Recycling opportunities for Regulated Medical Waste / Clinical Waste:

A comparison of output materials from Thermal and Non-Thermal treatment technologies

December, 2023

Comparative analysis of Autoclave Vs Envetec GENERATIONS® Technology

Abstract

The aim of this study was to assess the suitability for recycling of output materials from thermal and non-thermal treatment technologies. The study compares details of post-processed output materials from a laboratory autoclave and Envetec's GENERATIONS® technology. An identical material load consisting of a variety of common laboratory polymer materials (outlined in section 5 of this document) was processed through both systems under standard operating conditions. The material was assessed under the following criteria:

- Visual inspection
- Mechanical inspection
- Assessment of impact of sterilising chemical on polymers

The study found that thermal treatment technologies impacted the majority of the polymers processed to the extent that further inspection of mechanical impact was non-viable. Research shows that certain polymers should not be processed in autoclaves (include studies that Dean has). By contrast, the output from the non-thermal technology was suitable for further assessment and deemed suitable for polymer separation which enables high value recycling. Additional analysis proved that the non-thermal treatment did not impact the mechanical performance of the polymers and the sterilising chemical did not alter the materials.

Comparative analysis of Autoclave Vs Envetec GENERATIONS® Technology

Contents.

Comparative analysis of Autoclave Vs Envetec GENERATIONS® Technology

1. Introduction

1.1. Previous Recycling of Biohazardous Waste

The concept of recycling previously biohazardous waste is not new. A number of manufacturers, waste management organisations and working groups have launched projects over the years with the aim to recycle material that is considered biohazardous and therefore destined for incineration or disposal. Becton Dickinson (BD) in both 2011 and 2023 partnered with Waste Management and Casella Waste Systems respectively to run initiatives based on recycling a selection of their single use plastics post use. Also, Baxter New Zealand partnered with MATTA an industrial mat making company in 2014, to recycle their PVC IV bags. While all of the above mentioned programs found that it was possible to recycle biohazardous material post-treatment they did not become widespread for a number of reasons, a few examples of which are:

1) Programs required a high degree of pre-treatment separation to isolate specific products which would not be feasible for institutions on a large scale due to time and safety constraints.
2) There was often a large carbon footprint associated with the transport of one specific type of product for treatment.
3) Inseparable mixed polymers (often found in life science waste streams) are often low value and are not financially viable for recycling companies to reconstitute.

Joseph et al, published a study on the recycling of medical plastics in 2021 in the Journal of Advanced Industrial and Engineering Polymer Research highlighting some of the various barriers associated with recycling medical plastics, which can be found using the following link: https://www.sciencedirect.com/science/article/pii/S2542504821000348

1.2. Autoclaves & Biohazardous Polymer Treatment

In response to the cost and risk associated with transporting live biohazardous waste autoclaves have become one of the most common technologies life science facilities use to decontaminate biohazardous waste onsite. Standard autoclaves utilise pressurized steam and superheated water to treat potentially infectious material. However, a number of issues can present when using this material to treat polymer material:

1) Limited Scope – A number of institutions, journals and engineering firms have issued guidance on the usage of autoclaves to treat polymer materials. This guidance prohibits the placing of polymers such as PE, HDPE, LDPE, PVC, PS a large percentage of which are found in common plastics used in life science settings.
2) Potential Harm – Institutions such as the University of Maryland of highlighted the potential health hazard associated with autoclaving certain polymers, “Do not autoclave animal carcasses, sealed containers, flammable chemicals, volatile chemicals, bleach, or radioactive material. Please note that certain plastics can produce toxic gases, do not autoclave the following plastics: Polyethylene (PETE, Recycle #1), High Density Polyethylene (HDPE, Recycle #2), Polyvinyl Chloride, and Polystyrene."
3) Damage to Equipment – Melted or warped material can not only affect operator safety but also cause expensive damage to the autoclave chamber, this type of damage is not usually covered under warranty.

Comparative analysis of Autoclave Vs Envetec GENERATIONS® Technology

In recent years, the energy and water intensity of autoclaves has also come into focus. The non-profit My Green Lab published a report in 2022 titled "Autoclave Impact Evaluation Report", the purpose of which was to develop a standard testing method for steam sterilizers/autoclaves to enable the comparison of energy and water consumption across different manufacturers. The report found that the commonly used front-loading steam jacketed autoclave running on an average shift would use around 84 kWh and consume 2460.52 litres of water. To put this into context, when ran on a standard shift over a year one autoclave would use more water than seven Irish households and would require 6739 kg of coal to be burned to generate the energy required to run it.

1.3. Objective

With regulations around emission becoming significantly more robust in the wake of increased climate collapse alongside infection control and safety gaining prevalence in the wake of COVID, life science operations are trying to find a way to be more sustainable while increasing safety standards.

Envetec GENERATIONS is a novel, non-thermal, clean technology that treats biohazardous waste onsite using a combination of shredding and biodegradable chemical treatment. GENERATIONS receives a validated spore reduction of 6log10 while converting single use lab plastics into a flake material. The objective of this study is to compare polymer material treated using GENERATIONS to polymer material treated in a standard lab autoclave to assess the materials suitability for recycling processes post treatment.

If biohazardous material can be treated onsite, removing the dangers and cost associated with transporting live waste, and recycled this will unlock novel sustainability options for life science operations when it comes to managing their biohazardous waste safely.

1.4. Materials used

Quantity	Description	Supplier/Part Code	Material Type
1	Catheter	Sarstedt / 74.5330.520	PVC
10	Petri dishes	BioTrading/K073P090KP	PVE
2	300ml bottles (no lids)	Aquavie	PET
4	10L jug caps incl gasket	Quitmann O'Neill	PE
10	Salt Agar Petri Dishes	BioTrading/K040P090KP	PVE
4	Nitrile Gloves	N/A	Synthetic Rubber
5	15ml Conical Tubes and caps	N/A	PP

Table 1 – Materials used for study

Figure 1- Material for Trial

Figure 2- Material in Autoclave Bag prior to execution of study

2. Trial Process

2.1. Autoclave

The autoclave used in this study is the Tuttnauer 3870EL series autoclave.

Figure 3- Tuttnauer 3870EL series Autoclave

The autoclave will be run under normal operating conditions as outlined in the autoclave operating procedure by a fully trained and competent employee. The autoclave operates at 121°C for a 15 minute cycle. Total ramp up and ramp down time for the autoclave gives rise to a true cycle time of 110 minutes.

Figure 4 - Autoclave loaded with wire rack to contain potential leakages

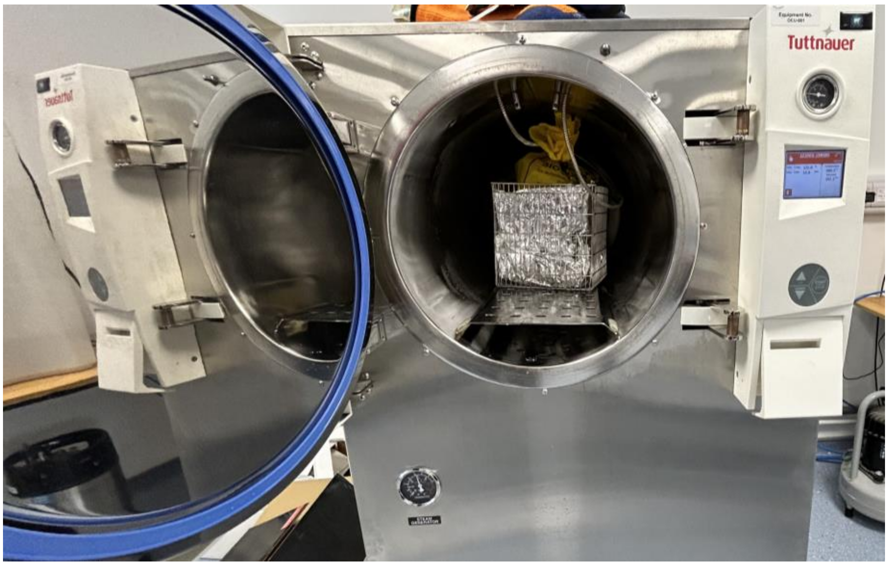

Figure 5 - Autoclave prepared to execute cycle

Figure 6- Autoclave in operation

2.2. Envetec GENERATIONS®

Envetec GENERATIONS® will be run under normal operating conditions as outlined in the operating procedure by a fully trained and competent employee. As previously mentioned, the identical material load as outlined in section 5 has been used for both trials to eliminate bias.

Figure 7 - Envetec GENERATIONS® used for trials

Figure 8- Material loaded into Envetec GENERATIONS® receiver for trial.

3. Trial Results

Post completion of trials the following results complimented by figures were obtained:

3.1. Autoclave

Initial odour emanating from the Autoclave bag even though the material was clean waste prior to trial with no biohazardous material present. The autoclave bag had melted slightly and adhered itself to the material inside as can be seen in the figure below.

Upon opening the bag, we can see that the 15ml tubes and the nitrile gloves remained fully intact. These were removed and disposed of.

Once removed, a large glomerulus of melted, intertwined material was observed which required a scissors to cut out as the autoclave bag was adhered to it.

Once the bag was cut open you can visibly see the conjoined material and also the black caps and catheter which did not melt.

The glomerulus upon further inspection had melted around various different materials which were used during the trial

Comparative analysis of Autoclave Vs Envetec GENERATIONS® Technology

3.2. Envetec GENERATIONS®

Post completion of the validated sterilization and shredding cycle the following was observed. It is worth nothing that the rinse cycle was performed manually to allow for collection of the material post cycle completion.

The material has been completed shredded into smaller particles of single base constituent polymers.

As previously stated, the resultant material has been broken down into singular polymers, there was no odour post completion of the trial and the waste has been reduced to circa 10% of the original volume

4. Analysis of Results

4.1. Overview

The comparison between the autoclave and Envetec GENERATIONS® technology reveals substantial differences in terms of recyclability and material processing efficiency, with crucial implications for sustainability and ease of recycling:

1) Material Condition: The autoclave process leads to the formation of larger pieces of plastic, which might initially seem advantageous for sorting purposes. However, it's essential to highlight a significant drawback: these larger pieces are often conjoined with different polymers, making it exceptionally difficult for recyclers to separate them effectively. This necessitates additional post-processing steps, such as maceration or shredding, to isolate and recover individual polymer types.

2) Odour: The autoclave process generates an initial odour, which could be a concern for sensitive applications, such as medical or laboratory settings. This odour issue, combined with the need for post-processing to separate conjoined polymers, not only raises environmental and health concerns but also complicates the recycling process.

3) Waste Reduction: Envetec GENERATIONS® significantly outperforms the autoclave in terms of waste volume reduction, reducing it to approximately 10% of the original volume. In contrast, autoclave waste is not only challenging to separate but also requires additional post-processing, such as shredding or maceration, to achieve a comparable level of waste reduction. These added steps consume more resources and add complexity to the recycling process.

4) Recyclability: Envetec GENERATIONS® appears to offer a more favourable outcome for recyclability due to its ability to break down materials into individual polymers, simplifying the recycling process. In contrast, the autoclave's production of larger pieces conjoined with various polymers introduces significant challenges and the need for further mechanical processing.

5) Energy Cost Comparison: An in-depth energy cost comparison between the autoclave and Envetec GENERATIONS® is available in Appendix 1 of the document. This comparison provides valuable insights into the energy efficiency and environmental impact of both technologies.

6) Consistency: Envetec GENERATIONS® provides more consistent results, with no reports of issues like melting and adhesion of materials. The autoclave's production of larger, conjoined pieces further introduces variability in the material output, necessitating additional effort and resources for recycling.

4.2. Conclusion

In light of these factors, the autoclave not only complicates the recycling process due to the need for manual efforts to open bags but also generates larger, conjoined pieces of plastic that are difficult to separate. These factors increase the environmental footprint associated with autoclave waste management and introduce complexities for recyclers, who must invest in additional post-processing steps to extract and recycle individual polymer types. The data presented underscores the advantages of Envetec GENERATIONS® technology in streamlining the recycling process and minimizing environmental impact compared to traditional autoclave methods, as detailed in the energy cost comparison in Appendix 1.

5. Appendices

1. Table of Figures.

2. Table of tables.