

# **Appropriateness of low cost sensor network for environmental monitoring in a tropical country: Experience and lessons learnt from real world deployment**

Despite the advances in low cost open hardware and open software IoT (Internet of Things) enabled devices, their application in regional scale environmental monitoring has not been explored until the launch of 4ONSE (4 times Open and Non-conventional technology for Sensing the Environment) project, which is an ongoing research project between University of Moratuwa, Sri Lanka and University of Applied Sciences and Arts of Southern Switzerland (SUPSI). The project has paved the path for deploying low cost, open technologies based, non-conventional environmental monitoring systems in Deduru Oya river basin area of Sri Lanka. This research presents the selection process of appropriate sensors suitable for tropical climatic condition of Sri Lanka, issues encountered and remedies taken during the design and deployment phases.

# 1 APPROPRIATENESS OF LOW COST SENSOR 2 NETWORK FOR ENVIRONMENTAL MONITORING IN A 3 TROPICAL COUNTRY: EXPERIENCE AND LESSONS 4 LEARNT FROM REAL WORLD DEPLOYMENT

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## 25 26 **ABSTRACT**

27 Despite the advances in low cost open hardware and open software IoT (Internet of Things)  
28 enabled devices, their application in regional scale environmental monitoring has not been  
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## INTRODUCTION

This research project aims at developing a low cost, experimental and non-conventional Environmental Monitoring Systems (EMS) based on open hardware, open software, open data and open standards. The system is able to measure eight environmental parameters - rainfall, wind speed, wind direction, relative humidity, air temperature, barometric pressure, soil moisture and solar radiation, using seven sensors.

In here, the word ‘tropical’ specifically means places near the equator. As a tropical country which is located closer to the equator, surrounded by Indian Ocean, Sri Lanka has a diversified climatic condition enriched with heavy monsoonal rainfalls and hot temperatures in all year round. Therefore, the most challenging task is to maintain the durability of the system by protecting the system from intense temperature, humidity, dust and entomological activities, which are more pronounced in the tropics than in other regions of the world.

At the beginning, the sensors were selected primarily considering the factors such as cost, measuring range, accuracy level and market accessibility to sensors. However, during the development and deployment stages, it was realized that some of the sensors showed very less or no capability in coping with the country’s climatic condition. Therefore, some sensors had to replace and modify as per the climatic condition of the country.

## CASE STUDY

The Deduru Oya River basin, which is the fourth largest river basin of Sri Lanka is the selected case study area to deploy the EMS systems. Under the 4ONSE project, two types of EMS systems have been developed to monitor the environmental parameters: 4ONSE-MOD (4ONSE Modular prototype) and 4ONSE-PCB (4ONSE Printed Circuit Board prototype). The symbols “M” and “P” in Figure 1 denotes the locations of the 4ONSE-MOD and 4ONSE-PCB respectively. The team was adhered for WMO guidelines on siting meteorological equipment as much as possible, in order to ensure the monitoring system is collecting representative data.



		sensor was selected as the candidate transducer to measure the atmospheric pressure. The sensors like MPL3115A2 and BMP280 are relatively higher in price compared to BME280. Although the MD-PS002 sensor is lower in price, the range of measurement is limited compared to other sensors.
Wind speed	Wind speed sensor	0-5V Anemometer equipped with mechanical three cups was selected to measure the wind speed. The sensor shell and wind cup is made up of aluminium alloy. The sensor has high strength, weather resistance, corrosion resistance and waterproof.
Wind direction	Wind direction sensor	4-20mA wind direction sensor was selected to measure the wind direction. This was entirely made up of aluminium alloy material to ensure high resistance to weathering.
Precipitation	Davis Aerocone Rain Collector – 6465	Davis Aerocone Rain Collector – 6465 was selected mainly considering its cost and the weather resistance capability. It was designed to meet the guidelines of the World Meteorological Organization. The body and base of rain collector are constructed with tough, UV resistant plastic.
Solar radiation	SI1145 UV IR Visible sensor	The previously used BH1750FVI sensor was incapable to measure the whole spectrum of Electromagnetic radiation and the illumination under bright sunlight condition. Hence, SI1145 UV IR Visible Sensor was selected to measure the solar radiation, while also considering its cost.
Soil moisture	YL - 69	YL-69 sensor was selected as the candidate sensor to measure the soil moisture, mainly due to its low cost.

Most of the BME sensors had to replace as a result of oxidization (Figure 2). In the course of time, we noticed that they were giving wrong values and sometimes stop sending values. Usually, they send relative humidity as 100% when they are not properly working. Accordingly, the sensors bought from the Chinese market were replaced with a good quality and high BME sensor bought from SparkFun online retail store. At the same, another set of BME sensors were bought from the local market and CRC plasticote 70 clear protective lacquer was applied to its circuit. It protects and seals electronic devices from water vapor, diluted acids, alkalies and high temperature.



Figure 2: Oxidized BME sensor

Sunlight is the Electromagnetic Radiation (EMR) receives from the sun in the forms of visible light, ultraviolet and infrared. At the beginning BH1750FVI module was used to measure the light intensity using Lux – one lumen per square meter ( $\text{lm/m}^2$ ) as the unit of measurement. Since it measures only the visible part of the radiation, it was decided to select a sensor which measures all 3 components of the EMR, which measured in Watts per square meter ( $\text{W/m}^2$ ). Conversely, there is no single conversion factor between Lux and  $\text{W/m}^2$ , since it depends on the wavelength of the spectrum in the electromagnetic radiation. Conversely, tropical countries receive more sunlight, than other parts of the world. Under the brightest and bright sunlight conditions, the illuminance is about 120,000 lux and 111,000 lux respectively (Bünning and Moser, 1969). However, the maximum level that the BH1750 can measure is about 65,000 lux. Therefore, SI1145 UV IR Visible sensor was selected for the monitoring system. During the designing stage of the weather station, YL-69 low cost soil moisture sensor was use and tested nearly 1 month. However, it had a short lifespan as the sensor got corroded gradually (Figure 3 (a) and (b)). Accordingly, the resultant readings were received with an incremental error. Figure 4 (a) and (b) shows the calibration curve at the beginning and the calibration curve received after one month time respectively.



Figure 3: (a) Soil moisture sensor (b) Corroded soil moisture sensor

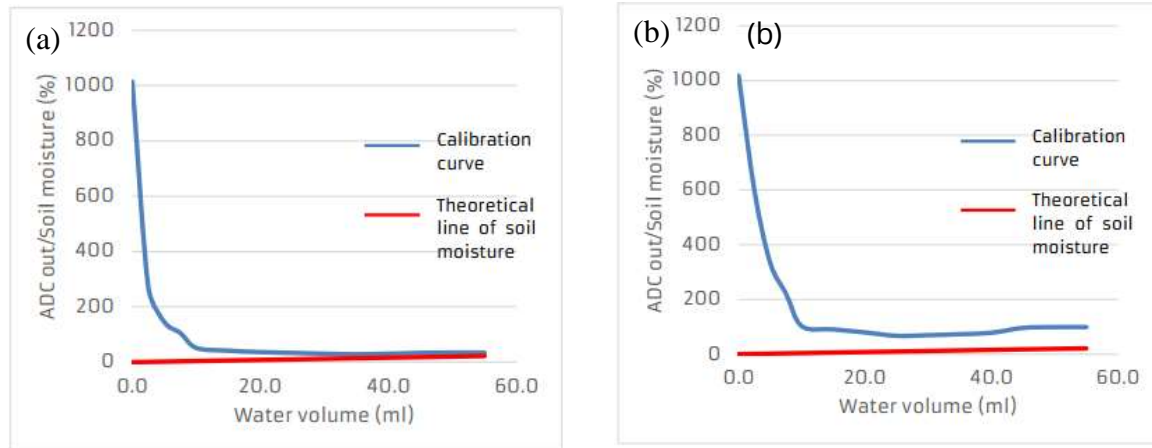


Figure 4: (a) Calibration curve of the soil moisture sensor at the beginning (b) Calibration curve of the soil moisture sensor after 1 month

Therefore, a new type of soil moisture sensor was designed using stainless steel tubes (Figure 5) and again tested for nearly 1 month. The same calibration curve which is depicted in Figure 4 (a) was received from the new sensor.



Figure 5: Soil moisture sensor developed by stainless steel tubes

Some issues were not associated with the tropical nature of the country. The issue had with the wind speed sensor was the length of the wires. Some connector wires of the sensor were much shorter. Therefore additional wiring was done to expand the cable to connect to the wind direction sensor easily.

Rain collector output cable comes with a rj45 connector. Due to the unavailability of rj45 connector, in 4ONSE station, default cabling was used instead of rj45 cabling.

### Other issues and remedies taken

It was evident that eventually RTC battery of the most of the stations get swollen. By scrutinizing the issue it was found that the RTC module had a circuitry to charge the battery. But since we are using the CR2032 battery which is not a rechargeable battery, every time the

module tries to charge the battery and the internal chemistry of the battery restrict it. So ultimately the battery got damaged & swollen. We have taken two remedies to solve this issue:

1. Disconnect the charging circuitry from the module so the CR2032 can work without charging.
2. Use of rechargeable battery such as LIR2032 (Lithium Ion) battery. This may be recharged by the recharging circuitry in the module. So the module and battery may work any issues.

Another issue found eventually was the SD cards of the some stations got damaged and data logging process got abrupt. By studying the data sheets and circuitry it was found that voltage levels in the tx and rx data lines cause for sd cards to get damaged. Currently it has a peak voltage of 5v. But in data sheet of “openlog” data logging module recommend a voltage level not more than 3.3v for the read and write (rx & tx) process. Use of level converter for the rx & tx terminals to reduce the 5v to 3.3v can be taken to solve this issue. This may increase the lifetime of the SD cards as well.

## CONCLUSION

One of the methods of monitoring the environment is measuring and analyzing the environmental parameters by placing sensors in monitoring stations. However, the current network coverage of the country equipped with traditional meteorological stations is restricted to certain locations due to high installation and maintenance cost. In recent years, the advancement of open source hardware has showed significant reductions in costs of sensors used for environmental monitoring. During the past few decade, several researchers and hobbyists have developed single and multiple parameter/s based environmental monitoring systems equipped with low cost open source hardware products. However, in literature, it is hard to find any assessment done in terms of deciding low cost, durable, reliable and rugged sensor network appropriate especially for countries with tropical climatic conditions. Accordingly, out of the seven sensors, two sensors (BME280 and YL – 69) had to modify as per the tropical nature of the country, while one sensor (BH1750) had to completely replace with SI1145 UV IR Visible sensor due to its low performance in measuring the intense solar radiation in tropical climates. As yet, the other sensors found to be consistent with the climatic condition of the country. Assessing system’s durability is a long term process which has to examine under fluctuating climatic conditions. Therefore, further investigations will be carried out with respect to sensors and other electronic devices used in the system to arrive into a more favorable judgement on more appropriate sensor network for a tropical country.

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