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Automated Plastic Collector (Autoplastor) with an Improvised Pyrolysis System as an Innovative Solution to Free-Plastic Waste towards a Greener School Environment

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Abstract
This research project aimed to develop an automated plastic collector with an improvised pyrolysis system as an innovative solution to free-plastic waste towards a greener school environment. The project was designed for automated segregation of plastic waste inside the school. It was carefully designed and built to separate plastic from other types of waste materials collected. In addition, this project includes an improvised pyrolysis system that enables segregated plastics to undergo the pyrolysis process. Servo motors were used to enable the blockage of plastic waste from other waste materials and redirect the route of the plastic waste towards the pyrolysis system. Motors were triggered by the sensors attached to the microcontroller. To ensure the accuracy of the designed project, a series of experimental trials and analyses of the results were done. Findings revealed that the designed project was effective in plastic waste segregation. In addition, an improvised pyrolysis system shows a remarkable result.

Keywords: *Automated plastic collector, pyrolysis system, free-plastic waste, and innovative solution.*

1. Introduction

Depletion of fossil fuel affects the rate of economic growth, unsustainable sources of this type of energy has led to the development of different methods in searching for useful methods and resources to help minimize the effect of degrading fossil fuel supply, particularly in the production of crude oil, natural gas, and coal. The present crisis that the world is facing today triggered the interest of many sectors to unleash the potential of renewable resources by exploiting possibilities of extracting energy from them. Consideration of plastic waste as one of the potential sources of energy has now been considered as full-scale economic activity [1]. Plastics have become a part of our daily routines; we eat in plastics even inside our homes. Oceans are polluted by plastics, in fact, about 80 million tons of plastics were thrown in the ocean every year. Every day, more and more plastics have become part of human lives with increasing capacities of available plastic waste disposal. Plastic biodegradation became part of the strategy used in mitigating the impact of plastic waste; then the biodegradable plastics developed by many companies around the globe. However, increasing numbers of generated plastic waste every year has become a modern pandemic that the world is facing today [2]. Incremental usage of plastics in human lives become detrimental to the environment, companies are using plastics for food packaging that requires less demand for work in waste disposal. Similarly, students find it handful to segregate plastics from other types of waste materials. In this regard, the development of machines has been introduced in addressing this prevailing problem, laws, and policies have been implemented, but still, human beings are hesitant to adopt. This is a cold hard truth that increasing demand for easily accessible products directly affected the environment [3]. Global generation of plastic waste significantly affected the environment, thus, conversion of this waste material into valuable usages such as hydrocarbons or feedstock in the petrochemical industry has opened a new door towards renewable energy resources [4].

In 2013, the development of automated machine as waste sorter disposal system has been introduced, this project sorts waste materials such as metal, plastic, glass, and paper automatically, and it uses conventional sensors to identify waste materials according to their category. This project transformed waste disposal into a more advanced waste disposal system in minimizing the effect of improper waste segregation practices [5]. An increase in population and the rapid growth of industrialization has led to a large scale of waste generation. Implementation of automated waste segregator have been introduced at a household level, this waste disposal scheme intended to improve the waste segregation process which identifies and separate waste materials into metal, wet and dry waste [6]. Each day, we are moving towards a digitized community, as we moved to digitization, more buildings and companies were rose which increased urbanization and industrialization and contributed a lot to the generation of large scale waste materials. Looking at this dilemma, innovations should take place to cope with this growing population and minimize the impact of untreated waste dumped in the landfill as much as possible [6]. Waste management demand work hour since dumping waste materials in the landfill requires tedious effort and somehow annoying to the households. Reducing human intervention in waste management disposal while ensuring proper disposal of waste is an effective method. In this scope, IoT based automatic waste segregator has been developed, this is to segregate waste materials with real-time monitoring of garbage level in the trash bin; this is done to ensure proper waste disposal management among households [7]. Standalone trash bins that automatically separate plastic bottles and tin cans have also been developed to help segregate recyclable materials for future use [8]. Plastic commodities have a direct or indirect contribution to the generation of plastic waste materials brought about by the modernization due to its easily accessible products and low-cost materials. Inevitable generation of plastic waste materials had been observed for a long year as it increases global impact day by day. In this concern, it is a wiser approach to look into the potential applications of plastic waste instead of dumping it in the landfills. Parallel to this concern, possibilities of harnessing fuel from plastic waste materials were taken into laboratory concern [1].

In the Philippines, waste generation contributed to the major problem in environmental degradation due to the rapid economic and population growth of the country. The 3R's (reduce, reuse, and recycle) program of the Local Government Units (LGUs) of the Philippines has become the solid waste management method of the country. The passage of the Republic Act No. 9003 (RA 9003) also known as the ecological solid waste management program of the country strengthens the waste management disposals of every municipality in the Philippines. However, despite the passage of RA 9003, about 21% and 4% of the Local Government Units (LGUs) in the country comply and have functional recovery facilities and sanitary landfills. Despite the implementation of the program, solid waste management of the country is considered to be ineffective. To have an effective program, Local Government Units (LGUs) should plan an innovative method to address the solid waste management problem of the country and to comply with the existing R.A.9003 [9]. According to the study conducted to capture the knowledge, attitudes, and practices among students in the Philippine state university on solid waste management, it was revealed that the knowledge and attitude of the students registered a higher average rating on solid waste management. However, students' practice on solid waste management was inconsistent with that of the knowledge and attitude average rating which registered a lower average rating. This means that students were both equipped with knowledge and attitude towards proper waste management but lacked of practices on proper waste segregation [10].

This matter pushed the interest of the researchers to develop a school-based research project known as an automated plastic collector (autoplastor) with an improvised pyrolysis system as an innovative solution to free-plastic waste towards a greener school environment to address the problem. Generally, this research project aimed to develop an automated plastic collector as a waste segregation system that collected and separated plastic waste from other types of waste materials, it also attempted to convert plastic waste into renewable resources such as fuel or gas as an alternative to the plastic waste dumpsite. Specifically, the research project aimed at a.) Determine the functional effectiveness of the project designed in terms of accuracy test reading of the following types of waste materials: plastic waste material recognition, metal waste material recognition, paper waste material recognition, wood waste material recognition, and organic waste material recognition, b.) identify the types of waste materials generated in the duration of implementation through the waste materials collected by the system, c.) determine the effectiveness of the project designed in the plastic waste material collection in terms of the number of masses per week, and d.) examine the potential aspect of improvised pyrolysis of the project design in an attempt to generate fuel or gas from the collected and segregated plastic waste materials.

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2. Materials and Methods

2.1 Materials

The hardware components used in the development of this school-based research project designed were Arduino Uno Microcontroller, capacitive proximity sensors, servo motor metal gears, DC motors, breadboard, jumper wires and wires, AC/DC power supply, and wood. Materials for building the pyrolysis system and all other materials needed were all recyclable materials found in the junk shop. Careful planning and design of the research project were done to ensure that all materials needed were available and ready to use. The microcontroller board that serves as the brain of the project design is based on the ATmega328. It has 14 digital input/output pins of which 6 can be used as PWM outputs, 6 analog inputs, 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller and write the appropriate algorithms. It can also power it with an AC-to-DC adapter or battery to make it a standalone controller. Layouts and blueprints of the project designed were collaboratively planned by the researchers. The design was shown to a qualified expert in the field for further improvement of the project designed.

2.2 Methods

2.2.1 System Design

The proposed system requires two (2) capacitive sensors, there are five (5) components namely, Arduino Uno Microcontroller, DC Motor, Breadboard, Jumpers Wires, and Power Supply. Our central processing system is Arduino Uno Microcontroller that receives data from the sensors and used it to command the system to perform specific functions based on the algorithms and parameters set in the Arduino. Capacitive proximity sensors were the triggering component of the design; it triggered the servo motors as it detected waste materials passes through the sensors. The Servo motor serves as the separator/segregator hand of the system that blocks the passage of waste materials and redirected the route of the detected waste, depending on the recognition of the sensors through the algorithms and parameters encoded in the microcontroller for plastic and non-plastic types of materials. To hook the waste materials thrown on the system, a wooden funnel shape like a cone that big enough to swallow a 16 oz plastic bottle was attached to the system. A conveyor belt powered by two (2) high torque DC motors were constantly rotating and moving that serve as the transporting mechanism of the design, as soon as the waste materials entered the funnel shape opener, it will be automatically transported by the conveyor belt for recognition purposes as it passes through the sensors. For some instances, if the waste material detected is plastic, it will then be delivered to the pyrolysis chamber by the conveyor belt. Other rubbishes will be blocked and put into a separate container by the servo motor. The system is designed primarily to collect plastic waste materials and delivered them to the pyrolysis chamber in an attempt to extract fuel or gas from it as an alternative to the plastic dumpsite.

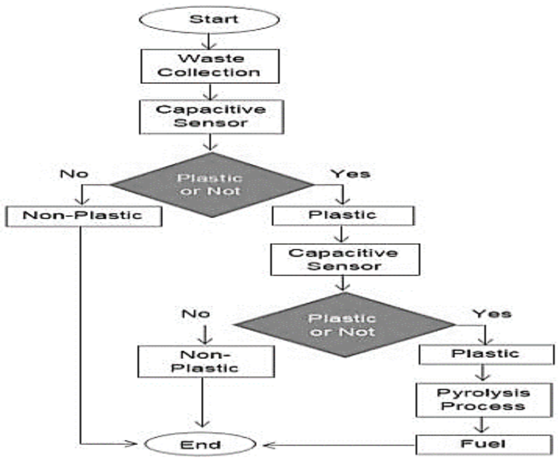

Fig. 1 Shows the Conceptual Design of the Project

2.2.2 Block Diagram

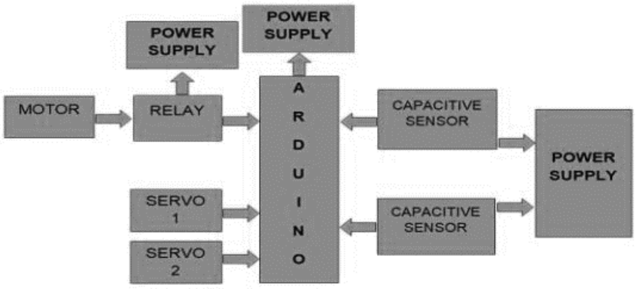

Fig. 2 Shows the Block Diagram of the Project

2.2.3 Collection of Waste Materials and the Pyrolysis Process

The research project was done to minimize plastic waste inside the school campus, careful planning was taken into a priority for the successful development of the research project. The project designed was placed nearby the school canteen in anticipation of the waste generated by the students from the food packaging, plastic bottles, and other sources of plastic waste from the school canteen. As part of the research project, students were instructed to throw their waste materials directly into the system, researchers are monitoring the collection of waste materials to ensure that students were not destroying or playing by with the project design. During the process, researchers have attentively recorded any observable traits during the collection of waste materials. The pyrolysis process took place when the pyrolysis chamber is full of plastics waste materials. Pyrolysis chamber placed in the secured area where safety protocols were taking into consideration, particularly in dealing with fire and thermal process. The need for human intervention in the pyrolysis process was employed particularly in the fire ignition of the pyrolysis chamber. This is done to ensure the safety protocols inside the school. All the necessary data needed during the entire process were carefully treated, recorded, and documented for data analysis.

2.2.4 Statistical Analysis

All the data obtained during the conduct of this research project were carefully treated and recorded to support the findings of this study. This project was built carefully. A series of intensive laboratory tests for accuracy was done to ensure the functionalities of the project design. To determine the accuracy and functionality of the components, descriptive statistics were used. Similarly, the same statistical treatment was used to identify the types of waste materials collected by the system. In an attempt to extract fuel or gas from the plastic waste, simple flammability tests using vertical and horizontal flammability testing were used and qualitative data were also employed to described the results.

3. Results and Discussion

3.1 Accuracy recognition test on the types of waste materials

Table 1 shows the accuracy recognition test done on the types of waste materials. To ensure the accuracy of project design components, a series of intensive experimental trials and analyses were made. Different types of waste material samples were collected and tested. For the researchers to set the parameters, each of the sample waste material was carefully tested using analog sensors and recorded its sensing range value. The analog value taken from these trials were used as initial recognition parameters for each of the waste material sample, final trials proceeded after the revision of the algorithms and parameters encoded on the microcontroller, all the necessary data were carefully recorded, documented, and analyzed. In this regard, mean computed values were used to write the functions, algorithms, and parameters' range accurately. Based on the series of intensive experimental trials, the following observations were noted: the paper waste material sample registered the highest mean during the trials with a 458.50 mean computed value. A metal waste material sample comes next with a 230.40 mean computed value. Next was the organic waste material sample as it registered 64 mean computed value. A wood waste material sample comes fourth with a 12.80 mean computed value, and Plastic waste material sample obtained a zero mean computed value due to its low permittivity value than the other waste material samples so that the parameter set for plastic seems to have no changes at all in the entire trials. However, plastic recognition of the system is still detected accurately by the sensors. This finding is affirmed by the study which stated that the capacitive proximity sensor detects materials such as plastic based on the difference of permittivity value of the sample [11]. Furthermore, the position and distance range of the materials from the system could also contribute to the accuracy of the detection of the materials. If correctly setup, a capacitive sensor is tested accurate in sorting and identifying different materials and can be used to accurately design an automated waste segregator [12]. Likewise, the correct setup of speed control and torque adjustment of conveyor belt in transporting material was effective in timely exposed material into the sensors [13].

Table 1. Accuracy recognition test on the types of waste materials based on its parameters 'range

Types of waste materials	Trial 1 (serial code)	Trial 2 (serial code)	Trial 3 (serial code)	Trial 4 (serial code)	Trial 5 (serial code)	Mean
S1. Plastic waste material recognition parameter	0	0	0	0	0	0
S2. Metal waste material recognition parameter	342	406	370	28	6	230.40
S3. Paper waste material recognition parameter	1023	203	38	4	1023	458.20
S4. Wood waste material recognition parameter	8	7	15	12	22	12.80
S5. Organic waste material recognition parameter	70	14	204	27	5	64

3.2 Types of waste materials collected by the project design

Table 2 presented the types of waste materials generated by the school as collected by the project design during the one-month period of implementation. Based on the table, the highest observed waste generated materials were Polyethylene terephthalate (PET) obtaining a mean value of 3.50 with a verbal description of *Highly Observed*. Food wastes also registered a mean value of 3.43 with a verbal description of *Highly Observed*. Other types of waste materials like Mixed paper with a mean value of 2.87, Highly density polyethylene (HDPE) with a mean value of 2.67, used beverage container with 2.87 mean value, and wood waste with 2.87 of mean value were also registered a verbal description of *Observed*. Likewise, corrugated cardboard, polystyrene, and aluminum were among the less observed waste materials. Based on the results, polyethylene terephthalate (PET) seems to be the most collected waste material generated in the school. This finding supported by the previous study which emphasized that plastics became part of human lives, companies were opted to use plastics in their products as a packaging material due to their flexibility, and this is commonly used in food packaging [3]. Thus, most of the selling products of the school canteen were wrapped in plastics. In addition, food wastes were also noted as one of the most collected waste materials, this means that despite the prevailing policies and methods in waste management, the students equipped with knowledge and attitude towards proper waste management, still lacked of voluntary practices on proper waste segregation [10].

Table 2. Types of waste materials collected by the project design within one (1) month of implementation

Types of waste materials	Mean	Verbal Description
1. Corrugated Cardboard	2.20	Less observed
2. Mixed paper	2.87	Observed
3. Polyethylene terephthalate (PET)	3.50	Highly observed
4. High density polyethylene (HDPE)	2.67	Observed
5. Polystyrene	2.13	Less observed
6. Used beverage container	2.87	Observed
7. Aluminum	1.90	Less observed
8. Food waste	3.43	Highly observed
9. Wood waste	2.87	Observed

Legend:
3.25 – 3.99 – Highly Observed
2.50 – 3.24 – Observed
1.75 – 2.49 – Less observed
1.0 – 1.74 – Least observed

3.3 Estimated collection of generated plastic waste material

Table 3 revealed the amount of plastic waste collected inside the school premises in kilograms per week. The AutoPlastor was used and implemented inside the school for four weeks. This is done to evaluate the effectiveness of the design in collecting plastic waste materials. In the first week of implementation, 9.8 kilograms of waste plastic were collected. For the following weeks, 13.5 kilos of plastic waste were collected. For week 3 of data gathering and observation, 19 kilos of plastic waste were collected while 28.7 kilos of plastic waste materials were collected for the fourth week. The last week of the implementation observed to be the highest collected amount of plastics waste materials due to the series of a program facilitated by the school which was occurred during this time of data gathering procedures. Likewise, this finding affirmed by the previous study conducted which stated that due to the large scale of its applications, plastic materials often used in many products for flexibility and less demand of work for disposal, this caused the throw-away culture leading to the accumulation of large scale amount of plastic waste generation per day [14]. Findings revealed that Autoplastor is effective in plastic waste collection.

Table 3. Estimated amount in kilograms (kg) of plastic waste generation as collected by the system per week

Waste material	Week 1 (kg)	Week 2 (kg)	Week 3 (kg)	Week 4 (kg)
Plastics (Polyethylene terephthalate & High density polyethylene)	9.8	13.5	19	28.7

3.4 Qualitative results of the pyrolysis process

As presented in this section, an improvised pyrolysis system was made in an attempt to recycle plastic waste materials into a useful one. As part of the research project design, the last stage of the plastic waste collection process was to extract fuel or gas from the mass of plastic waste delivered by the conveyor belt into the pyrolysis chamber. When the pyrolysis chamber is full, manual intervention was used for sealing the pyrolysis chamber ensuring no oxygen enters the chamber, after the fire ignition, the pyrolysis begun. To collect the possible sample of fuel or gas from the condensed liquid of the pyrolysis, a container was used as a collecting chamber and immerse halfway into the water. Simple flammability testing methods through the use of vertical and horizontal flammability methods were employed; qualitative data were used to describe the traits of the sample as perceived by the researchers. During the experimental and gathering of data, the time factor was neglected. The pyrolysis took place every end of the week at the science laboratory building of the school to ensure that the pyrolysis chamber is full of plastic waste materials collected by the autoplastor. The results of the first two weeks of pyrolysis seem to be unsuccessful; the suspected cause of this problem based on careful analysis and re-evaluation of the improvised pyrolysis was the leakage of oxygen and entered the pyrolysis chamber causing the plastic waste to thermal degradation without producing liquid condensed to the collecting chamber. As confirmed in the previous study, one of the major obstacles for unsuccessful pyrolysis is the presence of high oxygen content [14]. The last two weeks of the pyrolysis process was intensively monitored and controlled in an attempt to extract the expected end product of the pyrolysis. As a result, neglecting the time factor for the pyrolysis process to be done, the end product result was obtained. Flammability was tested and observed through vertical flammability testing. However, extracted liquid from the piles of plastics was very minimal in amount comparing to that of the high cost and high setting pyrolysis process. Temperature requirements for thermal degradation of the plastics were quite challenging, particularly in a low-cost improvised system. Yielded oil in the Pyrolysis depends on the temperature applied to the types of plastics, for high-density polyethylene, the increasing temperature decreased in the yields [15]. The temperature has strong effects on liquid characteristics and solid material properties; unstable temperature in the chamber causes the liquid to form a high aromatic content, likewise, viscous liquid with high hydrocarbon chains produced. Further, reaction time does not produce any effect on pyrolysis [16]. Thus, findings suggested establishing a pyrolysis system with temperature control to easily achieve the necessary amount of temperature in the pyrolysis chamber. Primarily, the research project design was built to address the plastic waste segregation problem in the school, pyrolysis results were obtained in an attempt to use the school generated plastic waste for economical use as an alternative to plastic waste dumping, the thermal degradation of the plastic waste is beneficial to minimize plastic waste dumping in the school even though a small number of oil yields was noticed in the end product of the process. This means that mass extraction of fuel from school plastics waste in the future is possible with proper modification of the design due to the promising results of this experimentation.

4. Conclusions

Based on the experimental results, it can be concluded that an automated plastic collector (autoplastor) is effective in segregating school plastic waste, while an improvised pyrolysis system shows a promising result in the conversion of school plastic waste into useful oil. Also, it is recommended that the modification of the low-cost pyrolysis chamber used in this research will be done. Gas Chromatography-Mass Spectrometry (GCMS) testing is also recommended to identify the chemical properties of the yielded oil in the pyrolysis.

Appendix

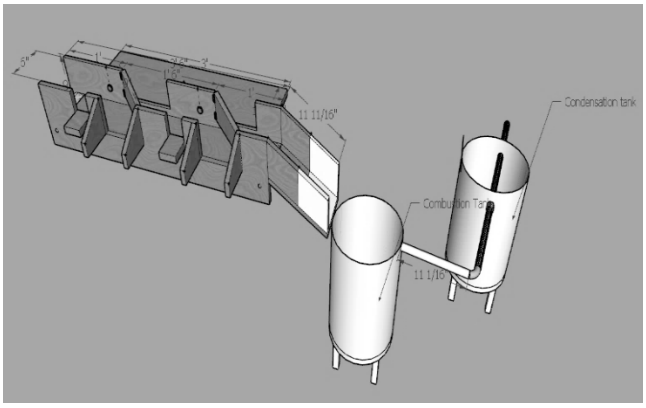

Fig. 3 Research Project Design

Fig. 4 Finished Project Design

Fig. 5 Improvised pyrolysis system

Fig. 6 Capacitive proximity sensor placement

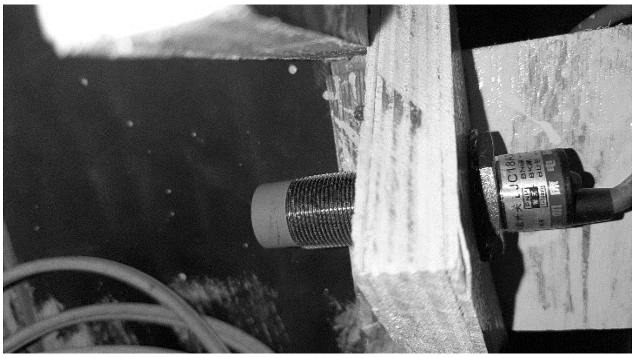

Fig. 7 Capacitive proximity sensor placement

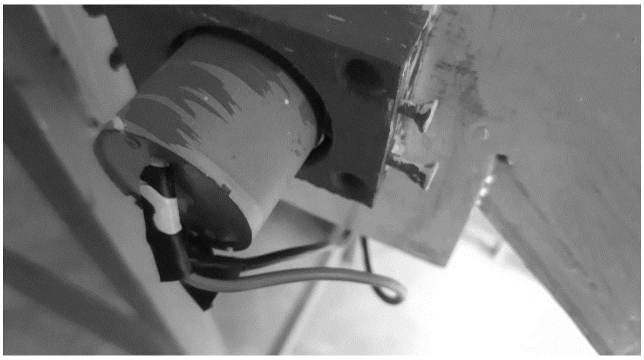

Fig. 8 DC motor placement for powering conveyor belt

Fig. 9 Waste disposal mouth of the project design

Fig. 10 Conveyor belt and servo motor hand

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