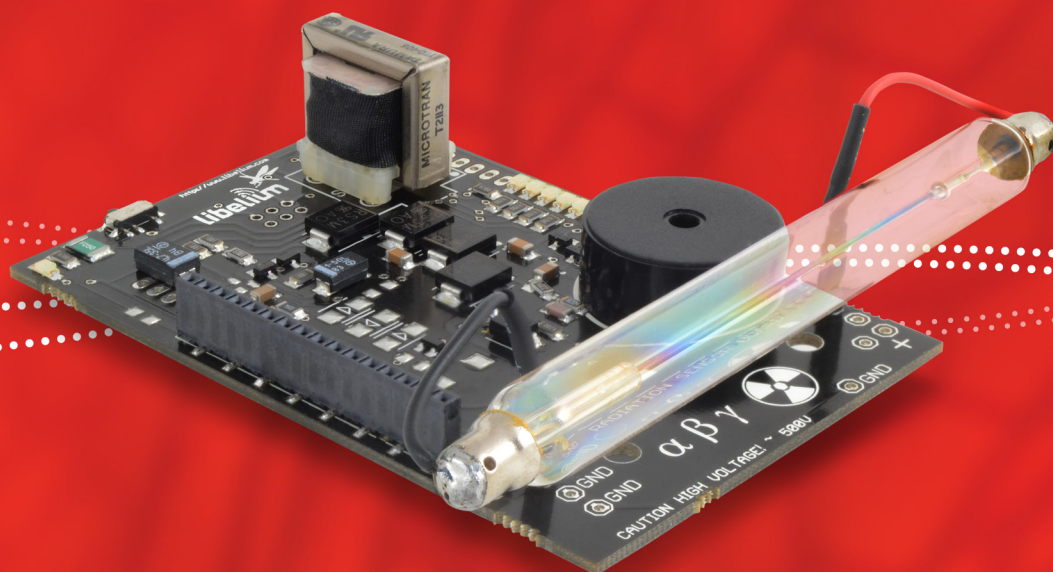


Radiation board

Technical Guide



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1. General

1.1 General and safety information

- In this section, the term “Waspote” encompasses both the Waspote device itself and its modules and sensor boards.
- Read through the document “General Conditions of Libelium Sale and Use”.
- Do not allow contact of metallic objects with the electronic part to avoid injuries and burns.
- NEVER submerge the device in any liquid.
- Keep the device in a dry place and away from any liquid which may spill.
- Waspote consists of highly sensitive electronics which is accessible to the exterior, handle with great care and avoid bangs or hard brushing against surfaces.
- Check the product specifications section for the maximum allowed power voltage and amperage range and consequently always use a current transformer and a battery which works within that range. Libelium is only responsible for the correct operation of the device with the batteries, power supplies and chargers which it supplies.
- Keep the device within the specified range of temperatures in the specifications section.
- Do not connect or power the device with damaged cables or batteries.
- Place the device in a place only accessible to maintenance personnel (a restricted area).
- Keep children away from the device in all circumstances.
- If there is an electrical failure, disconnect the main switch immediately and disconnect that battery or any other power supply that is being used.
- If using a car lighter as a power supply, be sure to respect the voltage and current data specified in the “Power Supplies” section.
- If using a battery in combination or not with a solar panel as a power supply, be sure to use the voltage and current data specified in the “Power supplies” section of Waspote technical guide
- If a software or hardware failure occurs, consult the Libelium Web Support section.
- Check that the frequency and power of the communication radio modules together with the integrated antennas are allowed in the area where you want to use the device.
- Waspote is a device to be integrated in a casing so that it is protected from environmental conditions such as light, dust, humidity or sudden changes in temperature. The board supplied “as is” is not recommended for a final installation as the electronic components are open to the air and may be damaged.
- Radiation board contains high voltage parts (500V and above). Do not touch them directly with hand or with any object under any circumstances. There is a high voltage risk.
- Geiger-Müller tube is the most sensitive part of radiation board. Never touch metallic tube contacts and do not hold the board by the Geiger tube because it can be permanently damaged.

1.2 Conditions of use

- Read the “General and Safety Information” section carefully and keep the manual for future consultation.
- Use Waspote in accordance with the electrical specifications and the environment described in the “Electrical Data” section of this manual.
- Waspote and its components and modules are supplied as electronic boards to be integrated within a final product. This product must contain an enclosure to protect it from dust, humidity and other environmental interactions. In the event of outside use, this enclosure must be rated at least IP-65.
- Do not place Waspote in contact with metallic surfaces; they could cause short-circuits which will permanently damage it.
- Never touch Geiger-Müller tube poles directly with hands or using any metallic object under any circumstance. Tube poles works with high voltages (up to 500V) which can produce spikes if they are touched. Internal circuits of radiation board and even the user could be seriously affected.

Further information you may need can be found at <http://www.libelium.com/waspote>

The “General Conditions of Libelium Sale and Use” document can be found at: <http://www.libelium.com/legal>

2. Hardware

2.1 General description

Radiation sensor board is based on a Geiger-Müller tube. Most detectors include an audio amplifier that produce an audible click on discharge. The number of pulses per second measures the intensity of the radiation field. Some Geiger counters display an exposure rate (e.g. mR·h), but this does not relate easily to a dose rate as the instrument does not discriminate between radiation of different energies.

The usual form of Geiger-Müller tube is an end-window tube. This type is so-named because the tube has a window at one end through which ionizing radiation can easily penetrate. The other end normally has the electrical connectors. There are two types of end-window tubes: the glass-mantle type and the mica window type. The glass window type will not detect alpha radiation since it is unable to penetrate the glass, but is usually cheaper and will usually detect beta radiation and X-rays. The mica window type will detect alpha radiation but is more fragile.

Most tubes will detect gamma radiation, and usually beta radiation above about 2.5 MeV. Geiger-Müller tubes will not normally detect neutrons since these do not ionise the gas. However, neutron-sensitive tubes can be produced which either have the inside of the tube coated with boron or contain Boron trifluoride or Helium-3 gas. The neutrons interact with the boron nuclei, producing alpha particles or with the Helium-3 nuclei producing Hydrogen and Tritium ions and electrons. These charged particles then trigger the normal avalanche process.

Although most tubes will detect gamma radiation, standard tubes are relatively inefficient, as most gamma photons will pass through the low density gas without interacting. Using the heavier noble gases Krypton or Xenon for the fill effects a small improvement, but dedicated gamma detectors use dense cathodes of lead or stainless steel in windowless tubes. The dense cathode then interacts with the gamma flux, producing high-energy electrons, which are then detected.

A Geiger counter, also called a Geiger-Müller counter, is a type of particle detector that measures ionizing radiation. They detect the emission of nuclear radiation: alpha particles, beta particles or gamma rays. A Geiger counter detects radiation by ionization produced in a low-pressure gas. Each particle detected produces a pulse of current, but the Geiger counter cannot distinguish the energy of the source particles. Geiger counters are popular instruments used for measurements in health physics, industry, geology and other fields, because they can be made with simple electronic circuits.

Modern instruments can report radioactivity over several orders of magnitude. Some Geiger counters can be used to detect gamma radiation, though sensitivity can be lower for high energy gamma radiation than with certain other types of detectors. The density of gas in the device is usually low, allowing most high energy gamma photons to pass through undetected. Lower energy photons are easier to detect, and are better absorbed by the detector. Examples of this are the X-ray Pancake Geiger Tube.

Wasp mote radiation board has two main parts, power circuit and signal circuit. The power part is used to provide necessary voltage for Geiger-Müller tube (~370V) and the signal circuit is used to adapt the pulses produced by the tube and connect them to microcontroller input.

Once the tube is powered, pulses can be received by Wasp mote and can be counted. Then, radiation value is obtained with an easy calculation.

Code used for radiation board is counting pulses during 10 seconds and then, number of pulses is multiplied by 6, so number of pulses per minute (cpm) is obtained. Besides that, according to tube documentation cpm is multiplied by a conversion factor of 0.00812037 to obtain radiation value in $\mu\text{SV/h}$.

2.2 Specifications

Weight: 50gr

Dimensions: 92 x 60 x 1.3 mm

Temperature Range: [-20°C, 65°C]

Electronic components used in the radiation board can be divided in next parts:

1. **High voltage power supply**

High voltage power supply uses a circuit based on an oscillator connected to a voltage multiplier made with diodes, transistors, resistors and capacitors (see schematic for detail).

2. **Adaptation circuit for the Geiger output**

The adaptation circuit for the output is based on a NPN transistor, this transistor will trigger the interrupt pin in the Waspote microcontroller which make the interrupt routine asociated to be executed, adding one to the current counter. Even this transistor is also activating/deactivating the piezo speaker and LED indicator generating the audio/visual signal.

3. **Piezo speaker and LED indicator**

The piezo speaker and LED indicator are connected to the adaptation circuit, so LED will blink with each pulse and speaker will sound with each pulse.

4. **LED bar**

LED bar is made with five standard LEDs, 3 green and 2 red. These leds are connected to digital pins of the microconroller with a series resistor. LED bar can be configured in order to give a visual information of the measured radioactivity level. Default configuration (loaded in the Waspote API example) is predefined for next threshold values in cpm units.

Radiation value (cpm)	LED bar
Value < 75	OFF
75 < Value < 150	1 Green LED
150 < Value < 400	2 Green LED
400 < Value < 600	3 Green LED
600 < Value < 900	3 Green LED, 1 Red LED
Value > 900	3 Green LED, 2 Red LED

In addition, LED bar can be handled by changing state of corresponding Waspote pin, using functions like `digitalWrite(pin,state)`, defined into Waspote API. Digital pin numbers are described on section 4.1.

All described parts and their board location are shown in next figure.

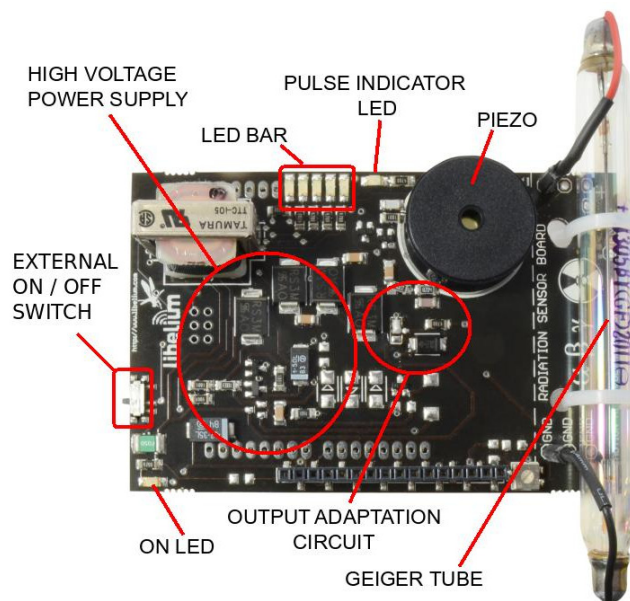


Figure 1: Parts of the radiation board

2.3 Electrical characteristics

Board power voltages: 5V / 3V3

Geiger-Müller tube power voltage: 370V

Maximum admitted current (continuous): 200mA

Maximum admitted current (peak): 300mA

Speaker: 95dB, 3.4KHz

External ON/OFF switch.

LED bar with 5 leds (3 green and 2 red).

Next figure shows schematic of radiation board.

3. Sensors

3.1 Radiation sensor. Geiger-Müller tube J305B

3.1.1 Specifications

Manufacturer: North Optic

Radiation Detection: Beta, Gamma [β , γ]

Length: 111mm

Diameter: 11mm

Recommended Voltage: 350V

Plateau Voltage: 360-440V

Sensitivity γ (60Co): 65cps/(μ R/s)

Sensitivity γ (equivalent Sievert): 108cpm / (μ Sv/h)

Max cpm: 30000

cps/mR/h: 18

cpm/m/h: 1080

cpm/ μ Sv/h: 123.147092360319

Factor: 0.00812037037037



Figure 3: North Optic Geiger-Müller Tube

Advertisement: Never touch Geiger-Müller tube ends directly with hands or using any metallic object under any circumstance. Tube ends works with high voltages (up to 500V) which can produce spikes if they are touched. Internal circuits of radiation board and even the user could be seriously affected.

3.1.2 Measurement process

Radiation sensor board is based on a Geiger-Müller tube, which consists of a tube filled with a low-pressure (~ 0.1 Atm) inert gas such as Helium, Neon or argon (usually neon), in some cases in a penning mixture, and an organic vapor or a halogen gas. The tube contains electrodes, between which there is a potential difference of several hundred volts, but no current flowing. The walls of the tube are either entirely metal or have their inside surface coated with a conductor to form the cathode while the anode is a wire passing up the center of the tube.

When ionizing radiation passes through the tube, some of the gas molecules are ionized, creating positively charged ions, and electrons. The strong electric field created by the tube's electrodes accelerates the ions towards the cathode and the electrons towards the anode. The ion pairs gain sufficient energy to ionize further gas molecules through collisions on the way, creating an avalanche of charged particles.

This results in a short, intense pulse of current which passes (or cascades) from the negative electrode to the positive electrode and is measured or counted.

There are **three types of radioactive particles**, Alpha, Beta and Gamma which are generated in the nuclear power plants, But the Geiger-Müller tube of the Wasp mote radiation board only measures Beta and Gamma particles.

More information about radioactive particles and how to measure them can be obtained following link:

<http://www.cooking-hacks.com/index.php/documentation/tutorials/geiger-counter-arduino-radiation-sensor-board>

From counts per minute (cpm) to Sieverts

Measured units by Geiger Tubes are basically the number of pulses generated. This means that in one second there will be “n” counts (counts per second - cps) and in 1 minute the counts per minute (**cpm**). This value is common for all the Geiger Tubes, however, it is not an energy value but just the number of pulses. In order to get the real energy irradiated and the amount that is absorbed by a body this value should be converted to Sieverts per hour.

The formula which passes from cpm to Sieverts depends mostly on the Geiger Tube: size, shape, material, sensibility, dead time, type of particle measured, etc. Normally a conversion factor can be extracted from the charts provided by the manufacturer in the calibration process:

$$\text{cpm} * \text{conversion factor} = \mu\text{Sv/h}$$

For example, the conversion factor for the J305B tube is 0.00812037. This means that detecting 120cpm will have the next value.

$$\text{J305B} : 120 * 0.008120370 = 0,9744\mu\text{Sv/h}$$

NOTE: This conversion factor is extracted by the manufacturer in the calibration process. However, this value is only accurate when the element which is radiating is the same as the one used in the calibration process eg: ¹³⁷Cs, ⁶⁰Co.

3.1.3 Socket

Radiation board is connected to waspmote using connector 1 and connector 2, as is shown in figure below. They are connected to Sensor I/O and I2C/UART connectors of Waspote respectively. See Waspote technical guide for a detailed description of Waspote connectors.

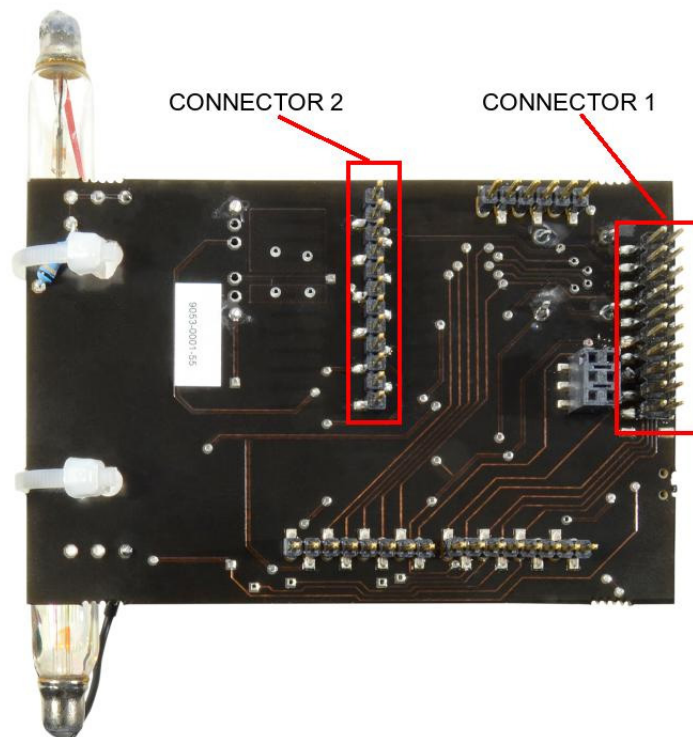


Figure 4: Connectors used with Waspote board

Moreover, the Geiger-Müller tube is connected to the radiation board using socket 1, by two pins (positive and GND). Next figure shows it in detail.

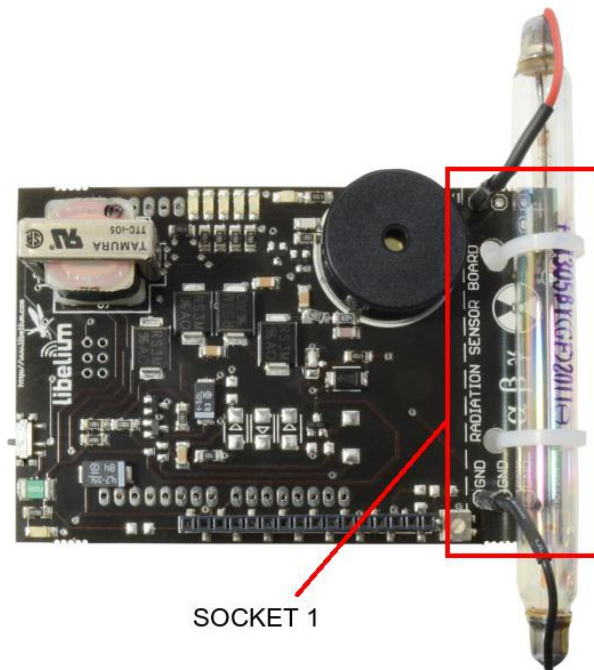


Figure 5: Connexion of Geiger tube to radiation board

4. Board configuration and programming

4.1 Hardware configuration

The radiation board has a dedicated ON/OFF switch. In order to power on the Radiation Sensor Board, place its switch in the required position as shown in next image:

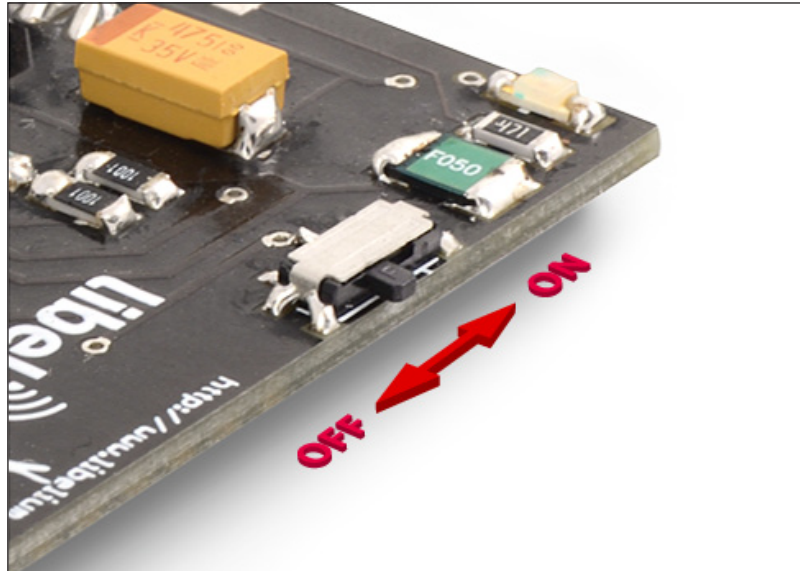


Figure 6: External ON / OFF switch

Take into account that radiation board can be switched ON/OFF also by software. **Therefore if radiation board is powered by software, dedicated external switch must be in the ON position.** The state of the board can be known looking for the led placed close to the external switch. If led is ON, board will be therefore ON.

Radiation board is powered by 5V power pin of the I/O sensor connector. However, the output is adapted to 3V3 to be able to read values with Wasp mote.

Moreover, there are several indicators on the radiation board used to show radiation levels to the user. A LED and a piezo speaker are connected to the Geiger tube output. The piezo speaker will play one audible sound, one “click” for each particle counted and the LED will blink also one time for each particle.

In addition, there is a LED bar (3 green LEDs and 2 red LEDs) which can be controlled directly by Wasp mote. LED bar is connected to these digital pins:

LED	PIN
LED green 0	DIGITAL8
LED green 1	DIGITAL6
LED green 2	DIGITAL4
LED red 0	DIGITAL2
LED red 1	DIGITAL3

This bar can be configured in order to give a visual information of the measured radioactivity level. Default configuration (**loaded in the Wasp mote API example**) is predefined for threshold values in cpm units described in 2.1, but can be easily modified by changing the code.

4.2 API

Wasp mote radiation board has its own library where necessary functions are included to handle interruptions and other events of the board.

Geiger tube output is connected to RXD1 pin to make an interrupt every generated pulse. Besides that, output is connected to DIGITAL 7 pin on order to monitor when an interrupt takes place.

In addition, the conversion factor is defined as a constant named CONV_FACTOR, with a default value of 0.008120. This constant is used to convert cpm units into $\mu\text{Sv/h}$. The user is free to adjust this value by changing the value of this constant, defined at the beginning of the radiation board header source file.

Radiation board API function are listed below. All functions are included in a class named WaspRadiationBoard.

ON()

This function powers radiation board by the internal solid state switch. External switch must be ON.

OFF()

This function removes power supply from radiation board.

init()

This function enables radiation board interrupts and test the led bar indicator by turning on all leds.

getRadiation()

Radiation value is measured during 10 seconds. After that, some calculations are done to obtain the cpm and the $\mu\text{Sv/h}$ values. It also manages interruptions caused by measured pulses of the radiation board.

Radiation value can be also read by checking public variable "radiationValue".

getRadiation(time)

Radiation value is measured during specified time. This time must be in milliseconds and also less than 60 seconds. After that, some calculations are done to obtain the cpm and the $\mu\text{Sv/h}$ values. It also manages interruptions caused by measured pulses of the radiation board. Radiation value is returned but also it can be read by checking public variable "radiationValue".

getCPM(time)

This function does the same as "getRadiation()" but the returned value is in cpm units. In addition, value can be read by checking public variable "radiationvalueCPM"

countPulse()

Adds one pulse to the pulse counter.

ledBar(int value)

Refreshes led bar value according measured value. User can modify LED bar value whenever, but always according to defined threshold levels.

An example code using the radiation board and the waspmote response through USB is listed below.

Wasp mote example code:

```
void setup()
{
  // Starting USB
  USB.begin();
  USB.println("Starting Wasp mote...");

  // Starting Radiation Board
  RadiationBoard.ON();
  RadiationBoard.init();
}

void loop(){

  float radiation=0;

  USB.println("Measuring radiation levels.");
  radiation = RadiationBoard.getRadiation();
  USB.print("radiation[uSv/h]: ");
  USB.println(radiation);
  USB.println();

  USB.println("Measuring during 25s.");
  radiation = RadiationBoard.getRadiation(25000);
  USB.print("radiation[uSv/h]: ");
  USB.println(radiation);
  USB.println();

  USB.println("Measuring during 5s cpm");
  radiation = RadiationBoard.getCPM(5000);
  USB.print("radiation[cpm]: ");
  USB.println(radiation);
  USB.println();

}
```

Wasp mote response:

```
Starting Wasp mote...
Measuring radiation levels.
radiation[uSv/h]: 0.1948800086
```

```
Measuring during 25s.
radiation[uSv/h]: 0.1559040069
```

```
Measuring during 5s cpm
radiation[cpm]: 12.0000000000
```

5. Consumption

5.1 Power control

The power of the radiation board is drawn from the Waspote and it is controlled by two ways. One way is using external switch and the other one is Waspote internal solid state switches which are accessed through the 2x11 connector, defined as SENS_5V and SENS_3V3 in the application. From solid state switch it is therefore possible to completely activate or deactivate the board power always taking into account the external switch position (see Waspote manual for more details about the switches to manage the mote's power and the appropriate section in Waspote API manual's library for more information on its handling).

5.2 Tables of consumption

Next table shows the power consumption of Waspote radiation board.

Consumption	
Minimum (constant)	11.9 mA

In addition, each pulse of Geiger tube can produce pulses of current up to 0.05 mA.

6. Maintenance

In this section, the term "Waspote" encompasses both the Waspote device itself as well as its modules and sensor boards.

- Take care with the handling of Waspote, do not drop it, bang it or move it sharply.
- Avoid putting the devices in areas of high temperatures since the electronic components may be damaged.
- The antennas are lightly threaded to the connector; do not force them as this could damage the connectors.
- Do not use any type of paint for the device, it may harm the functioning of the connections and closing mechanisms.

7. Disposal and recycling

In this section, the term “Waspote” encompasses both the Waspote device itself as well as its modules and sensor boards.

- When Waspote reaches the end of its useful life, it must be taken to a recycling point for electronic equipment.
- The equipment has to be disposed on a selective waste collection system, different to that of urban solid waste. Please, dispose it properly.
- Your distributor will inform you about the most appropriate and environmentally friendly waste process for the used product and its packaging.

