IJAAR PUBLISHING®
Scholarly Journal of Science and Technology Research & Development | ISSN: 2955-0807
Vol. 5, Issue 1 (2026) | www.ijaar.org/sjstrd

Reliability and Fault Analysis of Local Fabricated Dissolved Oxygen Sensor in Makurdi

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ABSTRACT

In this work, two dissolved oxygen sensors containing different electrolytes one of 1M KCL and the other 1 M KOH are used to measure dissolved oxygen in water at 29^0C in Makurdi town. The current was measured with digital meter to four decimal places. The current is directly proportional to the partial pressure of dissolved oxygen. This was done to observe the behaviour of such a sensor in a tropical and humid town like Makurdi. The sensor with KOH had a greater sensitivity detecting currents in the order of milliamperes without amplification compared to the sensor with KCl which indicated unamplified current in order of microampere. The histogram and data shows that the sensor with KOH has less scatter and also less deviation from the mean and hence recommended for use although care must be taken in design considering the corrosive nature of KOH in its tendency to cause more wears. In terms of instrumentation, the KOH sensor has a greater precision and resolution under the prevailing circumstance. This work indicates that these sensors are suitable for dissolved oxygen sensors and instruments calibrated to one or two decimal places which is very valuable to monitor oxygen in fish ponds.

Keywords: *Dissolved Oxygen Sensor, Fault Analysis, Reliability, KOH Electrolyte, Platinum Electrode.*

Amanyi, A. & Dike, E.O. (2026). Reliability and Fault Analysis of Local Fabricated Dissolved Oxygen Sensor in Makurdi. *Scholarly Journal of Science and Technology Research & Development, 5*(1), 17-25. DOI: https://doi.org/10.46654/h36rkn30

1.1 INTRODUCTION

Early detection of oxygen deficiency is very important in sustaining the productivity of fish stocks in aquaculture as the life of the fish depends on the availability or dissolved oxygen in the system. A most proactive way to warn of oxygen depletion is by use of sensors for dissolved oxygen. Dissolved oxygen sensors already are available that may be galvanic, polarigraphic or use optical effects. Most of these sensors use potentially hazardous electrodes like Lead and Cadmium which make them dangerous for aquaculture. The clark sensor use nonhazardous electrodes of platinum and silver but then silver is expensive to use so also are optical sensors. Since dissolved oxygen is affected by factors such as temperatures, pressure presence of biological plants turbulence and salinity then these parameter means that values of oxygen levels in the tropics will be different in temperate climates. There is also a strong possibility that the behaviour of dissolved oxygen sensors will be different in tropical and temperate region.

Makurdi is located approximately $7^0$44'N latitude on $8^0$32'E longitude is a low line town along the banks of River Benue. It's has a dry season and a wet season with a generally high temperature all year round. Since dissolved oxygen depends on temperature, it is important to monitor dissolved oxygen in fish ponds within Makurdi. The use of sensors to monitor oxygen level is then very important. But even so the local environment is important in determining the behaviour of an instrument due to such factors as humidity temperature, soil temperature and sun light intensity. These factors vary in places and are not the same in tropical climate and temperate climate. It is therefore apt to study the character of sensors locally taking into consideration the prevailing physical chemical and biological parameters.

These factors can introduce variation in results and even affect the instrument life as can be deduced from the fact that under greater heat acidity or other chemical agents the wear of instrument components can be accelerated resulting in introduction of systematic error hence faulty readings. Overall reduction of errors is achieved by reducing random errors by taking a large number of readings and taking their average. Due to the presence of factors affecting an instrument, the results can then be treated as a random variable. This permits the calibration to ensure reading that are accurate with respect to the prevailing circumstances. Also, analysis is enhanced by introduction of variance of random variables deviation to show the spread out of the probability distribution curve

The probability or an instrument to function correctly under a given operational condition and time is a measure of the reliability of the instrument. Therefore, taking a number of readings under the stated condition can aid in fault analysis. Deviation of reading from a value is an indicator of a fault which is the deviation of a property from the acceptable condition or value. Such information is important in trouble shooting. In this work two locally fabricated dissolved oxygen sensors are tested in Makurdi town for the intended purpose of adapting them for dissolved oxygen sensors in fish farms and comparing their behaviour to other similar sensors.

The electrodes are platinum and zinc. They have been used to replace the potentially harmful electrodes of lead and cadmium. Also, the costlier silver used in the Clark's sensor has been replaced. Another consideration in this work is the replacement of ceramic oxygen sensors they require high temperature to operate. The sensor used here are galvanic but can be adapted to perform other tasks by connection to amplifiers. The platinum is the cathode and the zinc is the anode. Two electrolytes are used and compared; potassium chloride and

potassium hydroxide. Dissolved oxygen passes through the membrane and reacts with water in the electrolyte by the reaction $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

Zinc is oxidized and goes into solution as Zinc ions releasing electrons that go to the cathode constituting an electric current that is proportional to the partial pressure of the oxygen in the water.

$2Zn \rightarrow 2Zn^{2+} + 4e^-$

And $Zn^{2+} + 2OH^- \rightarrow Zn(OH)_2$

This reaction wears the zinc and have gradually erodes it. Hence it is made thicker using a diameter of 1cm and 3cm length.

The platinum is thin about 0.23 mm thick the membrane is a thin layer or silicone of 50μm thick. The thickness is measured with a comb gauge. The components are housed in a Perspex glass. Temperature variation effect is compensated by the use of the thermistor.

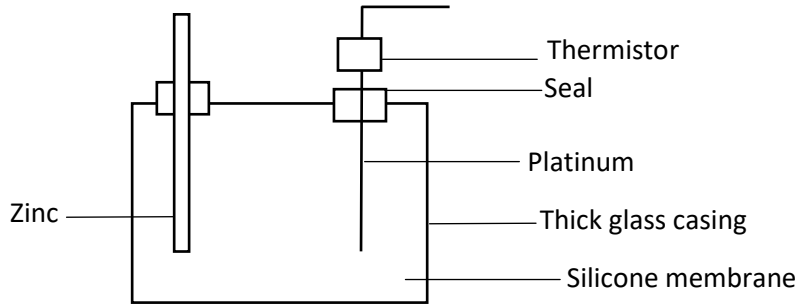


Figure 1: Cut view of sensor

Temperature stabilization is achieved by use of a thermistor.

The system is adaptable to a complete oxygen monitoring and warning system.

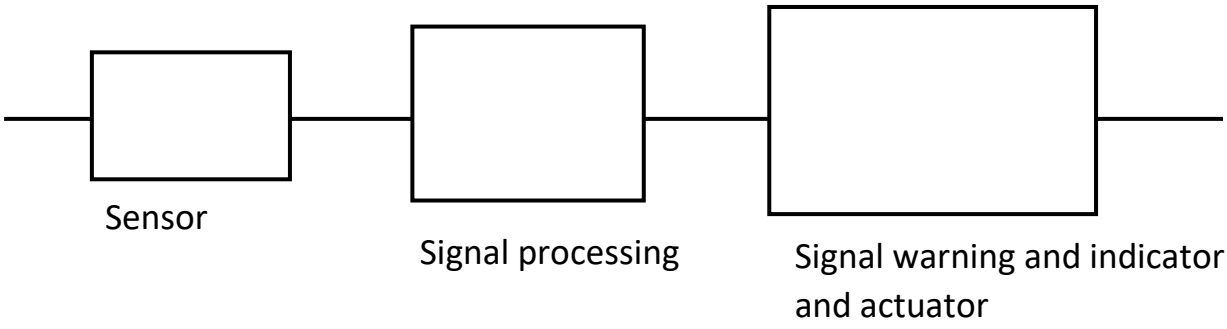


Figure 2: Block diagram of use of sensor for oxygen monitoring and control in a fish pond.

The signal indicator is adaptable to being actuated by solar power to warn of oxygen depletion and this could be done remotely after signal processing which may need amplification of the sensed signal.

1.2 Experimental Procedure

The sensor has strong glass containing the electrode and 1 mole of the electrolyte and then put into outdoor water of temperature 29^0C. The resulting current was measured with a digital

meter after 1 minute. This process was repeated 50 times for both sensors one containing 1 m KCl and the other 1M or KOH. The reading was tabulated and compared.

Frequency distribution for output current sensor using 0.1m KCl electrolytes.

2.1 RESULT AND DISCUSSION

(Saturation current = 1.87μA)

Table 1. Result for 1 mole KCL at 29^0C water temperature is show as following in μA

1.815	1.850	1.870
1817	1.850	1.871
1.823	1.850	1.879
1.82		
1.824	1.853	1.880
1.825		1.881
1.830	1.854	1.890
1.830		
1.832	1.854	
1.832	1.855	
1.837		
1.840	1.855	
1.840	1.855	
1.840	1.855	
1.841	1.857	
1.842	1.859	
1.842	1.859	
1.842		
1.843	1.859	
1.843	1.860	
1.847	1.860	
1.847	1.861	
1.847	1.864	
1.850	1.867	

The data was arranged in ascending order to obtain the median as $\frac{1.85+1.85}{2}$

$= 1.85\ \mu A$

The mean = $\Sigma\frac{x}{n}$

$= \frac{92.368}{50} = 1.84736$

The data shows a bimodal value or 1.85 and 1.855

The variance = $\Sigma\frac{(x-\overline{x})^2}{n}$

$= 0.00031\ \mu A$

Standard deviation $\sqrt{\Sigma\frac{(x-\overline{x})^2}{n}}$ $= 0.0177\ \mu A$

First quartile = 1.838
Second quartile = 1.849
Third quartile = 1.859
Interquartile range = 0.021
The data shows a tight spread

Table 2: Result for 1mole KOH at 29^0C current in mA in ascending order (saturation current = 1.52mA)

0.1489	0.1510	0.1522
0.1494		0.1522
0.1495	0.1511	0.1523
	0.1511	0.1524
0.1496	0.1512	0.1527
0.1497		0.1528
0.1498	0.1512	0.1529
0.1498	0.1512	0.1530
0.1498	0.1512	0.1531
0.1500	0.1512	0.1532
0.1500	0.1513	
0.1500	0.1513	
0.1501	0.1513	
	0.1513	
0.1501		
0.1502	0.1516	
0.1502	0.1515	
0.1503	0.1516	
0.1504	0.1517	
0.1505	0.1518	
0.1506	0.1518	
0.1507	0.1519	
	0.1520	

Mean = $\Sigma\frac{x}{n} = 0.145\ mA$

$=\frac{7.2536}{50} = 0.1512$

Mode is bimodal = 0.1512 and 0.1513

Range = 0.532 – 0.1489

= 0.3831

Variance = $\Sigma\left(\frac{x-\bar{x}}{n}\right)^2 = 0.00000391$

And standard deviation = 0.00625

Table 3: Frequency Distribution

Class in μA	Tally	Frequency
1.81 – 1.829	𝍸 ||	7
1.83 – 1.849	𝍸 𝍸 𝍸 |||	18
1.85 – 1.859	𝍸 𝍸	14
1.86 – 1.869	𝍸 𝍸	5
1.87 – 1.879	|||	3
1.88 – 1.890	|||	3
		50

Histogram for current with KCl

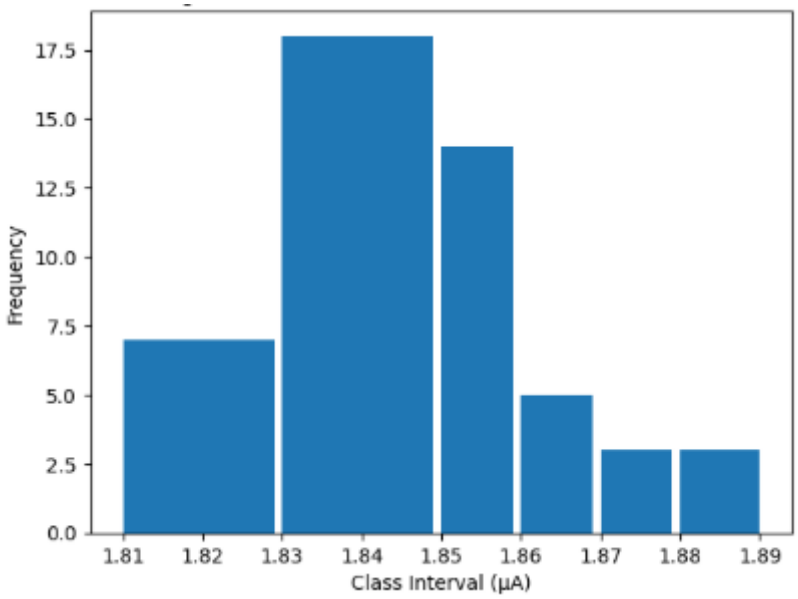


Figure 3: Histogram

Table 4: Distribution output current for sensor using KOH.

Class	Tally	Frequency
0.140 – 0.1455		
0.1456 – 0.1511	𝍸 𝍸 𝍸 𝍸 ||	22
0.1512 – 0.1567	𝍸 𝍸 𝍸 𝍸 𝍸 ||	28
0.1568 -0.1623		
		50

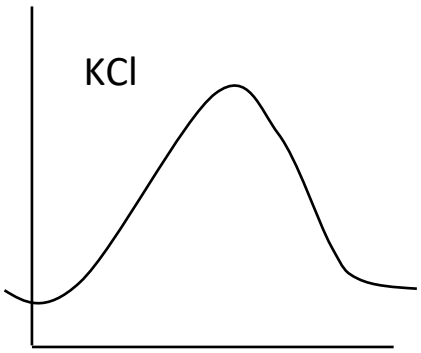


Figure 4: KCI

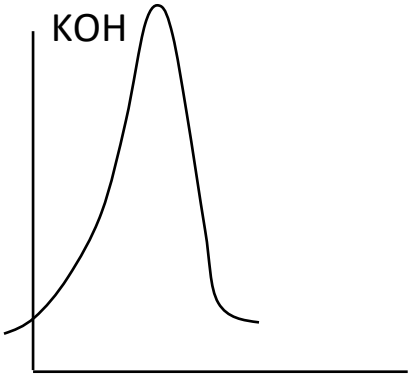


Figure 5: KOH

Probability distribution for KOH and KCl shows a less spread for KOH.

Histogram for current with KOH

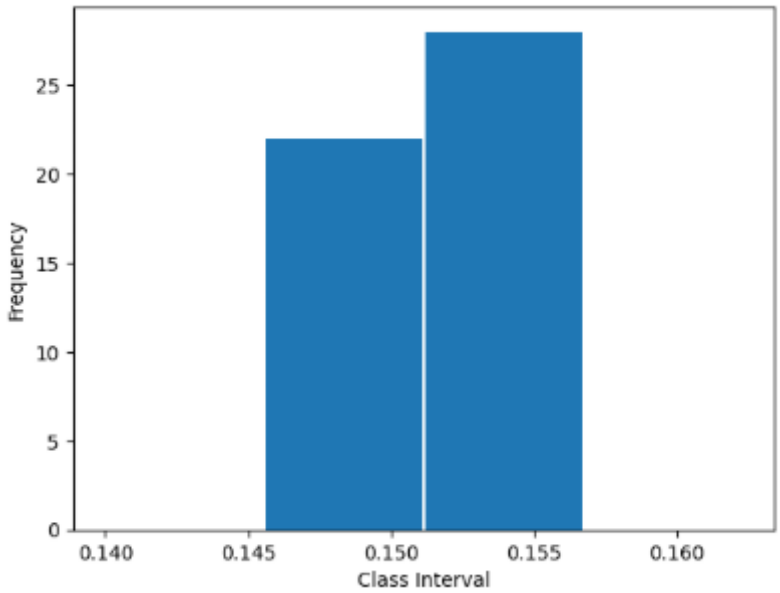


Figure 6: Histogram

The likely error in the mean for the KCl sensor is given by

$$\frac{SD}{(n-1)^{1/2}}$$

$$= \frac{0.0.177}{(50-1)^{1/2}}$$

$$= \frac{0.0.177}{(49)^{1/2}}$$

$$= \frac{0.0.177}{7}$$

$$= 0.002529$$

This implies that the correct reading is

$$= \frac{0.0.177}{(50-1)^{1/2}}$$

$= 1.847 \pm 0.002529\mu A$ for the KOH sensor, likely error is seen by $\frac{standard}{(n-1)^{1/2}}$

$$= \frac{0.00625}{(n-1)^{1/2}}$$

$$= \frac{0.00625}{(49)^{1/2}}$$

$$= \frac{0.00625}{7} - 0.0008929$$

The likely value for the current is $= 0.145000 + 0.000393\ mA$

These values for both sensors can be used to diagnose a system have the oxygen sensor as a component. A fault is an unpermitted deviation of a parameter of the system from the mean or acceptable value. Reliability is affected by faults and failures given rise to errors. The reliability of a component is then inversely proportional to the number of errors under a stated condition of operation.

3.1 Conclusion

Error evaluation was done for dissolved oxygen having the electrolytes KCl and KOH as a tropical water temperature within Makurdi town of 29^0C using platinum and zinc electrodes. It was discovered that the KOH electrolyte sensor has a less scattered values of output current and higher output current hence has a greater resolution, precision and instrument sensitivity. Hence has a greater reliability despite the increased chance of wear due to its more corrosive nature which has to be taken into account in maintenance. These sensors can therefore be used for instruments calibrated to 2 decimal places.

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