ELECTROLYTE SOLUTIONS: POTABLE WATER SOLVENT UTILIZING CONDUCTIVITY AND CONCENTRATION PARAMETERS

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Abstract

The conductivity measurements of potable water samples was carried out at 25^0C using KCl,$CaCl_2$,$NaNO_3$,$Ca(NO_3)_2$,NaCl and NaOH as electrolytes at various concentrations of 0.01M,0.02M and 0.05M respectively. The potable water under review include: Kastra table water, Eva table water, Divine table water, Obor tap water and Obrikom river water. Purity of the water samples was observed as a measure of the conductivity values of the electrolytes dispersed in the various water samples. However, some conductivity results of the water samples were consistent with the literature. In course of the study, the researchers observed that increase in concentration of electrolytes is not a direct correlation with some results obtained due to certain factors such as ionic interaction, formation of ion pair and ionic gap between cation and anion and the observation was also in line with the literature. Conclusively, the study made a wonderful revelation in the case of Kastra table water with the least conductivity value of $1545\mu s$ on the average beaten Eva table water to the second position, which ordinarily one would have thought that Eva table water ought to have been the puriest of all the water samples. The researchers recommended the conductivity measurements of waters used in pharmaceutical industries, agricultural outfits and beverage companies since conductivity measurement has proved to be a fast inexpensive way of measuring water purity worldwide.

Conductivity of electrolytesolutions is a measure of how well a solution conducts electricity. To carry out a current, a solution must contain charged particles, or ion. Most conductivity measurements are made in aqueous solutions, and the ions responsible for the conductivity come from electrolytes dissolved in the water. Salts, acids and bases are all electrolytes. Although water itself is not an electrolyte, it does have a very small conductivity, implying that at least some ions are present. These ions are hydrogen and hydroxide and they originate from the dissociation of molecular water.

$$H_2 + O \rightleftharpoons H + OH$$

However, there are strong and weak electrolytes. Conductivity applications encompass for instance, monitoring of water purity, drinking water, and process water quality. It is also a rapid and inexpensive way of determining the ionic strength of a solution. The conductivity partly depends on the pH, temperature and atmospheric carbon dioxide, which has been dissolved in the water to form ions(intrinsic conductivity).The conductivity also depends on the chloride, sodium and ammonium ions considered as water impurities(extraneous conductivity).The conductivity (intrinsic and extraneous) of the water is measured and compared to the value listed in the table to evaluate if the studied water is suitable or not for use in pharmaceutical, agricultural, demineralisers and effluent control applications.

Applications of Conductivity

Conductivity is extensively used in the measurement of water supplies for municipal, commercial, hospital and industrial uses. Whilst individual ions cannot be differentiated, this is usually not needed and conductivity gives a measure of the total impurities present in a water sample.

Table 1.1: Certified Conductivity Standard Solutions

TYPE	VALUE	QTY	PART NUMBER
KCl ID	111.3 μs/cm ± 0.5 @ 25ºC	500ml	S51M001
KCl 0.1D	12.85 μs/cm ± 0.35 @ 25ºC	500ml	S51M002
KCl 0.01D	1408μs/cm ± 0.5 @ 25ºC	500ml	S51M003
KCl 0.05%	1015 μs/cm ± 0.5 @ 25ºC	500ml	S51M004
KCl 26.6	26.6 μs/cm ± 2.5 @ 20ºC	500ml	S51M0012

Tolerance specified taking into account uncertainty with k = 2
NIST = National Institute of Standard and Technology
OIML = International organization of Legal Metrology.
Industries using conductivity

Agriculture,	Air conditioning
Brewing	Beverage
Chemical	Electroplating
Food processing	Hospital
Iron steel	Marine
Mining	Paper
Petroleum	Semi-conductor

Conductivity Applications

Aquaculture	Boiler Blowdown
Cooling towers	Condensate Return
Demineralisers	Desalination
Effluent control	Fruit peeling
Laboratory Analysis	Level detection
Oceanography	Reverse osmosis
Rinse tanks	Waste streams

Measurement Techniques

Contacting Conductivity

Contacting conductivity uses a cell with two metal or graphite electrodes in contact with the electrolyte solution. An AC current is applied to the electrodes by the conductivity meter. This technique can measure down to pure water conductivity. Its main drawback is that the cell is susceptible to coating and corrosion, which drastically decreases the reading. In strongly conductive solutions there can also be polarization effects, which result in non-linearity of measurements.

Toroidal "Inductive" Conductivity

A toroidal conductivity measurement is made by passing AC current through a toroidal drive coil, which induces a current in the electrolyte solution. This induced solution current in turn induces a current in a second toroidal coil called the pick-up toroid. The amount of current induced in the pick-up toroid is proportional to the solution conductivity.

The main advantage of toroidal conductivity is that the toroidal coils are not in contact with the solution. They are either encased in a polymeric material or are external to a flow through cell. One of the main disadvantages of toroidal conductivity measurement is that it lacks the sensitivity of contacting measurement. Toroidalsensors are also typically larger than contacting sensors.

Cell Constant or Cell Factor

A very simple conductivity sensor can be constructed as a cell consisting of a cube 1cm on a side, where the electrodes form the two opposite ends having an area of 1cm and distance between as 1cm. This cell has a constant of 1.0 which can be calculated for other cells from the formula:-

Resistivity cell constant = distance between electrodes divided by the electrode area. For very dilute solutions the electrodes can be placed closer so that the distance is reduced and cell constants of 0.1 and 0.01 result. This has the effect of raising the conductance as read by the electrodes and produce a value more easily handled by the electronic circuitry. For more conductive solutions the distance between the electrodes is increased so that cell factors of 10 or more result.

Conductivity Standard Solutions

The standards against which conductivity is measured are solutions of potassium chloride (KCl) which are measured to very high accuracy per ASTM standard D1125-77

Approximate Normally	$\frac{\mu s}{cm@250C}$
0.001	146.93
0.01	1408.8
	12,856
1.0	111,342

A precisely weighted amount of thoroughly dry KCl is specified to be dissolved in an exact volume in a volumetric flask. The normalities of the resulting solution are close to, but not the same as the values shown due to traces of conductivity in the distilled water used e.g. 0.01NKCl is normally taken as 1413$\mu s/cm@25°C$.

Experimental

Apparatus Used

The apparatus used for this study includes, conductivity meter, water bath, thermometer.

Reagents

The reagents used include;
Calcium Chloride ($CaCl_2$), Potassium Chloride (KCl), Sodium Chloride (NaCl), Calcium Nitrate $Ca(NO_3)_2$, Sodium Nitrate ($NaNO_3$), and Sodium hydroxide (NaOH).

Procedure

Five electrolyte solutions were prepared usingfive weighed different reagents and five samples of water from different sources in the concentration of 0.01M the conductivities/TDS of these solutions were tested using conductivity meter. The electrolytes used include KCl, $CaCl_2$, NaCl, $NaNO_3$, $Ca(NO_3)_2$ and NaOH. The process was repeated for two other concentrations of 0.02M and 0.05M using the same electrolytes and the readings were accurately taken.

Preparation of 100ml Electrolyte Solution

Five reagents were separately weighed out in an electronic weighing balance into a 250ml beaker, dissolved with a little amount of the water samples refrigerated to bring the temperature to about 25^0C, then more of the water was added to the beaker.
These preparations were done for four other water samples used in this experiment, with the same reagents earlier used.

Results and Discussion

Table 1.1: Conductivity Values of the Various Water Sources (µS) at 0.01M Concentration of the Electrolytes

Electrolyte	Divine Water	Kastra Water	Eva Water	Obor tap Water	Obrikom River Water
KCl	1463	1380	1533	1406	1653
$CaCl_2$	1626	1801	1790	1676	1794
NaCl	1117	1193	1394	1178	2590
$NaNO_3$	1468	1078	1324	1204	1181
$Ca(NO_3)_2$	2270	2200	2230	2130	2160
NaOH	2670	1608	3200	2900	2800
Average Conductivity	1769	1543	1912	1749	2030

The results obtained from the three stage study, using different concentrations of electrolytes to measure their respective conductivities revealed that at 0.01M concentration of the electrolytes, the conductivity ranges of the solutions were (1117 - 2670µS) for divine table water, (1078-2200 µS) for Kastra table water; (1324-3200 µS) for Eva water; (1178-2900 µS) for Obor Tap water and (1181-2800 µS) for Obrikom River water. The results showed that at0.01M solution of the electrolytes, Obrikom river water has the highest conductivity value on the average, while Kastra table water showed the lowest conductivity range.The conductivity of the various water samples revealed that Kastra table water has the least amount of impurity, which implies less amount of total dissolved solids (TDS)/ ions present in the water samples.

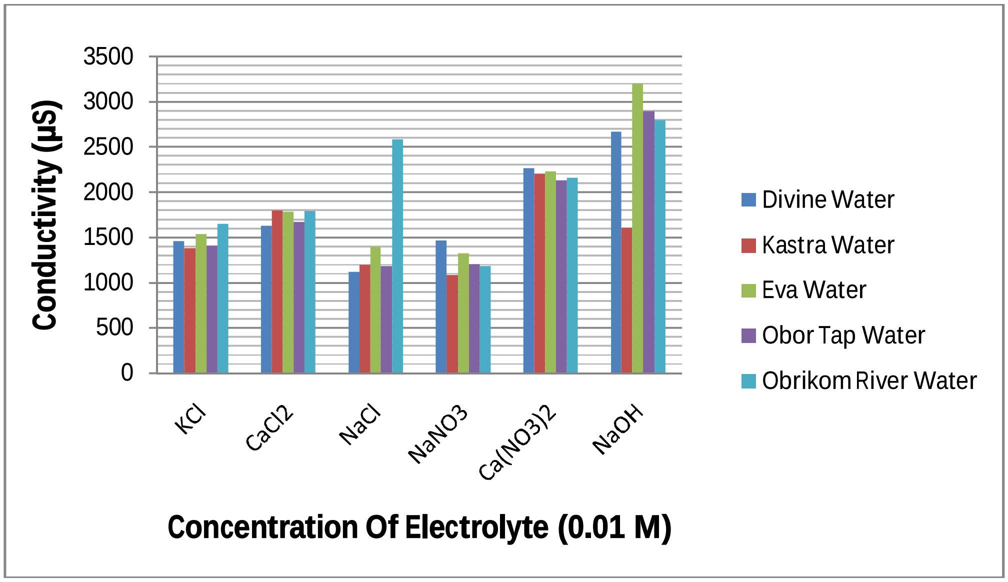

Figure 1.1: The conductivities of the various electrolytes at 0.01M

Table 1.2: Conductivity Values of the Various Water Sources (µS) at 0.02M Concentration of the Electrolytes

Electrolyte	Divine Water	Kastra water	Eva Water	Obor tap Water	Obrikom River Water
KCl	2760	3780	2940	2750	2770
CaCl	3300	3260	3180	3150	3200
NaCl	2470	2600	2550	2200	2560
$NaNO_3$	2220	2220	2260	2190	2160
$Ca(NO_3)_2$	3020	3940	4060	3870	3900
NaOH	3060	3090	3060	3120	3580
Average Conductivity	2805	3148	2631	2880	3028

It was observed that Conductivities of $NaNO_3$ and Ca $(NO_3)_2$ electrolytes prepared using Eva water were also higher when measured compared to other water sample sources. Electrolytic solutions prepared using Divine table water also showed appreciable conductivity values. However, Eva table water has the least conductivity value on the average.

The variations are further illustrated in figure (1.2).

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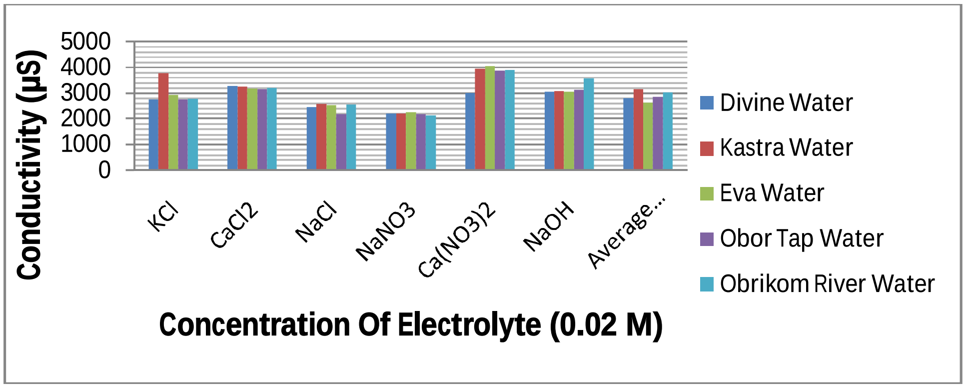

Figure 1.2: The conductivities of the various electrolytes at 0.02M

At 0.05M concentration of the electrolytic solutions prepared using different water samples, the conductivity ranges of ((5270-9190 µS); (5170-9460 µS); (5350-9360 µS); (5320-1202 µS) and (4970-9280 µS) were observed for Divine table, kastra table water, Eva water, Obor tap water and Obrikom river water respectively.

From the result, Obor tap water showed the highest range of conductivity values, while Obrikom river water had the lowest conductivity ranges. This stems from the fact Obrikom river water would have been saturated with impurities such that increase in concentration does not have much effect on the conductivity value.

Table 1.3: Conductivity Values of the Various Water Sources (µS) at 0.05M Concentration of the Electrolytes

Electrolyte	Divine Water	Kastra	Eva Water	Obor	Obrikom
KCl	6540	6920	6610	6440	6390
CaCl	8140	7610	7420	7710	7980
NaCl	5520	6240	5350	5320	5470
$NaNO_3$	5270	5170	5250	5450	4970
$Ca(NO_3)_2$	9190	8920	8820	9140	9280
NaOH	8420	9460	9360	12020	8340
Average Conductivity	7180	7387	7135	7680	7071

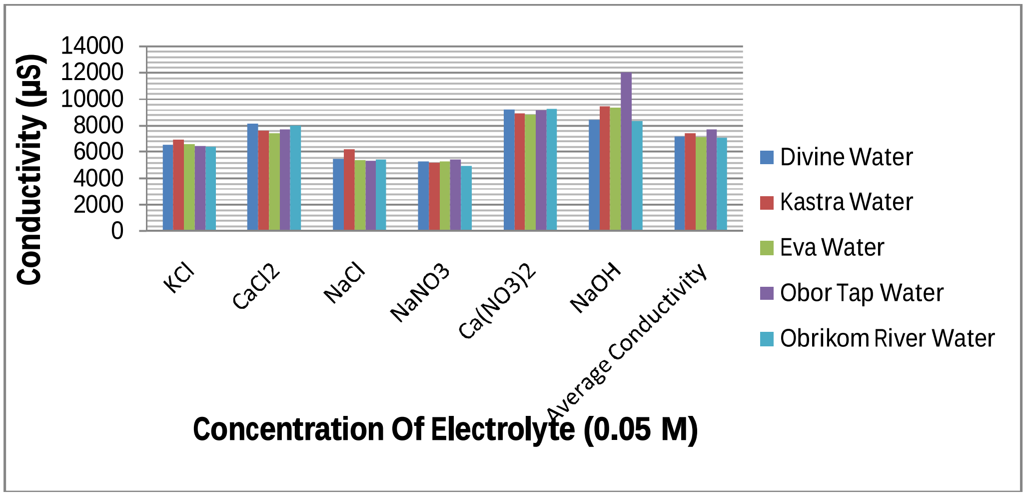

Figure 1.3: The conductivities of the various electrolytes at 0.05M

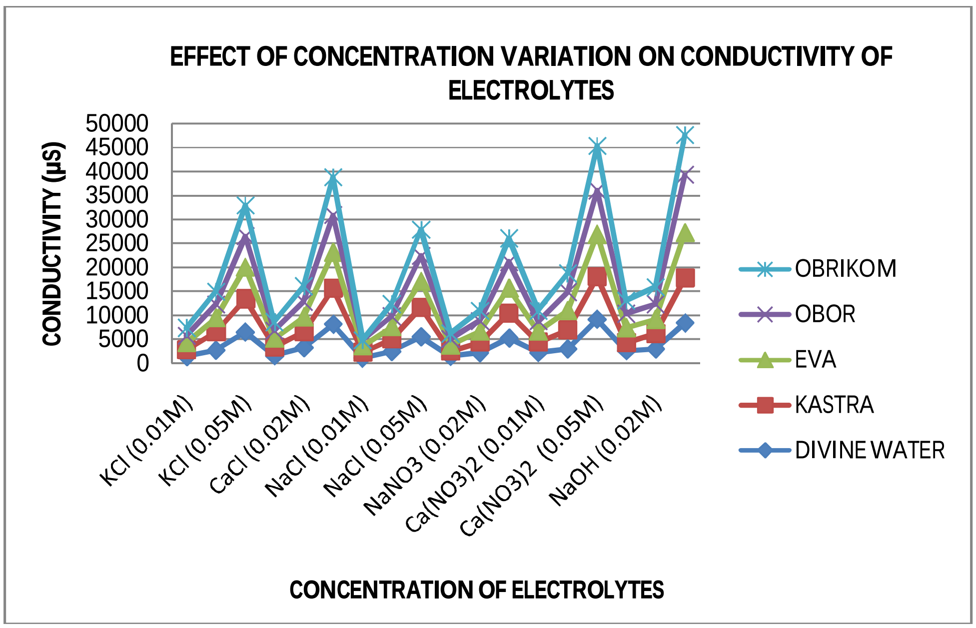

Figure 1.4: Effect of Concentration Variation on Conductivity of Electrolytes

Conclusion and Recommendation

A comparison of the individual conductivities of the water samples at different concentrations of the electrolytes (figure 1.4) showed a marked variation in the conductivity values measured. It is obvious from the result above (fig.1.4) that increasing the concentration of the electrolytes had a corresponding increase in the conductivity values. This result agrees with the fact that, at increased concentration, there are more free ions present in the electrolyte and electrical conductivity is increased.

The conductivity values of the electrolytes prepared using the various water samples are shown in table 1.2. From the result, it was observed that at 0.02M concentration of the electrolyte solutions, the conductivity ranges of (2220-3300 µS); (2220-3940 µS); (2260-4060 µS); (2200-3870 µS)and (1390-2340 µS) were observed for Divine table water, Kastra table water, Eva water, Obor tap water and Obrikom river water respectively. Electrolytes of KCl and NaCl prepared using Kastra table water had the highest conductivity values.

From the foregoings, it was recommended that pharmaceutical industries, agricultural industries, beverage companies, municipal water providers should as a matter of fact check the conductivities of their water sources after filtration to ensure that standards and quality are maintained.

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