Journal of Multidisciplinary Engineering Science Studies (JMESS)
ISSN: 2458-925X
Vol. 2 Issue 3, March - 2016

Introduction Of Langelier Saturation Index To Production Of Freshwater From Seawater

Robert Poku
Department of
Marine/Mechanical Engineering,
Niger Delta University,
Wilberforce Island,
Bayelsa State, Nigeria
robertpoku@yahoo.com
(Corresponding Author)

Bebeteidoh O. Lucky
Department of
Marine/Mechanical Engineering,
Niger Delta University,
Wilberforce Island,
Bayelsa State, Nigeria
engrpreye@mail.ndu.edu.ng

Ezenwa A. Ogbonnaya
Department of
Marine/Mechanical Engineering,
Niger Delta University,
Wilberforce Island
Bayelsa State, Nigeria
ezenwaogbonnaya@mail.ndu.edu.ng

Abstract—The role of water for both domestic and other uses onboard ships cannot be over emphasized. However, whether it is used for domestic consumption, cooling of equipment, boiler operations and other vital applications depend on its chemical composition. There are several known techniques of obtaining fresh water from seawater. This research therefore, employs distillation method in converting seawater to fresh water which can be used for drinking and for other domestic activities aimed at the smooth operation of a ship. Saltwater was drawn from Koluama and Nembe all in the Niger Delta Region of Bayelsa State, Nigeria. Both samples were analyzed for dissolved substances and the total contents of the various chemical compositions in the water were obtained. After the distillation process, test was carried out to confirm if the water produce from the process is suitable for human consumption. The result shows that the composition of the water in Koluama and Nembe contains dissolved minerals like Iron (0.02mg/l), Calcium (7.50mg/l), Chlorine (15.0mg/l), Total Suspended Solid (0.00mg/l), Magnesium (2.40mg/l), Alkalinity (0.05mg/l), Turbidity (0.00mg/l), Nitrate (0.01mg/l) each and the pH (7.08mg/l and 7.06mg/l), Total Dissolved Solid (14.40mg/l and 14.30mg/l), Sulfate (0.42mg/l and 0.43mg/l) respectively. The results were used to compare water from three different companies in Abeokuta and Langelier Saturation Index (LSI) was also applied. The results showed that beyond the distillation technique a confirmation by LSI is necessary to ascertain the true state of the distilled water.

Keywords— Distillation, Seawater, Desalination and Langelier Saturation Index.

1. INTRODUCTION

Water use is of fundamental importance for many industrial as well as domestic processes [1].Water from the sea is a useful medium for washing decks, heat exchanges, flushing heads, support of animals and plants life, and other uses, but not for human consumption or boiler feed. However, as in villages, cities, and industries that are located in arid and water-short areas of the world where sea or brackish waters are available, it is imperative to employ desalting techniques and obtain fresh water on board vessels for a given voyage.

For many years now, owing to population growth, rising living standards, and the increasing demands of industrialization; there is pressure on water resources and consequently, a corresponding interest in the possibilities of large-scale desalting of seawater. Desalting, desalination or desalinization refers to water treatment process that removes salt and other minerals from seawater [2].

Varieties of desalting techniques have been developed. Industrial desalinization technologies use either phase change or thermal processes, or involve semi permeable membranes or single-phase processes to separate the salts from the seawater. All processes require a chemical pre-treatment of raw seawater to avoid scaling, foaming, corrosion, biological growth, and fouling and also require a chemical post-treatment [3]. The choice of desalination method depends on Total Dissolved Solids (TDS) contents and compatibility of the treatment system to work under the presence of extra contaminants present in the produced water [4].

However, similar to the natural processing of seawater on earth, where water evaporates from the sea and eventually, condenses to form pure rain water. The phase change or thermal desalination process as seen in fig. 1 involves the application of thermal energy to saline water contained in a desalting device resulting to the evaporation and subsequent condensation of fresh water leaving the brine behind where the temperature remains constant [5],[6].

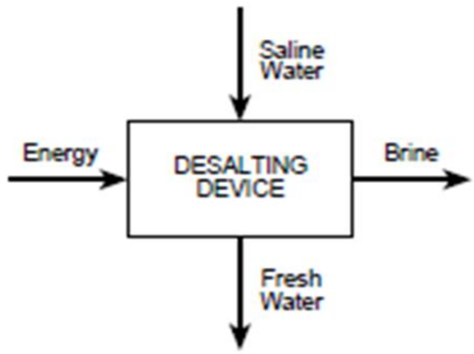

Fig. 1: Simple Illustration of Thermal Desalting Plant

This research seeks to study the distillation method of obtaining fresh water from salt water. The paper investigated the effects of distillation in two water samples drawn from two locations in Niger Delta Regions of Nigeria with the aim of eliminating undesirable phenomena like corrosion and fouling.

2. MATERIALS AND METHODS

Samples of seawater were drawn from both Koluama and Nembe and subjected to laboratory analysis and the results are as presented in tables 1 and 2. Materials employed are: 20 liters of seawater, water distillation set (1 liter size), heating mantle (1 liter size), 500ml conical flask (receiver), thermometer, conductivity meter, digital pH meter, salinity meter, burette 50ml, conical flask (three of 250ml each), spectrophotometer (UV/VIS), atomic absorption Spectrophotometer (AAS). The materials for the experiment were all washed and rinsed with water [7].

The distillation process was by using 750ml of seawater and placing in the 1 liter distillation flask fixed with an all glass condenser with chilled water passing through from an elevated 20liter bulked fixed with a tap. The distiller and the whole set-up were placed on 1 liter capacity heating mantle and the heaters were switched on. At the end of the distillation process, the seawater remaining in the distillation flask was about 150ml.The distillate was collected for potability analysis. The analyzed results are as shown in table 3 for Koluama sample and table 4 for Nembe sample test results respectively.

Spectrophotometer (UV/VIS) was used to determine the concentration of the dissolved and suspended particles in the water and reading was made with the help of a galvanometer attached. AAS was used to measure the number of elements present in the water. Thereafter, solochrome Black T was used as an indicator to test the presence of rare earth metals and the purity of the water. Ammonia/ ammonium Chloride was used to weaken the sodium chloride bond and subsequently, breaking the bond holding the salt together from the two heavy solids Na_2CO_3 and NH_4CL. 0.02ml of H_2SO_4 was applied as an inhibitor to scale formation on the surface of the equipment used for the distillation process. Potassium Chromate was used to identify the concentration of chlorine ions in the seawater solution in accordance with [8]. Barium Chloride was used to reduce the pH of the water. The water was treated with Silver Nitrate ($AgNO_3$) as a disinfectant as was the case with [9].

Thereafter, to ensure that the distilled water could have a wide range of applications, Langelier Saturation Index was applied to convert the results of the tests to factor values.

Table 1: Results of Analysis Koluama Seawater Sample before Distillation.

S/N	Particles	Amount (Mg/L)
1	pH	6.50
2	Salinity	10.07
3	Conductivity	37,500
4	Total Dissolved solid	18,750
5	Turbidity	20
6	Total suspended solid	13.87
7	Nitrate	38.75
8	Chlorine	7140.0
9	Sulfate	245.0
10	Bicarbonate (HCO_3)	10.80
11	Alkalinity (TA)	100.0
12	Total Hardiness	3400
13	Calcium	38.30
14	Sodium	2940
15	Potassium	240.0
16	Iron	3.561
17	Magnesium	0.780

Table 2: Results of Analysis Nembe Seawater Sample before Distillation.

S/N	Particles	Amount (Mg/L)
1	pH	6.45
2	Salinity	10.00
3	Conductivity	37600
4	Total dissolved solid	18,600
5	Turbidity	19
6	Total suspended solid	13.80
7	Nitrate, (No_3)	38.70
8	Chlorine	7130.0
9	Sulfate	244.0
10	Bicarbonate (HCO_3)	10.70
11	Alkalinity	100.00
12	Total Hardness	34.00
13	Calcium	3820
14	Sodium	2930
15	Potassium	2390.0
16	Iron	3.55
17	Magnesium	0.760

Heat Content Calculation

$$Q = mc_p\Delta T \qquad 1$$

Where:

Q = Specific Heat of Vaporization

$$m = Mass\ of\ Water\ (Volume, v \times Density, \rho$$

c_p = *Specific Heat Constant(4.186kJ/kg°C)*

ΔT = Change in Temperature

$V = 750ml\ and\ \rho = 1.025g/m^3$

$$m = \frac{750 \times 1.025}{1000} = 0.769kg$$

$$Where\ t_2 = final\ temperature$$

$$t_1 = initial\ temperature$$

$$\Delta T = (t_2 - t_1)$$

$$t_2 = 100°C\ and\ t_1 = 26°C (measured)$$

$$Q_D = Distillation\ process\ in\ Laboratory$$

$$Q_D = m_c\Delta T \qquad 2$$

$$= 0.769 \times 74 \left(\frac{kg \times kj}{kg}\right) \times °C$$

Therefore, the heat required to convert 750ml of sea water to vapor is:

$$Q_D = 238.2kj$$

Langelier Saturation Index (LSI)is given as:

$$SI = pH + TF + CF + AF - 12.1 \qquad 3$$

Where:

$TF = Temperature\ factor$

$CF = Calcium\ Hardness\ factor$

$AF = Alkalinity\ factor$

12.1 = A constant.

If LSI index is 0, then the water is balanced

LSI, negative water is corrosive and

LSI positive (greater than 0), water is scaling.

Fig. 1: Set up of the Experiment for the Distillation Process

3. RESULTS AND ANALYSIS

The distillate obtained from the experiment will now be used as a basis for comparison with other freshwater (potable) samples that are recommended by World Health Organization (WHO) to ascertain the effectiveness the process. The technique could be employed for the production of potable water for the use onboard ship for various domestic purposes. Tables 3 and 4 show the analyzed results of the seawater samples from Koluama and Nembe respectively.

Table 3: Results Analysis of Koluama Seawater Sample after Distillation.

S/N	Particles	Amount (Mg/l)
1	pH	7.08
2	Salinity	0.02
3	Conductivity	28.70
4	Total dissolved solid	14.40
5	Turbidity	0.00
6	Total suspended solid	0.00
7	Nitrate (NO_3)	0.010
8	Chlorine	15.0
9	Sulfate (SO_4)	0.42
10	Bicarbonate	0.40
11	Alkalinity	0.50
12	Total Hardness	7.50
13	Calcium	7.50
14	Sodium	
15	Potassium	1.40
16	Iron	0.02
17	Magnesium	0.00

Table 4: Results Analysis of Nembe Seawater Sample after Distillation.

S/N	Particles	Amount (Mg/l)
1	pH	7.06
2	Salinity	0.01
3	Conductivity	27.90
4	Total dissolved solid	14.30
5	Turbidity	0.00
6	Total suspended solid	0.00
7	Nitrate	0.010
8	Chlorine	15.0
9	Sulfate	0.43
10	Bicarbonate	0.41
11	Alkalinity	0.50
12	Total Hardness	7.50
13	Calcium	7.50
14	Sodium	4.83
15	Potassium	1.40
16	Iron	0.02
17	Magnesium	0.00

Data of potable water sample were obtained from three bottling company located in Abeokuta [10]. They were tabulated as shown in table 5 which was used as a basis for comparison with the analyzed results of Koluama and Nembe. From table 5, you will see that the composition of the distillate from Koluama and Nembe are almost the same with the water sample obtained from Abeokuta that were of WHO approved standard [11].

Table 5: Data of potable water sample of three bottling companies located in Abeokuta [10].

S/N	PARAMETERS	SAMPLE A	SAMPLE B	SAMPLE C	KOLUAMA SAMPLE	NEMBE SAMPLE	WHO RECOMMENDATION (Mg/l)
1	pH	7.17	7.23	6.94	7.08	7.06	6.5-8.5
2	Turbidity	2.0	0.33	1.33	0.00	0.00	5
3	Total Dissolved Solid	148.43	85.63	16.23	14.40	14.30	500
4	Total Suspended Solid	0.00	0.66	2.66	0.00	0.00	-
5	Alkalinity	140.86	49.33	10.0	0.50	0.50	500
6	Calcium	78.66	23.33	3.33	7.50	7.50	250
7	Magnesium	28.667	9.33	4.0	2.40	2.40	-
8	Chlorine	22.68	26.33	26.33	15.0	15.0	250
9	Sulfate	11.33	12.66	1.0	0.42	0.43	50
10	Nitrate (NO_3)	0.86	1.5	0.53	0.010	0.010	10
11	Iron (Fe)	0.01	0.03	0.02	0.02	0.02	0.3

Table 6: Numerical Values of the LSI used when converting the Test Results to Factor or value [12].

Temp.(°C)	TF	Calcium (Hardness)	CF	Total Alkalinity	AF
0	0.0	5	0.3	5	0.7
3	0.1	25	1.0	25	1.4
8	0.2	50	1.3	50	1.7
12	0.3	75	1.5	75	1.9
16	0.4	100	1.6	100	2.0
19	0.5	150	1.8	150	2.2
24	0.6	200	1.9	200	2.3
29	0.7	300	2.1	300	2.5
34	0.8	400	2.2	400	2.6
40	0.9	800	2.5	800	2.9
53	1.0	1000	2.6	1000	3.0

The pH value which is a measure of the hydrogen ion concentration of the water is in the range of 6.5-8.5 for potable water. Also, sample A is about 7.17 and that of sample B and C are 7.23 and 6.94 respectively. This shows that the distillation results from Koluama and Nembe with pH values of 7.08 and 7.06 respectively fall within the standard recommended by WHO as shown in fig 2.

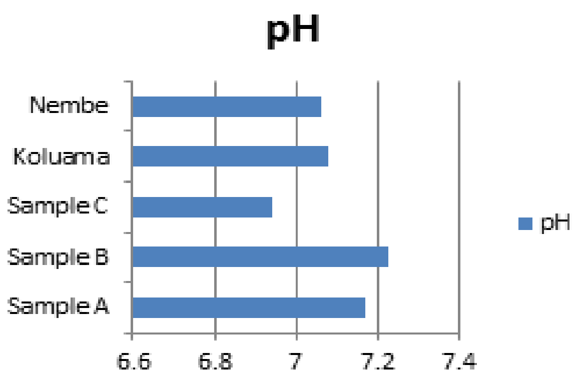

Fig 2: Bar Chart showing the PH value of the various samples.

The turbidity which is a measure of the degree of clarity of the water due to the suspended particle or materials that decrease light passage through the water [13] causes aesthetic impacts on the water. From fig 3, the samples A, B and C which have turbidity values of 2.0, 0.33 and 1.33 respectively and 0.00 turbidity for both distillates at Koluama and Nembe show that the distillates are of standard.

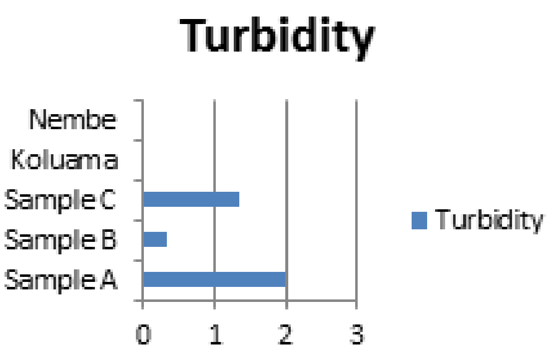

Fig 3: Bar Chart showing the Turbidity of the various samples.

When comparing the total dissolved solids of Koluama and Nambe with samples from A, B and C as shown in fig 4, that the distillates from Koluama and Nembe are of standard and therefore, consumable.

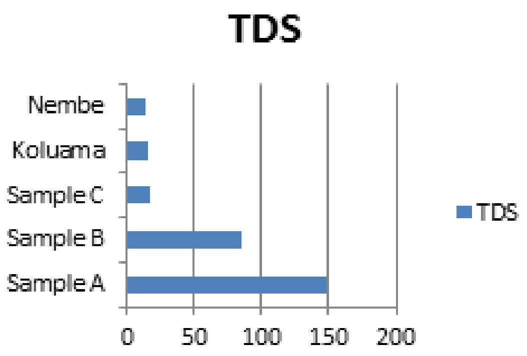

Fig 4: Bar Chart showing the TDS of the various samples.

The total suspended solids in sample A and that of Koluama and Nembe are zero, but that of sample B and C are about 0.066 and 2.66 respectively. The standard by the WHO is zero which also shows that the distillation process is good as shown in fig 5

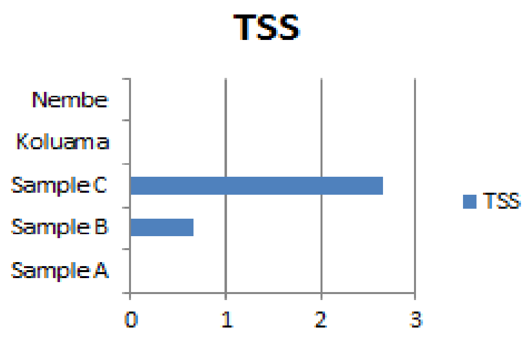

Fig 5: Bar Chart showing the Total Suspended Solid of the various sample.

The Alkalinity of the water which is the quantization capacity of an aqueous solution to neutralize an acid [9] indicates the presence of $CaCO_3$. Fig 6 illustrates that the alkalinity of sample A is very large when compare to the rest of the water samples. $CaCO_3$ contents depend on the source of the water and its distillation method. This again shows that Koluama and Nembe samples after the distillation process meet WHO standard of 500mg/l of Alkalinity.

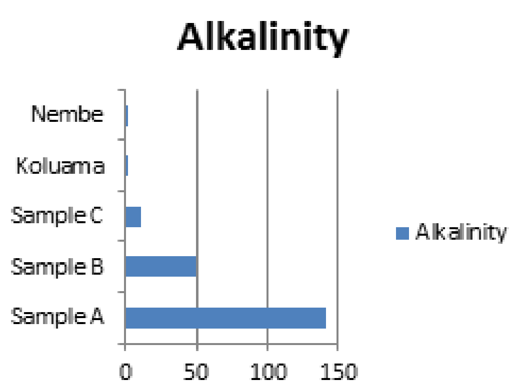

Fig 6: Bar Chart showing the alkalinity of the various samples.

The calcium content which is an indication of the water hardness as a result of the presence of $CaCO_3$ can be seen as sample A is higher than the rest of the water samples. Koluama and Nembe samples are having same calcium content after distillation process and do not exceed the WHO limits of calcium content required in water sample as in fig 7.

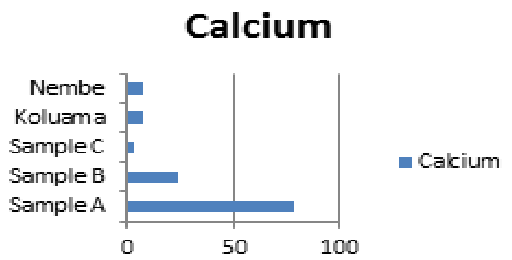

Fig 7: Bar Chart showing the Calcium Content of the various samples.

Magnesium is also more in sample A and B with sample A still in the high side but within WHO limits of magnesium content in potable water. Koluama and Nembe samples have the same magnesium content of about 2.4mg/l which is the lowest in all the samples as shown in fig.8.

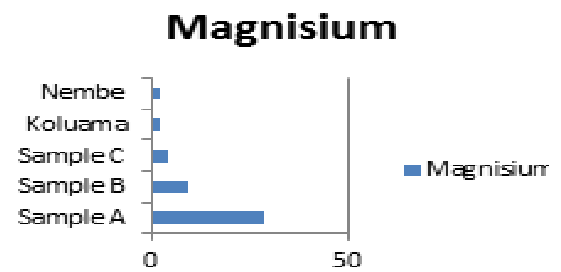

Fig 8: Bar Chart showing the Magnesium of the various sample.

Chlorine content in sample B is higher than the rest of the samples perhaps, higher than sample A with about 4.0mg/l. Fig 9 shows that at the end of the distillation, Koluama and Nembe, and sample C maintain almost the same level of chlorine.

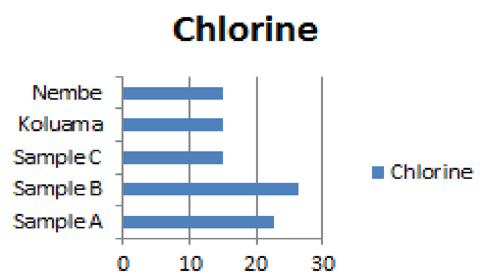

Fig 9: Bar Chart Showing the Chlorine of the various samples.

Fig 10 shows that the sulfate content in the water in Koluama and Nembe are almost the same and the lowest. While that of sample B is higher than the rest of the samples of about 12.66mg/l.

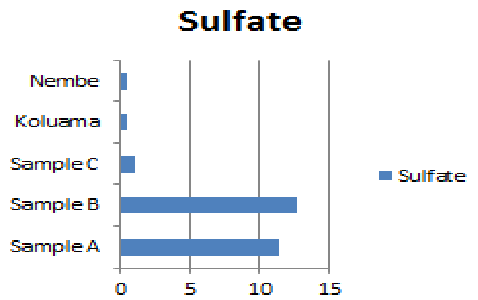

Fig. 10: Bar Chart showing the Sulfate of the various sample.

The Nitrate in the samples are very low when compare to WHO standard of content limit for potable water of 10mg/l, with sample A,B,C Koluama and Nembe samples content of about 0.86, 1.5, 0.53, 0.01 and 0.01mg/l of nitrate content as shown in fig. 11. But sample B is higher than the other samples.

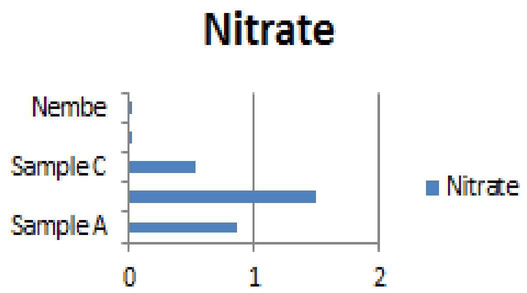

Fig 11: Bar Chart showing the Nitrate of the various sample.

Iron content for all the samples in fig.12 are low and acceptable by WHO standard of iron content in drinkable water with sample B at the same limit required by WHO of about 0.03mg/l.

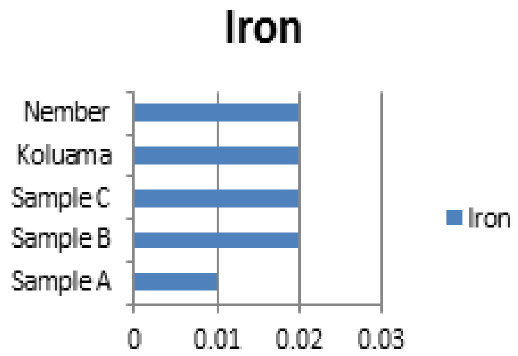

Fig 12: Bar Chart showing the Iron content of the various sample.

LANGELIER SATURATION INDEX APPLICATION

In juxtaposing tables 5 and 6 while at the same time applying LSI, the water samples from Koluama and Nembe gave negative LSI values. This implies they are corrosive. The inference from this is, over a long period of time this water would tend to cause pitting of metal and concrete surfaces. Again, from tables 5 and 6, the factors that are conspicuously low are: Alkalinity and pH. These components could be raised either by the addition of Soda Ash or Sodium Bicarbonate.

4. CONCLUSION

Fresh water is of utmost importance in our daily life both onshore and for the smooth running of a vessel because it is used for various purposes. It became therefore necessary to study ways of obtaining fresh water from the only available seawater. Samples of seawater obtained from two sources were subjected to experimentation.

The seawater gotten from Nembe and Koluama both in the Niger Delta Region in Nigeria, can be of immense benefits by distilling it and then adding either soda ash or sodium bicarbonate. With these, any other saline water could be made to comply with WHO recommendations in terms of removal of dissolved solids and consequently, for consumption both domestic and other uses onboard ships.

5. RECOMMENDATIONS

The recommendations are as follows:

(a) Effective distillation process for desalting seawater should be promulgated to take care of boiler corrosion.

(b) The state of water for cooling or boiling application should always be confirmed by the application of Langelier Saturation Index.

Acknowledgement: I must heartily thank Mr Theophilus, Wisdom for is unrelenting effort in seeing to the completion of this work.

REFERENCES

[1] Matino, I., Alcamisi, E., Filippo, G. and Porzio, V. C. (2014), Evaluation and Monitoring of Physico-chemical Properties of Water Streams through Unconventional Techniques. Retrieved 24 February, 2016 from the World Wide Web: http://ijssst.info/Vol-16/No-1/data/7412a281.pdf.

[2] Buros, O. K. (2012), The ABCs of Desalting. International Desalination Association. Topsfield, Massachusetts, USA.

[3] Kalogirou, S. A. (2011), Concentrating solar power plants for electricity and desalinated water production. World Renewable Energy Concress, Linkoping, Sweden.

[4] Arthur, J. D., Langhus, B. G. and Patel, C. (2005), Technical Summary of Oil & Gas Produced Water Treatment Technologies. Retrieved 12 February, 2016 from the World Wide Web: http://www.all-llc.com/publicdownloads/ALLConsulting-WaterTreatmentOptionsReport.pdf.

[5] Wood, W.J.B. (1969), Fresh Water Supply aboard Ocean-Going Marchant Ship; The Economic Merit of Distillation from Sea, SNAME, Michigam.

[6] Nicolae, D. and Stefan D. (2014), Performant Installation for Purification and Desalination of sea-water for ship. Scientic Journal of Mechanical testing and Diagnosis (ISSN 2247-9635).

[7] Ogbonnaya, E. A. (1998), Condition Monitoring of A Diesel Engine for Electricity Generation, M. Tech. Thesis, Rivers State University of Science and Technology, Port Harcourt, Nigeria, pp. 21-26 and 67 – 72.

[8]Everlt, H.D. (1952), The Utilization of Seawater. UNESCO, Paris. Retrieved 30 June, 2015, from the World Wide Web: Unledoc.unesco.org/report on the utilization seawater 148532eb. Pdf.

[9] Opio, C. (2012), Building Effective Drinking Water Management Policies in Rural Africa: Lessons from Northern Uganda. Retrieved 24 February, 2016 from the World Wide Web: https://www.cigionline.org/sites/default/files/no6.pdf.

[10] Taiwo, A. M., Gbadebo, M. A, and Awomeso, J. A. (2010), Portability assessment of selected brands of Bottled Water in Abeokuta, Nigeria. JASEM.

[11] Ak, A., Garzon, P, Eisenberg, M. J.(2001), Comparism of the mineral content of tap water and bottled waters. Journal of general internal medicine.

[12] Joshi, M. J. (2009). Swimming Pool & Spa Construction & Maintenance. Retrieved 11 February, 2016 from the World Wide Web: http://en.allexperts.com/q/Swimming-Pool-Spa-2261/2009/11/White-fluffy-threads-tile.htm.

[13] Lenntech (2010). “Water Conductivity.” Retrieved 24 February, 2016 from the World Wide Web:lenntech.com/applications/ ultrapure/conductivity/water-conductivity.htm