



Development of Trash Trio an Automated Waste Segregation System

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Abstract: The Trash Trio an automatic waste dispenser Project is an automated waste segregation system designed to address improper waste disposal in urban and industrial areas. With increasing waste generation, effective source-level segregation is vital to reduce landfill usage, control pollution, and enhance recycling efficiency. The system separates waste into Dry Waste, Wet Waste, and Electronic Waste (E- Waste) using sensors, microcontrollers, and mechanical units that detect properties such as moisture, conductivity, and material composition. Once deposited, waste is automatically sorted into the correct compartment, reducing human error and improving accuracy. To improve usability, the Trash Trio an automatic waste dispenser is integrated with a mobile application that enables real-time bin monitoring, collection alerts, and access to recycling guidelines. The app also includes an e-commerce feature for purchasing the system. By combining automation, smart sensing, and digital connectivity, the Trash Trio an automatic waste dispenser offers a practical and scalable solution for sustainable waste management.

Keywords: Automated Waste Segregation, Dry Waste, Wet Waste, Electronic Waste (E-Waste), Smart Waste Management, Sensors, Microcontrollers, Recycling Efficiency, Sustainable Resource Management, Mobile Application.

1. Introduction

The rapid pace of urbanization, industrialization, and population growth has resulted in a significant surge in waste generation worldwide. In India alone, municipal solid waste has been increasing at alarming rates, creating serious challenges for urban local bodies and waste management authorities. One of the primary issues is the lack of effective waste segregation at the source, which directly hampers recycling efficiency; increases landfill dependency, and

contributes to environmental pollution [1]. Without proper segregation, recyclable materials are often contaminated, organic waste is mis handled, and hazardous electronic waste is improperly discarded—leading to both ecological and health hazards.

To address these challenges, there is a growing need for innovative, technology-driven solutions that ensure accurate and efficient waste segregation while minimizing human involvement. Traditional manual methods are not only labor-intensive but also prone to errors, inconsistencies, and reluctance from users. Automation in waste segregation thus emerges as a promising solution for sustainable waste management in modern urban environments [2].

The Trash Trio a automatic waste dispenser Project has been conceptualized and developed as a smart automated waste segregation system aimed at simplifying and improving the waste management process.

The system classifies waste into three major categories— Dry Waste, Wet Waste, and Electronic Waste (E- Waste)—each requiring distinct treatment and disposal methods. By integrating sensors, microcontrollers, and automated mechanical units, the Trash Trio a automatic waste dispenser identifies waste based on its physical and electrical properties, such as moisture content, conductivity, and material composition. Once the waste is deposited, it is automatically sorted into its appropriate compartment, ensuring precision and eliminating dependency on user judgment.

To enhance practicality and user engagement, the system is integrated with a dedicated mobile application. This app provides real-time monitoring of bin levels, automatic alerts when bins are full, recycling guidelines, and sustainability tips. Additionally, the app features an e-commerce module, allowing both households and institutions to directly procure the Trash Trio a automatic waste dispenser system [3]. This digital integration not only improves accessibility but also encourages active participation from users in adopting sustainable waste management practices.

By combining automation, smart sensing technology, and digital connectivity, the Trash Trio a automatic waste dispenser Project serves as a practical, scalable, and eco-friendly solution to modern waste management challenges [4]. It reflects the shift towards smarter cities, circular economies, and sustainable development, where technology plays a pivotal role in reducing environmental impact and promoting responsible resource utilization.

The significance of the Trash Trio a automatic waste dispenser Project lies in its potential to revolutionize waste management practices at both household and institutional levels. With growing environmental concerns, improper disposal of wet, dry, and electronic waste continues to strain existing infrastructure and accelerate ecological damage [5]. The automation of segregation at the source ensures that recyclable materials are efficiently recovered, organic waste is processed in an eco-friendly manner, and hazardous e-waste is diverted from landfills. Beyond environmental benefits, the system also reduces manual labor, lowers health risks for waste

handlers, and supports government initiatives such as Swachh Bharat Abhiyan and Smart Cities Mission, aligning technology with sustainable development goals.

While the Trash Trio a automatic waste dispenser Project provides a robust foundation for automated waste segregation, it also opens avenues for future advancements. Features such as AI-based material recognition, IoT-enabled data analytics, and integration with municipal waste collection systems can enhance efficiency further [6].

2. Proposed System

The proposed system, Trash Trio a automatic waste dispenser, is an automated waste segregation solution designed to simplify and improve waste management at the source. Unlike traditional manual segregation, which is error-prone, time-consuming, and inefficient, this system ensures accurate and reliable sorting of waste using automation and smart sensing technologies.

The Trash Trio a automatic waste dispenser is designed to classify waste into three major categories— Dry Waste, Wet Waste, and Electronic Waste (E- Waste)—by utilizing a combination of sensors, microcontrollers, and automated mechanical components. The waste deposited into the system undergoes detection based on physical and electrical properties such as moisture content, conductivity, and material composition. Once identified, the waste is automatically directed to its respective compartment through an electromechanical mechanism, thereby eliminating dependency on user judgment and minimizing segregation errors.

In addition to hardware-based automation, the system integrates with a dedicated mobile application that enhances usability and monitoring. The app provides real-time updates on bin status, notifications when compartments are full, recycling tips, and sustainable waste management guidelines. Furthermore, it includes an e-commerce platform that allows households, institutions, and organizations to conveniently purchase the Trash Trio a automatic waste dispenser system. By combining smart sensing technology, automation, and digital connectivity, the proposed system offers a practical, user-friendly, and scalable solution for modern waste management. It not only improves recycling efficiency and reduces landfill dependency but also encourages public participation in sustainable practices, making it suitable for deployment in residential communities, educational institutions, offices, and urban municipalities.

3. Block Diagram

The Trash Trio a automatic waste dispenser and segregation system that uses Arduino technology to identify and sort waste into three categories: metal, wet, and plastic. In Figure 1 process begins with an IR sensor, which detects the presence of waste material. Once detected, the inductive sensor checks if the object is metallic. If it is, the waste is immediately directed into the metal bin. If not, the system relies on a rain drop sensor to determine the presence of

moisture, thereby identifying wet waste. When wet waste is detected, a servo motor activates a flap to guide the waste into the correct bin. Any object that is neither metallic nor wet is automatically classified as plastic and placed in the plastic bin. To ensure proper alignment during the sorting process, a stepper motor rotates the waste platform, while a buzzer provides an alert sound each time segregation takes place.

This smart setup significantly improves waste management by reducing manual labor, enhancing efficiency, and promoting recycling through accurate and reliable waste segregation.

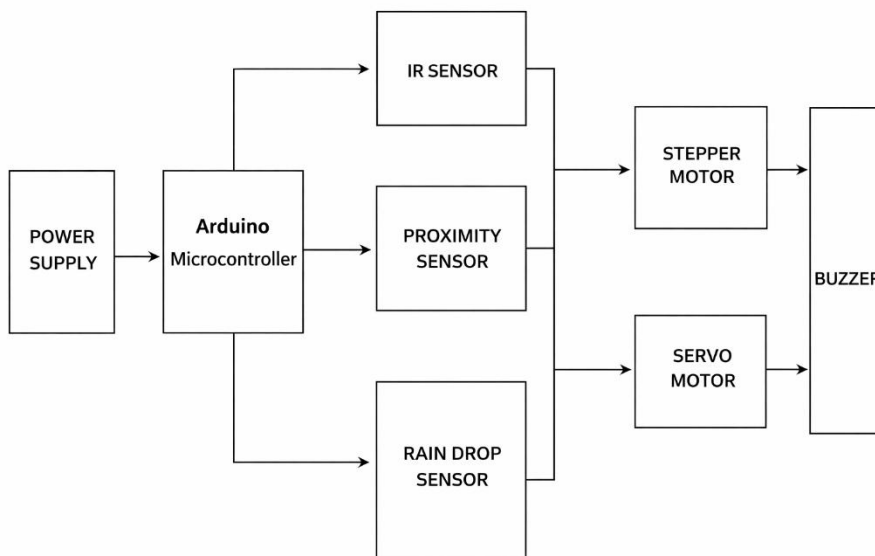


Figure 1. Block Diagram

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4. Circuit Diagram

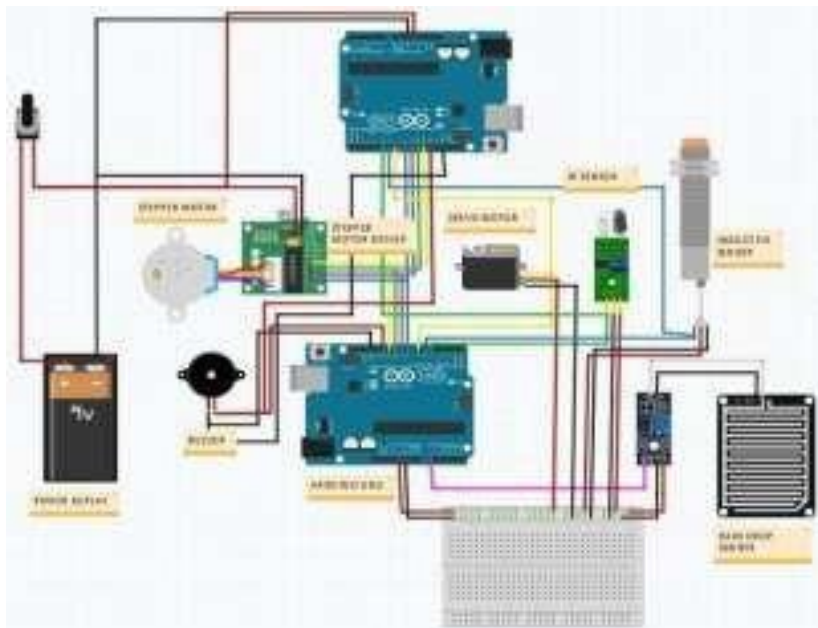


Figure 2. Circuit diagram

The Trash Trio is an automatic waste dispenser. Figure 2 circuit shows that it is designed using two Arduino Uno boards, multiple sensors, and actuators to achieve automated waste segregation. A 9V battery powers the system, ensuring portability. The IR sensor first detects the presence of waste, after which the inductive sensor checks whether the material is metallic. Based on this classification, the Arduinos coordinate the actuators: the servo motor acts as a gate or flap to direct the waste toward the correct bin, while the stepper motor, controlled through a driver, rotates the bin carousel precisely into position. A raindrop sensor is included to provide environmental protection; when rain is detected, the Arduino triggers the buzzer for an alert and can pause or cover the system to prevent damage. The use of two Arduino boards allows one to handle sensors and the other to control actuators, ensuring smooth operation without overload. Overall, the circuit enables accurate waste detection, classification, and disposal, making the Trash Trio an automatic waste dispenser system efficient and reliable.

5. Hardware Description

The Figure 3 infrared (IR) sensor is the entry detector of the waste segregation system and plays a key role in initiating the process. It works on the principle of emitting infrared light from an IR LED and detecting the reflected light using a photodiode. When no object is present, the emitted light does not return to the photodiode, so the output signal remains LOW. However, when waste is placed in front of the sensor, the infrared light reflects back from the

object and is received by the photodiode, which changes the output to **HIGH**. This digital signal is then sent to the Arduino, acting as the trigger for the segregation sequence.

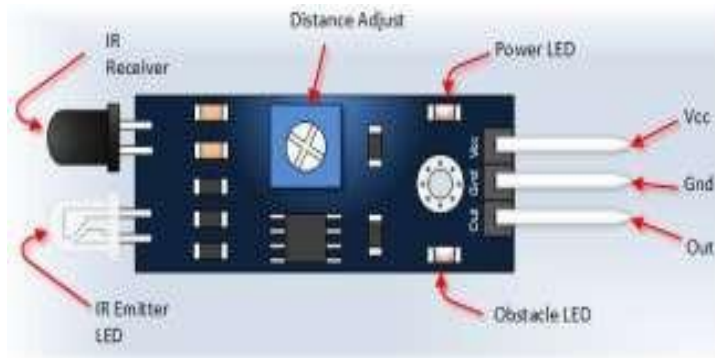


Figure 3. IR sensor



Figure 4. Inductive sensor

The figure 4 shows the inductive proximity sensor which is specifically used to detect metallic waste in the system. It operates on the principle of electromagnetic induction, where an internal coil generates a high-frequency electromagnetic field in front of the sensor. When a metallic object, such as an aluminum can, tin foil, or any other conductive item, enters this field, eddy currents are induced within the metal. These eddy currents create a disturbance in the electromagnetic field, which is sensed by the sensor's detection circuit. The sensor then converts this disturbance into an electrical signal and transmits it to the Arduino controller. This signal helps the system accurately identify metallic waste and direct it to the appropriate disposal bin.



Figure 5. Rain sensor

Figure 5 Raindrop sensor is used in the system to figure out whether the waste is wet or dry. It mainly has two parts - a sensor plate and a control module. The plate has conductive lines printed on it, and when it is dry, the resistance between these lines is very high. But when wet waste or moisture touches the plate, water bridges the gap between the lines, lowering the resistance. This change in resistance creates a signal, which the control module processes and then sends to the Arduino as either an analog value (showing how much moisture is present) or a digital signal (simply wet or not wet). The Arduino uses this information to decide if the waste should be classified as wet waste, like leftover food, fruit peels, or vegetable scraps. This sensor is very useful because it gives the system the ability to distinguish organic, biodegradable materials from dry ones such as plastic, ensuring proper segregation for recycling and composting.

The stepper motor (figure 6) plays a crucial role in the waste segregation system, as it is responsible for rotating the waste platform or bins in accurate and predefined steps. Unlike regular DC motors that spin continuously, a stepper motor moves in discrete angular steps, making it highly suitable for applications that demand precise positioning. However, since the motor coils require higher current and voltage than what the Arduino can directly supply, a driver module. The driver acts as an interface between the Arduino and the stepper motor, ensuring safe and efficient power delivery. The Arduino generates a sequence of electrical pulse signals, which are sent to the driver. The driver then energizes the motor coils in the correct order, converting these pulses into controlled stepwise movements of the motor shaft. This precise control mechanism guarantees that the bins or the rotating platform align exactly with the

designated position every time waste sorting is carried out, minimizing errors and ensuring smooth operation of the segregation process.

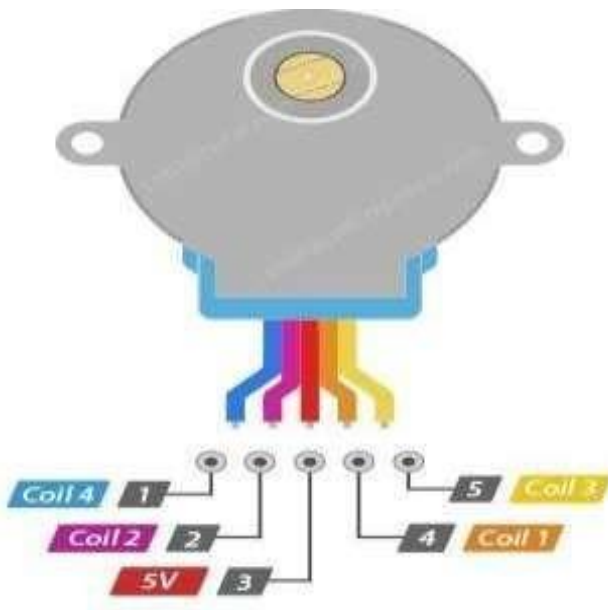


Figure 6. Stepper Motor



Figure 7. Servo Motor

The servo motor (Figure 7) is an essential component in the waste segregation system, primarily used to operate the flap mechanism that directs waste into the appropriate bin. Unlike a stepper motor, which rotates in steps, a servo motor can rotate to a specific angle within its range, usually 0° to 180° or sometimes 360°, depending on the type. It is directly controlled by

the Arduino using PWM (Pulse Width Modulation) signals, where the width of the pulse determines the angle of rotation. For instance, a signal commanding the servo to rotate to 0° may position the flap toward the metal bin, 90° toward the wet waste bin, and 180° toward the plastic bin. This direct control makes it simple yet highly effective for real-time waste sorting. The servo's key advantages are its high precision, stability, and quick response, ensuring that the flap always moves swiftly and accurately to the required position. This reliability helps maintain smooth waste segregation, avoiding misplacement of items and improving the efficiency of the system.

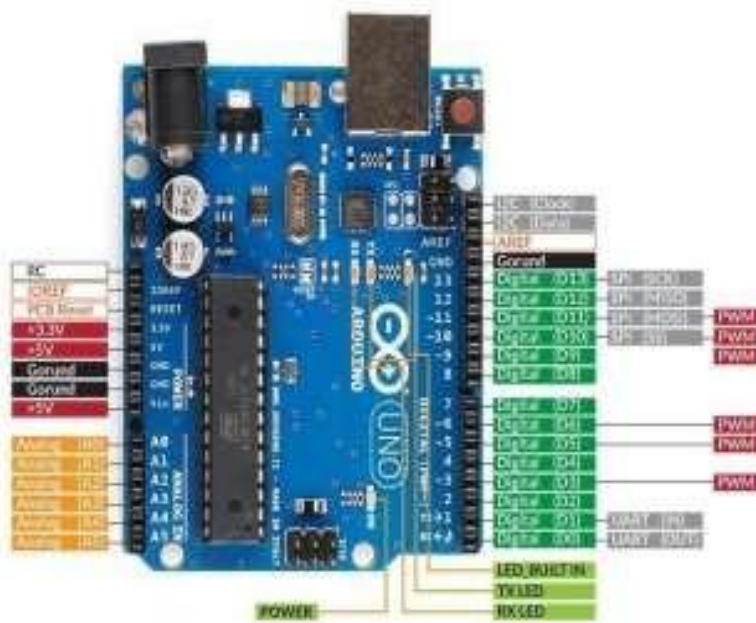


Figure 8. Arduino Uno

The system is designed with two Arduino boards working in coordination to ensure efficient and reliable operation. Instead of relying on a single microcontroller to handle all functions, the workload is divided to prevent delays and errors during sorting. One Arduino board is dedicated entirely to motor control, managing the precise operation of both the stepper motor (for rotating the waste platform or bins) and the servo motor (for operating the waste flap). The second Arduino board is responsible for handling all sensor-related tasks, including reading signals from the IR sensor, inductive proximity sensor, and rain drop sensor, and then making the necessary decisions about the type of waste detected. This clear division of responsibilities ensures that sensor data is processed quickly and accurately without being interrupted by motor control tasks, while the motors receive smooth and precise signals without lag from heavy computation. By sharing the workload in this manner, the overall system achieves faster response times, improved reliability, and more efficient waste segregation, even under continuous operation.

6. Input / Output Programming

General Purpose Input/Output (GPIO) pins in PIC microcontrollers are the most basic and commonly used peripherals that allow the microcontroller to interact with the external world by either monitoring signals as inputs or controlling devices as outputs. To provide more flexibility, many of these pins are multiplexed with alternate peripheral functions such as timers, ADC channels, UART, SPI, or PWM, and when such a peripheral is active, the pin cannot be used as a general-purpose I/O [7]. The direction of each I/O pin is controlled by a special register called the TRIS (Tri-State) register, where writing a logic '1' configures the pin as an input and writing a logic '0' configures it as an output. An easy way to remember this is that '1' looks like "I" for input and '0' looks like "O" for output. Data is written to or read from the port using the PORT register. When data is written to the PORT register, it goes to the output latch, which then drives the pin if it is configured as an output. When the PORT register is read, the actual logic levels present on the physical pins are read, not the latch values. This means programmers must take care when performing read-modify-write operations, as the value read may differ from what was previously written if external conditions affect the pin state [8]. It is also important to note that when a pin is used as an analog input, the corresponding TRIS bit must be set as input; otherwise, the analog function will not work correctly. In summary, GPIO pins, together with the TRIS and PORT registers, form the fundamental interface for communication between the PIC microcontroller and external devices, but proper care must be taken when handling multiplexed functions, read-modify-write operations, and analog inputs.

7. Flow Chart

This flowchart (figure 9) represents the working of a multi-sensor based automation system. The process begins with the start of the program, followed by the initialization of all the necessary components such as sensors, actuators, buzzer, stepper motor, and servomotor. Once the components are initialized, the system moves into the setup phase where the sensors are calibrated and the threshold values are configured to ensure accurate readings. After setup, the system enters the sensor checking stage, where it continuously monitors three types of sensors: the proximity sensor, the IR sensor, and the soil moisture sensor. If the proximity sensor detects an object nearby, it activates the buzzer and stepper motor to alert and perform a mechanical action, followed by executing a defined proximity action. If the IR sensor detects infrared signals, it activates the buzzer to provide an alert and then carries out the required IR action, such as obstacle detection or intrusion alert. Similarly, when the soil moisture sensor senses dryness in the soil, it controls a servo motor attached to a water tap, enabling automatic watering, and then executes a moisture action to maintain soil conditions. After performing the respective actions based on the triggered sensor, the process reaches the end state. In essence, this flowchart demonstrates an integrated system where multiple sensors work together to automate environmental monitoring and response actions effectively.

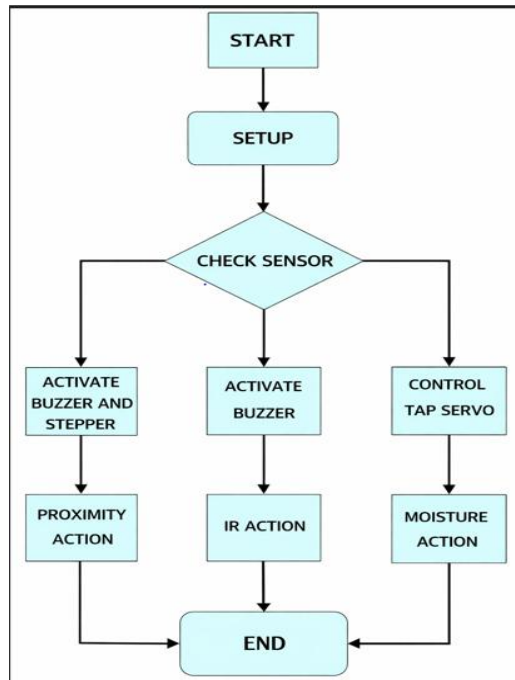


Figure 9. Flow Chart

8. Hardware Implementation

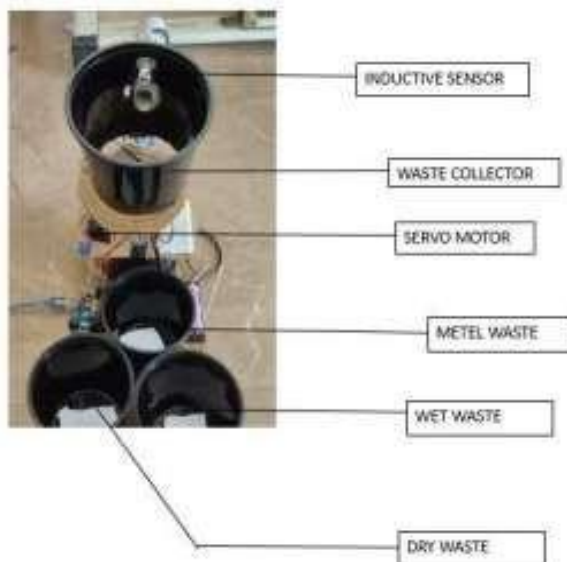


Figure 10. Hardware Implementation

The Figure 10 is the hardware implementation of an Automatic Waste Segregation System consists of a funnel-shaped chute with sensors and a servo-driven diverter directing waste into three bins (metal, plastic, wet). An Arduino microcontroller acts as the brain, interfaced with an inductive proximity sensor to detect metals, a moisture sensor to sense wet waste, and also able to identify plastic. Based on sensor inputs, the controller rotates a high-torque servo motor to align the diverter flap with the appropriate bin and used stepper motor for the rotation of bin. A 5 V power supply with a buck converter provides stable power to both sensors and control circuits, while the modular setup ensures easy maintenance. This compact design enables automated and efficient segregation of waste into three distinct categories.

9. Conclusion

The Trash Trio a automatic waste dispenser project has been developed as an innovative and efficient system to tackle one of the most pressing problems of modern society—improper waste disposal. By incorporating advanced sensors, microcontrollers, and automated mechanisms, the system is able to accurately detect, identify, and segregate waste into three categories: biodegradable, non-biodegradable, and metallic. This automation greatly reduces the dependency on manual segregation, thereby saving time, labor, and minimizing health risks associated with direct contact with waste. The project not only improves the efficiency of waste management but also supports environmental sustainability by ensuring that recyclable and reusable materials are properly separated at the source. Furthermore, it lays a foundation for smart city initiatives by promoting cleaner surroundings, effective recycling practices, and reducing landfill accumulation.

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Conflict of interest

The Author's have no conflicts of interest to declare that they are relevant to the content of this article.

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