no more than 0.4 %w/v .

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