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Design And Fabrication Of Syringe Needle Crusher

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Abstract: The rapid development in every facet of human endeavors like the financial, industrial, technological, economic, social, etc., leads to more waste being generated and needs to be disposed of without causing ahazard to the environment. This paper deals with designing and fabrication of needle shredder while the objectives are to quantify the needle generated globally as an indicator of the project viability, to crush needle and packaged as raw materials in other industries. The result indicated that the crusher can be used to crush highly hazardous sharps into harmless steel which can be gainfully used in other industries. It was observed that the crusher is a better sharp waste management technology than the traditional incinerator and landfilling.

Keywords: Designing and fabrication, Needle shredder, Crusher, Waste Management

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I. INTRODUCTION

Disposal of medical wastes is a growing global environmental concern. The problem is rising with an ever-increasing number of hospitals, clinics, and healthcare laboratories universally (Hassan et al., 2008). Medical wasteis been generated from health-care establishments, medical institutions, diagnostic laboratories, veterinary clinics, hospitals and research institutes; it includes absorbents, sharp and needles, glass gauze, paper, plastics and human anatomical remains and animal carcasses (Longe and Williams 2006). It is a waste capable of producing infectious disease. According to Manyele, 2004; Medical waste is extremely infectious and hazardous. Medical waste threatens the environmental health. Therefore it must be treated before its final disposal. Until now, The management of medical wastes has been so unpopular despite its potential environmental hazards and public health risks. Moreover, medical waste constitutes a minorquotaof the entire municipal solid waste. However, the potential environmental and health hazards could be dangerous if not properly handled, the worst scenario being in developing countries (Salkin,2004). In modern times, the disposal of medical waste has posed more difficulties with the appearance of disposable needles, syringes, and other similar items (Askarian et al., 2006). Wastes generated in a hospital are too hazardous to be treated and carefully managed as these wastes carry infections and contaminate the environment prevailing in a hospital (Habiburet al., 1999). However, fromthe late 80s, the spreading trend of Hepatitis B Virus (HBV),Human Immunodeficiency Virus (HIV), and other agents associated with blood-borne diseases has raised the awareness level of the public regarding the disposal of medical waste. Consequent on this, medical waste is required to be treated specially and not to be combined with municipal waste (George et al., 2011). The medical waste contains highly toxic materials, pathogenic viruses and bacteria which could lead to pathological dysfunction of the human body.

It is a common phenomenon in developing countries forscavengers to collect some of the medical wastes for reselling despite the deadly health risks. It is a general knowledge that the re-use of syringes can cause the spread of infections such as AIDS and hepatitis. The collection of disposable medical items and its potential re-use without sterilization could also cause serious diseases (Hassan et al., 2008).

The concern of medical waste is majorly the presence of pathogens and other organisms in significantly high concentrations. The presence of organisms of human origin in solid waste in a substantial quantity suggests the existence of contagious strains of viruses and pathogenic bacteria in undetected numbers. Improper handling of solid waste in the hospital may increase the airborne pathogenic bacteria, which could adversely affect the hospital environment, community and the Underground water (Benientet al., 1999). Improper medical management has aserious impact on thehuman environment. Apart from therisk of water, air and soil pollution, it has aconsiderable impact on human health due to aesthetic effects (Salkin et al., 2004).The safe disposal and subsequent destruction of medical waste, therefore, is a key step to the reduction of illnesses or injuries through contact with this potentially hazardous material, and in the prevention of environmental contamination (Saini et al., 2005).

The USEnvironmental Protection Agency reports that about 3.2million tons of medical wastes from hospitals were generated each year worldwide, which was about 2% of the entire solid waste stream. Presently, most generators of medical waste designate between 10 to 15 percent of it as infectious. Some discarded equipment such as thermometers introduces heavy metals such as mercury to water sources that serve human population. Mercury poisoning leads to permanent impairment of the nervous system or death. It also causes asensory loss in limbs, impaired vision and hearing, personality changes and loss of intellectual capacity (Jadhav, 1992).

Because of a lack of waste segregation practices in most hospitals, many of these hazardous wastesare depositedin a wastewater drain that flows directly to an open sewer ormixed with the general solid waste for disposal in municipal bins or combinedwith other wastes to be incinerated as potentially infectious waste. The management of medical wasteshould be of major concern due to potentially high risks to human health and the environmental context ofthehealthy medical facility will decrease the number of health-care settings associated infections(Blackman 1996).

The sustainable management of Medical waste hasconstantlyengendereda growing public interest based on the health risks associated with exposure to potentially hazardous wastes arising from healthcare (Da Silver *et al.,* 2005, Chartieret al., 2014). Presently considerable gap existsregardingthe evaluation of healthcare waste management practices in sub–Saharan African region. The quantity and nature of healthcare waste generated and the practices of the Institution concerning sustainable methods of waste management, including waste separation and waste recycling, are often poorlydocumented in various countries of the worldregardless of health risks associated with improper handling of Healthcare waste (Oke, 2008).The awareness level of health workers regarding healthcare waste mustbeevaluated anddocumented. HCW often contain materials that may be injurious and can cause ill health to those exposed to it.Various studies have shown that the improperhandling of medical waste exposes health workers who may be in direct contact and people near health facilities to various risks.Mostimportantly children and scavengers who may become exposed to infectious wastes and a higher risk of diseases like hepatitis and HIV/AIDS (WHO, 2002; Oke, 2008; Coker et al., 2009; Adegbita et al., 2010; St Vincent Hospital 2009).World Health Organization established that about 16 million new cases of Hepatitis B virus (HBV), 4.7 million cases Hepatitis C virus (HCV) and 160000 cases of human immune deficiency virus (HIV) due to poor waste management systems are recorded annually(WHO, 1999; Townend and Cheeseman, 2005).In Nigeria for instance, there are health challengeswith limited resources available to combat them; it is also not surprising that health care waste management has received less attention thanneccessary. The information on this vital aspect of healthcare management is insufficient, and research on the public health implications of inadequate management of healthcare wastes are not detailed enough (Stephen and Elijah 2011).

According to World Health Organization (WHO, 2011), 20% of the medical waste is hazardous and should be taken with utmost caution while the remaining 80% is regarded as normal municipal waste. Infectious and anatomic wastes together make up about 15% of the total healthcare waste. Sharps are a major source of disease transmission and is just is about 1% of the total waste. about 3% are Chemicals and pharmaceuticals while genotoxic waste, radioactive matter, and heavy metal content are about 1% of the total health-care waste.Developed countries generate about to 0.5 kg of hazardous waste per hospital bed per day; while developing countries generate on average 0.2 kg of hazardous waste per hospital bed per day. Health-care waste is in less developed countries are often not separated into hazardous or non-hazardous.

Good Health Care Waste Management (HCWM) has led to an improved hygiene and operational efficiency in health facilities; it also leadsto reduction in the environmental pollution that arises from poor waste segregation and destruction practices.The numerous advantages associated with incineration and its long history as an effective method of waste management, have led to its worldwide use as the preferred means of treating and disposing of infectious waste. The process converts combustible waste into residual ash and gases, the latter being expelled to the atmosphere.

More stringentemission limits for medical waste incinerators were introducedin the year 2000 in the European Union (Jorge, 2014). The result is the closure of many incinerators,and it also increases the number of non-incinerationtreatment facilities for infectious medical waste. The rate of adaptation of alternative treatments is slower in Europe than in America and incinerationremains the popular method of treating medical waste in Europe.

Although incineration is still widely used, non-incineration technologies are winning increasing support in Europe (Jorge, 2014).According to Jorge et al.(2004), infectious waste has been treated by with a steam-based system since 90's in Slovakia. Most medical waste incinerators have been shut down in Portugal and autoclaves is now used for treatment. Many operators in France have introducedcrushing and drying systems for medical waste treatment. Ireland alsodecided in 2003 to decontaminatemost its medical waste by autoclaves using hot steam.

World Health Organization (WHO, 2004) has recognized the enormous volume of pollution due to the incineration of waste. WHO stated that a long-term goal shall be: "Effective ad improved promotion of non-incineration method of waste disposal to prevent the disease from (a) unsafe health-care waste management and (b) exposure to dioxins."

Hepatitis B and C and human immunodeficiency virus (HIV) are the most deadly of 20 blood-borne pathogens. HIV infection is a chief threat in the workplace due to the serious consequences it has on the affected worker. Healthcareworkers (HCWs) are increasinglyat risk of getting blood-borne infections in their work through job-related factors like accidental needle-stick injuries (NSIs) andsubcutaneousexposure to body fluids. NSIs are injuries caused by penetration of the skin by an injection needle.

Globally, NSIs are the mostprominent sources of occupational exposures to blood which leads to the transmission of blood-borne infections. For example, NSI includesinjection overuse, lack of-of disposable safe needle and sharps-disposal containers, type of procedures performed, recapping of needles after use, passing instruments from one person to another in the operating room, lack of awareness and lack of training. In developing countries, HCWs are particularly at increased risk of infections from pathogens because of the prevalence in their communities as well as the lack of basicpersonal protective equipment(PPE)such as gloves, gowns, goggles and many more.

Oli et al., (2013) studied three health institutions from Southeast Nigeria;itwas observed that supplies of personal protective equipment were overlyinsufficient and observanceof safety practices was poor, these could increase the risk of contracting blood-borne infections.It is estimated that around three million HCWs are exposure to blood-borne pathogens annually;two million HCWs are exposed to HBV, 0.9 million to HCV and 0.3 million to HIV. Because of these injuries, 150000 HCWs contract HCV, 70 000 HBV, and 500 HIV. Most of these infections occur in the developing countries.The prevalence varies in Africa from 31% to 68%; it is 30.9% in Southern Ethiopia and increased to52.9% in Tanzania, 67.9% in Egypt and 68% among gynecologists in Nigeria.According toMuralidharet al., 2009, Indiahad a prevalence of 80.1% in a large tertiary care hospital. The occupational exposures to hazards occur in the developing world, but most of the reports of occupational infectioncome from the USA and Europe(Amira et al., 2014). Little or no study has been carried out on NSI among hemodialysis HCWs in Nigeria.Generally speaking,in Hemodialysis units, strict adherence to infection control policies should be observed due to the high risk of transmission of blood-borne infections to both patients and staff. NSI does affect not only the quality service delivery but also the safety andwellbeing of care providers (W.H.O.2004). HCWs in the operating theatre, emergency, delivery rooms, and laboratoriesare exposed to a very high risk. Similarly, waste handlers cleaners and other workers involved in handling blood-contaminated equipment are also at increased risk for NSI.

The aim of this research is to design and fabricate a device that will crush needle(s) waste generated in the health care system and convert it to useful materials.

II. MATERIALS AND METHODS

Design and fabrication of needle crusher

The table 1 below shows the materials used for design and fabrication

Table1: Fabrication materials

S/No.	DESCRIPTION	QUANTITY
1	Metal plate	1
2	Belt disc	1
3	Cutting net	1
4	Rotating shaft	1
5	Boris	2
6	Electric motor	1
7	Four-legged metal stand	1
8	Plank	1
9	Arc welding machine	1

10	Saw	1
11	Cutting machine	1
12	Electrode	10
13	Fly wheel	1

This stage involves the conceptualization of the equipment as part of medical waste management. The different part of the equipment is carefully designed to function with an acceptable level of safety. The crusheris made of 4mm thick metal plate. The metal plate is cut into the different designed sizes and joined together using arc welding. The crusher part is categorized into three main chambers. Namely: (1) Inlet Chamber (2) Crushing Chamber (3) Outlet Chamber.

Precautions taken during fabrication and the experiment

1. The inlet of the machine must be high enough to prevent needle from flying out during the experiment.
2. Proper personal protective equipment (PPE) such as hand gloves, goggles, safety shoes etc. must be worn during the experiment to prevent injury.
3. The test environment must be keptcleanso as to make any needle visible.
4. Avoid staying by the belt side during the experiment
5. All connections to electricity must be properly protected
6. The outlet was designed to prevent needles from flying out of the equipment and enhance easy entry into the receiving container.

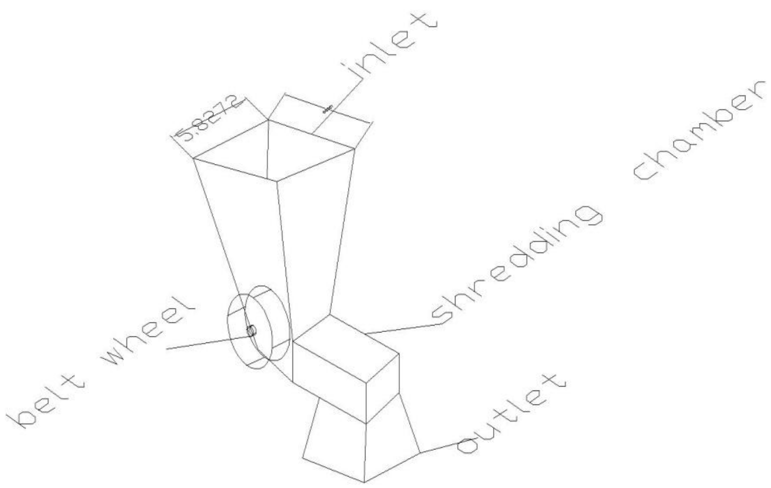

Fig 1 Crusher design

The crusher is designed to work with a slip ring rotor with minimum of 2.3 kilowatt engine. This motor can be of any capacity, depending on the volume of the needles to be crushed and the performance requirement of the machine.This motor will be connected through a belt to the driving shaft of the equipment.

The Inlet Chambers: The inlet is a rectangular metal box shape of adequate width and height. It is the contact point of the equipment and the needle. It receives the needle and then transfers it to the cutting chamber. The inlet is designed with the following assumptions: Length of needle= hDiameter of needle= D, Volume of needle = $V = \pi r^2 h$,where ‘r’ is the radius of the needle.On the average, d=1mm, r = 0 .5mm, L = 40mm

Therefore, Volume required for a needle = $V = \pi \ X \ r^2 X h$

V= $V = \pi \ X \ 0.5 \ X \ 0.5 \ X \ 40 =$ 31.3mm^3

Remark: Say for each needle about $40mm^3$ is required.
The size of the inlet depends on the volume of needle to be disposed and the capacity of the rotating motor. The inlet chamber designed in this project is 40cm X 40 cm at the mouth and 20cm X 10 cm at the base with a height of 40 cm. the approximate volume is $36 \times 10^6 mm^3$
But since the needle cannot be carefully stacked on each other, it can conveniently accommodate over 3000 needles at a time to allow for splashing and crushing rotation.
Cutting Chamber: The cutting chamber is the main part of the equipment. It houses the cutter and the rotating shaft. It is the main chamber where the whole process is carried out. It receives the needle from the inlet. It contains the rotating shaft and the cutting net. The electric motor drives the rotating shaft and the cutting machine. The cutting net also rotates in opposite direction of the shaft. The needle in the feeder is passed into the holes in the cutting net. The counter-rotating directing of the net and the shaft creates an impact which slices the needle into the distance between the chat and the cutting net. The needle is cut into three places and the plastic cap is separated from the steel. The crushed needle and plastic goes out of the machine from the effluent tap. The needle can then be separated from the plastic either manually or mechanically using magnet.

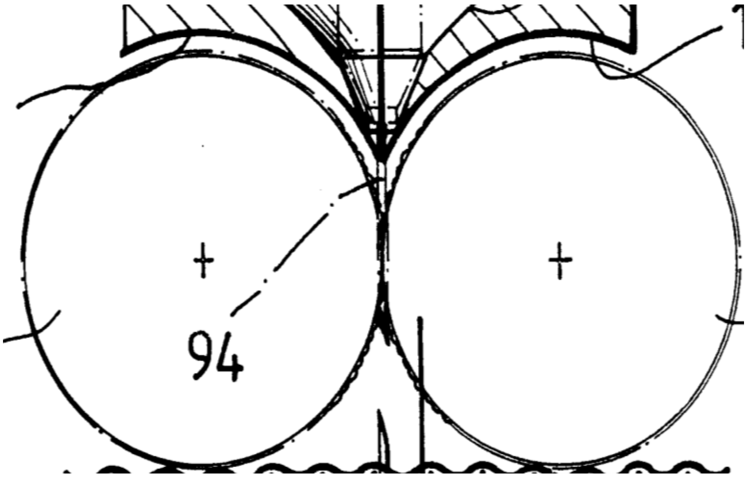

Figure 2: Component of Cutting Chamber

Figure 3: The Fabricated Crusher

Outlet Chamber: This is a rectangular shaped outlet that receive crushed needle(s) from the crushingchamber and transfer it to the receiving container. It is designed to avoid splashing of crushed needle (s).

Testing of the Fabricated Crusher on the Needle Samples

New needles were used first for the testing of the Fabricated Crusher. Three packs of 23g needles were purchased from a pharmaceutical store. Each pack of needles contains 100 needles with plastic covers. The cover is removed from the needle, placed in a plastic container and weighed before it was transferred to the machine feeder.

We further experiment the use of used needles. At this advanced stage, a disinfectant unit will be developed alongside with the crusher. The samples will first be cleaned with hot water and any other prescribed solvent to wash them before it is disinfected and finally crushed.

The prescribed hot water or solvent is to dissolve any clot blood present in the needle. Used needles will be placed in a sealed container of hot water and agitated vigorously to remove dirt and dissolve any blood from the needle. The disinfection is to remove and kill any bacterial that might be lodged in the needle. This can be done using household bleach (Sodium hypochlorite 2NaClO). Used needle must be placed in the bleach solution for a period of 30 minutes or 1 hour to inactivate the bacterial and eventually kill them.

III. CRUSHING AND PRESERVATION OF CRUSHED SAMPLE

The crushed sample was stored in a thick polythene bag. The crushed samples contain the needle steel and the plastic head. The samples were weighed before putting them into the machine and the weight was recorded as M1 (weight of initial sample).

After operating the equipment, the crushed sample from the machine were weighed and recorded as M2 (total weight of crushed sample).

However, the weight of initial sample should be equal to the weight of crushed sample if there is no loss of sample in the equipment called Retention.

Initial sample weight= Crushed sample + Retention Loss

M1 = M2+R

Retention (R) is the residual sample left in the machine after the experiment has been completed. The shape of the equipment is however designed to minimize the residual loss.

Then the plastic and the steel were separated using a manual decantation method where the plastic was hand-picked from the crushed sample.

The weight of the steel is recorded as M3 and the Weight of the Plastic head is recorded as M4.

The weight of the crushed sample must be equal to the combined weight of steel and the plastic head; M2= M3+M4

IV. MATHEMATICAL CALCULATIONS OF THE WEIGHT OF THE SAMPLES

The Initial weight of sample is M_1, Weight of crushed sample is M_2

Weight t Retained sample (Retention) is Rm, Weight of Steel is M_3

Weight of Plastic Head is M_4

$M_1 = M_2 + R$

M2 = M3+ M4

$M_1 = M_3 + M_4 + R$

Percentage Retained in the Machine is $\frac{Weight\ of\ retained\ sample}{Initail\ weight\ of\ Sample}\ X\ 100$

$= \frac{R}{M1}\ X\ 100$

Percentage of crushed sample is $\frac{Weight\ of\ shredded\ sample}{Initial\ weight\ of\ sample}\ X\ 100$

$= \frac{M2}{M1}\ X\ 100$,

Percentage of steel = $\frac{Weight\ of\ steel}{Initial\ weight\ of\ sample}\ X\ 100$

$= \frac{M3}{M1}\ X\ 100$

Percentage of Plastic head is $\frac{Weight\ of\ Plastic\ head}{Initial\ weight\ of\ sample}\ X\ 100$

$= \frac{M4}{M1}\ X\ 100$

However, if the efficiency of the machine is 100% and there is no retained sample in the machine, the initial weight of sample becomes the weight of crushed sample.

Then R=0

$M_1 = M_2 = M_3 + M_4$

V. RESULTS AND DISCUSSION

The crusher worked with an electric motor with power rating ranging between 220-230 volts and could also be used with a diesel or petrol-powered motor just like the normal commercial grinding machine.
The fabricated needle crusher worked with a satisfactory level of safety
Numbers of needle sample used for the experiment (N) = 300
Weight of the sample = (M_1)
Time of experiment (t) in seconds= T
Weight of crushed sample = (M_2)
Weight of sample retained in the crusher = Retention (R) = M_1-M_2
Weight of steel = (M_3)
Weight of plastic head = (M_4)

Table 2: Results

Experiment No.	N	M_1 (grams)	M_2 (grams)	R = M_1-M_2(grams)	M_3 (grams)	M_4 (grams)	T (sec)
1	300	300	270	30	189	81	120
2	300`	300	285	15	195	90	120

Product Performance

Retention: From the experiment, the retention in the first and second experiments was 30grams and 15 grams respectively.

% Retention in experiment 1 = $R/M1$ X 100

$= 30/300$ X 100= 10 %

% Retention in experiment 1 = $R/M1$ X 100

$= 15/300$ X 100= 5 %

The retention of the equipment is low. The machine has an average retention of 7.5%.

Judging by this alone, it can be deduced that the crusher works with 92.5 % efficiency. This is significant and indeed confirms the feasibility of the design.

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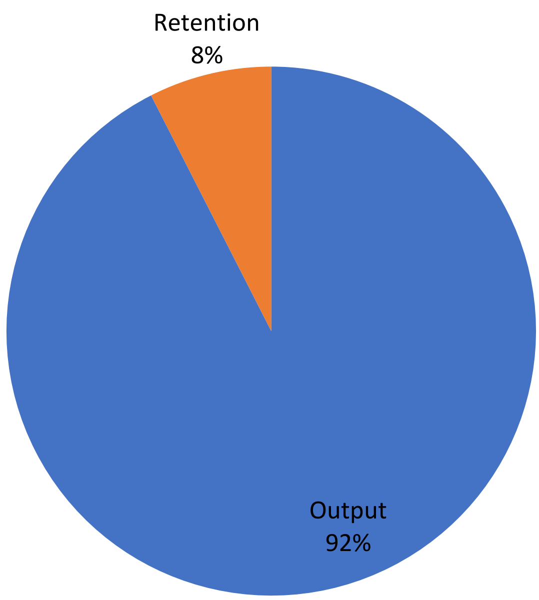

Figure 4: Retention versus output

System performance per time

The performance of the machine described the rate at which the machine operates. It's an expression of how many needles the machine can safely crush and separates per unit measure of time
The machine crushed 300 needles in 2 minutes.
The performance of the machine= 150 needles per minutes
Therefore, the machine can operate at 2.5 needles per seconds which is approximately 3needles/sec.

OutputComposition
From experiment 1,
Steel = 189 g
Plastic head= 81 g

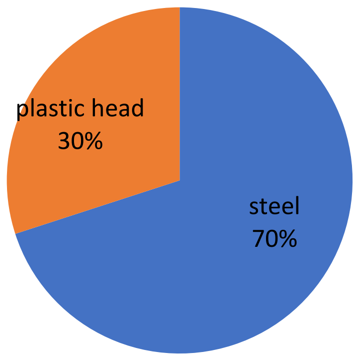

Figure 5: Composition analysis in experiment 1

From experiment 2,
Steel = 195 g
Plastic head= 90 g

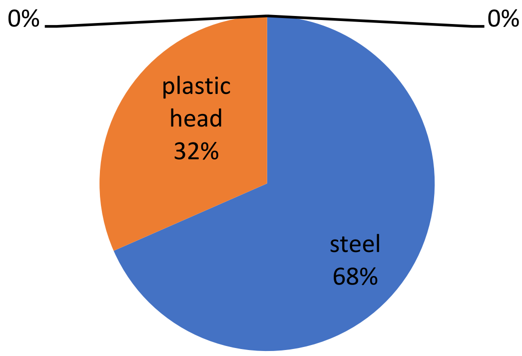

Figure 6: Composition analysis in experiment 2

Average steel weight = 192 g
Average plastic head weight =85.5 g

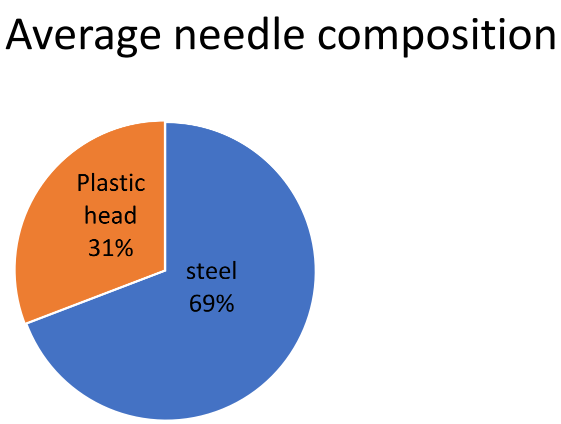

Figure 7: Average composition comparisons in experiments 1 and 2

VI. DISCUSSIONS

- From the results of the experiment conducted on the needles, the machine at an average of 7.5% retention and 92.5% passing efficiency.
- The average run rate of the machine is about 3 needles per seconds depending on the capacity of the electric motor.
- An injection needle contains steel and needles; the plastic head is about 31% while the steel is 69%. Therefore, for every injection needle disposal should conform to both the steel and plastic disposal standard.

Projections

The World Health Organization in 2011 stated that about 16 billion injections are administered globally every year. Based on the assumption that they are all 23G needle (not so in reality). And that each needle weighs 1gramme.

Total weight of needles = 16,000,000,000, X 1gramme

= 16, 000, 000,000grammes = 16,000,000 Kg

And 1 tons is 1000Kg

The total global weight of needle is 16000 tons.

From the result of these experiments, the total global steel in needles is 69% of 16000.

These amount to 11040 tons of steel and 4960 tons of plastic globally.

These huge volumes of plastic if properly separated can be recycled and reused gainfully.

VII. CONCLUSION

In conclusion, feasibility of using an appropriate technology (needle crushing and separation) for the sharps waste management was explored. As previously mentioned, the sharps waste especially needle is one of the most hazardous health care ware, as it can easily transmit disease if meets. Although control measures have been widely applied to dispose needles, in most of the cases, it remains ineffective due to over waste management system.

The technique herein, more or less helps in managing needle disposal as it converts it to a near harmless product that can be easily separated and used to produce an entirely different new thing.

Comparing with old tradition of landfill or incineration, it does not require a large area of land for the disposal rather a small equipment and electricity to power it.

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