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Electrically controlled artificial system for organic waste management using Black Soldier Flies with IOT monitoring

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***Abstract*—Waste produced in a country is broadly categorized in two types, firstly organic waste and the other inorganic waste. Organic waste is harmful to human race, as when left untreated releases harmful gases like carbon dioxide, methane, hydrogen sulphide, combination of these gases is called march gas. Marsh gas penetrates underground with rainwater polluting underground water belt thus treatment of organic waste is very essential. The common techniques used in organic waste management are dumping waste in landfills, burning waste. At industrial level waste is treated through incineration, fast fermentation, composting, biogas chambers and black soldier flies (BSF). Organic waste management with the help of black soldier flies, is a technique which does not produce any toxic end product like all the other techniques which can harm the environment. BSF technique is not very popular as a lot of human involvement is required in the process thus to overcome this an electrically controlled artificial system for organic waste management using black soldier flies with IOT monitoring is designed. The system involves minimum human interaction by artificially providing environment conditions for survival of black soldier flies larvae which are responsible for organic waste treatment. The whole system can be monitored using IOT from anywhere in the world. The monitoring of the system is done with the help of sensors. The end product of the system is not toxic for environment rather it can produce income by selling the end product as a food for other animals and fertilizer for crops.**

Keywords—Organic waste management, Black Soldier Fly, electrically controlled, artificial system, IOT.

I. INTRODUCTION

Organic Waste Management is one of the major problems, organic waste degrades naturally polluting the environment. When large quantity of organic waste degrades it pollutes the environment and is harmful for the people living near to it [1]. In the year 2016, 3 million metric tons of waste generated by 50% of the world population living in the cities. This number will double by the year 2025 [2]. Various reports from research paper shows organic waste increase the production of carbon dioxide along with harmful gases such as Methane, Carbon-mono-Oxide (CO), and H2S hydrogen sulphide which can cause respiratory problems. Unmanaged organic waste blocks sewage system causing overflow of sewage water which becomes home to mosquitoes who spread diseases like dengue [3]. Organic waste treatment techniques used are dumping waste in landfills, burning of waste. Dumping of waste causes water borne diseases and pollute the water bodies around it while burning of waste causes air pollution as it releases gases like carbon-mono oxide, carbon-dioxide, methane etc. and toxic ash as a residue which pollutes soil. In Industrial treatment of organic waste, the residue left after the treatment is toxic which is harmful for environment and human beings. Nowadays black soldier flies are being used for organic waste management [4], these flies do not harm environment or human beings. Adult BSFs only consume liquids such as flower nectar or do not eat at all. Black Soldier Flies do not disgorge (vomit) on food, thus does not spread disease and neither bite nor sting. Black soldier flies' eggs grow into larvae which needs warm climate hence an artificial eco- system is required so that larvae can live without human intervention in conditions which are not favourable to them. A system has been proposed called Electrically controlled Artificial ecosystem for organic waste management. This system consists of one breeding container, one composting container, and one pupation container. Conditions inside all the containers can be monitored over the internet with the help of the Internet of Things (IoT) at any time. Sensors are used for monitoring the emission rate of harmful gases which are being released from the organic waste. Composting the organic waste through Black Soldier Flies is an aerobic process [5] hence small holes have made to let in oxygen in the system for aerobic composting of organic waste. The system is designed in a way that the whole process is cyclic in nature with less involvement of humans. The end product of the system is food for other animals and fertilizer for crops which is rich in nitrogen, phosphorous and potassium which are the basic requirements for plant growth.

II. OBJECTIVE

The main objective of this system is to manage organic waste naturally and more efficiently by developing an Artificial eco-system in the containers. The system provides an artificial environment suitable for the growth of larvae which are responsible for consuming organic waste. It is a system which automatically controls the environment of the containers by sensing the condition and acting accordingly with the help of fans, bulb, and sprinklers. The system is electrically controlled with a power of 220-volt AC supply which is further divided into 12-volt DC. The system is designed such that the process takes place automatically with less human intervention, containers are interlinked so that larvae can crawl on their own and process continues without human involvement. The system gives real time data on mobile phones with the help of IOT. The system works in a never-ending cycle as the new larvae are feed again and again in the system. The system is designed to not only manage waste but give two end products one in the form of black soldier flies processed organic waste which can be used as a

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fertilizer, other in the form of Larvae a stage of black soldier flies which can be feed to animals as food.

III. Literature Review

A technique used for organic waste management requires black soldier flies to consume waste. The scientific name of Black Soldier Fly is *Hermetia illucens*. The processes in organic waste management through Black Soldier Flies are composting of organic waste, pupation, and breeding of flies these processes are carried out cyclically. First of all, organic waste is broken down by larvae in this process larvae eat the organic waste feed to them, then the pupation process occurs in which the larvae move away from the food to burry themselves in the compost, and finally the breeding process occurs. For the first process a 4 to 6 days old black soldier flies' larvae are placed on a prefeed bed which consists of moist oat meal. For 5 days the new born are feed with fresh protein rich food which makes their digestion strong, after 5 days they are capable of eating any organic waste except bones. Black Soldiers Flies are then used for breeding to produce more larvae so that the cyclic process never ends and organic waste is managed without interruption. The Composting container is placed on a wooden frame which is 1 meter high. This system is portable because flies, larvae and pupae can be transported to any region of the world along with the system, to operate the system only power supply is required and real-time monitoring of conditions inside the containers over the internet by IoT with the help of Node MCU, temperature and humidity is by DHT-11 temperature sensor connected with Arduino Mega. The system described in this paper also give the facility of real-time monitoring of the gases released during composting of waste with the help of the MQ135 sensor, MQ7 sensor, and MS-1100 sensor. Conditions inside the containers can be controlled electrically with the help of relay, pump, sprinkler, fan and bulb. All these components are connected with Arduino Mega. The temperature required for larvae to survive is 13°C and for breeding 23°C, flies live in dark and moist place but at the time of mating, they need an adequate amount of light for hatching the eggs and mating since black soldier flies have visual receptors [6]. The end product of the system consists of pupae which acts as a food for animals and a compost rich in nitrogen, phosphorous and potassium is left over which can be used as a fertilizer for crops.

IV. Methodology

A. Controlling Unit

Arduino mega in the system is used for interfacing the components, receiving the inputs from the sensors, and for giving commands to relay, fan, bulb, pump. Arduino mega is used because it has 16 analog pins and we require 12 analog pins for connecting sensors to Arduino. It is also used for giving power supply to the sensors. Node MCU is an open-source IoT Platform. It includes a firmware which runs on ESP 8266 wi-fi chip. It is configured to connect to the Internet of Things (IoT) and similar technology systems. Node MCU is used in the system to receive input values from Arduino Mega and displays it on the Internet so that conditions inside the containers can be monitor at anytime from anywhere in the world. A dc 12-volt power supply is given to the system with the help of AC-to-DC convertor. AC power supply is directly provided to bulbs.

Environmental conditions inside the containers are maintaining the temperature at 20°C to 30°C and humidity 70%. By using a relay as a switch, bulb as heater, sprinkler sprays for moisture, and fan to cool down the temperature. Relay takes command from Arduino to turn ON or OFF the fan, bulb, and sprinkler. Fan is covered with mosquito net in container 2 and container 3 so that flies don't get hurt. As the temperature inside the container falls or rises above the desired range of temperature fan and sprinkler or bulb starts working. The temperature range has set between 20°C to 30°C as the temperature increases beyond 30°C Arduino commands the relay to switch ON fan and sprinkler to cool down the temperature. When the temperature falls below 20°C Arduino commands the relay to turn ON bulb to increase the temperature.

When BSF are feed with organic waste the temperature of the system rises. A fan is used as an exhaust to cool down the temperature inside the containers according to the conditions, the fan receives power supply from AC-to-DC convertor adaptor. Sprinklers are connected with the pump, and the pump is connected with Arduino mega. This Sprinkler is used to cool down the temperature and controlling the humidity. Bulbs have been used as heaters to heat or raise the temperature inside the container1 and container 2 when temperature falls below 20°C as below this temperature larvae will start dying. Bulb in container 3 is used for moving flies from container 2 to container 3 where they reproduce, flies follow the light source as they have light receptors. The flies lay eggs after matting on cardboard which are placed manually in container 1 where the eggs hatch and fall on the prefeed for eating and start their life cycle.

B. Gases and Temperature Monitoring

DHT-11 sensor consists of a humidity sensing component that has two electrodes with moisture holding substrate between them. As the humidity changes the conductivity and the resistance between the substrate is changed, this change in resistance is measured by the IC and read by the microcontroller. DHT 11 is a temperature and humidity sensor used in the system to sense the temperature and humidity at every one second. DHT-11 sensor is calibrated such that it gives digital values of humidity and temperature. In the system humidity values are obtained in percentage and temperature values are obtained in Celsius. The mean of the measurements is used to give commands in the system. In MQ7 Sensor SnO2 is used as sensitive material, it works on a cycle of low and high temperature and detects CO when the temperature is low (heated by 1.5V). MQ7 gas sensor has a high sensitivity to Carbon Monoxide it has high conductivity to natural gas. MQ 135 sensor is used in the system for sensing Ammonia, H2S, and other harmful gases. MQ-135 operates at 2.5V to 5.0V, it consists of a small heater with an electrochemical, uses SnO2 as conducting material with low conductivity in air. It converts the charge of conductivity to the output signal of gas concentration by using a simple electronic circuit. MS-1100 VOC formaldehyde sensor is used to detect formaldehyde gas. All the real time data is sent to mobile phones using IOT which helps in ensuring proper functioning of the system.

C. Cyclic Process

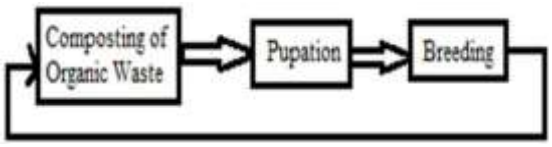

Fig. 1. Cyclic Process of Organic waste management

Organic waste management is a cyclic process which has three process involved in it which are: -

1) Composting of organic waste.
2) Pupation.
3) Breeding.

These processes are performed one after the other, first composting of organic waste, then pupation process occurs and finally at the last is the breeding process.

1) Composting of organic waste

The cardboard on which eggs are available is placed at a height in container 1. The eggs hatch and falls on the oat meal be and start eating the oat meal for first 5 days food good is supplied in the system after 5 days the digestion of larvae is strong enough to digest organic waste for next 2 weeks. It is a simple process where waste is consumed by black soldier flies' larvae. In this process organic waste is collected from different sources and put in the composting container (41 cm X 32 cm X 34 cm) for larvae to eat, larvae are introduced into the first bin, which start eating or consuming organic waste till the prepupae stage. The larval stage remains for 17days hence composting can be performed until 17 days. Larvae consume the organic waste and the excreta of these larvae is the end product. The end product is rich in Nitrogen, Phosphorous, ammonia, potassium which can be used as a fertilizer for crops. The larvae after eating are ready to become pupae at this stage conditions of container 1 are made unfavourable for their living thus, they start crawling through an opening. The pipe has holes in it so that only 10% of larvae move forward to become pupae rest are collect in a tank to be feed to animals as food.

2) Pupation

After 16 days the conditions of container 1 are made unfavourable while conditions of container 2 are made favourable due to this condition larvae start moving from container 1 to container 2 which is connected through pipe with holes in it so that only 10% of larvae moves for next stage. This process takes place in a pupation container (41 cm X 32 cm X 34 cm) covered with a mosquito net to protect the larvae from predators and insects. Larvae grow in stages when it reaches its sixth stage, then the larvae are called prepupae. In this stage, larvae stop eating and move to moist places, their mouth parts change to an appendage that aids climbing, and they seek a humid, sheltered area to pupate, they reach to the pupation container by the ramp provided in the composting container. Black soldier fly larvae pupate for 10-20 days. For pupation moisture is required which can be provided by coco peats, compost, etc. where prepupae burry in the organic waste to pupate. After 10-20 days their size increase at this time they need dark place to live thus bulb is turned off. When all pupae convert into flies, they need light to reproduce thus follow path to container 3 which has light bulb on.

3) Breeding

After flies are fully grown in container 2, they follow light and travel to container 3 where mating of flies and laying of eggs on cardboard takes place. This process happens in the breeding container (50 cm X 45 cm X 45 cm) which is also covered with a mosquito net to avoid insect and house flies, soldier flies lay their eggs which hatch in 3-4 days, soldier flies do not eat but drink water which is provided in a container. Cardboard pieces, and wood pieces can be used as a place where black soldier flies can lay eggs. Within 3 to 4 days all the eggs are laid and flies die the wood is moved and placed at a height in container one so that when eggs hatch they fall on the prefeed bed and start eating for first 5 days good food which in protein is feed which makes them strong to digest organic waste easily. This cycle continues as larvae eat, grow, reproduce and die.

D. Software Used

For programming the sensors, motor driver ICs and relay Arduino IDE has been used, ISIS proteus is used for testing the interfacing of the components interfaced with Arduino Mega.

V. DIAGRAM

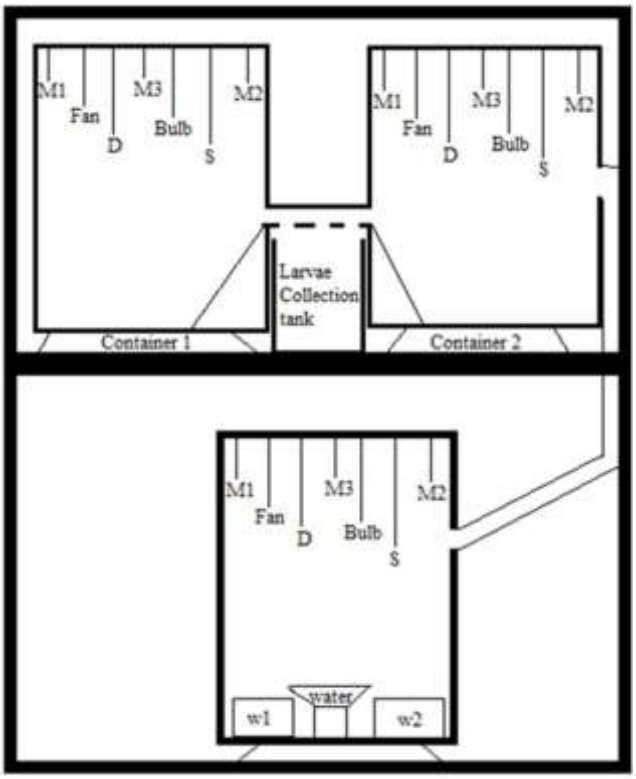

Fig. 2. Chamber3

S denotes sprinkler

M1 denotes MS-1100 (Formaldehyde sensor)

M2 denotes MQ7 sensor (Methane sensor)

M3 denotes MQ135 (Air quality sensor)

D denotes DHT-11(Temperature and Humidity sensor)

w1 denotes the first wood stand in the breeding container.

w2 denotes the second wood stand in the breeding container.

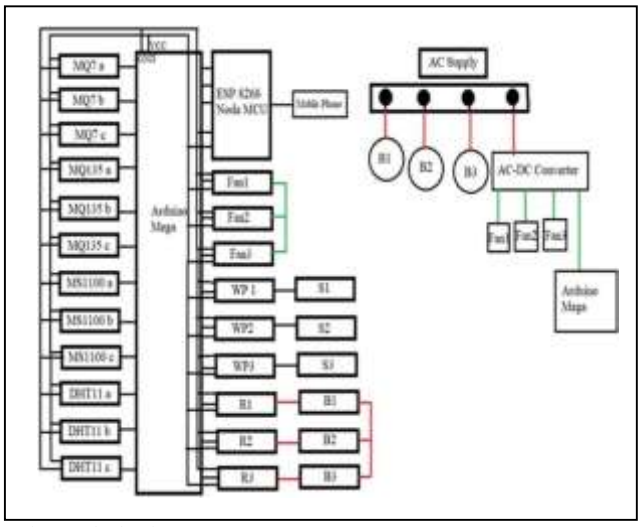

Fig. 3. Block Diagram

WP1 denotes water pump 1.

WP2 denotes water pump 2.

WP3 denotes water pump 3.

S1 denotes sprinkler 1.

S2 denotes sprinkler 2

S3 denotes sprinkler 3.

R1 denotes relay 1.

R2 denotes relay 2 R3 denotes relay 3 B1 denotes bulb 1.

B2 denotes bulb 2 B3 denotes bulb 3.

Sensors MQ7 a, MQ135 a, MS1100 a are in container 1.

Sensors MQ7 b, MQ135 b, MS1100 b are in cotainer 2.

Sensors MQ7 c, MQ135 c, MS1100 are in container 3.

VI. Working

The system described in this paper used for organic waste management, as mentioned is Black Soldier Flies technique for organic waste management. The system consists of three containers: composting container, pupation container, and breeding container respectively. To manage the organic waste using this system first of all food waste is put in the composting container which already has a moist oatmeal bed, then larvae are put in the composting container. Conditions inside the composting container are managed or controlled by the fan, sprinkler, and bulb. As the temperature rises above 30°C, Arduino commands the relay to turn ON the fan and sprinkler for spraying water sprinkler which sprays twice in a run, the bulb does not work in this condition. When the temperature falls below 20 °C again Arduino commands the relay to turn on the bulb to increase the temperature, fan and sprinkler do not work in this condition. Larvae consume the organic waste till their prepupal stage, which is after 2 weeks of waste consumption, at their prepupal stage larvae come out of the waste in search of a moist and sheltered place for pupation. This step is possible only when the condition of composting container 1 is made unsuitable for living which is done with the help of bulb. When the temperature of composting container rises the larvae move from the container to pupation container 2 where the conditions of living are suitable. The larvae crawl through pipe connecting both the containers, pipe has holes in it from where larvae drop in a collecting container and only 10%move in container 2. In the pupation container, coco peat is used to provide moisture for pupation, survival conditions for pupae are managed inside the pupation container by using the same technique used in the composting container through bulb, fan, temperature sensor and water sprinkler. When pupation stage is over Black Soldier Fly come out from the coco peat bed, Black Soldier flies need light for reproduction and hatching the eggs hence flies go to the breeding container 3 following light where matting and laying of eggs occur. Conditions inside the breeding container are managed by the same technique used in the composting container 1 and pupation container 2 but the fan is not provided here for the safety of flies, sprinkler sprays once in one run. A water container is provided in this stage as flies only drink water. For the flies to lay eggs a wooden plate or cardboard is placed in which each fly lay around 200-300 eggs. In this way survival conditions for flies are controlled. During the composting of waste gases that are released which are monitored by the sensors mentioned describe above in the paper, the sensor receives input from the environment of containers and sends it to the Arduino. Arduino sends data to Node MCU and Node MCU connects with the Internet and displays the reading of sensors on your mobile phone over internet. The power consumed by the system is less as fan, bulb and sprinkler only starts when required. A single AC power supply is given to system which gets divided and converter to 12v dc for proper power distribution. Power distribution in the system is important because the system is electrically controlled, disrupted power supply will lead to hindrance in the system.

VII. Future Scope

This system is helpful for managing the organic waste on large scale and also help to reduce the pollution. This system is helpful as it produces great quality fertilizer. farmers can compost their waste crops by using this system instead of burning their crops which will help in reducing air pollution, it produces rich protein food for fish farms and poultry farms in the form of Larvae. This system can also be used in the regions where the Black soldier flies organic waste treatment technique cannot be used due to unsuitable environmental conditions.

VIII. Result

In the proposed system temperature and humidity are major factors that have controlled efficiently by using fan, bulb, and sprinkler. It has been observed that the temperature range in the composting container 1 was 25.0 °C to 25.7 °C and humidity range from 60.4% to 62.1%. The mean temperature in the composting container has been observed as

25.5 °C. The pupation container 2 temperature range has been recorded from 25.4 °C to 25.6 °C with a mean temperature of 25.5°C and humidity range from 60.2% to 62.5%. In the breeding container 3, 25.5 °C to 25.7°C with a mean temperature of 25.9°C was observed.

In this system, Arduino mega is the master controller along with relay controlling the temperature and humidity in all the containers. Sensors measure or sense the emission rate of gases released during composting. Node MCU provides connectivity to the internet, with the help of the Internet of Things results are displayed in digital form on the internet on mobile phones.

IX. Conclusion

This system manages the organic waste naturally, standard quality natural fertilizers are obtained which can be used by farmers instead of using toxic Urea and DDT. The fertilizer obtained from this system is rich in Nitrogen and ammonia. This system creates income opportunities by selling the larvae and prepupae as food to poultry farms, fish farms and by selling fertilizer produced by this system. The system helps in reducing pollution by reduces dumping of organic waste and rotting of organic waste does not take place hence reducing global warming and water pollution. As it is a cyclic process ton of waste is managed using this system.

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