Binos Air Monitor

Maintenance Manual

Version *1.0*

Contents

1.0 Introduction/Overview

The Binos Air Monitor requires routine maintenance to enhance the device's uptime and efficiency. Device failures or inefficiencies in a large interconnected network are inevitable and restoration of operation normalcy is achieved through consistent infrastructure maintenance.

1.1 Purpose of the Maintenance Manual

This manual has been prepared to provide guidance to personnel responsible for maintaining the device. It is intended to serve as the primary reference source for procedures relating to safety and equipment maintenance. The manual is structured such that depending on the level of expertise, different persons can select appropriate procedures and follow the steps prescribed for conducting the maintenance that meets air quality monitoring requirements. This manual should be considered supplementary to the specific and detailed user guide which has more device-specific information. Hence, for proper maintenance of the AirQo monitor, this manual and the user guide complement each other and offer necessary guidance and information to understand the techniques and procedures for device maintenance.

The manual addresses the most common maintenance scenarios but it is not comprehensive nor does it provide information to deal with all possible situations. If the device is not operating as designed or the alarms are unusual, the AirQo hardware team should be contacted via our website:www.airqo.net/contact or email: info@airqo.net immediately.

1.2 Safety Information

The safety of the system and maintenance personnel must be observed at all times. Maintenance personnels are advised to ensure all personal safety precautions are observed to be protected from injuries resulting from workplace hazards. Personal protective equipment (PPE) items such as gloves, safety glasses and shoes, earplugs or muffs, hard hats, respirators, or coveralls, vests and full body suits are recommended for all maintenance personnel.

To ensure safety of the system:-

- Maintenance should never be performed when the monitor is powered or connected to the power adapter.
- Device and sensors should be protected from susceptible electrostatic discharge

1.3 Understanding the Binos Air Monitor

The Binos Air Monitor is a low-cost air quality device that measures particulate matter ($PM_{2.5}$ and PM_{10}) as well as ambient meteorological conditions such as humidity and atmospheric pressure. The device is locally built and uniquely designed for the African setting to withstand environmental and physical conditions. Powered by either mains or solar, the device is optimised to work in settings characterised by unreliable power.

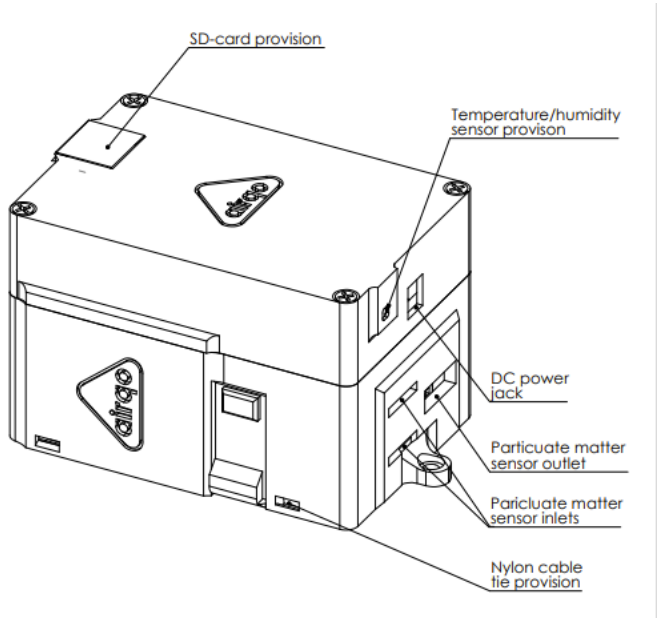

Figure 1. Binos Air monitor

2.0 Maintenance Checklist and Toolkit

There are three levels to maintaining the Binos air monitoring device as explained below.

Level 1: Can be a beginner or any 3rd party with little knowledge and experience with electronics.

Level 2: Authorised agent/Someone experienced with air quality monitoring devices and has a good experience and knowledge of electronics

Level 3: An AirQo hardware engineer.

2.1 Maintenance Checklist

Following the above explained levels, we list the different components required for maintenance which are:-

Tools	L1 (Beginner)	L2(Experienced)	L3(Expert)
Ladder or a raised stable platform about 1.5 m high.	☑	☑	☑
Hex and Flat head screw drivers	☑	☑	☑
Protective Gear	☑	☑	☑
8mm,10mm,12mm,13mm,14mm spanners	☑	☑	☑
Screws and Tower clips	☑	☑	☑
Cables(wide range and length)	☐	☑	☑
Mounts and solar panels	☑	☑	☑
Sim cards	☐	☑	☑
Power drill	☐	☑	☑
Electric blower (dust-blowing mechanisms)	☑	☑	☑
Inverter	☐	☑	☑
PVC electrical insulating tape	☑	☑	☑
FTDI programmer	☐	☐	☑
Laptop	☐	☐	☑
Spare sensors,BME,PMs,DHT11,GSM,GPS,AirQo units	☐	☐	☑
Power bank	☑	☑	☑
Power adapter	☑	☑	☑

Table 1. Tools and equipment required for maintenance depending on personnel level of expertise

Based on the level, below is a tabular representation of maintenance works that can be performed.

Action	L1 (Beginner)	L2(Experienced)	L3(Expert)
Site installation/Site Update	☐	☑	☑
Monitor Swapping/Device Equipment check	☑	☐	☐
Power Adapter Swap	☑	☐	☐
Solar Panel Swap/Installation	☐	☑	☐
SimCard Swap	☐	☑	☐
External power works (Cabling)	☐	☑	☐
Cleaning and dust removal	☑	☐	☐
Sensor works and replacement	☐	☐	☑
Battery and internal power works	☐	☐	☑
GSM Communication	☐	☐	☑
Software programming and debugging	☐	☐	☑
Mount replacement	☑	☑	☐
PCB works (rare)	☐	☐	☑

Table 2. Actions recommended for maintenance depending on personnel level of expertise

2.2 Maintenance Toolkit

Requirements for maintenance	• Blower • FTDI programmer • Batteries (lithium-ion(18650)battery #solar powered battery/lithium polymer) • Device charger heads • Spare PM sensors • Jumper wires • Power banks • Screw driver set • GSM modules • Insulating tape • Solar panels • Power wire rolls • Device casings • Filters • Multimeter • IoT sim-cards • PM sensor cables • PPEs - Boots, gloves, helmet, reflector jacket, safety glasses in case of soldering/grinding etc
Vulnerable device components and accessories	Batteries, sensors, GSM modules and sim cards

Table 3. Recommended maintenance toolkit

3.0 System Maintenance

3.1 Maintenance Types

Maintenance type	• **Preventive**: scheduled routine maintenance every three months or as advised • **Corrective**: prompted by device failure or malfunction for more than 48 hours or any visible physical defect

Table 4. Maintenance types

3.2 Device Fault Diagnosis

Fault diagnosis is critical for defining the type and level of maintenance required. The process of fault diagnosis is three-fold:

Level 1: Remote Support Level,
Level 2: Field Level
Level 3: Lab/Depot Level checks.

These levels are based on the expertise of the operator or personnel on ground and type of fault. This section guides the device operator on the different steps that can be undertaken to know whether the device requires maintenance, potential faults and how these faults can be solved to restore normal device operation.

3.2.1 Level 1: Remote Support Level Diagnosis

Basic level fault diagnosis does not involve opening up the Binos Air Monitor. It takes into consideration the device communication, power supply and sensor inlet clearance checks.

Below is a summary of the checks performed on the devices with potential faults and solutions summarised:

Notable Patterns	Possible Issue	Suggested Solution
No data from the device at all	• Device unplugged • Solar panels covered with dust • Device sim-card out of data bundles. No internet access.	• Check and plug back the device if unplugged • Clean the solar panels with a squeegee or dry cloth • Buy data bundles (internet access packages) for the device sim card
Device sending uncorrelated data	• Dusty or covered PM sensors	• Carefully blow dust off the sensors
Limited speeds of data uploads Long intervals between uploads.	• Low battery	• Wait on the device to charge

Table 5. Summarised level 1 fault diagnosis

3.2.2 Level 2: Field level diagnosis

Intermediate fault diagnosis is only advisable after the basic level checks have failed to fix the issues because it requires advanced knowledge of electronics and involves opening up the device. Maintenance checks at this level involve performing advanced device communication, power supply, sensor inlet clearance and data quality and completeness checks. Below is a summary of the intermediate checks performed on the devices with potential faults and solutions summarised:

Solar panel checks

Parts	Issue identification	Expected output

Solar Panel(voltage measurement consistency)	Check for the panel voltage	6v to 7v
Solar Panel(current measurement consistency)	Check for the panel current	1A to 2A
Solar Panel Frame	Check for health of solar panel surfaces or skeleton if it is in good	Inspection if its not deformed
Solar Panel wires	Check for joint connections, wire corrosion.	If are not corroded

Table 6. Summarised solar panel inspection

Power follow ups checks

Parts	**Issue identification**	**Expected output**
Battery voltage terminals	Check for voltage	4.15v
voltage terminal points	Check for voltage	5v
GSM voltage terminals	Check out for voltage	4.2v

Table 7. Recommended voltage level checks

Fault diagnosis

Possible Failures	Issue Identification	Suggested Solutions
No communication from the device	Power Issue	• Check for loose connection/plug and possible wire corrosion. In case of loose connections or corroded wires, consider swapping the solar power cables. • Check for possible short circuiting within the device. Secure the naked wires by insulating the cables with a tape to avoid short circuits. • Clean the solar panel using a squeegee or dry cloth • Check for loose battery connections • Swap out swollen battery
	Communication Issue	• Replace IoT sim-card with a local sim-card that has data • Replace the device GSM module • Load data to the sim-card • Add an antenna to any GSM module without an antenna
Issues with received data	No data received from the sensors iePM levels = 0.0	• Make sure the sensors cables are well connected and fixed • Swap the sensors with new sensors
	Mismatch with sensor data correlations	• Blow the sensors and monitor • Swap out the sensors with a new set of sensors

Table 8. Summarised level 2 fault diagnosis

**** Where possible, reset the device following any of these maintenance works.

3.2.3 Level 3: Lab/Depot Level

Some of the faults require extensive knowledge of the air quality device operation. If the issues are not resolved at level 2 of the diagnosis process, the devices go through the third level which is executed by AirQo engineers and is fully based on the data provided by the AirQo platform. Device performance data on the AirQo platform is used for this advanced checks and and conclusions with proposed solutions provided after a rigorous cross-team analysis. Below is the step by step analysis of potential faults based on the AirQo platform data with descriptions of the device state based on the fault definitions:

Netmanager section	**Observation**	**Issue**	**Suggested Solutions**
Battery Section	Battery readings greater than the expected 4.15 or below 3.3 Battery Voltage graph i.e optimal voltage graph as shown on *figure 2a*	• Electronics connection issue • Old battery	• Adjust the regulator to fix the battery charge voltage to 4.2v • Switch the Battery
	Device not sending data - Last battery reading below or equal to 3.3V Run device test under edit section of the netmanager *figure 2b*	• Device is not powered	• Check the device plug output voltage • Check for corrosion of the solar panel wires • Check whether electricity from main switch is on
	Battery depleting with in a short period of time Battery Voltage graph *figure 2a* Swollen battery	• Old and spoilt battery	• Replace the battery • Safely dispose off the faulty batteries

Sensors Section	Sensor correlation less or equal to 0.98 Sensor correlation graph *figure 2c*	• Sensors filled with dust • Sensors are old	• Blow dust off the sensors and monitor • Check for blockage of the laser beam in the detection chamber of the PM sensor. The sensitive photoelectric sensor should be handled with care. • Swap with new sensors in case the steps above are insufficient. • If no data coming from both sensors or one after swapping sensor wires resolder the pads for JST connectors of PM sensors could be having dry joints.
Communication Section	Device not sending data - Last battery reading above 3.6V Run device test under edit section *figure b*	• Possible GSM failure issue • Possible data depletion	Check whether the GSM gets network then go on to: • Swap the device GSM module • Add an antenna to the existing GSM • Send data to the sim-card

Table 9. Summarised level 3 fault diagnosis

Visual illustrations of level 3 diagnosis are shown below:

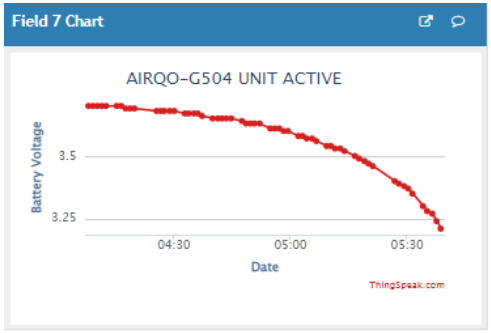

Figure 2a. Battery Voltage graph

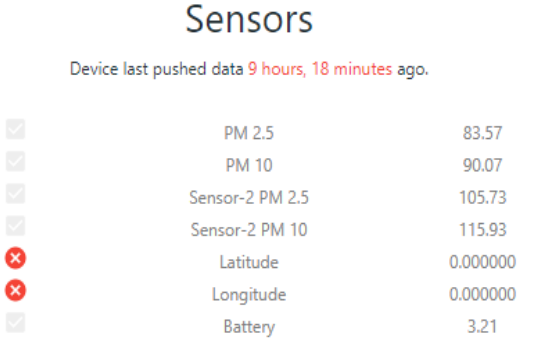

Figure 2b. Run device test output

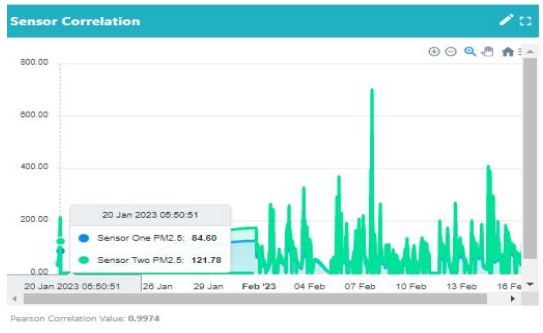

Figure 2c. Sensor correlation graph

3.3 Maintenance Levels

AirQo recognizes three levels of maintenance informed by the maintenance personnel, fault diagnosis report and severity of the fault: remote support level, AirQo field level and AirQo lab/depot level maintenance.

3.3.1 Level 1: Remote Support Level Maintenance

The remote support field-level is an organisational maintenance phase that includes off site inspections, on site servicing, handling, preventive and corrective maintenance that is carried out by a third party with remote support from AirQo engineers team. Off site inspections is a unique remote debugging service offered by the AirQo engineers and prevents the need for operators to move to device locations for fault diagnosis of the devices.

At this level, the following maintenance steps are recommended:

1. Unplug device from the power source if connected to the mains power supply.
2. Safely remove the device from the mounting.
3. Check for power source if it still delivers above 6v and current 1A or more with a multimeter.
4. Using a dust blower with medium pressure setting, blow off dust from the sensor inlets below the device.
5. Using a clean rug, gently wipe the solar panels surfaces to clear the dust.

3.3.2 Level 2: Field Level Maintenance

Field level maintenance is an intermediate maintenance carried out by AirQo engineers or authorised agents and it includes assembly and disassembly beyond the capability of the third party organisation.

At this level, the following maintenance steps are recommended:

1. Unplug device from the power source if connected to the mains power supply.
2. Safely remove the device from the mounting.
3. Gently unscrew and open the device.
4. Check whether GSM is working as expected (onboard LED starts blinking). If GSM is not working, carefully detach the module and swap with another one.
5. Check if the buzzer is working.
6. Check for battery physical state. Battery status should be as described in *table 8* above. If the battery is depleted or swollen, swap it out with a new battery.
7. Check out for power supply to the Atmega chip, GSM and from the battery.

3.3.3 Level 3: Lab/Depot Level Maintenance

Lab/Depot-level maintenance involves alterations performed on the materiel or software during inspection, repair, overhaul, or the modification or rebuild of parts. Lab/Depot level maintenance executed by AirQo engineers generally requires extensive laboratory

facilities with specialised tools and equipment. AirQo engineers are uniquely experienced and trained to undertake this level of maintenance activities.

3.3.3.1 Level 3: Three Lab/Depot Level Maintenance Works

AirQo engineers should be able to carry out the following maintenance exercises on each device at this level of maintenance:

Firmware updates

Firmware updates on the device are done using a computer and a programming cable (USB to USART) converter.

1. Download the latest version of firmware from the drive link.
2. Download the XLOADER tool for uploading the firmware to the device.
3. Plug the USB to USART converter into the computer, and open the XLOADER tool downloaded earlier.
4. Select the COM port that is assigned to your cable.

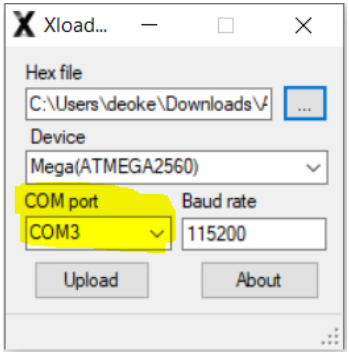

Figure 3. XLoader user interface indicating COM port selection

5. Select the downloaded firmware hex file. Make sure the selected device is (atmega2560) and baud rate is 115200, and click upload.

6. A successful upload will display the number of bytes uploaded to the device.

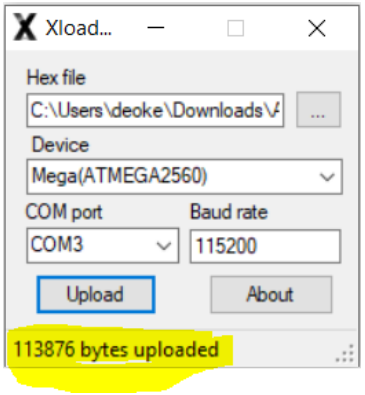

Figure 4. XLoader user interface indicating successful Firmware update

7. After the update, the device will reboot and run the updated firmware.

Battery performance check and Maintenance

Battery performance is analysed from the voltage measurements of the battery. Li-ion batteries charge up to 4.2v and discharge to 3.3v. This is the safe operating range of the device. The battery maintenance procedure is summarised in the steps below:

1. Inspect the battery for any physical damage, swelling.
2. If any damage is observed, desolder the battery and swap it out with a new battery, ensuring to maintain the correct polarity.

Maintenance guide to PM sensor change

The guide below shows order instructions on how to carry out a sensor swap from the Binos Air Monitor.. Following successful opening of the device, Go on to:-

1. Unplug the sensor wire connectors/cables.

2. Pull the sensor and pivot it away from the board.
3. Lift PM sensor from the case.
4. Fix the cables to the new set of sensors and replace them gently.
5. Using an FTDI, follow the sensor readings to learn whether the sensors are performing as expected (within +-10 ug/m^3 of each other)
6. Gently close the device.

Solar panel maintenance steps

1. Ensure the solar panel is fairly clean.
2. Physically check the cables to ensure there's no damage.
3. Measure the voltage and current output of the panels, expected to be (6v to 7v, and 500mA to 1A).
4. Replace solar panels if needed.

Power follow up checks

At this level, the following maintenance steps are recommended:

1. Unplug device from the power source if connected to the mains power supply.
2. Safely remove the device from the mounting.
3. Gently unscrew and open the device.
4. Look out for the alarm indicators as shown below.

Alarms	Alarm Tones	Tone Details	Duration
Power on	One beep	High	0.5 second
Device restart	Three beeps	High Low High	1.5 second

Transmission failure	One beep	Low	0.5 second
Low battery	Two beeps (repeated 8 seconds)	Low High	1 second

Table 9. Alarm indicators

5. Refer to troubleshooting matrix and possible corrective actions.
6. Perform corrective actions as prescribed by the matrix.
7. Refer to the AirQo Platform to ensure the device is performing as expected.

3.3.3.2 Post-Maintenance Requirements/Level 3 Maintenance

Following successful maintenance, level 3 engineers/technicians are expected to update the maintenance logs for every device on the AirQo platform to ease tracking of the maintenance and provide data for the next routine maintenance schedule.
Maintenance reports on learnings from the battery status of the device, communication as well sensor related correlation are also required for short and long-term analysis of the impact of these activities.

For further assistance, contact the AirQo Engineering team at the Makerere University, Plot 56 University Pool Road, College of Computing and Information Sciences. Level 3, Block B Software Systems Center and online via our website: www.airqo.net or email: info@airqo.net.