



Developmet of Solar Powered Infiltrrometer

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Abstract

This research involves the design, fabrication, and calibration of the solar-powered infiltrrometer. An infiltrrometer is an instrument used to measure the rate of water infiltration into soil. There are variant methods of determining the infiltration capacity of soil with different peculiarities. The most common and simplest being Double Ring Infiltrrometer. The rate of infiltration can be measured by the use of an infiltrrometer which usually takes days before steady rate is achieved, interruption during the night affect the accuracy of the test and as such an automated system that can measure the infiltration all-round the night is eminent. As a result of this, there is a need to develop a system that will make automatic charting/recording of infiltration rate more accurate, efficient and minimize error as much as possible. This automated system charts/marks infiltration rate continuously on calibrated circular chart with a motor designed to rotate the chart at a speed of 0.00139rpm (1 revolution in 12 hours), and readings will be taken automatically, which saved time and minimize error. In development of solar powered infiltrrometer, the following are some of the materials that was put together for a successful design. A 3watt D.C motor, 30cm and 60cm Double ring infiltrrometer, 6watt AC Float Switch, recording box Motor (12v 3watt), Pump (12v 3watt) etc. The required ratings of solar set up were solar charge controller (24.4 A), PM (160 W Peak, VM (17.9 VDC), IM (8.9 A), VOC (21.4 A), ISC (10 A)), battery (220Ah) and inverter (1500watt). Solar powered infiltrrometer was developed and tested. This research has assisted in solving problem of intermittent test of infiltration of soil and providing of a good ground for accurate determination of infiltration capacity of soil.

Keywords: Infiltrrometer; Solar-Powered; Infiltration rate; Recording chart

Introduction

One of the infiltrmeters that addresses the lateral movement of water during measure as against the Single ring infiltrrometer is Double ring infiltrrometer. It is an instrument used to measure the rate of water infiltration and infiltration capacity into soil with concentrically center two rings and monitoring methods. The process of monitoring level of water in the infiltrrometer can be backed electronically and as such can be powered with different sources and Solar is the most available and accessible. Solar-powered infiltrmeters are an emerging technology that allow for more efficient and sustainable measurement of soil infiltration rates. Traditional methods for measuring infiltration rates often involve the use of electrical equipment or the manual recording of data, which can be costly, time-consuming, and may contribute to environmental pollution. The development of solar-powered infiltrmeters has the potential to address the need for electrical power, providing a more environmentally-friendly and cost-effective alternative to traditional methods. These

devices are equipped with a solar panel that provides power to the system, eliminating the need for external power sources such as batteries or electricity. This can reduce costs, increase portability, and make the technology more accessible to researchers and practitioners.

Approaches to the development of powered infiltrrometer include development of a solar-powered infiltrrometer that uses a load cell and a pressure transducer (Du *et al.*, 2021), Du *et al.* (2019) demonstrated the potential of solar-powered infiltrmeters for studying the effects of land use and vegetation cover on infiltration rates. Adeniyi *et al.* (2018) presented the design and development of a low-cost solar-powered infiltrrometer for soil hydraulic conductivity measurement, Cheng *et al.* (2019) presented the design and evaluation of a portable solar-powered mini-disk infiltrrometer for field measurements, Caniego *et al.* (2020) presented the development of a wireless solar-powered mini-disk infiltrrometer for continuous monitoring of soil infiltration capacity.

Generally, the use of solar-powered infiltrometers has helped to reduce the cost, the drudgery, the time and increase the accessibility of soil hydraulic conductivity measurement, especially in areas without a reliable power supply.

The rate of infiltration can be measured by the use of an infiltrometer which usually takes days before steady rate is achieved, interruption during the night affect the accuracy of the test and as such an automated system that can measure the infiltration all-round the night is eminent. As a result of this, there is a need to develop a system that will make automatic charting/recording of infiltration rate more accurate, efficient and minimize error as much as possible. The development of a solar powered infiltrometer ensures that there is continuous recording of infiltration rate. And readings will be taken automatically, which means it will save time and minimize error. When the infiltration capacity of an area is known, it helps to select the best crop to cultivate and other activities to be carried out.

The study is to develop a Solar-powered Infiltrometer which is cost-effective and sustainable alternative to traditional infiltrometers through the design and fabricate an infiltration charter/recorder, develop a solar system to power infiltrometer, and test running of the solar power infiltrometer.

Materials and method

Design Considerations

A number of factors are specifically taken into considerations which are of great importance in selection of materials, they are; durability, strength, availability and affordability

Materials

In development of solar powered infiltrometer, the following materials were put together for a successful design. Solar Panel, Battery, Inverter, 30cm and 60cm Double ring infiltrometer, Data recording Chart, 6watt AC Float Switch, Ball Valve, Floating Bed, Lever arm, Marker, Recording box, 1/2 inch Hose, half inch white pipe, Reservoirs, Mounting platform (Stool), Cardboard, Recording box Motor (12v 3watt), Pump (12v, 3watt), and Cables and Connectors

Methods

Infiltrometer

A prefabricated/existing double ring infiltrometer of $\varnothing 30$ cm x 30 cm and $\varnothing 60$ cm x 30 cm were adapted for the research work.

Recording Box Motor

A 3watt D.C motor was adopted to rotate the chart inside the recording box. The speed of the motor was 0.083 rev./hr.(1 rev in 12 hours) as shown in Plate 1

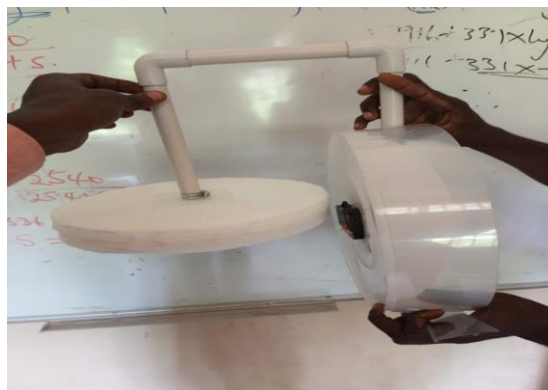


Plate 1: A 3watt D.C motor attached to the Recording box

Recording Chart

A circular cardboard of 20cm diameter was calibrated in centimeters to indicate the level of water in the reservoir as it enters the soil. The chart was formed by marking concentric circular lines in the interval of 1cm as shown in Figure 2.

Recording Box

A plastic container of diameter 20cm was adapted to form a box of 20cm by 4cm as shown in Figure 1 to house the Recording Chart.

Marker Arm

A half inch white pipe of length 50cm and two 1/2 inches elbows were used to form an inverted U shaped arm to hold the marker at the recording box end and the arm at the other end was attached to a floating plate/bed in the reservoir as shown below in Figure 2.

Reservoir

A 20 liters of transparent plastic container (30cm in diameter) was calibrated and adapted as reservoir. The upper and lower limit was indicated in the reservoir. 1/2 inch inlet and outlet were made at the top and bottom of the reservoir respectively with

the use of a back-nut and $1/2 \times 1/4$ reducer connector.

The lower and upper limit is at distance of 10cm apart which is equal to chart spacing of the chart as shown in Plate 2 (b)

Limit span

= radius of the chart area

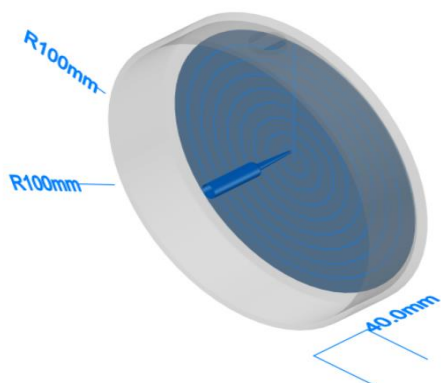


Figure 1: The Recording box with the Recording chart inside.

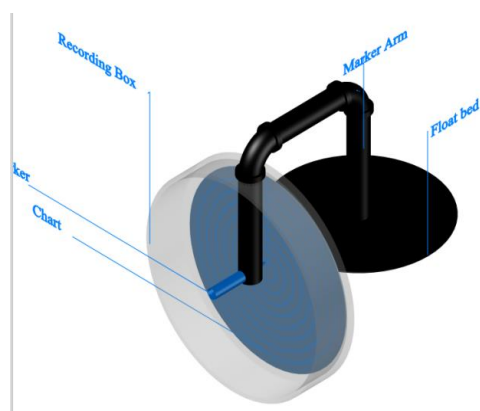


Figure 2: The Marker arm and Recording box components

A float Switch was installed inside the reservoir to regulate the flow of water from the source and into the infiltrometer.

Hose

$1/2$ inch hose of length 6m was used to connect water source to pump, pump to reservoir, and reservoir to infiltrometer's ball valve which maintained a constant water head in the inner and outer ring infiltrometer. The hose connected to ball valve is shown in Plate 2 (a)



(a)



(b)

Plate 2: (a) Outlet and hose connections, (b) The Reservoir adapted with Inlet

Development of the Solar System Energy Requirements

The size of a stand-alone PV system depends on the load demand. The load and its operating time vary for different appliances; therefore, special care must be taken during energy demand calculations. The energy consumption of the load was determined by multiplying the power rating (W) of the load by its number of hours of operation. Thus, the unit was written as watt $\times$ hour or simply Wh.

Energy demand Watt – hour

= Power rating in Watt

$\times$ Duration of operation in hours.

Thus, the daily total energy demand in Wh was calculated by adding the individual load demand of each appliance per day.

$$\begin{aligned} & \text{Total energy demand Watt – hour} \\ &= \sum (\text{Power rating in Watt} \\ &\times \text{Duration of operation in hours}). \end{aligned}$$

Sizing of Solar System Components

Solar Panel:

A solar panel is needed to capture the energy from the sun and convert it into electrical energy. The size and wattage of the solar panel will depend on the power requirements of the infiltrometer. One of the most common way to determine the sizing of the PV array is to use the lowest mean daily insolation (Solar irradiance) in peak sun hours as follows;

Total watt peak rating for modules is calculated using the energy required to be produced from the solar PV modules and the panel generation factor (Khelif, *et al.*, 2012).

$$\begin{aligned} & \text{The total size of PV array (W)} \\ &= (\text{Energy demand per day of a load (Wh)} \times \text{PGF} \\ & \quad \text{Nmodules}) \\ &= \frac{\text{Total size of the PV array (W)}}{\text{Rating of selected panels in peak}} - \text{watts}. \end{aligned}$$

Battery:

A rechargeable battery to store the electrical energy generated by the solar panel was used. The size and capacity of the battery depends on the power requirements of the infiltrometer and duration of use. While sizing the battery some parameters are needed to be considered as follows:

- Depth of Discharge (DOD) of the battery and ampere-hour (Ah) capacity of the battery.
- The number of days of autonomy (It is the number of days required to power up the whole system (backup power) without solar panels in case of full shading or rainy days.

Therefore, the charged capacity that is required is determined as follows;

$$\begin{aligned} & \text{Required charge capacity} \\ &= \text{energy supplied by the battery to the inverter input} \\ & \quad \text{/system voltage} \\ & \quad \text{Thus, Capacity of the Battery (Ah)} \\ &= \frac{\text{the usable capacity of the Battery/DOD}}{\text{Total Battery Capacity}} \\ &= \text{autonomy} \times \text{Battery Capacity} \end{aligned}$$

Charge Controller:

A charge controller is needed to regulate the amount of energy flowing from the solar panel to the battery. It helps to

prevent overcharging and damage to the battery. The charge controller rating should be 25% greater than the short circuit current of solar panel.

$$\begin{aligned} & \text{Size of solar charge controller in amperes} \\ &= \text{Short} \\ & \quad - \text{circuit current of PV} \\ & \quad \times 1.25 (\text{Safety factor}). \end{aligned}$$

Inverter:

Based on the total connected infiltrometer load to the system, the inverter power rating can be specified. Hence an inverter with power handling capacity having a size of 20-30% higher than the power running the infiltrometer system was chosen from the market. In the case of motor load, it should be 3-5 times higher than the power demand of such an appliance. (Khelif, *et al.*, 2012).

$$\begin{aligned} & \text{Inverter Size} \\ &= \text{Infiltrator Power demand} \times 1.3 \end{aligned}$$

Installations of Double Ring Infiltrator Components

Ball valve was installed on the infiltrometer to serve as water regulator to maintain constant head in both rings. ½ inch hose was used to connect the reservoir outlet to the ball valve on the infiltrometer. The record chart box was positioned and installed at one side of the reservoir with the center of the box concise with 30cm from the upper limit of the reservoir.

The float was installed half way between the limit.

$$\begin{aligned} & \text{Position of the float switch} \\ &= \text{half of the limit span}. \end{aligned}$$

½ inch hose was used to connect pump to the inlet of the reservoir and pump to the water source.

Testing and Operation Procedure.

After the double ring infiltrometer has been installed on the experimental site and ball valve installed, the power system was activated. Water was filled into the reservoir through the pump to the upper limit and as the float switch reached the upper limit, it triggered off the pump, there by stopping the pump. The infiltrometer rings were filled with water to the brim and as such, the ball valve maintained a constant head in both rings. Any infiltration from the inner ring on the soil was noticed in the reservoir.

The reduction in the level of water in reservoir due to movement of water into inner ring infiltrometer because of the infiltration caused the float bed to move down and such moved down the marker arm in recording box to indicate the level of water in the reservoir.

As water reduces due to infiltration or increases due to pumping as the float switch reach the lower limit in the reservoir, the marker marks the level in the chart against the time as the chart rotates (speed 1 revolution in 12 hours) in the recording box. The level of water in the reservoir was marked at various time of the test. The chart can be read off after 12 hours and be recorded in a report sheet.

Reading and Recording of Chart

The chart was read by noting the marks on the chart against the time interval.
Since

$$\frac{\text{the diameter of the inner ring}}{\text{= diameter of the reservoir}}$$

Then, reading at various time is as indicated on the chart and read with desired time interval.

Results and Discussion

Power Demand by the Infiltrometer

The energy required by the infiltrmeter from external power source is as tabulated in the Table 1 below. The total power demand by the infiltrmeter was 864 watt-hours. The designed rating of solar power set up for the infiltrmeter is as tabulated in Table 2. The battery designed was 220Ah of the solar system (Table 2) which supported conveniently the infiltrmeter for two days and more.

Table 1: Power Demand by the Infiltrmeter.

S/n	Items	Quantity	Energy (w)	Period (hour)	Total energy (wh)
1.	Pump	2	6	24	288
2.	Float Switch	2	10	24	480
3.	Electric Motor	1	4	24	96
					864

Designed Solar System for the Infiltrmeter

As shown in the Table 2, the solar system that supported the Infiltrmeter has two 150watt solar Panel, 30A Charge Controller, 220A Tubular Battery and 1500watt Inverter for a two-day autonomy. At full battery level (100%), the system was able to power the infiltrmeter for two days of no sunshine.

Table 2: Solar System Specifications

S/N	Item	Specification
1	Solar Panel	2 x 150 watt
2	Charge Controller	30A
3	Battery	220A
4	Inverter	1500W

The Solar Power Infiltrmeter

The double ring infiltrmeter and infiltration recorder/chartter designed and installed is as shown in the Figure 3 below and the detailed dimensions of the infiltrmeter is shown in the Third Angle Orthographic Drawing as in Figure 4. With this, automation charting of infiltration is assured.

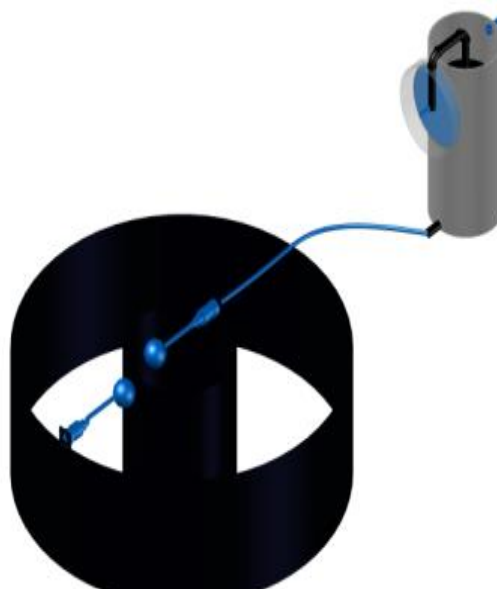


Figure 3: The Solar Powered infiltrmeter Components and installation.

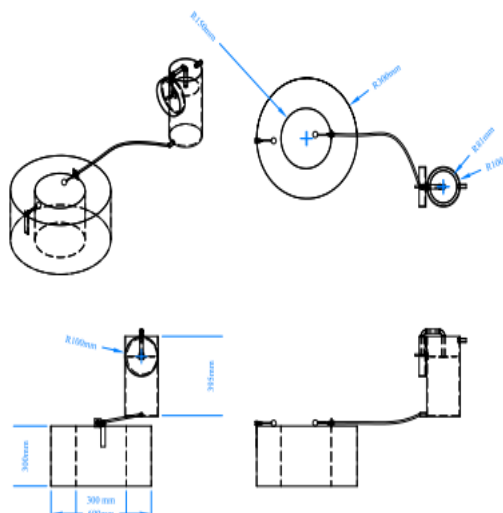


Figure 4: Third Angle Orthographic View the Solar Powered infiltrrometer.

Conclusion and recommendation

A solar powered infiltrrometer was developed and tested. The infiltration recorder helped to record/chart infiltration through the day and night without interruption and as such achieved the objectives of the project. This research has assisted in solving problem of intermittent test of infiltration of soil and providing of a good ground for accurate determination of infiltration capacity of soil.

The development of this project is a rewarding project that combines the knowledge of solar energy systems and soil engineering. As a result of this research, I recommend the use of solar powered infiltrrometer for studying infiltration rates and soil water movement in various research areas. However, I encourage and suggest that further research should be done on the mass production with industrial torches.

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