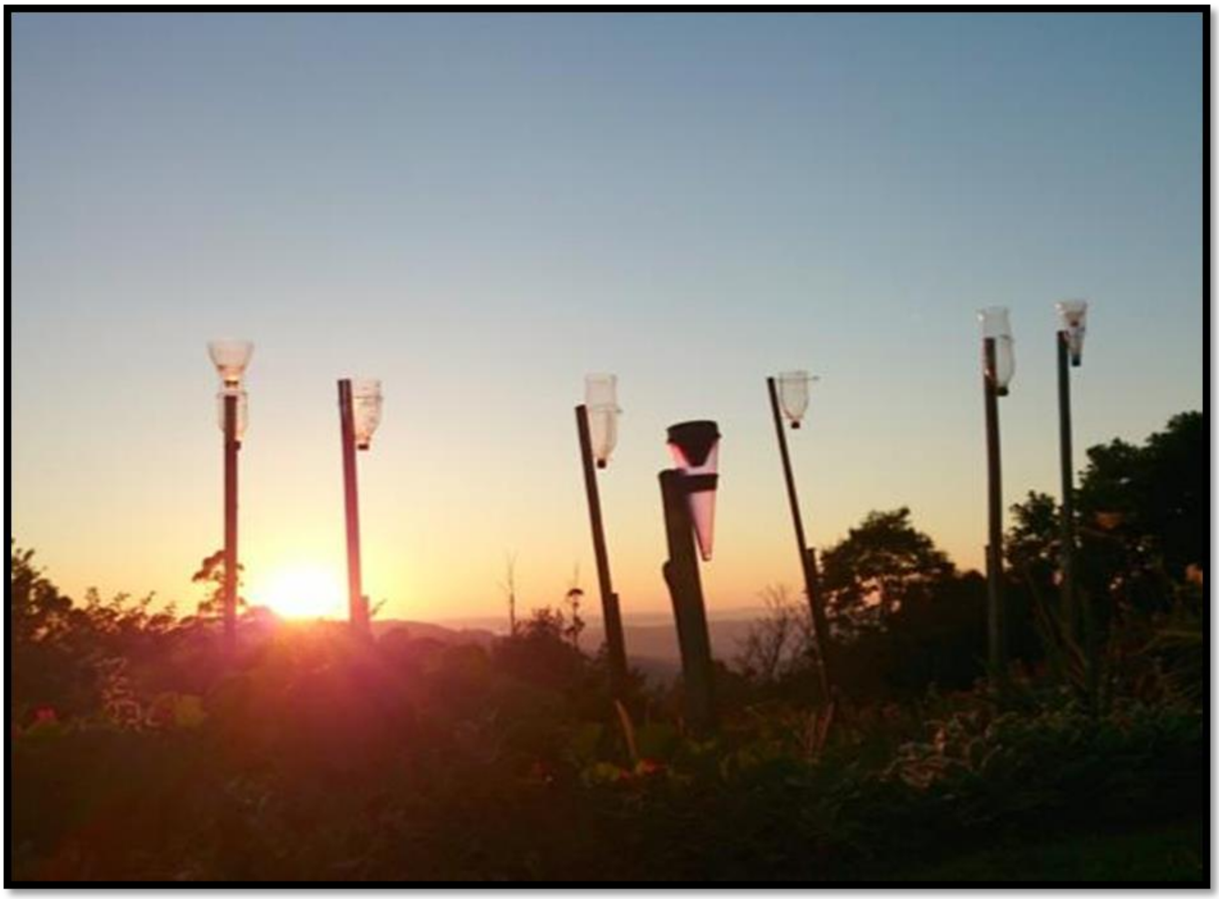
Rain Gauge Tool



A simple Citizen Science tool to measure rainfall

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Contents

1. Introduction and Background 3
   1.1. Introduction 3
   1.2. Why is Rainfall Information Important? 3
   1.3. Why do we use mm to measure rainfall? 3
   1.4. Where to use the Rain Gauge Tool: 4
2. The hydrological cycle 5
3. Rain gauge design 6
4. How to build a rain gauge 7
5. How to use the rain gauge 14
6. Acknowledgements 16

List of Figures

Figure 2.1 *Graphic representation of the water cycle* 5
Figure 3.1 *Recycled coca-cola bottle rain gauge* 6
Figure 3.2 *Bottle shapes* 6
Figure 4.1 *Materials needed* 7
Figure 4.2 *Cutting of the plastic bottle* 7
Figure 4.3 *Measuring the diameter of the plastic bottle* 8
Figure 4.4 *Using the volumetric flask and syringe to measure equivalent depth* 10
Figure 4.5 *Marking points on the bottle* 10
Figure 4.6 *Marking points on the bottle* 11
Figure 4.7 *Labelling depths on the rain gauge* 11
Figure 4.8 *Photo of a rain gauge ready for installation* 11
Figure 4.9 *Suitable distance from nearby trees* 12
Figure 4.10 *Materials needed for installation* 13
Figure 4.11 *Installation of rain gauges* 13

List of Tables

Table 4.1 **Summary of essential and potentially useful fieldwork items for the Riparian Health Audit** ... 9

1. INTRODUCTION AND BACKGROUND

1.1. Introduction

Citizen science rainfall networks are not a new concept, as they have been investigated and tried in Europe and North America (Cifelli *et al*., 2005; Micheal *et al*., 2014), where they proved to work in gathering accurate information over large spatial areas with limited resources. There is also an overabundance of information available to the layperson on the internet regarding the construction and use of homemade rain gauges, although not all of these methods are accurate.

The aim of this document is to introduce users to the water (Hydrological) cycle, and to provide a method to make and use a homemade rain gauge constructed from household items, so that the rain gauge is low cost but scientifically robust.

1.2. Why is Rainfall Information Important?

Rainfall is important in South Africa because it is our primary source of water, especially in terms of agriculture which is so vital to rural communities. The question now is: Why is it necessary to record rainfall data? This is most important in rural areas because by collecting rainfall information using a rain gauge the information can help us better understand rainfall patterns and predict future events. The data collected may also assist in planning a response to extreme rainfall events such as floods, droughts and storm frequencies. Flood warnings may be more accurate when there is evidence of rainfall patterns. The data recorded from the rain gauge can be used for analysing water supply and drainage systems as well as water resource planning. Comparing rainfall levels to the success of crops at that time is useful because understanding how rainfall affects crops may help in terms of planning when to plant crops in the future in order to obtain maximum productivity. If possible, long term data should also be recorded (year -to-year) because these records are extremely important in understanding rainfall fluctuations, seasonality and possible future patterns.

1.3. Why do we use mm to measure rainfall?

Typically, rainfall is measured in mm (or inches). But how can this be? Rainfall is a liquid, which is usually measured in mL or L. How is it that we measure rainfall in mm, which is a measure of length or depth or height, not a volume scale?

The equation for volume:

- Volume = length x width x height

So, if we were to measure rainfall by volume, it would be *the length x the width* and then multiply by the *height* of the water in the tank. Consider this example …

… Let's imagine a large water tank and next to that, an imaginary bucket. Both are empty, and then there is an imaginary thundershower. During the same storm, the water tank will collect a much **<u>larger volume</u>** of rainwater compared to the bucket. But what about the *height* of the water in the tank?

<u>Does the collected water rise by the same height in the tank as in the bucket?</u>

The answer is **YES!** …But because the tank is bigger (length and width) than the bucket, the volume that the tank collects is more than the bucket. So, we rather use height – in mm – to measure rainfall, rather than volume.

1.4. Where to use the Rain Gauge Tool:

- In schools for research and learning purposes
- In rural areas where rainfall information is sometimes limited
- In your own garden or office parking lot

2. THE HYDROLOGICAL CYCLE

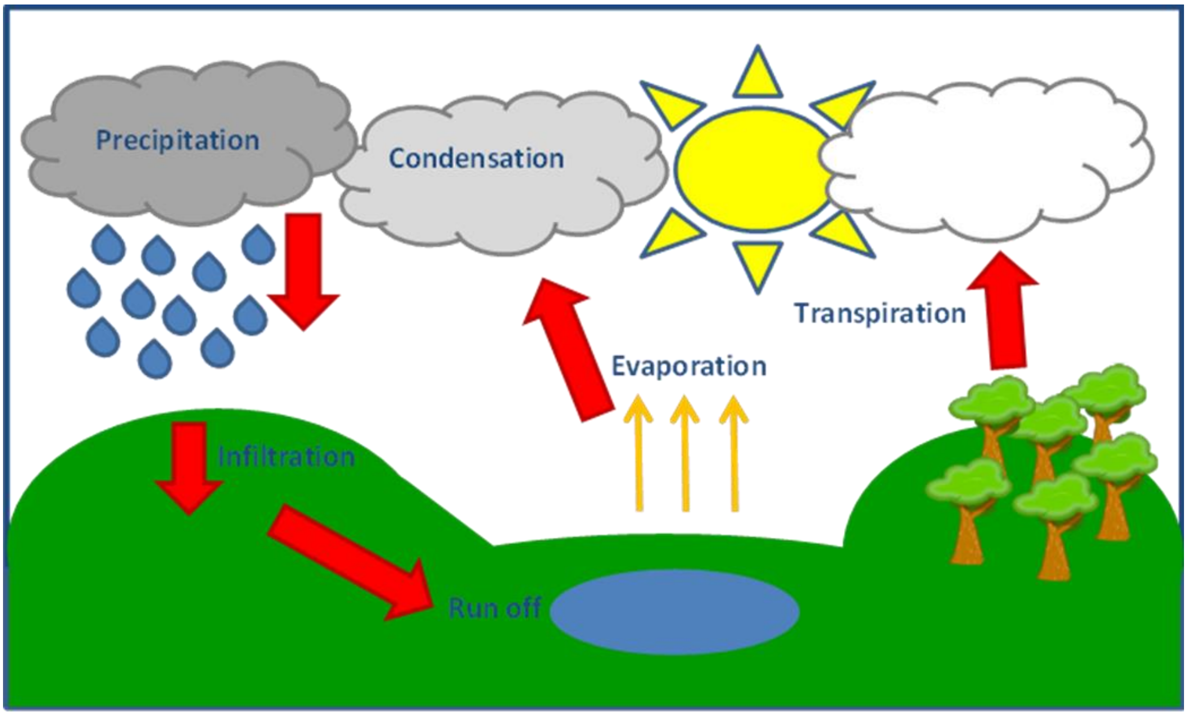

Figure 2.1 Graphic representation of the water cycle

- **Evaporation:** Is the process of water changing to a water vapour due to an increase in temperature. This occurs gradually and is dependent on the rate of temperature increase and the amount of water.
- **Condensation:** Is the opposite of evaporation, it is the process where water vapour is transformed back to water due to a change in temperature/pressure. This is a crucial stage in the hydrological cycle because it is responsible for the formation of clouds.
- **Precipitation:** Is the stage where water falls from the sky in the form of rain, sleet, hail or snow.
- **Infiltration:** Is the stage where a portion of the water that has fallen is absorbed by soil of is infiltrated into rocks through cracks and pores.
- **Run-off:** Is simply the water that has not been infiltrated by the soil, this water is transported down a gradient and so it is often a cause of soil erosion.
- **Transpiration:** Is the discharge of water vapour from plants and trees (leaves) into the atmosphere. This is one of the many reasons why trees are so important to our environment.

3. RAIN GAUGE DESIGN

The most commonly used design used to create a recycled rain gauge uses a standard 2L plastic bottle which in South Africa, is the Coca-Cola bottle. The Coca-Cola bottle has an irregularly shaped bottom, similar to that of the bottles used in the studies of Wrage et al. (1994) and Micheal et al. (2014). In their studies, they overcame this disadvantage by filling the bottom of the bottle with liquids that do not mix with water, such as cooking or motor oil or jelly.

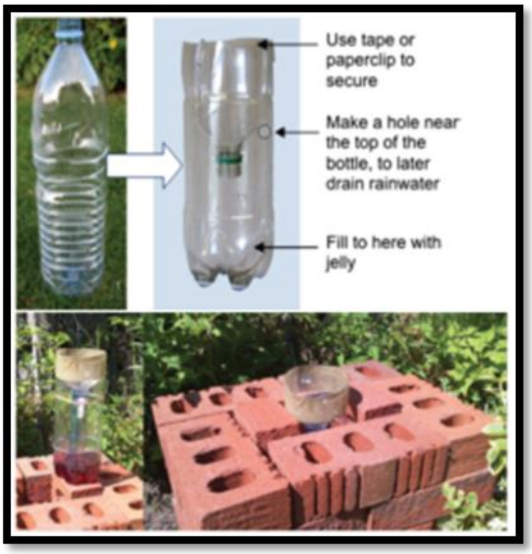

Figure 3.1 *Recycled coca-cola bottle rain gauge*

Alternatively, a slightly different design can be used that uses the bottle upside-down, with the sprout at the bottom and the base at the top, which is similar to the shape of a standard rain gauge. This eliminates the problem of calibrating the amount of rainfall with an irregular shape.

Figure 3.2 *Bottle shapes*

4. HOW TO BUILD A RAIN GAUGE

Aim:

The purpose of this guide is to give step-by-step instructions on how to build a rain gauge, including the list of materials needed and factors to consider for placement of the rain gauge. This guide shows you how to use ordinary, everyday items to make a rain gauge.

Materials

A rain gauge can be made easily and cheaply out of plastic cool-drink bottles such as Coke or Sprite etc. To begin making the rain gauge the following items will be needed:

- Plastic 2L *Coca-Cola* bottle.
- Craft knife or pair of sharp scissors
- Silicone or wax
- 10ml and 5 ml syringe
- Paper and pen to do the calibration
- 2 wire coat hangers or some wire.
- Wooden pole 1.8m tall.
- Spade.
- Axe or saw.
- Wire

Figure 4.1 Materials needed

Procedure

Step 1:

Use the craft knife to cut off the base of the bottle along the bottom ridge. Try to do this as neatly as possible as the top of the rain gauge must be level. Sand paper can be used if necessary to smooth off the edges. Highlight the central line (present in every soft-drink bottle). This will be used as a measurement line.

Figure 4.2 Cutting of the plastic bottle

Step 2:

With the cap tightly screwed on, fill the inside area of the cap with candle wax or silicone. Allow to dry.

Step 3:

Calibrating the Rain Gauge

Step 3.1. Calculating the radius of the rain gauge

You will notice that the circumference of the soft drink bottle may not be even. To compensate for this you can measure the diameter of the bottle 3 times, and then calculate the average diameter. This is necessary to do as soft drink bottles can be skewed on other sides (Figure 4.3). To obtain the radius of the gauge from the diameter we divide it by 2.

- Example: our diameter readings were: 10.2; 10.5 and 10.8. To get the average we first add these three numbers together. The answer is 31.5. We now divide this answer by 3 (the total number of measurements), to get the average. The average is: 10.5 – this is the average diameter for the gauge. The radius (r) of the bottle is ½ the diameter, so we divide the diameter (10.5) by 2. The radius is 5.25.
- Now that we know the radius of the rain gauge, we can get the surface area of the bottle.

Figure 4.3 Measuring the diameter of the plastic bottle

Step 3.2. Calculating the surface area of the bottle

To calculate the surface area of the bottle we use the equation;

Bottle surface area = π x (radius)^2; we now know the radius and the Pi (π) is a constant given as 3.14159265359. Thus;

Bottle surface area = 3.142 x (5.25)^2

Area = 86.590148cm^2

Pi is a number that is approximately equal to 3.14. It is the number you get if you divide the circumference of any circle by its diameter. It's the same for all circles

Done! We now know the surface area of the bottle, but we're not really done with our calculations since our objective was to move from mL (volume) to mm (depth).

Step 3.3. Conversion of water mL to mm

The equation for the calculation is given as:

Example 1: $$Precipitation\ (mm) = \frac{Volume\ of\ water\ (ml)}{area\ of\ funnel\ (cm^2)}\ x\ 10$$

Now, if we look at this equation we can see that $Precipitation\ (mm)$ is the subject of the equation however we want $Volume\ of\ water\ (ml)$ to be the subject because that is what we want to calculate. So this means that we need to manipulate the above equation.

After manipulation of the equation we end up with an equation that looks like this:

$$Volume\ of\ water\ (ml) = \frac{Precipitation\ (mm)\ x\ area\ of\ funnel\ (cm^2)}{10}$$

Using the above equation for volume of water represented by depth of water (mm) over the surface area of the gauge we found that 1 mm depth of water is equivalent to 8.5 mL of water added, so is 7.5 mm, 15 mm and 130 mm equivalent to 63.7 mL, 127.4 mL and 1104.3 mL, respectively. This is shown in the table below:

Table 4.1 **Summary of essential and potentially useful fieldwork items for the Riparian Health Audit**

Rain (mm)	Water (mL)	Difference (mL)	Diameter	Radius (Diameter/2)	Area= pi x rad ^2
1	8.7		10.5	5.25	86.5901
1.5	13.0	4.3			
2	17.3	4.3			
2.5	21.6	4.3			
3	26.0	4.3			
3.5	30.3	4.3			
4	34.6	4.3			
4.5	39.0	4.3			
5	43.3	4.3			
5.5	47.6	4.3			
6	52.0	4.3			
6.5	56.3	4.3			
7	60.6	4.3			
7.5	64.9	4.3			
8	69.3	4.3			
8.5	73.6	4.3			
9	77.9	4.3			
9.5	82.3	4.3			
10	86.6	4.3			

The column (A) on the left is the theoretical rainfall amount (mm), column (D) is the average diameter measured in 3.1, Column (E) is the radius obtained from the diameter measurement and column (F) is the area of the bottle calculated using the equation (1). Column (B) gives the water volume (mm) that obtained using equation (2). Lastly column (C) gives the differences in measurements from column (B).

Step 3.4. Calculation

After all the calculations have been done we can use the measuring tools such as a volumetric flask and syringe (as shown below); one can add the volume of water to represent the equivalent depth in mm.

Figure 4.4 Using the volumetric flask and syringe to measure equivalent depth

- Now that we know exactly how much water (mL) can be represented by certain length measurement (mm) we can then begin to construct and install our rain using the materials outlined in the beginning of the guide.

<u>Step 4:</u>
Calibrating the rain gauge.

Remember the excel spread sheet before? Now we are going to use it to guide us as to how much water in mL to add using the volumetric flask and syringe to give us the rainfall depth in mm. In the example given above, the addition of 8.7 mL of water is equivalent to 1 mm depth in a rain gauge. Mark that as your first point on the rain gauge as shown below.

So, how do we get the second point? Easy, we use the difference column in our table (Column C) to guide us on how much water to add next. In the example we are to add 4.3 mL of water to add 0.5 mm equivalent depth, and 43 mL for an equivalent of 5 mm. See the images to follow for a demonstration.

Figure 4.5 Marking points on the bottle

From here we can then easily add the cumulative depth of water, which is equivalent to its respective water volume (Table 1).

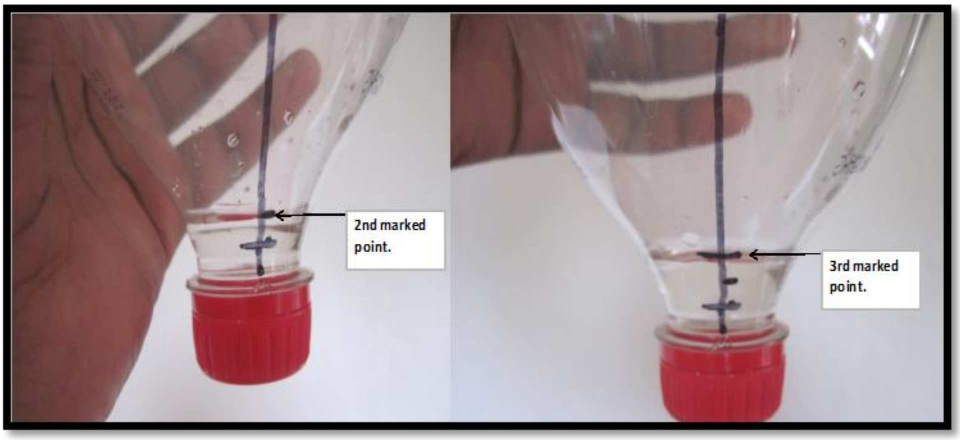

Figure 4.6 *Marking points on the bottle*

After marking all the points on the gauge, the depth represented by the lines can then be labeled.

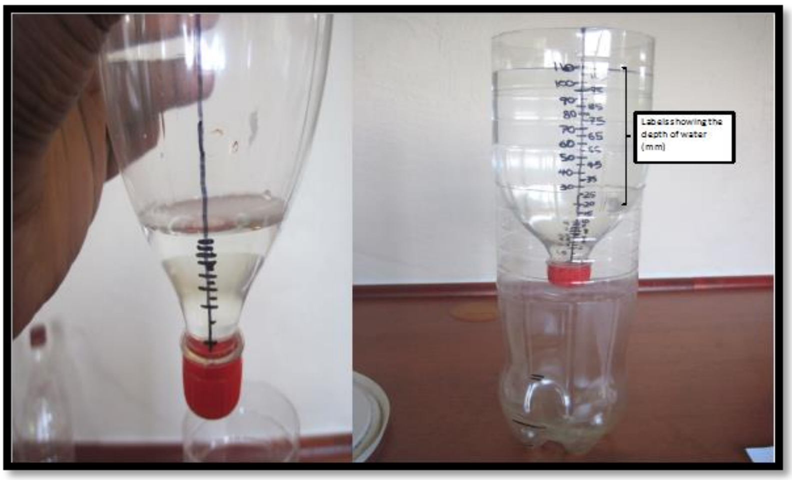

Figure 4.7 *Labelling depths on the rain gauge*

After labeling the rain gauge, it is then complete and ready for installation. However, before the gauge is installed it is important that the protocols guiding the installation of rain gauges are read.

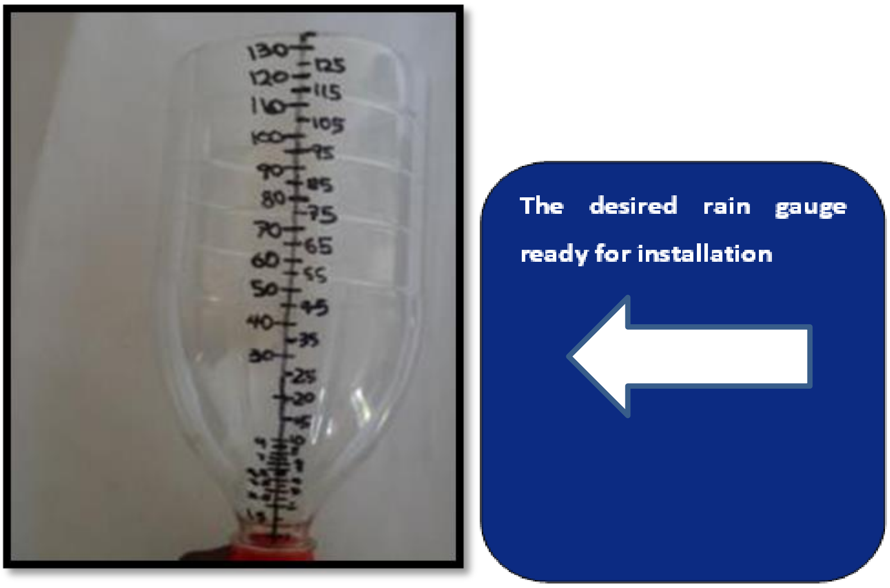

Figure 4.8 *Photo of a rain gauge ready for installation*

Step 5:

Placement (factors to consider for placement of the rain gauge):

The placement of the rain gauge is critical. There are two main criteria to consider for selecting a site for the rain gage namely:

- **The exposure of the gauge to rainfall**
- The general rule is that the rain gauge must be located at a distance no lesser than 2 x height of nearest tree, i.e. $D_{gauge} = 2 \times h_{tree}$ (see image below)

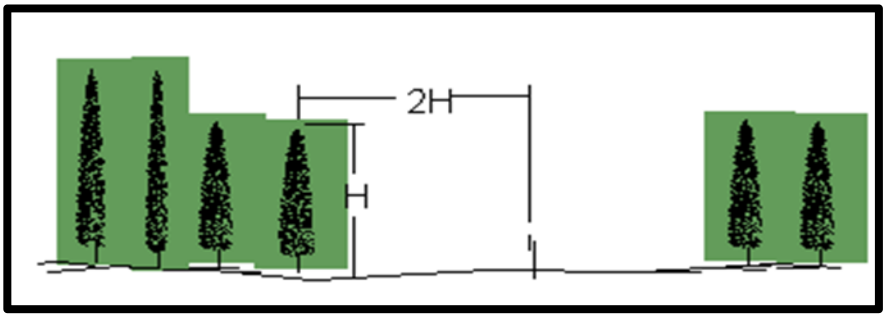

Figure 4.9 Suitable distance from nearby trees

- The gauge must also be protected from the wind in all directions as the greater the disturbance from wind, the greater the measurement error. Thus, gauges should not be placed in wide-open spaces or on top of buildings, because of wind and turbulence.
- Gauges should also not be placed close to ever-present obstructions such as trees and buildings, as these may rebound precipitation under turbulent conditions.
- The gauge should stand at least 1.2m above the ground as per South African standard requirements. This is to prevent creeping in of droplets from splash erosion and tall vegetation. It is up to the individual to decide how far below the ground the rod supporting the gauge should penetrate, but as long as the gauge will be anchored strong enough so it will not be affected during turbulent conditions.
- **The suitability of the gauge for the reader while minimizing access to trespassers.**
- The gauge should be placed in a suitable location for the observer, i.e. in a place where it can be readily accessible so to encourage daily observations. However, the gauge should not be in a conspicuous location that will attract defacement from trespassers.
- Now that we are aware of the protocols around the placement of the rain gauge we can then proceed to the installation phase.

Step 6:

Installing the rain gauge

For this step, you will need the resources below:

- A wooden stake (approximately 1.8m)
- Thin wire

Figure 4.10 Materials needed for installation

NOTE: As has been mentioned above, the gauge should stand at least 1.2 m above the ground as per South African standard requirements. It is advisable to use a log or rod of at least 1.5 m long to allow for at least 0.3 m below the ground penetration of anchoring. If however you are not able to get that length of material, you can join together two logs to make that height (as shown below in a red rectangle). You can use any material (woody or metal), as long as the gauge can stand at least 1.2 m above the ground and 0.3 m above ground if possible.

If you look again at the image below (circled in light green), you can see that wire strings are attached in such a way as to hold a rain gauge. Soft wire was used as it can be adjusted easily by any age group. A subsequent image shows the gauge being attached around a wire and ready to operate.

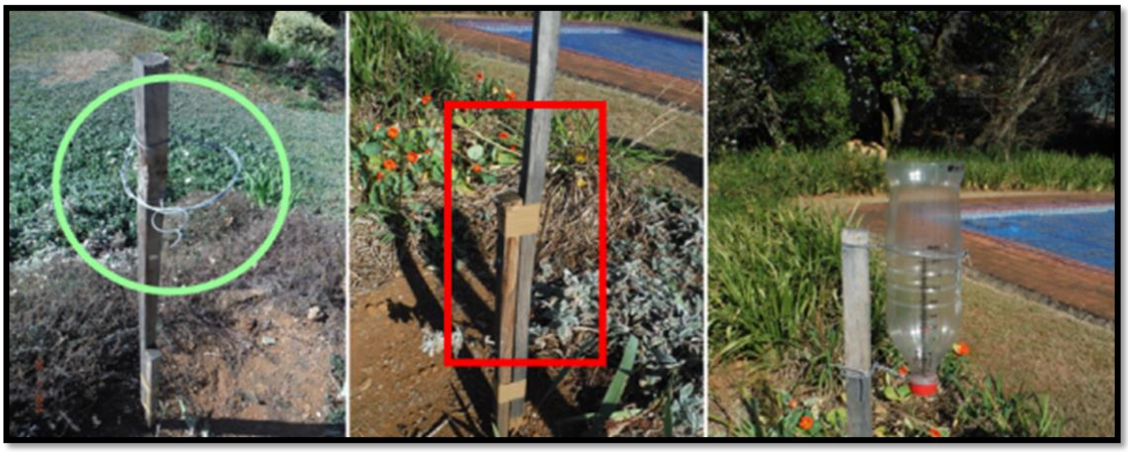

Figure 4.11 Installation of rain gauges

Step 7:
Place your bottle at the top of the wooden stake where it will be secured and mark off where the neck and the middle of the gauge are. Once these have been marked, use a saw or knife to carve ridges into the wood along your markings to make sure your gauge does not slide down the pole once it has been attached.

Step 8:
Straighten out the coat hangers that will be used to attach the gauge to the wooden stakes. Twist the wire tightly around the pole in the ridges and then into a small loop lower down for the cap of the bottle to fit into, and a larger loop higher up for the opening of the bottle.

- Make sure the wire loops can hold the bottle, and that the bottle can be removed.
- Test whether the wire is able to hold the bottle upright on the pole. It should also be strong enough to hold the bottle with water in and this should be tested.

Step 9:

Height and location of the rain gauge is important:

- In **open areas,** the rain gauge should sit approximately 60cm (2 feet) above the ground and be placed twice as far from the nearest obstacles as the height of those obstacles.
- In **developed areas,** the rain gauge should sit approximately 1.5m (5 feet) above the ground and be placed as far from the nearest obstacles as the height of those obstacles.
  - This is to ensure that nearby obstacles do not affect the catch of the rain gauge.

Step 10:

The hole can be dug, using the spade, which should be at least 25-30cm deep to ensure the pole remains sturdy.

Step 11:

Make sure the pole is standing vertical before refilling the hole with soil and compacting it so that the gauge remains level.

5. HOW TO USE THE RAIN GAUGE

- Gauges need to be placed in areas that are protected from strong wind, but at the same time, not near any obstructions such as vegetation or buildings (obstructions may affect the amount of rainfall that is falling into the gauge therefore the gauges need to be placed at a distance that is further than twice the height of the surrounding obstructions).
- Take note that rain that is less than 1mm cannot be measured as this fills the area of the cap.
- Different substances that have been considered and used in previous studies to fill the caps of the rain gauges include; silicone, gelatin, wax and oils – Silicone and wax are optimal because they are not as affected by the elements (oil can work but would have to constantly be refilled).
- The gauges with filled caps tend to perform slightly better than those that do not have filled caps.
- Smaller bottles that have a filled cap and a sprout taped on require a small hole near the top of the bottle to allow water to be emptied out.
- Continued monitoring and statistical analyses are required to determine if there is a statistical difference between the precipitations measured in the standard rain gauge and homemade gauges.

Measuring Rainfall

- Measure the widest diameter of the opening in centimeters and divide by 2 to get the radius.
- Square this number (multiply by itself) and then multiply by 3.142 (π) to get the area of the top of the funnel in cm2. This formula is area = πr2which gives us the area of a circle.
- Use the formula: rainfall (mm) = area x (interval/10) to mark off your intervals or precipitation of rain.

For example:

If the diameter of the opening is 10cm: 10/2 = 5cm.

$5^2 \times \pi = 78.55cm^2$

To mark off 1mm of rain: 78.55 x 1/10 = 7.855ml

Measure 7.855ml into your gauge and make a mark at the bottom of the meniscus

To mark off 2mm of rain: 78.55 x 2/10 = 15.71ml

Empty the gauge and measure 15.71ml into the gauge and mark the bottom of the meniscus

To mark off 50mm of rain: 78.55 x 50/10 = 392.75ml

Empty the gauge and measure 392.75ml into the gauge and mark the bottom of the meniscus

And so on.

Factors that could affect accuracy of citizen science gauges are:

- **Human error whilst marking**
- **Error whilst reading (if bottle is tilted and not level whilst marking or reading measurements)**
- **Incorrect measurement is recorded**
- **Calculation errors while calculating the area of funnel.**

6. ACKNOWLEDGEMENTS

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