

DEVELOPMENT OF A FOOT OPERATED WASTE BIN FOR SANITARY DISPOSAL OF FACE MASKS TO REDUCE THE SPREAD OF COVID-19

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ABSTRACT

The general public is faced with challenges of disposal of face masks that are used to curb and prevent the spread of the novel Corona Virus, Delta variant and Omicron virus. People usually use their hands to open the lid of the waste bin in order to dispose off those face masks and gloves hence the need of a waste bin. This study is aimed at developing a foot operated waste bin achievable by the use of a foot pedal and series of other mechanical linkages connected together by welding and bolting. The major material used for the construction was sheet metal. After the design calculations and performance evaluation, the volume of the waste bin was 32,000cm³ while the capacity in terms of weight was 11.05kg. After testing, the developed waste bin was found to be promising in terms of its performance with an efficiency of 85%. Further design of a smart waste bin with a sensor to open the lid and other features like an outlet for offloading accumulated wastes is recommended.

Keywords: Waste bin, disposal, metal sheet, foot pedal, facemasks.

1 INTRODUCTION

Waste is an important by-product of human activities that are mostly thrown away because they are considered useless. All humans produce wastes of various types; urine and faeces, wastes from vegetables, fruits, food, face masks, hand gloves and other medical or solid wastes produced from hospitals and general public [1]. It is a global issue and if not properly dealt with, will pose threats to both public health and the environment. It is a growing issue linked directly to the way society produces and consumes. Hospital waste can be said to be any unavoidable material resulting from clinical activities, for which there is no economic demand and which must be disposed off. It can also be referred to as garbage and rubbish created from the day-to-day activities of various forms of treatments, pharmaceutical and surgical works. Some health centres are faced with the challenges of not having functional waste bins for storage of solid wastes materials especially COVID-19 waste materials, which include, face masks, hand gloves, overall coat, and other personal protective equipment (PPE). The risks in the wastes include sharps, pathological, pharmaceutical, chemical, and radioactive waste, whereas non-risk waste is equivalent to general domestic garbage and introduce no greater risk than normal home waste (paper, packaging, and food waste). A portion of hospital and laboratory waste management processes includes collection, disinfection, storage, transportation, mutilation, and final disposal as the foundation for safe waste management [2]. Medical waste can be infectious, causing high contamination and cross contamination risks to both people and the environment especially from patients known or suspected of having a communicable disease, this includes corona virus. Items that have been soiled with blood or body fluids should also be treated as clinical waste [3]. The major problem has been observed that people usually use their hands to open the lid of the waste bins in order to dispose of those facemasks. This method of disposal is unhygienic, increases vulnerability to the disease and often consumes time hence the need to develop a foot operated waste bin that can open its lid freely, and be able to move it from one location to another. Other problems associated with this traditional lid method of disposal is that it often leads to contact with germs since hands are used to open the lid, Some face masks are littered around while

some are disposed in open dumpsites which rag pickers may want to re-use. This also can transmit viruses and other vector diseases. The waste bin can be described to consist of the following components: bin lid, handle, bin frame, link 2 pipe, link 1 pipe, foot pedal, bin, and the wheels. Therefore, there is a need to design and construct a foot operated waste bin for disposing facemasks and other medical wastes with wheels for moving the bin from one location to another. Initially, waste bins in the hospital are not equipped with many features such as wheels and foot pedal to aid the movement and opening of the lids easier to patients and the health personnel as well. Therefore, a waste disposal bin with wheels will assist the disposal of the various forms of hospital wastes particularly those wastes from COVID-19 wards or intensive care centres.



Plate 1. Disposed face masks on the ground [4].

2 MATERIALS AND METHODS

Preliminary investigation of the relevant types of waste bins used, were found in hospitals and other public places in Jimeta-Yola, Adamawa state. The information obtained such as local construction materials, various types of waste disposal bins, littered facemasks and their purposes assisted in the development of the foot operated waste bin with wheels for movement. The existing ones in the market lack wheels for moving it from one place to another.

2.1 Materials selection and design considerations

Sheet metal materials (gauge 2) were selected for the construction of the waste bin and it was because of its qualities such as: strength, resistant, light, durability, pliable, sustainability, adoptability and finishing ability, economic and safety factors. The cost effectiveness was also considered as it cost the sum of Ninety Six Thousand Naira (₦96,000) to produce the waste bin.

2.2 Principal Parameters of Design

The most important factors considered during the design were the kind of wastes to be disposed. As stated by [3]. These parameters include: Peripheral speed of the pedal, the type of wastes to be disposed, size of waste bin and lid clearance.

2.3 Description of operation of the Waste bin

The waste bin is a foot operated one (Figure 3), and was constructed with a metal sheet as it has been recommended that metal waste bins are good emitters of foul odour from wastes, they are also perfect for heavy-load rubbish. They have a relatively long life span and they are more recyclable than their plastic counterparts. The foot pedal is located at the right side of the bin, and swings downward when a force is applied. It is mounted slightly raised to ensure that the foot will not strike the floor, nor will the pedal strike the foundation which the bin rests on. The foot pedal was sized to allow for minimal foot pressure to be applied while maximum vertical lift is applied to open the lid during trash disposal. When a user approaches the bin frame, the user can use either of his feet to press on the pedal mounted to the exterior of the bin. The handle is used moving the frame bin on the two wheels provided at the bottom of the facility (Figure 1). The orthographic views of the waste bin (Figure 2); has its exploded view of the mechanism in (Figure 3) respectively. The mechanism was assembled with common tools, and the parts were made from simple and fundamental components such as sheet metal, bar stock, square pipes, and fasteners. Welding was applied in the assembly process. The foot operated waste bin was finally painted red; indicating that only hazardous wastes are disposed there.

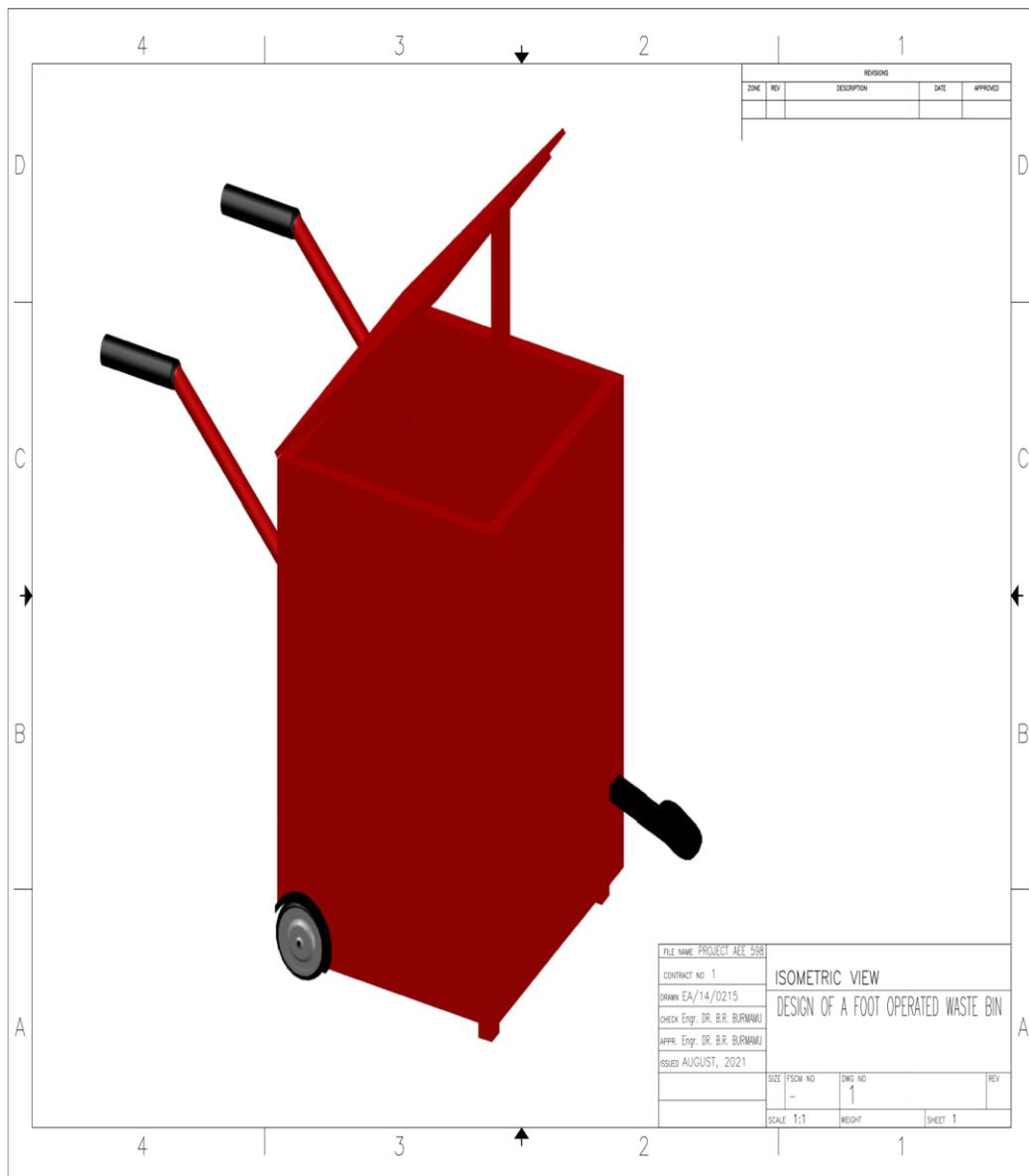


Figure 1: Pictorial (Isometric) View of the Foot Operated Waste Bin with Wheels

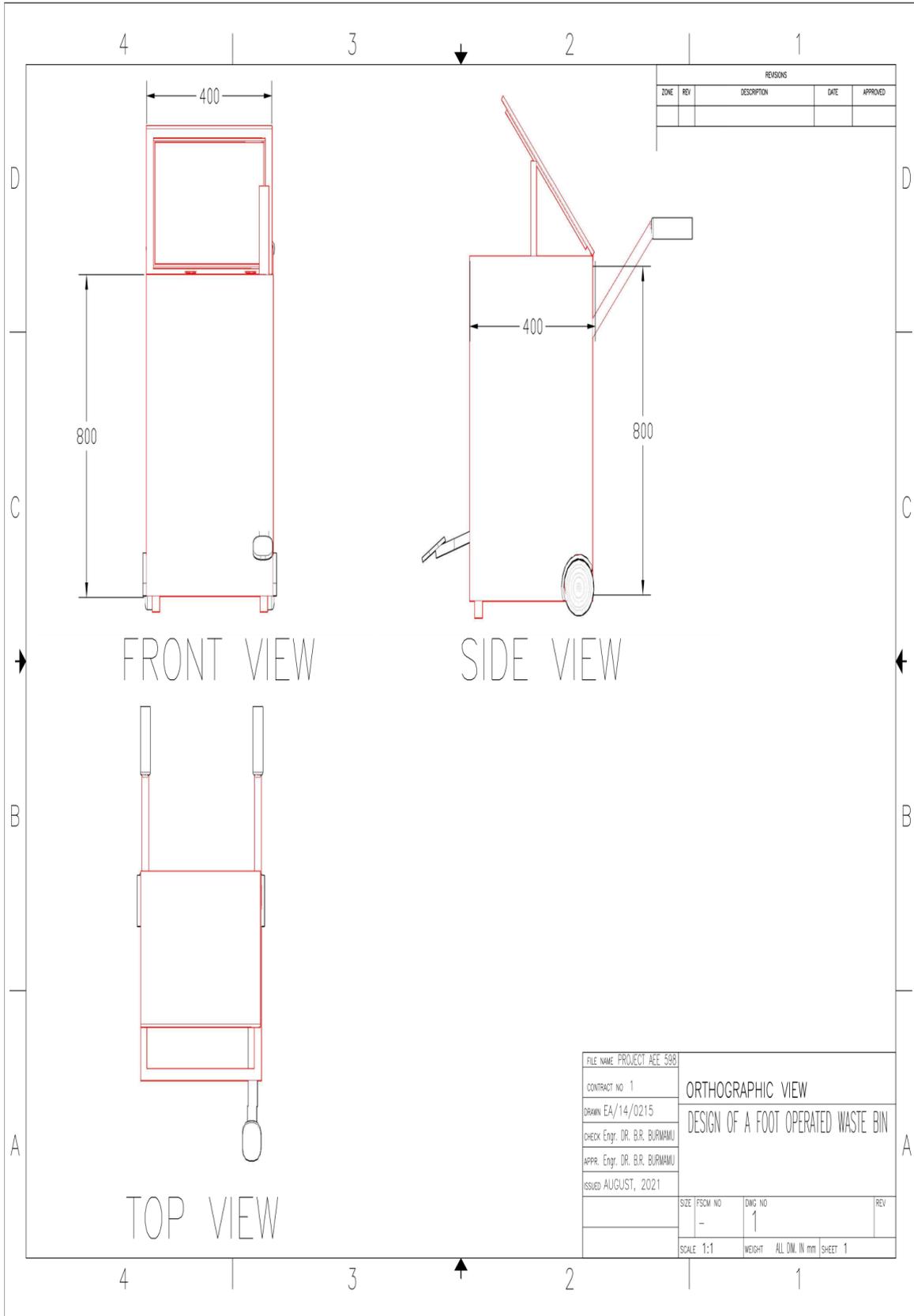


Figure 2: Orthographic View of the Foot Operated Waste Bin

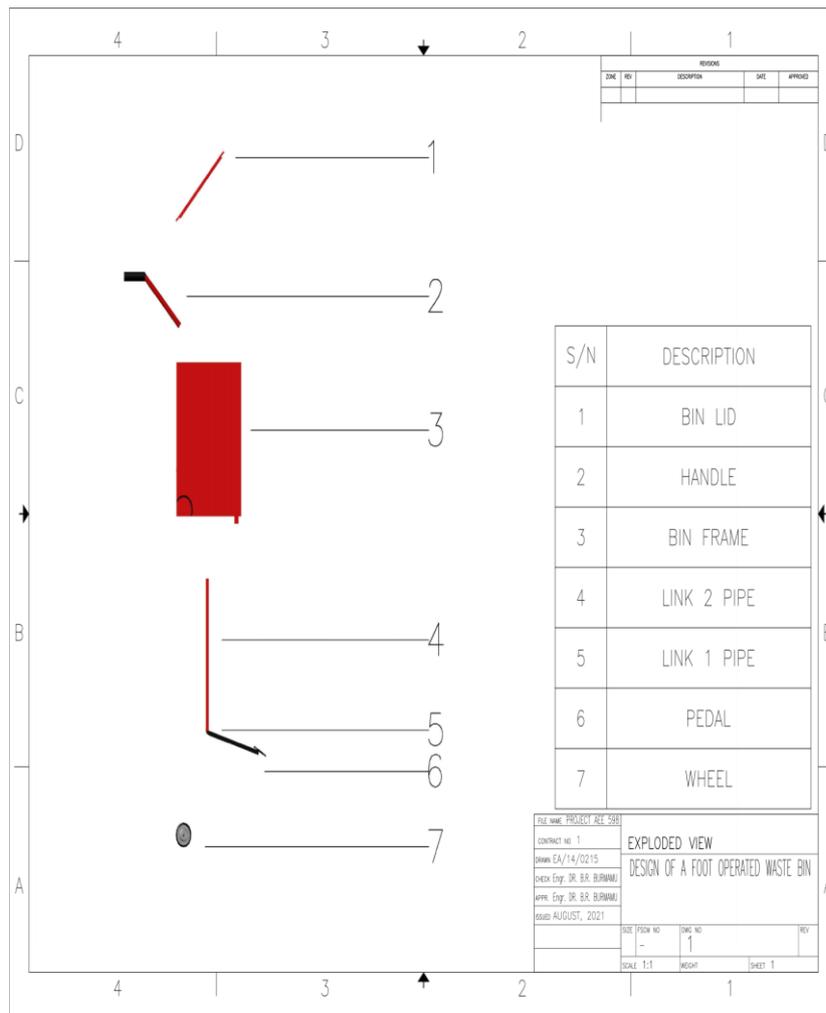


Figure 3: Exploded view of the Waste Bin

2.4 Design Calculations

In the design of the components of the waste bin, the following design major components and parameters were selected: The pedal mechanism that depends on the force applied to allow movement through a linkage. Other parameters were sum of vector and moment forces of fixed and moving pivots and levers at the lid end which allows lifting of the lid. Hence the force required to lift the lid was calculated according to Newton’s second law of motion as.

$$F = ma \tag{1}$$

Where; F = force (N); m = mass (Kg); a = acceleration (ms^{-2})

For any rigid body in a static equilibrium, conditions for equilibrium can be applied. Thus,

- i. The vector sum of all forces acting upon it is zero.
- ii. The sum of the moments of all the forces acting about any single point is zero [5].

Mathematically, these two statements are expressed as

$$\sum F = 0 \quad \sum M = 0 \tag{2}$$

Where; F = force; M = moment

2.5 Drive Shaft diameter

The drive shaft is a rod-like component that transmits torque from the waste bin wheel. It is essentially the shaft and the bearings that move the waste bin. Based on the design, the bin used a horizontal circular steel shaft [5]; hence the torque on the shaft was calculated as:

$$T = F \times r \times \sin\theta \quad (3)$$

Where; T = Torque; F = force applied; r = length of shaft; $\sin\theta$ = angle of shaft rotation and the power transmitted by the shaft is given as:

$$\text{Work done per minute} = \text{force} \times \text{distance} = T \times 2\pi N = 2\pi NT \quad (4)$$

$$\text{Work done per second} = \frac{2\pi NT}{60} \text{ (kN-m)} \quad (5)$$

The general formula for torque on a solid shaft [5] was calculated as:

$$T = \tau \times \frac{J}{r} \quad (6)$$

Where: T = torque; τ = shear stress; r = length and direction of the lever arm; J = Polar moment of inertia; J is given as $(\frac{\pi}{2})r^4$

Where: r^4 = Inner and outer radii of the shaft [5]

2.6 The Bin handle

The handle of the waste bin was made up of a metal rod. This was to minimize the effects of handle friction and inward torque when the maximum axial push force was applied. In the design of the bin handle, the handle diameter, push strength, hand torque, hand biomechanics and hand ergonomics were considered. To determine the resultant force and decrease in moment about the hand grip, the equations below were used [6].

$$M = F \times d \quad (7)$$

Where: M = moment; F = force; d = perpendicular distance; and also, applying the equations of equilibrium $\sum F = 0$ $\sum M = 0$

Therefore;

$$\text{Moment about the hand grip} = \sum(\text{Reaction force} \times \text{Moment arm}) \quad (8)$$

$$= \sum(\text{Reaction force for axial push} \times \text{Moment arm}) - (\text{Reaction force for downward force} \times \text{Moment arm}) \text{ by [7].} \quad (9)$$

2.7 Determination of Bin Volume

From the orthographic view above, the volume of the waste bin was calculated according to [7] as follows:

$$\text{Volume of bin } V_b = \pi r^2 \times h \quad (10)$$

Where; V_b = volume of bin; $\pi = 3.142$; r = radius of the bin (200mm); h = height of the bin (800mm). Lastly, the foot operated waste bin was developed and painted red so that it serves the purpose of storage of hazardous materials as indicated in (Figure 1).

3 RESULTS AND DISCUSSION

3.1 Performance Evaluation of the Waste bin

According to equation (10), the volume or capacity of the bin was evaluated as:

$$V_b = \pi \times 200^2 \text{ mm} \times 800 \text{ mm.}$$

$$\text{Volume of bin} = 32000000 \text{ mm}^3 \text{ or } 32000 \text{ cm}^3$$

$$\text{Capacity of bin} = \frac{32000 \text{ cm}^3}{1000} = 32 \text{ Litres}$$

The developed waste bin was tested with the lid of the bin initially closed. Then the pedal was also tested and was able to perform effectively by lifting the lid opened for facemask disposal. The lid was opened and it remained at an angle of 60° to the horizontal of the bin. Its performance efficiency

was 85%. After the test, the mechanism was found to be workable because the lid of the bin opened immediately as soon as force acted upon the pedal. Also, the bin closed as soon as the pedal was released. The performance of the constructed waste bin indicates that the bin would be the reliable and affordable option for reducing the spread of COVID-19 and other related viruses both at hospitals and other public centers because it has saved time when compared with the manually operated waste bins. Other performance evaluations showed that the entire weight of the waste bin was measured to be 11.05kg. Finally, the foot operated waste bin was developed and painted red so that it serves the purpose of storage of hazardous materials as indicated in (Figure 1).

4 CONCLUSIONS

In conclusion, the main purpose of this innovation was to reduce the spread of corona virus from an infected person to others while using the same waste bin in which the lid was opened without touching the bin with hands was achieved. This was done by pressing the pedal with a foot, the lid opened immediately for wastes to be disposed with an efficiency of 85%. The consequences of this research had provided solutions to the conceived objectives such as the elimination of the inconvenience of containing the bio-medical wastes into a garbage bag and bringing it to a designated drop point for collection. Also, helping the patients and health workers in reducing the drudgery and time associated with waste disposal in terms of opening the lid with manual hands. In conclusion, the efficiency of this innovation was 85% and the total volume or capacity of the waste bin was found to be 32000cm^3 (32 liters) while the entire weight of the waste bin was measured to be 11.05kg which is very portable as it can be moved from one place to another on wheels easily. The cost of production was Ninety Six Thousand Naira Only (₦96,000.0). The bin was then tested, and after the test the mechanism was found workable as an affordable option for reducing the spread of COVID-19 and other related variants both at hospitals and institutional centres. Some recommendations were made which include; The wheels of the bin frame should be modified with the wheels brakes to minimize movement of the facility when a greater force acts on the pedal. The waste bin should be upgraded with some features like air spaces to filter odor and also an outlet for offloading accumulated wastes. It is recommended that the bin should be adopted at household, community and institutional levels for sanitary management of solid wastes. Further design of a waste bin be modified with an electrical sensor or smart card in order to minimize the little effort put towards the opening of the lid.

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