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Non-Burn Treatment of Health Care Risk Waste

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Abstract**—**This research discusses a South African case study for the potential of utilizing refuse-derived fuel (RDF) obtained from non-burn treatment of health care risk waste (HCRW) as potential feedstock for green energy production. This specific waste stream can be destroyed via non-burn treatment technology involving high-speed mechanical shredding followed by steam or chemical injection to disinfect the final product. The RDF obtained from this process is characterised by a low moisture, low ash, and high calorific value which means it can be potentially used as high-value solid fuel. Due to the raw feed of this RDF being classified as hazardous, the final RDF has been reported to be non-infectious and can blend with other combustible wastes such as rubber and plastic for waste to energy applications. This study evaluated non-burn treatment technology as a possible solution for on-site destruction of HCRW in South African private and public health care centres. Waste generation quantities were estimated based on the number of registered patient beds, theoretical bed occupancy. Time and motion study was conducted to evaluate the logistics viability of on-site treatment. Non-burn treatment technology for HCRW is a promising option for South Africa, and successful implementation of this method depends upon the initial capital investment, operational cost and environmental permitting of such technology; there are other influencing factors such as the size of the waste stream, product off-take price as well as product demand.

Keywords**—**Autoclave, disposal, fuel, incineration, medical waste.

I. Introduction

THE management of healthcare waste is predicted by the draft HCRW Management Regulations of 2008 [1]. According to these regulations 'healthcare risk waste (HCRW)' is defined as that hazardous portion of healthcare waste that includes infectious waste, infectious sharps, and pharmaceutical waste. Pharmaceutical waste is defined as expired, unused, spilt or contaminated drugs, medicines and vaccines, and includes their packaging materials.

South Africa has traditionally used the conventional thermal incineration for treatment of HCRW generated by both public and private health care centres. HCRW is typically stored at the waste generators facility and collected by a licensed HCRW contractor who transports the waste to a centralized incineration facility. The incinerator operator would treat the waste and issue a safe disposal certificate after destruction of the waste. The certificate is forwarded to the waste generator for billing and record keeping. In some instances, handling and transportation of HCRW includes tracking, cleaning and circulation of re-usable waste containers.

Alternative treatment technologies for HCRW were recently introduced in South Africa, these technologies include autoclaving, microwaving and electro-thermal deactivation. These specific technologies employ various methods to destruct HCRW to acceptable sterilizations levels. The South African Environmental Management Act 59 of 2008 requires that HCRW be managed in accordance with the minimum requirements for the handling, classification and disposal of hazardous waste. This regulation requires that infectious waste such as HCRW be thermally incinerated or treated by any other methods until acceptable sterilisation is achieved prior to disposal at a permitted hazardous landfill site [2]. According to this Act, classification and control of hazardous substance, as defined by the hazardous substance Act, should be undertaken in accordance with the guidelines stipulated by the South African Bureau of Standards (SABS) [3]. The minimum requirement and the SABS guidelines do not clearly define the requirements for HCRW.

HCRW is generated everyday by both public and private health care centres in South Africa, although this is not a large fraction of the total waste generated in the country, the waste stream has a significant impact on the environmental health due to its infectious nature. Untreated HCRW is considered hazardous and infectious. Handling, transportation and destruction of HCRW is strictly regulated in South Africa. There are few permitted HCRW treatment facilities in the country, mostly incineration and autoclave and some of these facilities are operating without valid air emissions licenses [4].

The recent introduction of non-burn, HCRW treatment technologies, such as autoclaving, microwaving and steam sterilization into South Africa, has identified the need to develop standards that will ensure adequate monitoring of non-burn technologies and also to define the "acceptable sterilization limits". This initiative has lead to the South African Government taking a decision to use the procedures developed by the State and Territorial Association of the United States of America (STAATT). STAATT tests requires that acceptable sterilization of treated HCRW should attain level III microbial inactivation which is defined by a reduction of greater or equal to 6 Log_{10} of vegetative bacteria, fungi, viruses, parasites and mycobacteria, and a greater or equal to 4 Log_{10} reduction of *Bacillus stearothermophilus* or *Bacillus subtilis* spores [7]. HCRW is usually collected from the waste generator by an approved contractor and transported to a central destruction facility whereby a gate fee is charged by a treatment facility owner to safely destruct the waste. This approach has made the total cost of HCRW treatment expensive since most permitted destruction facilities are located far from the waste generators. Handling and storage of HCRW is an additional cost adder on to the overall disposal fee due to the use of sacrificial waste containers, sharps containers and re-usable containers in some instances. The state of HCRW management in South Africa is still

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unacceptable. In the past few years, few cases of both general medical and HCRWs disposed illegally in unauthorized sites have been reported [5]. This practice poses a significant threat to environment, animals and human health. The South African government has taken a stance to engage with the relevant stakeholders in both public and the private sector to ensuring that a sustainable solution is achieved. This may require amending legislations to accommodate alternative HCRW treatment methods and regulation of pricing models for HCRW.

This review discusses HCRW treatment and conversion systems integrated for green energy generation and recovery, thereby eliminating the environmental footprints of the conventional HCRW management processes in South Africa.

II. Methods

A. Estimation of HCRW Volumes

Table I presents the estimated quantities of HCRW generated in selected provinces in South Africa. These quantities were estimated by considering the number of registered patients beds and average bed occupancy as published in the hospital and nursing yearbook [6]. Based on the HCRW generation quantities reported in Table I, significant amounts of HCRW are generated from four of nine provinces in South Africa. The public sector contributes a significant amount of waste in the country. The waste quantities exclude, anatomical waste, which must be incinerated by law. HCRW generated from doctors consultation rooms, day clinics are assumed to be part of the waste associated with the major health care facility.

TABLE I
PROVINCIAL HCRW VOLUMES IN SOUTH AFRICA

	Gauteng	KZN	Eastern Cape	Western Cape
Public (tpa)	970	1231	830	212
Private (t/m)	432	101	83	177
Public Facilities	70	19	92	18
Private Facilities	30	71	15	15
Total Private (tpa)	5,588	1,278	986	2,100
Total Public (tpa)	11,236	14,706	9,970	2,568
Total (tpa)	16,824	15,984	10,956	4,668

This waste stream could be transformed in to a high calorific value RDF via a non-burn treatment technology described in this study. The resulting product can be used as a feedstock for gasification and co-generation stream.

B. Non-Burn Treatment Technologies

1. The Positive Impact Waste Solutions (PIWS)

PIWS non-burn HCRW treatment technology has an on-board computer interface that monitors the entire process, as shown in Fig 1. The operator stages and loads the waste directly into a feed hopper.

Fig. 1 PIWS non-burn HCRW Treatment System [7]

The correct amount of the registered dry chemical and water mist required to treat the volume of waste to be processed is then added. The automated cart lift mechanism transfers the waste into a twin treatment chambers for the large unit and a single grinding chamber for the smaller unit, where the dry chemical is chemically bound to the material.

The HCRW is ground and mixed for approximately 10-30 minutes per load. This process balances the pH level and renders the organic material and microbiological organisms non-infectious. In addition, the processing blades of the PIWS-3000 reduce the original volume by more than 70% and render the waste unrecognizable. The treated material is continuously monitored as it is augured out for the required pH level.

Once the destruction process is completed, the treated fluff could be discharged into the general waste stream for further handling. The mobile PIWS-3000 consists of a programmable logic controller equipped with a touch screen computer system for data capturing and record keeping of critical information relating to the quantities, date and time of treatment. The system is also capable of issuing a printed safe destruction/disposal certificate immediately after the destruction cycle.

PIWS has developed a proprietary CaO based disinfectant (Cold-Ster) that is added into the waste to kill the pathogens. Sara Stumph, 2002 [7, p. 82-111], [7, p. 8-41] conducted tests on 7.5w/w % Cold-Ster treated HCRW using B. *subtilis* and M. *terrae* in accordance to STAAT test procedures. It was discovered that cold-Ste at 7.5w/w% kills $4\log_{10}$ of B. *subtilis* and kills $7\log_{10}$ of M. *terrae* in the field of disinfecting after an exposure time of 45 minutes and 30 minutes, respectively. The above results meet the STAAT II standards for acceptable kill of spore-forming bacteria and mycobacteria. The PIWS HCRW converter can be a mobile or fixed with Treatment capacities ranging between 180-900 kg/hr. Indicative Budget prices ranges between ZAR 2.2-6.5million.

III. The OMPECO Converter

The OMPECO Converter is designed to treat and sterilise potentially infected medical waste to produce a dry and odour free fluff with reduction of 70% in volume and 30% in mass [8]. The processing steps involve thermal decomposition of protein constituting living cells. This is followed by crushing of infected waste, which has the effect of increasing temperature due to friction, this results in evaporation of water in the waste, sterilisation of the shredded waste carried out at a temperature of 151 °C with the injection of water and generation of saturated steam. The final product is cooled and discharged as dry fluff, as shown in Fig. 2 [9]. The treated waste is considered non-hazardous and can either be disposed at the general landfill site or used as RDF due to its high calorific value of 25-30 MJ/kg, low moisture content of 3.17% and un-compacted dry bulk density of 272 kg/m^3.

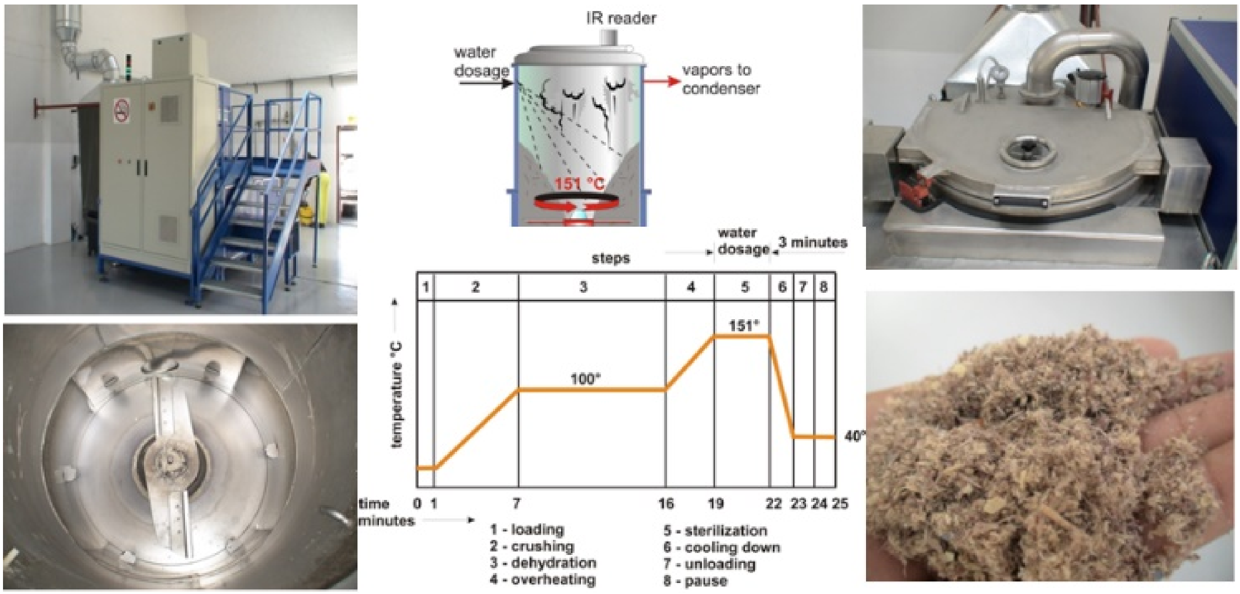

Fig. 2 OMPECO HCRW convertor system [10]

Arnese and Cavallotti [11] investigated the effectiveness of a sterilizing process for infectious hazard sanitary, at Second University of Naples. The results did not indicate any growth of the biological indicator and therefore it is shown in practical way the effectiveness of the sterilization process of the Converter equipment starting from a bioindicator containing 106 live spores of Geobacillus stearothermophilus per each waste load. Based on these findings it was reported that the technology could guarantee both the sterility of the treated waste as well as, through its size reduction and dehydration, a remarkable reduction of weight and volume facilitating the disposal operations, without further risks for the operators. According to [17], ongoing monitoring and validation of microbial inactivation of HCRW in accordance to STAAT III procedures could be a costly exercise, as such, alternative monitoring options needs to be evaluated.

IV. Results

A. Discussion of Results

1. Combustible Waste- RDF

Production of RDF is a thermal or mechanical pre-treatment method suitable for general waste and pellets are produced which can then be used as fuel in approved facilities. This fuel can be used as a feedstock for gasifiers to generation gas for running combined heat power plants [12]. Such processes produce higher quality fuel products with a higher calorific value than the initial waste and it is in a physical condition, which makes it easy to handle, transport and use. It is normally then sold, or given away for free to industries who can burn it as fuel [13]. Although there are a number of RDF plants in the world, to date none has been erected in South Africa, and a market for the RDF would have to be investigated and developed first, as well as assessing any environmental impacts if this fuel is burned in normal burners.

Fig. 3 Treated HCRW [14]

A sample of treated HCRW was received from OMPECO, as shown in Fig. 3; this sample was sent to the Pharmaceutical Microbiology Department at the South African Bureau of Standards (SABS) to conduct independent tests to determine the presence of pathogens indicated in Table II in accordance with the State and Territorial Association on Alternative

Technologies (STAAT) tests.

TABLE II
MICROBIAL LIMIT TESTS ON TREATED HCRW [15]

Sample	Total aerobic count	Total Yeast & Mould Count	*Pseudomonas aeruginosa*	*Staphylococcus aureus*
Treated HCRW	<10	<10	ND	ND

ND =Not detected
D =Detected
<10 reflect the accuracy of the test procedure and for all practical purposes imply the absence of the organism indicated.

Based on the test results presented in Table III, it is evident that the RFD obtained from non-burn treatment of HCRW using steam injection for disinfection does not contain any pathogens and potential for infection.

TABLE III
PROPERTIES OF HCRW RDF AS SOLID FUEL

Parameter	Test Value
Gross Calorific Value	25.981 MJ/kg
Moisture	3.7%
Total Carbon	81.6%
Total Ash	18.4%
Total Sulphur	0.028%

Table II present the properties of RDF obtained from HCRW, the results show that the RDF has excellent combustion characteristics for a solid fuel.

2. Technology Discussions

The proposed non-burn treatment solution for HCRW is designed to treat the waste at the waste generator's facility (health care centre). This option eliminates the challenges associated with long term storage and long distance transportation of infectious waste to a permitted centralised treatment facility. The solution offers short treatment cycle times, which possibly allows treatment of HCRW generated by multiple heath care facilities within a short period of time. The treatment is undertaken by a high speed mechanical shredding action followed by steam injection and chemical sterilisation to convert the waste into an inert non-infectious fluffy combustible material.

The solution has significantly low input energy and does not generate any emissions or ash. There is minimal contact with the waste as the system is designed to receive waste in sacrificial containers and convert it completely into inert combustible fluff. The system is equipped with an automatic bin lifter and built-in weighing device that captures the mass of HCRW treated, time, date and mass of the fluff produced. The operator can also capture details of the waste generator using the touch screen on-board computer on the system. All these information including treatment conditions such as cycle time, steam pressure and temperature and pH are captured by the system and printed/e-mailed to the relevant client official, immediately at the end of the treatment cycle. This is recorded as proof of safe destruction/disposal and also for billing purposes. The fluff produced is non-infectious and has good combustion characteristics for possible use as RDF. This solution could possibly eliminate a number of challenges associated with conventional treatment systems. Although this technology is proven in the country of origin, it would require to be tested in South Africa.

B. Challenges Relating to Current HCRW Treatment

- Thermal Incineration treatment, autoclaving and illegal disposal;
- Shortage of licensed HCRW treatment facilities;
- HCRW is generated in small quantities at source and often require long distance transportation to centralized treatment facilities;
- Existing centralized facilities have high capital and operational cost requirements compared to mobile treatment facilities;
- Non-regulated and relatively high conventional treatment cost;
- Risk of possible infection while handling HCRW;
- Tracking and cleaning of reusable sharps containers;
- Non-viable contract structure and payment delays from the public facilities.

C. Advantages of Non-Burn Treatment Method

- No combustion of wet HCRW;
- Significantly reduced input energy required for waste treatment;
- No ash and emissions;
- No contact with HCRW due to the use of sacrificial waste containers;
- No container tracking and cleaning;
- Immediate issuing of safe destruction certificate;
- No long term storage of HCRW on site, planned waste destruction occurs daily;
- Customised pricing and immediate billing method;
- Viable pricing, including treatment, containers, power and logistics;
- Zero transportation/handling of infections HCRW.

D. Alternate Treatment Technologies

Listed below are the alternative technologies that are available for consideration [15], [16].

- Hydroclave;
- Autoclave;
- Microwave treatment;
- Incineration (with air emission license).

V. CONCLUSION

Alternative energy production from HCRW in South Africa may be of a great interest. The use of RDF as alternative fuel for cement production is currently practiced in South Africa. The combustion characteristics and microbial tests of the HCRW, suggests that it could potentially be used as RDF. This option could potential reduce the greater environmental impacts associated with conventional methods of handling and treating HCRW. Non-burn treatment of HCRW is a proven technology currently employed in some countries; however, this method needs to be adapted to the South African waste management regulations before it can be implemented.

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