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Design and Development of an In-Situ Saline Meter for Nigerian Agricultural Soils

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Abstract — **The increase of salinity in the soil and water bodies which simultaneously declines the productivity of plants is of great concern to agriculture in Nigeria and the world at large. However, for effective and timely regulation of salinity, a proper measurement is required. The microcontroller unit (MCU) was programmed by micro-basic structural language displaying 8-bit binary values in analogue digital converter (ADC) I6 characters per line form. The hardware, software and power supply sub-systems were basic parts of the system design. The design and development of an in-situ salinometer proved efficient with the instant resulting of salinity values for soil and water samples with two (2) each – samples A and B. The salinity results of the four samples were 640 mg/l and 5760 mg/l (soil samples) and 640 mg/l and 5120 mg/l (water samples) indicating low salinity and moderate salinity respectively. The result of this work could be adopted and applied in the agricultural sector in measuring the salinity and conductivity of different soil and water samples with 90 % efficiency. The percentage rating is directly proportional to efficiency, voltage and resistivity.**

Keywords — **In-Situ Salinometer, Salinity Values, Microcontroller Unit, Micro-Basic Structural Language And Efficiency**

I. Introduction

It is increasingly recognized that Nigeria in recent times is immensely involved in the importation of food items and other agricultural products and services from other countries due the failure of our home agricultural systems, thus leaving the country's survival at the mercy of the benefactor countries [3]. [1],[11] through their intense studies established that soil salinization is one of the major factors that has caused this failure. [6],[7] also indicated that soil salinization which is the increase in the salt content of the soil, arising from either natural or humanly induced, leads to an increase in concentration of dissolved salts in the soil profile to a level that impairs food production, environmental health and socio-economic wellbeing. It has been discovered in recent researches that the salinized areas are increasing at a rate of 10 % annually for various reasons, including low precipitation, high surface evaporation, weathering of native rocks, irrigation with saline water, and poor cultural practices. [4], estimated that more than 50 % of the arable land would be salinized by the year 2050. Also, a report from the European Commission Joint Research Centre [2],estimated that the menace of soil salinization over the years will hype drastically, showing that only 15 % crop harvest maybe procured as a result of indelible loss of seedlings due to wilting.

In this world of technology and scientific development, there has been great need to intensify researches on the development of salinity monitoring systems using sensor devices designed and constructed with a microcontroller and voltage regulator (L7805CV) respectively [8],[9],[10]. The Federal Ministry of Agriculture and Rural Development [3], stipulated the need for immediate control of salinized soils, outlining the proper and timely monitoring of the soil as a major approach. This work was aimed at the construction of a quick soil monitoring in-situ salinometer for the measurement of salinity of different agricultural soils for enhanced food for man, feed for animals and fiber for industry.

II. Materials and Method

A. Materials

The materials used as shown in Table I were locally sourced.

Table I: List of materials

S/N	Material
i.	Microcontroller (IC-ATmega8)
ii.	Visual liquid crystal display (LCD) (2*16)
iii.	Measuring Probes
iv.	Temperature sensors-thermistor (PTC)
v.	Potentiometer (100KΩ)
vi.	Resistors (100Ω)
vii.	Capacitors (1000μF, 10μF)
viii.	Fixed voltage regulator (5V)
ix.	Lithium battery (9V)
x.	Power switch
xi.	Vero board
xii.	Soldering lead
xiii.	Soldering iron
xiv.	Thermoplastic casing

B. Methods

In this work, it becomes appropriate to employ cheapest method in project designs and construction. This involved necessary technology and availability of materials /components required for project implementation. A bottom-top approach method was adopted with each section of the project developed and tested before final coupling.

System Specification

The digital integrated circuits (IC) used in the design and construction of the in-situ salinometer system is ATmega8 microcontroller and 7805 voltage regulator. The 7805 voltage regulator regulates the voltages from the battery to a 5 V as approved standard voltage for the microcontroller. A 2*16 character liquid crystal display (LCD) screen was used in the output display unit.

System Design

The designed system according to Figure I, was divided into three basic parts which are: *Hardware Sub-system*, *Software Sub-system* and *Power Supply System*.

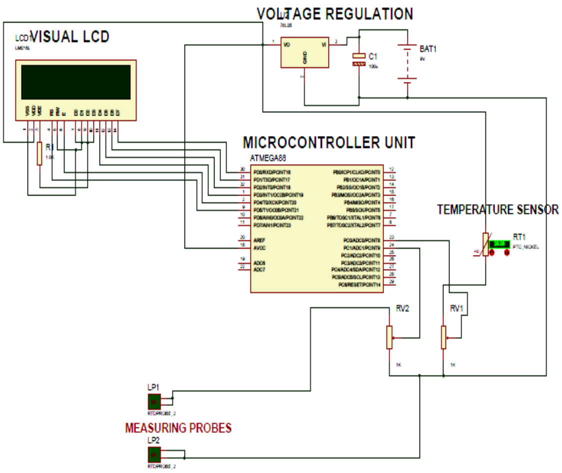

Figure I: Overall circuit diagram

Hardware subsystem

The hardware subsystem in Figure II comprise the input interface, the output interface and the control system.

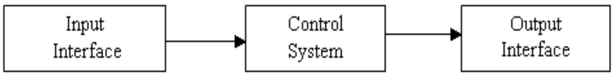

Figure II: Hardware subsystem

The input interface (sensor unit) comprises the probes (salinity sensors), the thermistor (PTC temperature sensor) and potentiometer (100kΩ). The sensor unit was designed using the principle of the voltage divider rule. The thermistor and the probes were connected individually across a 100kΩ potentiometer (variable resistor) 0 to 100kΩ resistance. The sensors (thermistor and probes) in parallel with the limiting resistor (potentiometer) formed a voltage divider whose resultant voltage determines the voltage drop of the resistors. The analogue voltage output of the thermistor and the salinity probe were converted to an 8-bit binary value through the ADC for the microcontroller unit to process and display on the LCD. In the control system, the microcontroller unit (MCU) is an ATMEGA 88 which has an internal analogue to digital converter (ADC) with the conversion clock speed of 8MHz. The input interface (the thermistor and the salinity probes) was connected to the microcontroller through a 100kΩ potentiometer (variable resistor) at pins 23 and 24 respectively. The MCU was programmed by a structural language called the micro-basic.

The output interface involves the interfacing of the Liquid Crystal Display (LCD) to the micro-controller with a rating voltage of 5V. The LCD displays the analogue voltage output of the thermistor while the salinity probes transmit 8-bit binary values through the internal ADC, display other data programmed into the microcontroller and display a 2*16 display format i.e. 2 rows of character line with 16 characters per line form.

Software subsystem

The software subsystem concerns basically the programming of the microcontroller. The microcontroller is a high level integrated computer that executes any program burn into it. It is the brain box of the system where all calculations, linear relations etc. are encoded in program language to perform a particular task. The calibration of the meter was calculated and programmed into the microcontroller to execute its output for several conditions.

Power supply system

As shown in Figure III, the power supply comprises a 9 V lithium battery and a voltage regulator. The power supply unit has a voltage regulation to a quincent point of 5 V_{DC}, 600 mA. The unregulated voltage of qV_{DC} from the lithium battery feeds the input of the voltage regulator (7805). The output 5 V is filtered with a capacitor of 1000 µF/25 V to adjust AC ripple voltage.

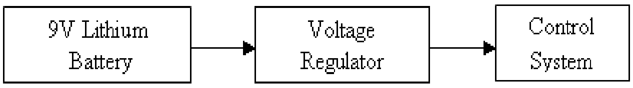

Figure III: Power supply system

C. *Working principle of the salinometer*

Every material possesses an ability to conduct electricity as well as resists the flow of electricity through it. Most materials are sometimes classified by their conductivity or resistivity to electricity. Conductivity of any material is inversely proportional to the resistivity of the material.

$$\sigma = 1/\rho \qquad (1)$$

The salinity probes were designed to measure the resistivity across any soil or water sample. The conductivity of the sample was evaluated from its resistivity via the relationship stated in Eqn. (2.1).The salinity values were calculated from the corresponding conductivity of the sample. According to [5], the salt concentration (salinity) S (mg/l or ppm) of a sample is equivalent to the product of its electrical conductivity EC (mmhos/cm) and a constant value of 640, implying that;

$$S = E.C. \times 640 \qquad (2)$$

Equations 1 and 2 were encoded into the microcontroller with defined output range of low, moderate and high salinity corresponding to its salinity value and calibration range in Table 2.2. [5], further stated that the range for these classes are

$$\text{Low salinity} = E.C<3\text{mmhos/cm or } (3 \times 640 = 1920\text{mg/l}) \qquad (3)$$

$$\text{High salinity} = E.C>10\text{mmhos/cm or } (10 \times 640 = 6400\text{mg/l}) \qquad (4)$$

$$\text{Moderate salinity} = E.C \text{ between 3 and 10mmhos/cm or (between 1920mg/l and 6400mg/l)} \qquad (5)$$

Table II: Calibration range of the salinometer

Class	Range	
	EC (mmhos/cm)	**S (mg/l)**
Low Salinity	< 3	< 1620
Moderate Salinity	btw 3 and 10	btw 1620 and 6400
High Salinity	> 10	> 6400

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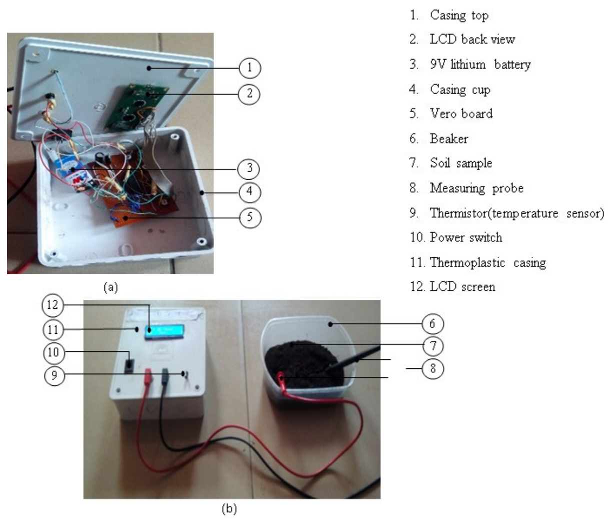

(a) Salinometer operational circuit
(b) Salinometer set

Figure IV: Equipment set-up of the salinometer with its operating components

III. Performance and Test Evaluation

In the laboratory, two soil samples A and B, water samples A and B and a standard NaCl salt compound (crystalline) were used for the performance test of the salinometer. 5g of NaCl salt was mixed in sample B of soil with water. Also, 5g of NaCl salt was dissolved in water sample B. Using the constructed in-situ salinometer, these four samples were tested for their salinity and temperature, Table III.

Table III: Test result on the four different samples

	Sample			
	Soil sample		Water sample	
	A	B	A	B
Temperature (ºC)	29.58	29.58	29.66	29.66
E.C. (mmhos/cm)	1	9	1	8
SAL.(mg/l)	640	5760	640	5120
Salinity Level Displayed on LCD	Low salinity	Moderate salinity	Low salinity	Moderate salinity

Applying Eqn. (2.1) it would be noted that the resistivity of samples without salt mix is

$\rho = 1/1 \ = 1\ \Omega cm$

and samples with salt mix would be

$\rho = 1/9 = 0.11\Omega$ cm and $\rho = 1/8 = 0.125\Omega$ cm respectively.

Thus, it can be deduced that the resistivity of the samples decreases with increasing salinity.

As the current flows through the samples at the insertion of the probe, the salinity of the sample reduces/falls below the peak value of the range respectively due to the decrease in its resistivity (caused by a decrease in its voltage according to ohms law). The efficiency (η) of the circuits could be calculated using Eqn. (6) as;

$$\eta = (\text{salinity output}) / (\text{salinity input}) \times 100 \qquad (6)$$

$$\eta = 5760 / 6400 \times 100 = 90\ \%$$

This implies that efficiency of the system depends on the voltage. As the voltage decreases, the efficiency of the system also decreases alongside the percentage rating.

IV. Discussion

From the analysis, it is observed that sample A indicated a low saline condition with an electrical conductivity (E.C.) of 1mmhos/cm while samples B of soil and water indicated a moderate salinity of E.C.'s 9mmhos/cm and 8mmhos/cm respectively. This implied that the conductivity of samples with a small amount of salt is very low while samples with a high amount of salt have a high conductivity. Thus it can be quoted that the higher the salinity of a sample, the higher the conductivity of a sample as shown in Eqn. (2).

V. Conclusion

Monitoring soil salinity is an important parameter associated with crop yield monitoring/prediction, land usefulness, water purity and salinity control. Thus, monitoring salinity demands a fast, accurate, reliable and non-destructive method. The design and development of this in-situ salinometer however satisfies the above demands as it can be used to measure the conductivity and salinity of the sample and appropriates it to a saline range. The design base has however improved the use of sensor devices for monitoring soil conditions. This work is recommended for projects relating to the measurement of salinity and conductivity.

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References

[1] Corwin D.L. (1989). Soil-Water-Solute Process Characterization-An Integrated Approach: Soil Salinization as a Causative Factor of Soil Salinization, pp.37-38

[2] European Commission Joint Research Centre (ECJRC), (2012). Stand. Management and Natural Hazards Unit, http://eusoils.jrc.ec.europa.eu/, Joint Research Centre—The European Commission's In-house Science Service, http://ec.europa.eu/dgs/jrc/index.cfm, and Institute for Environment and Sustainability (IES), http://ies.jrc.ec.europa.eu/

[3] Federal Ministry of Agriculture and Rural Development (FMARD) (2008). FAO Country Programming Framework (CPF) Federal Republic of Nigeria: Situation of Agriculture, Natural Resources and Environment.

[4] Jamil A., Riaz S., Ashraf M., and Foolad M.R. (2011). Gene Expression Profiling Of Plants Under Salt Stress. Crit. Rev. Plant Sci. pp30, 435–458.

[5] Micheal A.M. (1999). Irrigation Theory and Practice. pp.690-691 ISBN 0-7069-822-2

[6] Ondrasek G., Romic D., Rengel Z., Romic M., and Zovko M. (2009a). Cadmium Accumulation by Muskmelon Under Salt

Stress In Contaminated Organic Soil. Sci. Tot. Enviro. Vol.407, pp. 2175-2182.
[7] Rengasamy P. (2006). World Salinization with Emphasis on Australia. J Exp Bot., Vol.57, pp. 1017-1023.
[8] Uzoigwe, L.O., Mbajiogu, C.C. and Igbe, O.C. (2011a). Operational Principles of A House or Farmstead Curtain Operation Using A Multiple Function LDR Sensory Device. 32nd Annual Conference of the NIAE (ILORIN 2011). Pp 1050-1058.
[9] Uzoigwe, L.O. (2011b). Operational Principles of A Pressure Mat Sensor (PMS): A Device for Monitoring Intruders in Agricultural Farm. 32nd Annual Conference of the NIAE (ILORIN 2011). Pp 1066-1072.
[10] Uzoigwe, L.O., and Maduakolam, S.C. (2013). Design and Construction of a Moisture Level Detector for Nigerian Soil Conditions. Elixir International Journal (elixirpublishers@gmail.com) Index Copernicus Poland Value (ICV) Pp 31002-31008.
[11] Wild A., (2003). Soils, Land and Food: Managing The Land During The Twenty-First Century. *Cambridge*, UK: Cambridge University Press.

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