

Laboratory Experiment of the Evaporation Level of Surface Water Salinity

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ABSTRACT: Evaporation causes a very significant mass loss in any kind of surface water body and is significant for attempts at resource recovery (Uche and Amgbara, 2020). Evaporation from surface water depends on the water body's salinity. This investigation is on direct measurement at the scale of natural water body collected from a free surface water body in Afikpo Ebonyi State. Five different salts such as NaCl, NaOH, MgSO₄, NH₄Cl, and KNO₃ were selected based on the fact that saline water bodies contain these salt compounds. These salts applied to the 500g of water varied as follows 0g, 15g, 25g, 35, 45g, and 55g. These samples after mixing were kept at room temperature in the water laboratory of Akanulbiam Federal Polytechnic Unwana and evaporation allowed to take place within 24 hours interval for 15 days. The results show that the higher the concentration of salt in the water samples the less evaporation occurred. Ammonium Chloride (NH₄Cl) has the highest rate of evaporation followed by Potassium Nitrate (KNO₃), Magnesium Sulphate (MgSO₄), Sodium Hydroxide (NaOH) and Sodium Chloride (NaCl) has the least rate of evaporation.

Keywords: Salinity, surface water, evaporation, salts

I. INTRODUCTION

Evaporation from a free surface water body occur when water from liquid or solid state passes into the vapour state and diffuse into the atmosphere. Evaporation from open water bodies depends on many factors which include water temperature, air temperature, air humidity and air velocity above the water surface. The effect of surface water salinity on evaporation increases the complication of the challenge of quantifying evaporation (Salhotra et al., 1987). It has been difficult to ascertain the rate of evaporation of a saline water by direct measurement at the scale of

natural water bodies Mor et., al (1995). Salinity can cause unfavourable environment and hydrological situation that restrict the production of crops. Certain factors contribute immensely to the development of saline water upon evaporation on a free surface water. Salinity desiccates the soil as air pores in the soil act like a sponge and the salt water is drawn up to the surface of soil as a result of capillary rise buildings, roads and other structures can be damaged. Salinity is one of the serious environmental problems that cause osmotic stress and reduction in plant growth and crop production as when enough salt accumulate in the root zone. It also affects soil physical properties by causing fine particles to bind together into coarse aggregates. The factors contributing significantly to the development of saline soil are tidal flooding during raining seasons (June – October). When there is water logging within two meters of the surface, there is high concentration of salt compounds within the surrounding environments causing damages to building, roads and other structures. Soil pH values (pH) in coastal regions range from 6.0 – 8.4, the organic matter content of the soil is also pretty low 1.0 – 1.5 %. The mechanism that induces salinity can work very quickly to affect vegetation in drainage lines and on sporting ovals and to damage buildings, roads and pipe systems. Salinity shortens the life of infrastructures and increase building cost due to the need for protective works and use of the higher specification materials. There are different types of salinity such as dryland salinity, irrigation salinity, urban salinity, river salinity and industrial salinity.

II. SALINITY

- **DRYLAND SALINITY.** Dryland salinity occurs when removal or loss of native vegetation and its replacement with crops and pastures that has shallower roots and different

water use requirements result in more water reaching the groundwater system. The groundwater rises to near the ground surface in low-lying areas or on the break of slope called discharge. Groundwater can also flow underground directly into streams. The groundwater carries dissolved salts from the underlying soil and bedrock materials through which it travels. As saline groundwater comes close within two meters to the soil surface, salt enters the plant root zone. Even where groundwater does not bring much salt with it, the water-logging to the root zone alone can damage or kill vegetation. The impact of water-logging and salinization will vary depending on soil type, climate and land use.

- **IRRIGATION SALINITY.** The main reason for this type of salinity is the application of large volumes of irrigation water, equivalent to as much as four times the average naturally occurring rainfall, compounded by the replacement of native vegetation by plants with different water use patterns.
- **URBAN SALINITY.** Urban salinity is a combination of dryland and irrigation salinity. It is caused both by rising water tables due to clearing, and by the application of additional quantities of water from watering garden and parks; leaking water, sewage and drainage pipes; and obstruction or modification of natural surface and sub-surface drainage paths.
- **RIVER SALINITY.** River salinity is caused by saline discharges from dryland, irrigation and urban salinity into creeks and rivers. Overtime, as salinity within catchments worsens, the quality of river water declines, becoming more saline.
- **INDUSTRIAL SALINITY.** Industries, towns, intensive agriculture, coal mines effluents influence salinity.

III. IMPACTS OF SALINITY

Increasing river salinity levels will put pressure on the provision of municipal water supplies and increases treatment and infrastructure costs. Where the water for municipal supplies is 'hard' (the salinity being made up of high levels of calcium and magnesium), water may require extensive and expensive treatment before it is suitable for consumption. Hard water can result in damage to hot water system and household appliances, and increase use of soap, detergents and water conditioners. The implications of river salinity are also costly for agricultures. The yields of some particular sensitive plants such as rice and horticultural crops, are affected by saline water at

levels as low as 700EC (Electrical Conductivity). The impact of river salinity is more costly on high value enterprises such as irrigated crops and horticultural crops. Dryland salinity can lead to lower agricultural production, lower profitability due to costs of mitigation, reduced yield, changed land use, and in extreme case to the total removal of land from agricultural production. Recreational and tourism opportunities may also be reduced, and cultural heritage including aboriginal cultural heritage may be damaged.

❖ Effect of Salinity on Evaporation

Salinity is the saltiness or dissolved salt content of water in soil such as sodium chloride, magnesium, and calcium sulfates, and bicarbonates of a water body. In oceanography it has been traditional to express salinity not as percent but as per million (parts per thousand) which is approximately grams of salt per kilogram of solution. Salinity is the sum weight of many different elements within a given volume of water (DeCosmo et al., 1996). The factors significantly contributing to the development of saline soil are tidal flooding during wet seasons (June – October) direct inundation by saline water, and upward or lateral movement of saline ground water during dry season (November – March) the severity of salinity problems increase with the desiccation of the soil. It affects crops depending on degree of salinity at the graphical stages of growth, which reduces yield and in severe case cause total yield lost.

❖ Factors Affecting Evaporation

There are many factors affecting the rate of evaporation from a free surface water. These include:

- **Climate Effects**

For evaporation to take place, energy is required to change the water from a liquid form to a vapour form. The air above the evaporation pond becomes saturated with water vapour and this moist air must be removed in order to allow the process to affect the rate of evaporation.

- **Temperature**

Heating the water molecules to the required temperature for vaporization will change the water from liquid form to vapour form. The higher the temperature, the higher the rate of evaporation. When the temperature of the water increases, it makes the water molecules to gain energy, move faster and escape at a faster rate.

- **Evaporation Rate**

The rate at which water evaporates depends on the temperature of the liquid as how compact the molecules bonds to each other, the surface area of the liquid and the temperature, pressure, and air movements in the surrounding

into which evaporation occurs. The warmer the liquid, the faster the evaporation rate. The stronger the molecules bond to each other the slower the evaporation rate.

- **Properties of the Liquid being evaporated**

Dissolved salts in the water result in a lower saturation vapour pressure due to the decreased chemical potential of the water and thus, lower the evaporation rate. The second law of thermodynamics implies that an increase in ion activity as a result of the presence of solute reduce the chemical potential of a liquid solvent and also the rate of spontaneous transformation of the liquid phase into the vapour phase (Kokya and Kokya, 2006).

- **Surface Area**

The surface area of the water body will have an effect on the evaporation rates for some areas of similar climate and evaporation rates from a maximum value for small water bodies, as determined for a standard evaporation pan, to a fraction of that value for larger of that bodies. The larger the exposed surface the faster the evaporation rate. Procedures for calculating evaporation rates indicate that an evaporation rate is directly proportional to vapour pressure. The vapour pressure of saline water is lower than that of fresh water resulting in a reduction in evaporation cohesive forces between the dissolved ions. Evaporation rate decreases exponentially with increasing salinity. The evaporation rates of saline solutions are calculated by multiplying the rates of evaporation of water by a salinity factor.

- **Humidity**

Composition will have an effect on the humidity level at which evaporation will cease, for example, for a water body saturated with sodium chloride there will be no evaporation during periods when the humidity is above 70% for other salt evaporation may cease at lower humidity

levels. If the humidity level is high, less evaporation occurs as saturation levels are quickly reached when humidity is high. It is more difficult for water to evaporate. If the space above the water becomes completely filled with water vapour, (100% relative humidity) then evaporation is balanced by the opposite process i.e. condensation.

IV. METHODS

Sampling Techniques

The sample of these salts include: Sodium Chloride, Magnesium Sulphate, Sodium Hydroxide, Ammonium Chloride and Potassium Nitrate.

The concentration of the salts were varied ie (0g, 15g, 25g, 35g, 45, and 55g)

Laboratory Procedure

500grams of water was measured and put into an evaporation can which served for the control sample. ,then another 500grams of water with the salts while the salts varies with 0g, 15g, 25g, 35g, 45g and 55g. The mixtures were thorough.The entire set-up were kept at room temperature, evaporation allowed to take place at 24hours interval for 15days; to check the effect of salinity on evaporation process at free water surface. Electronic weighing balance was used to know the amount of water that has been evaporated in the concentrations every day for 15 days. Graphs of cumulative evaporation were plotted against time in days. After the experiments, data were collected on evaporation for the different salts.

V. RESULTS

The rate of evaporation was determined by using electronic weighing balance to know the amount of water that has been evaporated in the concentrations every day for 15 days

Fig. 4.1 Variation of Cumulative Evaporation with time for control experiment of all salts

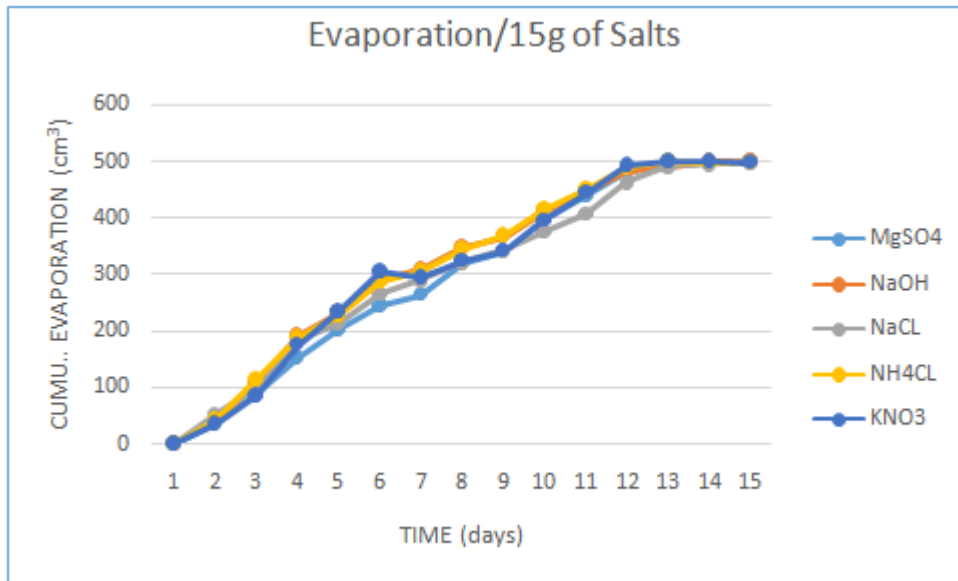


Fig. 4.1 Variation of Cumulative Evaporation with Time at 15gConcentration experiment of all salts

Figure 4.1 shows variation of cumulative evaporation with time at 15gconcentration. At this concentration, evaporation is highest with NH₄CL because on the 12th day, all the moisture in the can

has evaporated. Next is KNO₃, MgSO₄, NaOH, while the least is NaCL on day 12. This shows that inhibition of evaporation is highest with NaCL while NH₄CL has the least inhibition.

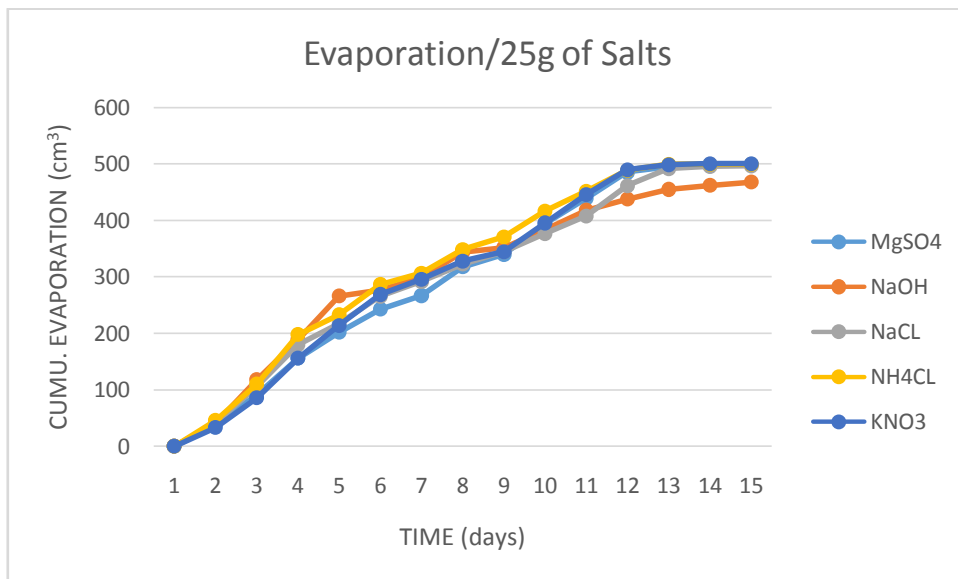


Fig. 4.2 Variation of Cumulative Evaporation with Time at 25gConcentration experiment of all salts

Figure 4.2 shows variation of cumulative evaporation with time at 25g concentration. At this concentration, evaporation is highest with NH₄CL, KNO₃ and MgSO₄ because on the 13th day, all the moisture in the cans had evaporated. Next is NaCL,

while the least is NaOH on day 13. This shows that inhibition of evaporation is highest with NH₄CL, KNO₃ and MgSO₄ while NaOH has the least inhibition.

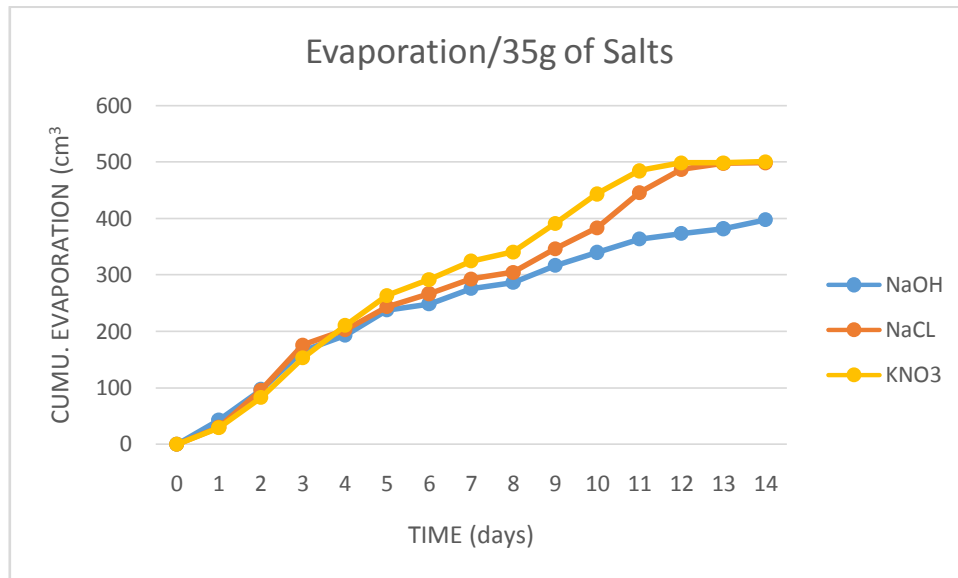


Fig. 4.3 Variation of Cumulative Evaporation with Time at 35g Concentration experiment of all salts

Figure 4.3 shows variation of cumulative evaporation with time at 35g concentration. At this concentration, evaporation is highest with NH_4CL and MgSO_4 because on the 12th day, all the moisture in the cans had evaporated. Next is

$\text{KNO}_3, \text{NaCL}$, while the least is NaOH on day 12. This shows that inhibition of evaporation is highest with NH_4CL , and MgSO_4 while NaOH has the least inhibition.

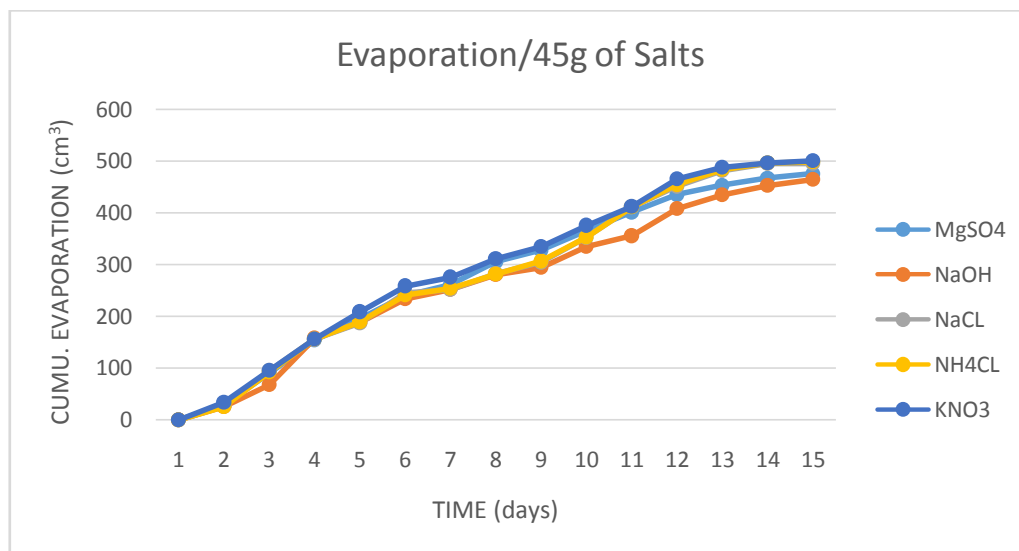


Fig. 4.4 Variation of Cumulative Evaporation with Time at 45g Concentration experiment of all salts

Figure 4.4 shows variation of cumulative evaporation with time at 45g concentration. At this concentration, evaporation is highest with NH_4CL because on the 12th day, all the moisture in the cans had evaporated. Next is KNO_3 and MgSO_4 ,

followed by NaCL , while the least is NaOH on day 12. This shows that inhibition of evaporation is highest with NH_4CL while NaOH has the least inhibition.

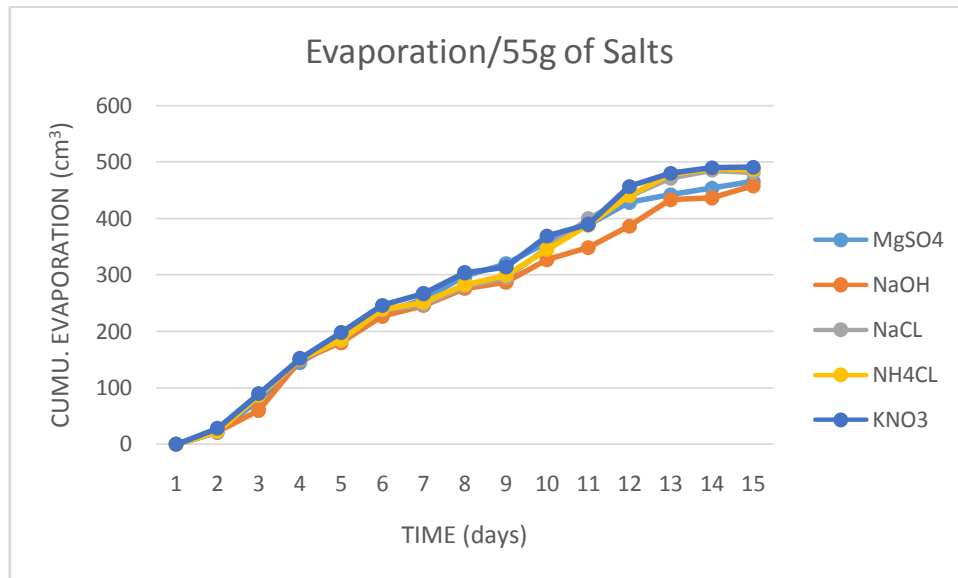


Fig. 4.5 Variation of Cumulative Evaporation with Time at 55g Concentration experiment of all salts

Figure 4.5 shows variation of cumulative evaporation with time at 55g concentration. At this concentration, evaporation is highest with KNO₃ because on the 12th day, all the moisture in the cans had evaporated. Next is NH₄CL which have values 498cm³ followed by MgSO₄, and NaCl while the least is NaOH on day 12. This shows that inhibition of evaporation is highest with KNO₃ while NaOH has the least inhibition.

VI. CONCLUSION

From the experiment, it was observed that evaporation decreases the mass per unit volume of water with time. The higher temperature and surface area, the higher the rate of evaporation. It was observed that the higher the quantity of salt, the lesser the evaporation that is 15g of salt has the highest rate of evaporation followed by 25g, 35, 45, and 55. On comparison between the salts, Sodium Chloride (NaCl) has the least rate of evaporation, followed by sodium hydroxide (NaOH), Magnesium sulphate (MgSO₄), ammonium chloride (NH₄CL) and potassium nitrate (KNO₃) which has the highest rate of evaporation. Salinity decreases as evaporation takes places in the present of various salt. Precipitation will be limited in areas prone to salinity and this will invariably affect the hydrological balance.

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