UNIVERSITY OF KWAZULU-NATAL

Exploring the biochar supply chain to determine the potential for biochar production in KwaZulu-Natal

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DECLARATION

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ABSTRACT

Biochar is a product that has many beneficial properties but there are several socio economic and financial challenges associated with its production. By studying a potential biochar supply chain, many of these challenges can be identified and solutions sought. The available literature was studied in order to analyse the biochar supply chain from biomass collection to end product usage. This included all the steps involved in the collection of biomass and the logistical implications before and after production. Furthermore, it looks at how the feedstock and production method impact end product quality and how this would impact the commercialisation of biochar.

For the purpose of this study, empirical research was utilised with participants chosen via a judgment sampling method. All participants were selected on the basis of their expertise on the subject of biochar. All research done was qualitative in nature in order to gain a deeper insight into the subject and to open up avenues for future research. The possibility of using biochar as a potential means of waste management does exist, but there are many challenges that make the undertaking of such a task difficult.

The consensus amongst the majority of participants is that while a project is possible, many considerations need to be taken into account beforehand in order to assess the viability of such a project. Unless a very specific feedstock and production method is used, the end product may be limited in its usage. Making a higher-grade biochar will have a lot more end uses and a lot more commercial application, but this may require substantial capital and a quality feedstock source would have to be secured. While the benefits of biochar may be many, implementation will be a challenging task and necessary capital and knowledge will be required to make such a project a success.

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CHAPTER 1: INTRODUCTION

References to biochar often only consider environmental or agricultural perspectives and omit the commercial perspective regarding feedstock procurement and the sale of biochar. Whilst biochar is an effective agricultural amendment and can be utilised as a tool to combat climate change, biochar is a relatively unheard-of commercial product that has considerable potential. Over recent decades, interest in biochar has begun to grow as more and more of the benefits of biochar become apparent. The applications of biochar are not confined to environmental rehabilitation; there is also a great deal of potential with regard to commercial applications. As with most new products, potential investors need evidence of the product's commercial viability. If a product like biochar is going to be produced and utilised, such an endeavour would most likely be driven by the commercial sector rather than any environmental rehabilitation programmes or climate related endeavours.

If a biochar enterprise is to be initiated, it is important that vigorous testing be done with potential feedstocks in order to ascertain the quantity and quality of the biochar yielded. Feedstocks are often contaminated and the question that needs to be asked is whether the separation of the feedstock from other waste would be cost effective in relation to the end product's value. This question is especially important when looking at feedstock sources such as municipal dump sites and household rubbish. By using biochar production as a waste management method, would this biochar product be of an acceptable quality? The quality and quantity of the end biochar product are important elements of the supply chain. In order to ensure quality, quality checks should be carried out throughout the entire supply chain.

Whilst extensive research has been carried out looking at the properties, production methods and many uses of biochar, very little research has been done on the supply chain involved in the production and distribution of biochar from a commercial perspective. By looking at biochar from a supply chain perspective, it may be possible to detect some of the problems that could be encountered during production and distribution as well as solutions to these problems.

Essentially, this study considers the entire biochar supply chain from point-of-origin to point-of-consumption, it assess production methods, how feedstock quality affects the end product and yield and it identifies some of the potential applications for the end biochar product in the KwaZulu-Natal region of South Africa.

1.1 Background of the study

The world's population is growing, and development is happening on a larger scale than ever before. Pollution is becoming more and more of an issue. This pollution is prevalent in wastewater that is not being adequately treated which in turn greatly impacts both the ecosystem and human habitats. In South Africa, the paper and pulp industry is an example of a substantial contributor to pollution and, internationally, is counted as the sixth largest contributor to pollution after the textile, oil, cement, leather and steel industries. The current rapid population growth means that waste is being generated at an increasing rate and the number and capacities of disposal sites are shrinking. The majority of waste is being processed in ways that are inefficient and harmful to the environment. By utilising a process such as biochar production, this means that waste will be managed in a safer, more environmentally friendly way while at the same time various commercial and economic benefits could be realised. Benefits include energy recovery, greater crop yields from an agricultural perspective, water filtration systems, etc. (Dahal, Acharya, & Farooque, 2018 2018, p. 1)

In theory, biochar can be produced from all forms of biomass, however, overseas producers of biochar have learnt that careful consideration needs to be taken when choosing potential feedstocks for production. Certain feedstocks may not be suitable for biochar production due to their innate properties and the conditions these feedstocks have been exposed to (Ndirangu, Liu, Xu, & Song, 2019 & Song, 2019, p. 8).

In order to fully understand biochar, its production process and how it could be put to better use, the biochar supply chain will be looked at in great detail. Superficial examination of the main processes involved in the biochar production process indicates that the supply chain could be divided into five areas. These areas are production/procurement of the biomass, the logistics involved in moving the biomass (feedstock), the production or conversion of the biomass into biochar, the logistics involved in distributing the end biochar product and the end use of biochar. There are obviously many more activities involved within each area. Furthermore, if a supply chain approach is taken, the information flows between the segments would also need to be studied in order to be able to optimise efficiencies (Anderson, Bergman, & Page-Dumroese, 2016, p. 26).

1.2 Research problem

According to Stats SA, only a mere 10% of the 59 million tonnes of general waste was recycled in 2011, with the rest of the waste being sent to landfill (StatsSA, 2018). No official studies

have been done since then to assess the situation, but it can be assumed that the situation is more likely to worsen as time goes by (Godfrey & Oelofse, 2017, p. 8). Currently, the majority of South African waste goes to landfill which in turn means that we are running out of landfill space and are experiencing an exponential increase in harmful gases from the existing landfills. Decomposition of waste is a slow process with the rate of solid waste dumping far exceeding the rate of decomposition. This often leads to permanent damage to the environment in the vicinity of the landfill. Hazardous gasses can cause damage to the environment as well as nearby water bodies and the toxic fumes from the landfills often impact the quality of life and health of residents in proximity to the landfill (Gunarathne et al., 2018, p. 228).

Although there are many ways to better manage waste, one of the simplest methods that could also have the most benefit is biochar production. However, there are several issues that need to be studied before attempting to enter into production. Numerous benefits can be derived from biochar but the process of making the product can still pose many challenges. By tracing a biochar supply chain, issues regarding feedstock quality and the production of biochar can be investigated and potential solutions may be found. In turn this may contribute to creating a better biochar end product and many more opportunities for biochar use. The main potential benefit is a better waste management method. The quality of the biochar end product has a direct impact on the potential areas where biochar can be used; improved quality means a wider range of applications. This contributes to better climate mitigation and improved commercial potential. By looking into the commercial applications of biochar production, this may garner more interest in biochar production.

1.2.1 Problem Statement

Currently, dump sites in the Pietermaritzburg and Durban area get thousands of tons of waste on a monthly basis with a large portion of it being organic. By diverting organic waste away from landfill into a value adding activity like biochar production, this could lead to multiple benefits being garnered such as an alternate, more environmentally friendly method of waste management, job creation along the biochar production supply chain and an end product that could have a multitude of beneficial end uses.

1.3 Research questions

- What are the processes and enterprises involved in a biochar supply chain and how could these processes and enterprises be better integrated?
- How does the production method affect the quality and yield of the biochar?

- How does feedstock quality affect end product quality and yield?
- To what extent does the cost of separating contaminants from feedstock affect the financial viability of biochar production?
- What is the scope for large scale biochar commercialisation and could potential investors be attracted to a biochar initiative in South Africa?
- How does biochar pricing vary according to the quality of the product?

1.4 Research objectives

- To understand the processes and enterprises involved in a biochar supply chain and how these processes and enterprises can be better integrated
- To identify how the production method affects the quality and yield of the biochar
- To identify different potential feedstocks, including contaminated feedstocks, and to assess how feedstock quality affects end product quality and yield
- To assess the viability of using a contaminated feedstock when the costs incurred in separating and removing the contaminants are considered?
- To assess the commercial potential of biochar production in South Africa.
- To assess how biochar quality affects its price

1.5 An overview of the literature

Anderson et al. (Anderson et al., 2016, pp. 27,28) trace some of the processes involved in a biochar supply chain from the collection of the biomass to the biochar end use. Included in this is feedstock harvesting, some of the production techniques and how a biochar supply chain could be run sustainably. Their research considers how the many supply chain segments in a biochar supply chain would interact whilst keeping in mind the impact biochar production and logistics would have environmentally. There is further explanation that a biochar supply chain would need to be run in a manner similar to any other successful supply chain i.e. there needs to be mutual trust and understanding between all parties in order to facilitate the proper flow of information, resources and materials across the supply chain. Only once this is achieved can a successful biochar supply chain be built (Anderson et al., 2016, p. 29). Utilising this as a base, a supply chain specific to certain feedstocks and production methods could be drawn up.

Elkhalifa, Al-Ansari, Mackey, and McKay (2019, p. 311)describe the implementation of a biochar waste management system for food waste. Instead of industries utilising a linear approach when it comes to waste management, a circular approach should be adopted in order to facilitate sustainable waste management. Rather than simply being dumped, organic waste

should be channelled into the creation of new products such as fuels and chemicals via a thermochemical method (Elkhalifa et al., 2019, p. 312).

Annually, an estimated 1.3 billion tons of edible food is disposed of globally (Elkhalifa et al., 2019, p. 311). If some of this is channelled into use as a biochar feedstock instead of it simply being disposed of, it could have largescale benefits such as a carbon emission mitigation measure, soil amendment, an alternate fuel source, an adsorbent of toxic metals, etc. Furthermore, this would mean less waste being sent to landfill, which is a big step toward decreasing greenhouse gases and becoming more environmentally friendly. A similar comparison could be drawn to other forms of organic waste. To use Pietermaritzburg as an example, 698 tons of garden refuse was dumped in the New England Road Dump Site in the month of May, 2019 alone, according to Municipal records (Refer to Appendix A). If this garden refuse could be put to better use as a potential feedstock, many benefits could be reaped including relieving some of the capacity issues that the dump currently faces.

Ghani, Vogiatzis, and Szmerekovsky (2018, p. 40) discuss the challenges faced when implementing a successful biomass feedstock supply chain. Due to an increasing demand for greener solutions that have a positive impact on society, the economy and the environment, renewable energy such as bio-power and biofuels have been gaining popularity. These fuels are produced from biomass which is directly derived from organic materials such as agricultural waste. Due to this growing interest in biofuels, there has inevitably been a spike in research done on biomass, specifically on the optimisation of a biomass supply chain from the initial procurement of the biomass to the end consumer. The challenge lies in running the biomass supply chain in a way that production and logistics costs are kept to a minimum. The focus of Ghani et al. (2018, p. 40) is finding a way to improve efficiency in the biomass supply chain whilst keeping costs and Green House Gas emissions to a minimum.

Maroušek, Vochozka, Plachý, and Žák (2017, p. 311) maintain that biochar has many great applications such as its carbon sequestration, its toxic waste adsorption and its applications in the farming sector. However, it is still not being put to proper and widespread use as a tool to combat climate change or as a method to increase crop yield in the agricultural sector. Due to high demand from the energy sector and industry, the price of biochar still remains high which makes it difficult for widespread commercialisation of biochar to take place. There is a gap in the literature concerning the commercialisation of biochar.

Daful and Chandraratne (2018) describe the different production methods for biochar produced from waste derived materials. A better understanding can be gained of how different production methods affect biochar quality and yield by looking at the different methods of production. This would help in assessing the viability of potential feedstocks such as garden refuse and organic household waste.

Tag, Duman, Ucar, and Yanik (2016, p. 2) give further credence to this by describing how utilising different feedstocks pyrolysed at different temperatures has a direct impact on the quality and the yield of biochar. Different parent feedstocks pyrolysed under different temperatures produced different varieties of biochar, some of which were more suitable as fuels and some which were more suitable as agricultural amendments. Furthermore, biochar could still be produced from contaminated feedstocks even though the quality of the biochar end product proved to be inferior with limited usage options. This shows that it is possible to utilise contaminated feedstocks provided the production method, feedstock and utilisation of the end product is carefully considered (Tag et al., 2016, p. 3).

1.6 Theoretical framework

In order to ensure that the objectives of the study were met, a theoretical framework was utilised. The theoretical framework was used to structure the biochar supply chain in order to better understand the challenges that would be faced if such a supply chain were implemented.

Anderson et al. (2016, p. 27) consider the supply chain required to make and distribute biochar. Each block described in this supply chain model contains many processes contributing to a fully functioning biochar supply chain. Their supply chain was adapted for this study in which a more practical approach was taken. This framework, illustrated in figure 1.1, can be followed and allows for adjustments where necessary. A quality assessment loop was added in to signify an information flow from the end product back to the feedstock sourcing and production process to show that if necessary the production method or feedstock source should be changed to improve the quality of the end product.

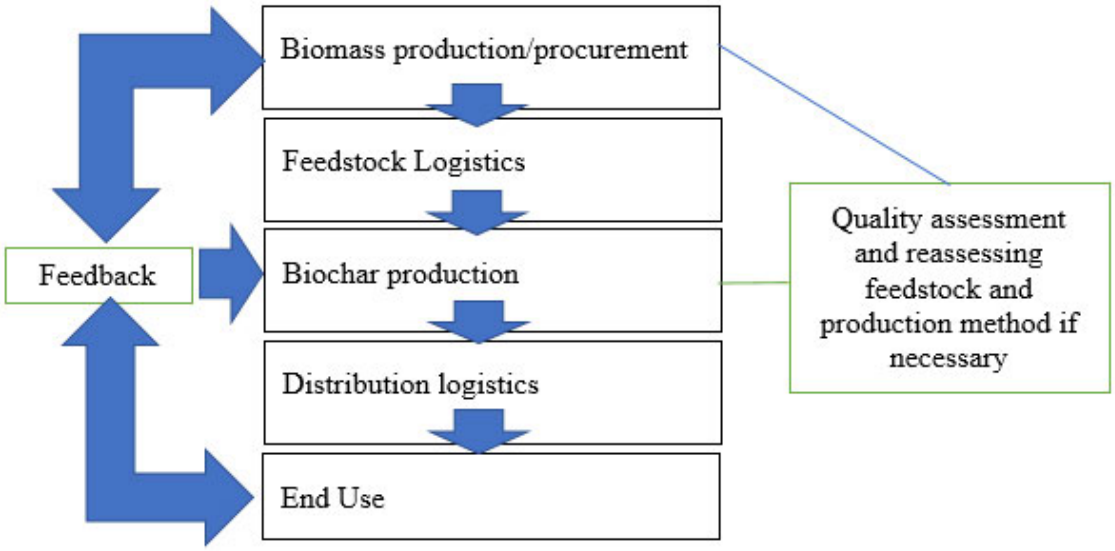

Figure 1.1: A biochar supply chain framework (Anderson et al., 2016, p. 27))

The commercial applications of biochar should be assessed as part of the supply chain. Maroušek et al. (2017, p. 315) describe how biochar is not being utilised to its full potential and is an expensive commodity. They describe biochar as being a revolutionary product and yet it is still being widely underused on a commercial scale. This tends to suggest that biochar could have great potential on a commercial level but the theory needs to be considered from a commercial perspective in order to understand why biochar is not being produced by industries such as the farming industry. Biochar production is a relatively simple process when producing low grade biochar that could be used as a soil amendment to increase crop yield.

1.7 Contribution of the study

Biochar is an under recognised and under used commodity. By exploring the applications and beneficial uses of biochar, this demonstrates that biochar doesn't have to be utilised solely as a climate change mitigation measure, but has other practical, commercial applications. This study also explores the potential to utilise biochar as a waste management option and may make it easier to implement a biochar supply chain in the future. The description of the potential benefits associated with using biochar production as a potential waste management method may garner further interest too, especially with a clearer description of commercial potential. The study contributes specifically to a better understanding of the potential to use biochar production as a waste management method in Pietermaritzburg.

1.8 Rationale of the study

The study was conducted in order to explore the potential for biochar production to be utilised as a waste management method and for the end product to be used for commercial gain within South Africa. A lack of research in this area would result in the potential use of common organic waste as a viable feedstock for biochar production not being known. Answers to the research questions may contribute to more interest being shown in biochar and, as a result, more profitable applications for biochar production being found.

1.9 Research methodology

The research was exploratory and the research strategy included interviews with subject experts. The empirical study recorded qualitative data by conducting interviews with the various experts who agreed to participate in the study. Due to time and cost constraints the study site was confined to the Pietermaritzburg and Durban areas with participants drawn from this location.

Biochar is not a very well-known substance and thus, experts that know about it are far and few. Due to the nature of the topic and scarcity of experts in this field, a non-probability, purposive sampling technique was utilised to select participants. Participants were chosen based on their experience and expertise with biochar. Essentially, instead of a quantity approach, a quality approach in choosing participants was utilised. All participants are well known for their expertise in either waste beneficiation or biochar production, with there being a large overlap between the areas. Due to the lack of experts on the topic of biochar, only 8 potential participants were identified and from these 6 agreed to participate in interviews.

1.10 Ethical considerations

Gatekeeper's letters were requested from all the biochar experts who potentially would participate in the study and all the gatekeeper's letters that were obtained were then submitted to the UKZN ethical clearance committee. Approval was granted by the UKZN Humanities and Social Sciences Research Ethics Committee (HSSREC). All participants were informed that their participation was entirely voluntary, they could withdraw at any time with no negative consequences and if they wished, their confidentiality and anonymity would be preserved. They were asked to sign an informed consent declaration before participating. All data was recorded and stored on a password protected laptop. Research ethics are of vital importance and for this reason an ethical code was adhered to during the course of the research in order that the research presented would be authentic, true and free from any bias or error (Chetty,

2016). When conducting the interviews, both parties sought to respect and trust one another and demonstrate a mutual level of accountability and fairness (Chetty, 2016).

1.11 Limitations of the study

The field study was centred on the Pietermaritzburg region with a situation and materials not necessarily being common to other regions in South Africa or elsewhere. The findings and conclusions may differ from field studies conducted in other regions. Costs and production performances and yields may not be entirely accurate as kilns and production methods vary. The pool of biochar experts is limited so this may have resulted in an element of bias influencing the findings and conclusions.

CHAPTER 2: LITERATURE REVIEW

If one has to define the major operational and supply chain management functions in a business, it involves the designing of the product, the purchasing (of materials), the manufacturing process, the service operations and finally the element of logistics and distribution. The flow of these core functions may be amended depending on the end product or service. An example of the core functions of a television manufacturing company is illustrated below(Jacobs, Chase, & Lummus, 2014, p. 3):

Similarly, Min (2015, p. 2) defines a supply chain as a fully connected system that coordinates all the interrelated business processes in order to:

- Create a demand for the product/s
- Raw material acquisition
- Manufacture into finished foods
- Value adding activities
- Distribution to retailer or consumer
- Information exchange

Noting that, "The information exchange aspect is a relatively new aspect that has been seen as a great value adding activity in recent years due to its ability to enhance operational efficiency, lead to greater profitability and create a competitive advantage for a firm and all its interconnected supply chain partners".

The production of biochar requires a supply of biomass, a series of processes that transform this into biochar and a market or other application for this product. In the designing of a biochar supply chain, it is imperative that all variables are taken into account, in order to obtain a complete overview of the chain and the costs involved. An in-depth understanding of the volumes and labour involved in the harvesting or gathering of the feedstocks, the transportation requirements (before and after pre-processing), the quantities of feedstock that the production plant would be able to process, and any other resources consumed during production (energy,

human labour, equipment required for gathering or harvest etc.) and the marketing and distribution of the biochar product must be considered (Ba, Prins, & Prodhon, 2016, p. 2).

2.1 Supply Chain Management

2.1.1 Biomass sourcing

Biomass is the term used to describe matter derived from living organisms (including the organisms and their waste) and containing the element carbon (C). It is generally quantified by its mass of carbon. According to Senthil and Lee (2021, p. 1), in 2016 the total biomass globally could be estimated at approximately 550 gigatonnes of carbon (550 Gt C). This figure could further be broken down into biomass from plant sources, contributing approximately 80% to the figure above (450 Gt C), biomass from sources of bacteria (microbial biomass which is the living component of soil organic matter) contributing 15% (70 Gt C), with the remaining contribution from other microorganisms, such as fungi, and animals.

Biomass has the potential to serve as an environmentally friendly and easily accessible source of energy and chemical products. Biochar is one such carbon-rich substance, produced by subjecting organic material to high temperatures under oxygen-deficient conditions (Suliman et al., 2016, p. 38). Sources of biomass can include, crop residues, forestry residues, agricultural animal wastes (biosolids), organic waste derived from municipal dump sites and organic wastes from production in the industrial sector (Iakovou, Karagiannidis, Vlachos, Toka, & Malamakis, 2010, p. 1860).

Within South Africa, the Department of forestry (2021) has outlined a few areas where biomass is being underutilised and could potentially be diverted into the production of biofuels or other valuable products, including but not limited to:

- Meat production in the agricultural industry which produces large quantities of animal waste that requires careful management and processing in order to mitigate environmental impacts.
- Bagasse produced as a by-product in the sugar industry which has the potential to be used as an alternate fuel source.
- Agricultural residues in the form of grains, fruits and vegetables.
- Biomass produced from the removal of alien vegetation in The Working for Water Programme where there is a need for alternate means of disposal. Since its launch in

1995, the programme has cleared more than one million hectares of invasive plants from around South Africa

- Decomposing biomass at municipal sewerage treatment plans where untapped opportunities exist for re diverting this waste
- Waste from the food industry that is currently an issue
- Large amounts of biomass waste are currently being produced in the paper and pulp industry which could be used in the production of alternate fuels

Table 2.1 summarises these and other potential sources of biochar feedstock.

Table 2.1: Potential origins of biomass for biochar production and the various types of feedstocks that could come from these sources (Conte, Schmidt, & Cimò, 2016 p. 417)

Origin	Biomass feedstock
Local waste collection services with waste separation	Biodegradable waste, biodegradable waste with kitchen waste, biodegradable waste with kitchen waste and leftover
Garden Wastes	Leaves, flowers, vegetables, roots, pruning from trees, vines and bushes, clippings from nature conservation measures, hay, grass
Agriculture and forestry	Harvest leftovers, straw, used straw, husks and grain dust, grains, feedstuff, pruning from biomass plantations fron for energy or biomass users (renewable resources), pruning from trees, vines and bushes, seeds and plants, bark, chipping, wood, sawdust, wood shaving, wood wool
Kitchens and canteens	Kitchen canteen, restaurant leftovers
Vegetable productions	Material from washing, cleaning, peeling, centrifuging and separation
Waterway maintenance (vegetable material)	Raked material, flotsam, fishing residues, harvested material, water plants

Animal by-products	Hides and skins, bristles, feathers, hairs, bones, manure
Materials from food and packaging	Seasoning residues: residues from potatoes, corn, rice and starch production: residues from dairy processing: fruit and grain residues, marc: residues from beer production
Textiles	Cellulose, cotton, vegetable fibers, hemp, wool leftovers and wool dust
Paper	Paper fiber sludge
Biogas plats	Fermentation residues

The variety of sources and potential for conversion on a neutral CO_2 basis makes biochar an attractive product for soil amendment and other purposes (Song & Guo, 2012, p. 138). One of biomass's more appealing qualities is that it can be regarded as a renewable resource, providing fixed carbon for the creation of a useful end-product.

Woody and fibrous plant material used can be of a variable quality, depending on the innate qualities of the resource (e.g. plant species), its environmental surroundings (growth conditions), the methods used in harvesting this organic resource and even the time of harvest, depending on the feedstock type (Williams, Westover, Emerson, Tumuluru, & Li, 2016, p. 1). Differing quantities of lignin, hemicellulose, cellulose and any other organic or inorganic compounds and residues present have a direct relationship with the makeup of the resultant biochar (Suliman et al., 2016, p. 37).

Whilst the organic portion of municipal solid wastes as well as other waste streams from the commercial or industrial sector are attractive and potentially significant biomass sources, the processing requirements before any type of utilization or conversion would possibly be extensive (Bridgwater, 2006, p. 1755).

When considering the source of biomass, the supply chain should analysed in its entirety, from the sourcing process to logistics. In a forestry operation, for example, multiple social and environmental benefits could be created during the sourcing and production operations, whilst

at the same time ensuring efficiency in the process and optimising economic outcomes (Cozzi, Di Napoli, Viccaro, & Romano, 2013, p. 1122)

2.1.2 Supply Chain logistics considerations

The logistical considerations of a biomass supply chain require various factors to be taken into consideration, such as the distribution of the raw materials (may be randomly spread out which would require labour and timeous collection), the biomass source's sensitivity to weather and time, the moisture content of the biomass (this would affect weight and production) and the bulk density of the biomass for transportation purposes (Ravula, Grisso, & Cundiff, 2008, p. 34). Distribution of the final product must also be considered.

In their natural states, most biomass sources would possess both a low mass and a low energy density which would lead to economic constraints due to the inefficiencies that would be experienced during the transportation of the unprocessed feedstock. In order to achieve greater efficiency and overcome these constraints, a form of pre-processing is recommended where the biomass undergoes size reduction and densification which would allow for more efficient and easier transportation (Lin et al., 2016, p. 163).

A major factor that would influence transportation costs would be the concentration of biomass available in the immediate radius. A large concentration in a narrow radius could decrease costs substantially, meaning that the plant location is also of vital importance (Börjesson, 1996, p. 305). Creating a large biochar production plant would lead to a decrease in overall production costs through economies of scale, however, it should also be kept in mind that the bigger the production plant becomes so too does the feedstock requirements leading to a larger sourcing radius which could increase transportation costs substantially (Leboreiro & Hilaly, 2011, p. 2712).

Feedstocks concentrated in a single location would be more suitable due to the increased cost of gathering and transporting dispersed feedstocks. An ideal situation would be for the production plant to be on the same site or in close proximity to the source of the biomass collection site as this would drastically reduce logistical costs as well as any emissions produced from transportation (Anderson et al., 2016, p. 38). This would either require building a conversion plant at the biomass source or finding a biomass supplier within close proximity which may require a collaborative relationship.

2.1.3 Biomass drying

In the converting of biomass to biochar products or other derivatives, high levels of moisture in the feedstock leads to a reduced rate of thermal efficiency during the combustion process which could lead to production inefficiencies, higher transportation cost, storage complications and impact the end quality of the biochar (Yi, Li, He, & Duan, 2020 & Duan, 2020, p. 1). Biomass drying is considered an important pre-production process.

The drying of biomass can either be a direct or indirect process through techniques such as flue gas utilisation, pressurised steam or simply air drying. However, with a forced evaporative approach to drying, expensive machinery is often required which often comes with sizeable energy requirements in order to operate. In order to reduce the costs associated with drying, it has been found that by integrating the drying process with production through the redirection of surplus heat or energy into the drying process, the cost of drying can be significantly reduced whilst at the same time increasing plant efficiency (Fagernäs, Brammer, Wilén, Lauer, & Verhoeff, 2010, p. 1268)

According to Pang and Mujumdar (2010, p. 690), during the drying cycle of the biochar supply chain, there are some factors that should be kept in mind, these being:

- The method of drying should be suited toward the feedstock type
- The acceptable moisture content that the conversion technology is able to handle without negatively impacting quality
- The energy efficiency of the drying process should be at an optimal level to keep costs and emission level down so that it doesn't diminish the end product value
- The environmental impact of the drying should be minimal so that it doesn't outweigh whatever environmental benefits could be realised from the end product
- The drying method should be safe to reduce the risks of fires and explosions
- The source of energy used for the drying of the biomass
- Costs should be kept to a minimum

2.2 Biochar production

The conversion of biomass into biochar, biofuels and other bio-based end products occurs through a variety of thermochemical processing methods including pyrolysis, gasification, torrefaction and hydrothermal carbonization (HTC) and these processes happen under differing temperature ranges (Qambrani, Rahman, Won, Shim, & Ra, 2017, p. 256).

2.2.1 Pyrolysis

The pyrolysis process of creating biochar involves the thermal decomposition of the biomass in an oxygen free environment at temperatures ranging from 300 to 900°C (Cha et al., 2016, pp. 7,8). During pyrolysis, thermal decomposition happens at varying rates depending on a multitude of factors such as the changes in the heating rate, the pressurization, the residence time of the vapour, the configuration of the reactor, the temperature and the properties of the feedstock (Patra, Mukherjee, Nanda, & Dalai, 2021, p. 1126). Based on these various factors, pyrolysis can be classified into two categories being either fast pyrolysis or slow pyrolysis.

2.2.1.1 Slow pyrolysis

With the use of slow pyrolysis, the production of char is favoured with gas and liquid being produced in small quantities as by-products of production. This type of production can be characterised by slower heating rates and a longer residence time in the reactor with the end result being a biochar of a solid carbonaceous nature (Tripathi, Sahu, & Ganesan, 2016, p. 472).

In this type of production, the heating of the biomass takes place in an environment with limited or even devoid levels of oxygen with the reactor usually being heated at typical rates of 1 to 30 °C in a minute (Ronsse, Van Hecke, Dickinson, & Prins, 2013, p. 105). The typical temperature range the biochar is heated to is between 400 to 500 °C in slow pyrolysis (Elkhalifa et al., 2019, p. 313)

The typical steps involved in the production of biochar with slow pyrolysis are the initial stage of the dehydration of the biomass, thereafter the formation of the primary biochar from the dehydrated biomass, during which stage some of the volatile gasses and other volatile components are removed and in the final step, the slow decomposition of the primary char leading to the formation of the secondary char which is the final, carbon-rich product (Chi et al., 2021, p. 2).

2.2.1.2 Fast pyrolysis

In contrast to slow pyrolysis, fast pyrolysis involves much higher and rapid heating rates of approximately 1000 °C per minute until a pyrolysis temperature of approximately 500 °C is reached with a vapour production time of typically less than 2 seconds. Rapid decomposition of the biomass particles leads to the production of a bio-oil liquid which is collected from the vapours so that biochar is a secondary product of this type of production (D. Wang, Jiang, Zhang, & Yuan, 2020 & Yuan, 2020, p. 8). From this form of pyrolysis high volumes of bio-oil are produced which make up 75% of the yield. Gasses of a non-condensable nature make

up a further 13% of the yield and the remainder is solid biochar, contributing 12% to the overall yield (Qambrani et al., 2017, p. 257).

2.2.2 Gasification

With gasification as a method of biochar production, it involves the conversion of carbonaceous materials into gasses such as carbon dioxide (CO_2), carbon monoxide (CO) and hydrogen (H_2) at high temperatures at a range of above 700 °C with a stream of oxygen and steam in a controlled supply in order to get the required reactions (Gabhane, Bhange, Patil, Bankar, & Kumar, 2020, p. 8).

The gasification process could be broken down into four sequences: the drying stage, the pyrolysis stage, partial oxidation and finally reduction (You et al., 2017, p. 3). With the use of gasification as the production method the primary output product is syngas. This mixture of CO, H_2, CO_2 and methane (CH_4) could thereafter be converted into value-added chemicals, liquid fuel or even used directly as a fuel source (You, Ok, Tsang, Kwon, & Wang, 2018, p. 2).

Biochar is a by-product of the gasification of lignocellulose biomasses and is produced in lesser quantities from this process, compared with pyrolysis (Pedrazzi, Santunione, Minarelli, & Allesina, 2019, p. 274). Table 2.2 summarises the processes and products of these options.

Table 2.2: A comparison of pyrolysis and gasification biochar production methods (Nsamba, Hale, Cornelissen, & Bachmann, 2015, p. 12)

Mode	Condition	Liquid (bio-oil)	Solid (biochar)	Gas (syngas)
Fast pyrolysis	Moderate temperature (~500°C) Short vapour residence time (<2s)	75% (25% water)	12%	13%
Intermediate pyrolysis	Low-moderate temperature Moderate hot vapour residence time	50% (50% water)	25%	25%
Sow pyrolysis	Low-moderate temperature Long residence time	30% (70% water)	35%	35%
Gasification	High Temperature (>800°C) Long vapour residence time	5% tar (55 water)	10%	85%

2.2.3 Torrefaction

Torrefaction refers to the low-temperature thermal decomposition of biomass leading to a biochar product that is rich in carbon (D. Wang et al., 2020, p. 13). During this process a partial decomposition of the biomass occurs resulting in the generation of non-condensable and condensable gasses (Pulka, Manczarski, Koziel, & Białowiec, 2019, p. 2). During torrefaction biomass properties are transformed and the energy density of the biomass is increased (D. Wang et al., 2020, p. 13). Torrefaction's milder treatment conditions lead to a higher productivity level and a solid mass yield that is higher when compared to the usual pyrolysis production methods where a higher temperature is used during the production process (Gan et al., 2018, p. 153).

Torrefaction is considered to be a form of pre-treatment for biomass which allows for the conversion of the biomass into solid fuel which is densely packed with energy and possesses an increased heating value and better grindability when compared to its biomass form. The improved biomass (torrefied biomass) can be estimated to have an energy density of around 30% better than the non-torrefied biomass (Niu et al., 2019, p. 2).

2.2.4 Hydrothermal carbonization (HTC)

HTC can be described as the thermal treatment of water that contains a mix of organic substances such as starch, glucose, sucrose (saccharides) or other organic compounds at temperatures ranging between 150 and 350°C, the end results from this process being water-soluble organic substances and a solid product that is carbon-rich (Sevilla & Fuertes, 2009, p. 2281). With the application of elevated temperatures to the mixture of biomass and water (biomass suspended in water) under saturated pressure conditions ranging over a period of several hours, an easy to handle fuel (similar to lignite in nature) with easily identifiable properties can be produced from the residual biomass regardless of the high moisture content (Funke & Ziegler, 2010, p. 161).

A major advantage of using HTC over other conversion methods such as pyrolysis is the differing processes of production which allows for the HTC process to utilise wet waste during the conversion process thereby removing the pre-drying process required for other means of conversion. The feedstock types suitable for utilisation in the HTC process include industrial and animal wastes, agricultural residues, and aquatic biomass (Sivaprasad, Manandhar, & Shah, 2021, p. 1).

2.3 Biochar applications

Bolan et al. (2022, p. 2) identified the multifunctional values of biochar in the following areas:

- As a soil amendment
- As an adsorbent of toxic metals and contaminants in soil and water
- Mitigation of greenhouse gases and odorous comounds
- As a feed supplement for animals
- Applications as a catalyst in the industrial sector
- Microbial and nutrient carrier

Schmidt and Wilson (2012, p. 5) identified 55 uses of biochar while mentioning that these were not all the possible applications as more uses are being found through the conducting of research.

The applications of biochar production are best seen from a holistic, supply-chain wide perspective, since the benefits may be derived from the upstream supply chain (e.g. waste management) or the downstream environmental benefits (e.g. soil amendment and carbon sequestration). Below are a few of these uses:

2.3.1 Biochar production as a method of waste management

Over the last few decades, a rapid increase in population growth has led to increased demand for goods and services from consumers, this has led to the generation of significant quantities of waste from multiple sectors. The classification of waste could be broken down into dried sewage sludge, medical wastes, construction wastes, electronic wastes and municipal solid wastes which has led to increased challenges in the management and safe disposal of such wastes (Elkhalifa et al., 2019, p. 310).

Organic and animal waste sent to landfill end up undergoing a process of anaerobic digestion which results in the release of large amounts of methane (CH_4) and Nitrous Oxide (N_2O). By diverting waste from landfill into an avenue such as biochar production, greenhouse gas emissions are reduced and there are costs to be saved, furthermore, the biochar obtained from production could add value by being used in other ways. In this way the diversion of waste from landfill in order to produce biochar could be seen as a potential method of waste management (Qambrani et al., 2017, p. 266).

By creating biochar production facilities, organic waste streams could be a sustainable feedstock too in the creation of biochar, on a larger scale, economies of scale could be achieved

driving down costs and providing a clear advantage over traditional waste management methods due to the end benefits that could be attained (Montanarella & Lugato, 2013, p. 467). Waste residues often contain carbohydrate in great quantities, providing ample material for the process of bio-refining. There are also wastes that possess a high lignin content which can enhance yield rates from pyrolysis production leading to the creation of bio-oil, syngas and biochar (Kwapinski et al., 2010, pp. 182,183)

2.3.2 Biochar as a soil amendment and as a tool for carbon sequestration

Biochar is regarded as a valuable additive to soil due to its inherent characteristics. Unlike other organic compounds, biochar is highly stabilised and resistant to decay leading to a sustainable method of soil enhancement (as evidenced by Amazonian *Terra Preta*) and it also possesses the exceptional ability to retain nutrients that are essential to plant growth (Nanda, Dalai, Berruti, & Kozinski, 2016, p. 224). Through biochar's ability to act as a soil amendment, a number of changes in the properties of the soil both chemical and physical take place after its application. These changes may include a greater availability of nutrients and water, larger quantities of carbon in the soil, a higher pH level in acidic soils and a change in soil biota (Konz, Cohen, & van der Merwe, 2015, p. 13).

In recent years the attention on climate change has resulted in increased attention and research on the reduction of carbon dioxide emissions in the atmosphere. In the global carbon cycle, soil has been identified as a vital carbon sink that could have direct impacts on climate change. Along with biochar's ability to have a positive effect on soil health and plant growth, its carbon sequestration abilities have been identified as a potential method of CO_2 mitigation in soil. Its highly condensed aromatic structure and resistance to biodegradation allow it to sequester carbon for extended periods (J. Wang & Wang, 2019, p. 20).

2.3.3 Biochar as a compost additive

Due to the biochar's natural porosity, it has been shown to promote the growth of microbes in a compost heap thus increasing the speed of nutrient recycling. As a compost additive, it can lead to a rate of increased composting. By utilising a mixture of organic waste (suitably chosen for the purpose of composting) with biochar in a carefully calculated ratio, biochar has been shown to drastically increase the composting rate leading to a much shorter composting time (Hu et al., 2021, p. 13).

By adding biochar to a composting pile, it leads to a raised temperature level during the thermophilic phase, this in turn causes microbial activity within the pile to increase due to these

environmental changes. The benefits of this increased microbial activity is realised through a faster composting time as well as a faster stabilization time of the compost mix (Sanchez-Monedero et al., 2018, pp. 3,4).

When combined with a compost and applied to soil, biochar is able to significantly enhance nutrient availability which in turn enhances crop productivity when compared to chemical fertilisers (D. Wang et al., 2020, p. 20). When applied to soil, chemical fertilisers get depleted at a rapid rate by deteriorating to another form. Alternatives such as compost or manure may eventually get depleted as well, which is unsustainable and could cause long term financial constraints. By mixing fertilizers or compost with biochar, it provides a more beneficial and sustained supply of nutrients (Gabhane et al., 2020, p. 12).

Distribution and application of the biochar product for agricultural purposes does present logistical challenges. For example, (Husk & Major, 2010, p. 4) conducted a commercial scale test on the application of agricultural biochar to farmlands. One of their observations was that in the handling, transporting, storage of biochar, the application method and even in the final incorporation there exists a significant risk of biochar loss depending on the size and texture of the biochar product. In their case the biochar consisted of fine particles of which an estimate of 60% was able to pass through a 0.5 mm sieve. The majority of loss could be blamed on the feeding of the biochar into a specially calibrated lime spreader for largescale application purposes. In total 30% of the biochar was lost of which approximately 25% could be traced back to the loading of the biochar into the lime spreader, 2% was attributed to handling with the remaining 3% being attributed to transportation. In order to mitigate losses in the supply chain they recommended that best management practices should be developed before production, such as the application of moisture to their biochar to reduce losses.

2.3.4 Adsorption of organic pollutants in water and soil

Biochar's porosity, large surface area and ability to adsorb inorganic compounds has resulted in it being used to remove various contaminants from both wastewater and soil. Biochar has been used to adsorb heavy metals, phosphorus and nitrogen and other pollutants from aqueous solutions. Its ability to adsorb contaminants depends on the quality and characteristics of the biochar (higher quality biochars have larger surface areas and porosity levels) with reports showing that biochar's adsorption abilities could be similar or possibly greater than that of activated carbon (Sakhiya, Anand, & Kaushal, 2020, p. 264). Biochar is recognised as an

affordable potential alternative to other carbonaceous materials (Bartoli, Giorcelli, Jagdale, Rovere, & Tagliaferro, 2020, p. 6).

The ability of biochar to remove or adsorb organic pollutants from water and soil has been an area of significant interest in recent years. The organic chemicals targeted for removal include: agrochemicals, antibiotics/drugs, industrial chemicals, volatile organic compounds, cationic dyes and many other organic compounds commonly found in waste streams (Oliveira et al., 2017, p. 2). Some of the organic pollutants adsorbed by biochar are listed in Table 2.3.

2.3.5 Biochar as a precursor to activated carbon

In the production of activated carbon, a multitude of carbonaceous materials could be used including coal, petroleum pitch, lignite, waste biomass and biochar. Due to its high porosity, activated carbon created from biochar has high levels of micro-porosity (Nanda et al., 2016, p. 222). Hence biochar is an ideal precursor for the creation of this product. Biochar produced from agricultural waste and thereafter used as a precursor for activated carbon production is an area of great interest in recent years due to it being a more feasible and readily available material whilst at the same time being a possible method of waste management based on the feedstock used in its production (B. Wang, Gao, & Fang, 2017, p. 28). Biochar created from wood biomass and thereafter activated has shown positive results with an end product being suited to being used as an activated carbon substitute (Callegari & Capodaglio, 2018, p. 15).

The production of activated carbon could be simplified into two major steps: the carbonisation of biomass in an oxygen-deprived environment and thereafter the activation of the char by either physical or chemical means. The physical method involves exposure of the char to an oxidized atmosphere (a mix of air, steam and CO_2) with no chemical involvement. The chemical process of activation on the other hand involves using chemicals as an activation process instead. Both methods possess advantages, the former due to the lack of chemicals involved and the latter due to the ability to create a superior product (Callegari & Capodaglio, 2018, p. 15).

Activated carbon could be used as a cheaper energy storage material compared to carbon nanotubes and graphitized carbon which are products that are in high demand. An example of the use of activated carbon is as the material for electrodes in supercapacitors (B. Wang et al., 2017, p. 28).

Table 2.3: Organic pollutants adsorbed by biochar amended soil with the biochar produced from various feedstocks & by different production methods. (J. Wang & Wang, 2019)

Organic pollutants	Initial concentration (mg/kg)	Feedstock	Pyrolysis temperature (°C)	Applied Dose	Removal efficiency
Dibutyl phthalate	100	Bamboo	650	1%	87.5%
Phenanthrene	150	Conifer	600	0,50%	100
Pentachlorophenol	150	Poplar	600	0,50%	100
Imidacloprid	n.a.	Rice-Straw	600	5%	n.a.
Imidacloprid	n.a.	Wheat-straw	450	5%	n.a.
Diethyl phthalate	50	Bamboo	820	0,50%	~90%
Carbamazepine	n.a.	Wood	450	0,50%	n.a.
Carbaryl	20	Pig Manure	700	n.a.	71.8%
Sulfamethazine	n.a.	Hardwood	600	2%	n.a.
Tylosin	50	Hardwood	850	10%	66%
Acetamiprid	250	Eucalyptus spp.	450	0,50%	52.3%
Atrazine	50	Dairy Manure	450	5%	>66%
Pentachlorophenol	50	Rice-straw	n.a.	2%	96.2%
Chlorpyrifos	50	Gosyypium	850	1%	34%
Fipronil	50	spp.			32%
Terbuthylazine	20	Sawdust	700	n.a.	>80%

2.3.6 Biochar as an animal feed additive

Biochar as an animal feed additive has been shown to provide numerous benefits to animals such as aiding in an increased feed intake and weight gain; a greater intake of nutrients;

enhanced health levels; detoxification from pollutants, toxins and other contaminants; reduced methane emissions and a reduction in antibiotic residues (Man, Chow, Man, Mo, & Wong, 2021, p. 13). After being used as an animal feed additive, further beneficiation of the biochar occurs within the animal. During the digestion process, the biochar is enriched with organic compounds that are rich in nitrogen, this leads to the excreted biochar transforming into a highly valuable organic fertilizer which would have applications as a soil additive (Schmidt, Hagemann, Draper, & Kammann, 2019, pp. 2,3).

2.3.7 Biochar as a fuel source

Compared to biochar, raw biomass has a reduced efficiency level in the generation of fuel due to its high bulk and low energy density, a high moisture content and its hygroscopic characteristics. However, after undergoing the pyrolysis process, the end product biochar has both a high carbon content and calorific value making it much more suitable as a fuel source (Sakhiya et al., 2020, p. 69).

2.4 Legislative barriers to biochar production on a commercial scale

In the commercialisation of biochar production, two potential barriers have been outlined, these being a lack of access to biochar in the agricultural industry and legislative barriers affecting production and application (Maroušek et al., 2017, p. 314). While this article referred specifically to developed countries, South African legislation may also constrain the production and application of biochar.

2.4.1 National Environmental Management Act (Act No. 107 of 1998)

The National Environmental Management Act (NEMA) was introduced to the Republic of South Africa in 1998 and addresses all aspects of environmental management in South Africa, including waste management, pollution and air quality. According to NEMA, any activities that could have an environmental impact require pre-authorisation from an Independent Environmental Assessment Practitioner (EAP) who will be required to perform an Environmental Impact Assessment (EIA). This assessment is a tool for the assessment of listed activities (Konz et al., 2015, p. 75).

The hiring of an EIP consultant is a cost that is born by the applicant and not government. The consultant will thereafter conduct the assessment either as a basic assessment or as a scoping and environmental impact report (S&EIR), depending on the activities being assessed. A basic assessment typically takes 6 to 9 months to complete whilst a S&EIR could take anywhere between 12 and 18 months ("National Environmental Management Act 107 of 1998," 1998).

The application for a basic assessment costs R2 000 with the application for a S&EIR costing R10 000. To these costs should be added the consultant fees of the EIP, which could vary depending on the nature of the project.

2.4.2 National Environmental Management: Air Quality Act (Act 39 of 2004).

Further to this, any production facility producing more than 20 tonnes per month falls under NEMA's Air Quality Act (Act 39 of 2004). The objective of this Act is environmental protection through air quality enhancement in order to ensure sustainable ecological development and prevention of air pollution. Under this act details regarding minimum emission standards of char, carbon and black charcoal are outlined. Table 2.4 lists these emission specifications.

Table 2.4: The description, applicability and minimum emission standards for char, charcoal and carbon black production as stipulated in section 21 of the National Environmental Management: Air Quality Act (Konz et al., 2015)

Description:	Production of char, charcoal and the production and use of carbon black		
Application:	All installations producing more than 20 tonnes of char or charcoal per month Installations consuming more than 20 tonnes per month of carbon black in any processes		
Substances or mixture of substances		Plant status	Limit value (dry mg/Nm^3) under normal conditions of 273 Kelvin and 10.3 kPa
Common name			
Particulate matter	N/A	New	50
		Existing	100
Polycycic aromatic hydrocarbons	PAH	New	0.1
		Existing	0.5

2.5 The commercialisation of biochar

The interest and awareness in biochar has seen a rapid increase over the last few years with potential for usage identified in the forestry, agriculture and the mining industry along with its climate mitigation abilities. Even though various governmental agencies as well as scientists, committees and non-profit organisations have supported and contributed to the exposure and

research into biochar, commercial enterprises involved in the manufacturing of biochar and biochar production technologies have remained sparse (Anderson et al., 2016, p. 31).

The International Biochar Initiative's (IBI) report on the current state of the biochar industry by Jirka and Tomlinson (2015, p. 50) infers that a possibility for the slow uptake of biochar in the commercial sector may be due to poor communication channels between players in the commercial industry and academics and scientists involved in the research of biochar and its applications. It is further suggested that by increasing communication between researchers and entrepreneurs this could lead to research that is more focused on entrepreneurial applications through education and demonstrations of beneficial uses whist at the same time opening new avenues of investigation through a two-way communication channel. Whilst communication does exist through online forums, conferences and the like, a more focused collaborative effort between the spheres could promote industry growth.

In order for industry growth to occur, all participants across the supply chain are required to make a combined effort. On the supply side, identifiable parties include biomass providers, biochar producers, technology developers, bioenergy promoters, researchers and government agencies with and active interest in biochar. On the demand side parties who could be drivers in the adoption of biochar on a large scale include, farmers, forestry operations, power plants, nursery and garden owners as well as activated carbon manufacturers.

The barriers to the commercialisation of biochar include environmental, socio-political, economic and technical barriers. Individual barriers faced by potential biochar producers include a lack of capital for the initial investment into the plant and thereafter the scaling up of the production facility once established. This is regarded as one of the biggest obstacles to entry into the biochar sector (Thengane et al., 2021, p. 11).

Maroušek et al. (Maroušek et al., 2017, p. 314) suggests that in developed countries there is still a fear regarding the unknown elements of biochar implementation, mainly the long-term impact biochar could have on soil health as well as the inability to remove it from soil once applied. This along with other factors such as the high cost of biochar application to farmlands due to their vast scale, as well as a return on investment that could possibly take years has severely hindered biochar's commercialisation in the farming sector. Even though the clear benefits of biochar have been highlighted, barriers to entry in the farming sector still remain and due to this it may be worthwhile to look at other sectors for commercial application.

2.6. Conclusion

In the creation of a biochar supply chain, just like any other supply chain, there are core elements that form the baseline of this chain. The steps involved would be:

- Biomass sourcing

  This refers to the actual sourcing of feedstock in preparation for biochar production. Sources of biomass can include, crop residues, forestry residues, agricultural animal wastes (biosolids), organic waste derived from municipal dump sites and organic wastes from production in the industrial sector.
- Logistical considerations

  When it comes to transportation, various factors need to be taken into account such as raw material distribution, weather considerations and the bulk density of the biomass.
- Biomass Drying

  The drying of biomass can either be a direct or indirect process through techniques such as flue gas utilisation, pressurised steam or simply air drying. In order to reduce costs, it would be perfect if the biomass could be dried on site in order to reduce transport and energy costs. It would be even more ideal if the energy from production was re-diverted into drying the feedstock.
- Biochar production

  There exist many types of production such as pyrolysis, gasification, torrefecation and Hydrothermal carbonisation. It is important that the production method be chosen based on what qualities are required from the biochar end product.
- Biochar applications

  There are more than 55 officialy documented uss of biochar including but not limited to:
  - As a soil amendment
  - Its ability to sequester carbon
  - As a method of waste management
  - As an adsorbant (organic pollutants and metals)
  - An animal feed additive

The commercial application of biochar is something that is happening but at a slow rate. This may be due to a multitude of reasons but one of the outlined ones is that it is due to a lack of coordination and communication between academics researching biochar and commercial enterprises where biochar could be of use.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

The literature review discusses the components of a biochar supply chain, the challenges that could potentially arise in such a supply chain, the commercial applications of biochar, a more detailed examination of biochar production, including aspects affecting quality and recovery rates, and an overview of the potential that biochar has to offer. All these areas are relevant to the research objectives and provide a better understanding of biochar and a foundation for the field study.

The aim of the research methodology is to describe the research methods that were used to conduct the study and address the research objectives. The research was exploratory in nature and designed to gather qualitative data using semi-structured interviews of recognised experts with experience in different areas related to biochar.

3.2 Research questions

- What are the processes and enterprises involved in a biochar supply chain
- How could these processes and enterprises involved in a biochar supply chain be better integrated?
- How does the production method affect the quality and yield of the biochar?
- How does feedstock quality affect end product quality and yield?
- To what extent does the cost of separating contaminants from feedstock affect the financial viability of biochar production?
- What is the scope for large scale biochar commercialisation and could potential investors be attracted to a biochar initiative in South Africa?
- How does biochar pricing vary according to the quality of the product?

3.3 Research objectives

- To understand the processes and enterprises involved in a biochar supply chain
- To determine how these processes and enterprises involved in a biochar supply chain can be better integrated
- To identify how the production method affects the quality and yield of the biochar
- To identify different potential feedstocks, including contaminated feedstocks, and to assess how feedstock quality affects end product quality and yield

- To assess the viability of using a contaminated feedstock when the costs incurred in separating and removing the contaminants are considered
- To assess the commercial potential of biochar production in South Africa.
- To assess how biochar quality affects its price

3.4 Research design

According to (Sekaran & Bougie, 2016, p. 95), the research design can be described as the blueprint used to answer the research questions, it defines the methods used for the collection, the measurement and finally the analysis of the data. When coming up with the research design for a study, it is important to note that there is no single design that can be regarded as the most appropriate, instead, every study needs to have a tailor-made design that is most suitable for that particular study. The design is influenced by factors such as the objectives of the study, access to relevant data, the research questions and what constraints the study may face (Sekaran & Bougie, 2016, p. 107).

For the purpose of this study, an exploratory research approach was chosen. Exploratory research was seen as an appropriate research method due to its high level of flexibility. It is especially useful for areas of study where the problem area may be large and thus it serves as great starting point (Jajoo, 2014, p. 49). The purpose of exploratory research is not to solve the problem or to provide conclusive answers, instead it explores the problem in order to gain a deeper understanding of the problem or topic. Exploratory research could even be described as providing a baseline for further research to be conducted in the future (Dudovskiy, 2019).

3.5 Research approach

Quantitative research is useful as a method of analysis that emphasises a measure of objectivity when studying certain phenomena. Due to this, data in the form of statistics and numbers can be especially useful as they represent a measure of control or structure. Qualitative research on the other hand differs as it is more appropriate for collecting data on phenomena that occur in a more natural environment with most of the data being in the form of words that are collected through various methods of investigation and exploration until insights can be drawn (Govender, 2015, p. 39).

Typically, qualitative research could be described as inductive, subjective and contextual whilst quantitative research could be described as deductive, objective and general. While these are not the only dimensions that define qualitative and quantitative research, the characteristics mentioned above could be described as the essential differences between qualitative and

quantitative analysis, without considering specific research procedures and purposes (see Table 3.1) (Morgan, 2013).

Table 3.1: Integrating qualitative and quantitative methods: a pragmatic approach (Morgan, 2013)

Comparing Qualitative and Quantitative Research	
Qualitative Research	**Quantitative Research**
Induction **Purposes** • Generates theory from observations. • Oriented to discovery, exploration. **Procedures** • Emergent design. • Merges data collection and analysis.	**Deduction** **Purposes** • Tests theory through observations. • Oriented to cause and effect. **Procedures** • Predetermined design. • Separates data collection and analysis
Subjectivity **Purposes** • Emphasises meanings, interpretation. • Tries to understand others' perspectives. **Procedures** • Researcher is involved, close to the data. • Researcher is the "research instrument."	**Objectivity** **Purposes** • Emphasises things that can be measured. • Results do not depend on beliefs. **Procedures** • Researcher is detached, distant from the data. • Relies on standardized protocols.
Context **Purposes** • Emphasises specific depth and detail. • Analyses holistic systems. **Procedures** • Uses a naturalistic approach. • Relies on a few purposively chosen cases.	**Generality** **Purposes** • Emphasises generalization and replication. • Analyses variables. **Procedures** • Uses experimental and statistical controls. • Works across a larger number of cases.

For the purpose of this study, qualitative data was collected by means of semi-structured interviews. Due to the nature of the study and the sampling method utilised, this method was seen as the most suitable way of data collection for the study.

3.6 Study site

The collection of qualitative data was be done via interviews conducted with experts in both the Pietermaritzburg and Durban area. These experts were chosen via a judgement sampling method. Interviews were done in person or via video conferencing where face-to-face interviews were not possible. These areas were chosen due to a familiarity with the location and easier access to the research participants.

3.7 Target population

When conducting a study, the target population refers to the entirety of individuals, events or any other aspects of interest that the researcher desires to investigate during the course of the study. It is this same target population that the researcher draws conclusions from in order to complete the study (Sekaran & Bougie, 2016). The target population in this study included any individual residing in the Pietermaritzburg or Durban areas who had expert subject knowledge relevant to biochar or biochar production. However, due to lack of participants, the sample pool size was increased and a participant from the Gauteng region was interviewed and included.

Unfortunately, there are few experts on the subject of biochar in South Africa and, for this reason, only a few potential participants were identified on the basis of either their knowledge or experience with biochar production and its application. The total number of experts are unknown but for the purposes of this study, a total of 8 subjects were identified and 6 were able to participate in the study.

3.8 Sampling technique

The population refers to the set from which the researcher draws their sample. When there are time and resource constraints or the target population is too large for the researcher to analyse the entirety of the population, a sampling technique is used in order to select a sample that adequately reflects the entirety of the population (Taherdoost, 2016, p. 20). For this particular study, a nonprobability, judgement sampling method was chosen for the study.

With nonprobability sampling designs, there exists a lack of probabilities attached to the elements in the population when it comes to their selection as sample subjects. What this means is that unlike with probability sampling, the conclusions drawn from studying the sample cannot be said to confidently represent the entirety of the population. However, at times, researchers may utilize such a method in order to attain preliminary information in a way that is inexpensive and relatively fast. At other times, nonprobability sampling may be the only way to attain data (Sekaran & Bougie, 2016, p. 247).

Judgement sampling is a method that is often used when people, settings or events are specifically chosen based on their importance to the study and that the relevant experience or information may not be available from other choices. The relevant cases or participants are included in the sample simply because the researcher believes that they are important enough that their participation is warranted (Taherdoost, 2016, p. 23).

Due to the participant selection process having a convenience factor, the ability to generalise the findings of the study may be curtailed. In this study, due to the nature of the topic, judgement sampling was the only method that was viable to attain the necessary information from the limited number of participants who both possess the required expertise and were willing and able to participate in the study. Judgment sampling is appropriate when only a limited number of people have the desired information (Sekaran & Bougie, 2016, p. 247) as was the situation in this study.

3.9 Sample size

Following extensive enquiries in various departments of the University of KZN and after conducting internet searches using terms such as biochar, kiln and pyrolysis, names of local experts were discovered. Eight individuals were identified and then approached with a request to participate in the study and of these eight, six agreed to be interviewed. All participants interviewed gave permission for their names to be included in the dissertation; it is for this reason the participants are listed below.

The sample comprises the known experts on biochar from the Pietermaritzburg and Durban areas. Two agriculture students from UKZN were interviewed, Anne Chisa and Nqobile Nkomo. Douw Harilal is a horticulturalist by profession and actively uses biochar in his studies. Dave Still is a civil engineer who has led many projects in the Pietermaritzburg and Durban area and is well versed in biochar. Riaz Jogiat, a manager of solid waste in the uMgungundlovu District Municipality is well versed when it comes to waste management in Pietermaritzburg and Durban. Darryl Phipps from Adsorb Technologies is an expert when it comes to producing biochar for commercial usage and has founded a company that works in collaboration with York Timbers in the United Kingdom. While he is from Gauteng, his input was too valuable to pass up.

3.10 Data quality control

All participants in the study were chosen on the basis of their experience and expertise with biochar, all of these participants had a verifiable background in either the biochar industry or

had conducted research in this field during the courses of their academic careers. . All interviews were recorded in order to ensure that an accurate account of the interviews was obtained. After each interview, a transcript was written up and used for the qualitative analysis. The transcripts of the six interviews are attached as appendices D to J.

3.11 Data collection

Qualitative data collection during research can be done using a variety of methods. These methods could be visual, textual or observational analyses and through interviews that could either be done individually or in groups (Gill, Stewart, Treasure, & Chadwick, 2008, p. 291). For the collection of qualitative data, interviews were used. There are three forms of interviews that can be utilised. These are structured, unstructured and semi-structured interviews.

Structured interviews can be compared to verbal questionnaires in that all the questions are predetermined with very little room for divergence and follow up questions. Whilst in some cases structured interviews are highly suitable, sometimes the limited responses of participants can be counterproductive if the questions require a greater depth. On the other hand, unstructured interviews often leave too much up to the interviewee as there is no or very little structure to follow. While such a form of interviewing could be beneficial if a lot of depth is required, such a method could be time consuming and the interviewer may have trouble getting the relevant information due to the lack of guidance during the interview. Semi-structured interviews could be thought of as a middle ground between structured and unstructured interviews. While it does follow a structure in that it outlines what areas it is looking to explore, it also allows the interviewee to diverge from this path and offer their own opinions or a more in depth explanation if they feel it is relevant to the study. This is a good method of attaining information from the interviewees that the interviewer themselves may not have thought of; essentially it leaves the study open to fresh outlooks (Gill et al., 2008, p. 291).

After assessing the above information, semi-structured interviews were found to be most suitable. Participants can be guided during the interview while also making suggestions or elaborating on certain areas that then allows for greater insights during the study. All interviews were recorded and the transcripts of the recordings were then analysed. Whilst 5 of the 6 participants participated in a verbal interview, it is of note that one participant was unable to participate in a verbal interview and instead opted to answer the semi structured interview question in writing.

3.11.1 Interview Guide

A semi structured interview guide was developed for the purpose of the interview. Due to the limited number of participants the semi structured interview was unable to be tested on external participants. The interview guide was refined and amended if necessary, thereafter it was pre-tested on the study supervisor (Dr Salisbury) due to his experience with the subject

3.12 Data analysis

Qualitative data analysis involves the researcher drawing valid conclusions from the large amount of data collected during the course of the study. While the methods of qualitative data analysis often differ from one researcher to the next, there are a few generally acceptable approaches to qualitative data analysis that have been developed. According to Sekaran and Bougie (2016, p. 333), the general approach to analysing qualitative data involves three steps, these being:

3.12.1 Data reduction

Data reduction is a process that continuously occurs throughout the analysis due to the large quantity of data dealt with in these types of studies, the idea is to reduce the data without any loss of information resulting from the reduction. This way the data is preserved within its relevant context. The method of reduction may change throughout the research process, it would usually begin with the summarisation and editing of the data in the early stages, which would then lead to coding the data and thereafter lead to conceptualising and expanding on the concepts in the latter stages (Mayer, 2015, p. 58).

3.12.2 Data display

During all stages of the analysis, visual displays could be a useful qualitative analysis tool. A display may be useful for the representation of basic, exploratory or end analysis information to assist with the visualisation and explanations be they detailed or causal. The purpose of the display is to illuminate the message rather than obscure it and it could even be used as a way of developing theory or generating research hypothesis (Verdinelli & Scagnoli, 2013, p. 360). This could be in the form of diagrams, charts, matrices, graphs or any method that enables the researcher to organize the data in such a way that they are able to identify patterns or relationships between the data which in turn helps with the drawing of conclusions from the data (Sekaran & Bougie, 2016).

3.12.3 Drawing conclusions

The final step in qualitative data analysis is the drawing of conclusions. At this step the researcher is finally able to answer the research questions by analysing the themes found in the data and identifying what these themes mean. Meaning could be found through understanding relationships or patterns or by making comparisons and contrasts (Sekaran & Bougie, 2016, p. 348).

Content analysis of the data was used. According to Erlingsson and Brysiewicz (Erlingsson & Brysiewicz, 2017, p. 94), qualitative content analysis often begins with the transcription of interviews. The main aim of this form of analysis is to systematically convert the often-large amounts of data into a condensed and organised summary of the crucial results. Using the transcripts of the raw data, themes or categories can be created in order to form new ideas or as a form of further analysis.

It is important to remember that qualitative content analysis is not a necessarily a linear process and what this means is that categorising, or coding units of data may happen on more than a single occasion. After data is coded and categorised the researcher often finds themselves going back to the raw data in order to review the preliminary analysis (Erlingsson & Brysiewicz, 2017, p. 96)..

3.13 Qualitative reliability and validity

While the importance of reliability and validity have long been recognised and accepted in quantitative research, there has been some debate on the relevance of reliability and validity in qualitative research. Researchers do find these criteria to be important in qualitative research, but many are of the opinion that the definitions of the two terms should be altered when it comes to qualitative research (Bell, Bryman, & Harley, 2018, p. 394).

One method of adapting these definitions has been to assess qualitative studies according to the same dimensions while somewhat adjusting the meaning.

According to (Golafshani, 2003, p. 598), one possible definition of reliability in a qualitative study is “The extent to which results are consistent over time and an accurate representation of the total population under study is referred to as reliability and if the results of a study can be reproduced under a similar methodology, then the research instrument is considered to be reliable”

According to (Long & Johnson, 2000, p. 31), while there is a lot of debate about the assessment of validity in qualitative research, it is usually established through the verification of three aspects, these being:

- Content validity
  Largely dependent on the sampling method and instrument used for sampling
- Criterion-Related validity
  A comparison between the actual instrument and the findings with an established standard being used to investigate the correlation between the actual and measured performance.
- Construct Validity
  This considers the proximity of the instrument to the construct
  Consideration of the proximity of the instrument to the construct in question

When it comes to reliability and validity in qualitative research, there exists the question whether these terms (reliability and validity) are an appropriate measure of qualitative research. Whilst in the broad sense these terms are applicable, if the method of qualitative research is fundamentally different compared to quantitative research, then it may be necessary for alternate frameworks of assessing rigour to be utilised (Noble & Smith, 2015, p. 34).

For the interviews, a non-probability judgement sampling method was used to select interview participants. The reliability and validity of the study was assessed according to the definitions described above. While external reliability in a study may be hard to achieve in a qualitative study, this may be possible for this specific study due to the sampling method being used. All participants were chosen for their expertise in biochar and their answers are unlikely to change unless further information regarding biochar is brought to light. The study should have a sufficient level of internal reliability due to the interview method; all interviews were recorded with both the recordings and transcriptions of the recordings being made available at the end of the study; this should ensure a greater measure of accuracy. According to the definition mentioned above, with regard to internal validity, the researcher committed work and thought to the study before drawing conclusions, but in the end, it is up to the reader to decide on the internal validity of the study. The external validity of the study is questionable due to a number of factors including the limited number of respondents and the study being confined to a specific geographic region.

3.14 Content analysis

Exploratory research was used in the study due to the limited sample pool. Transcripts of all interviews were drawn up and after analysing these transcripts common themes were identified and included in the findings.

3.15 Limitations of the study

Due to the limited number of participants in the study and the confined geographic area of the study, the external validity of the study cannot be justified, meaning that the ability to apply the study to other geographic regions may not be possible.

The sampling method used in the study is a non-probability judgement sampling method. This means that the number of participants chosen for the study were limited. Participants were chosen according to their levels of experience or expertise when it comes to biochar. It could be argued that those who qualified as an expert in biochar was based on the researcher's subjective opinion which may affect the credibility of the study.

3.16 Ethical considerations

Field research only began once approval was granted by the University of KwaZulu-Natal ethics committee. As part of the ethical requirements, a gatekeeper's letter was obtained from each of the participants. All respondents were then provided with an informed consent sheet to complete before the interviews began. This sheet ensured that respondents were aware of their rights and knew that they were participating in the study of their own free will. Only once the informed consent sheet was signed did the interview begin. Respondents were informed that they were free to withdraw from the study at any given time. All the data collected was saved onto a password protected laptop. All secondary data used in the paper has been referenced accordingly.

3.17 Conclusion

In this chapter, the research methodology of the study has been explained in detail. The logic behind choosing a study that has recorded qualitative data has been explained. All important aspects of the study such as the research design, the research approach, the study site and data collection methods have been clarified and justified. Furthermore, in this chapter the framework for ensuring that reliability, validity and ethical compliance were ensured has been outlined.

CHAPTER 4: FINDINGS AND ANALYSIS

The participants interviewed in this study had expertise in different areas. The university participants first encountered biochar whilst pursuing their fields of study, with some of the students integrating biochar into their projects. A few of the projects investigated biochar as a tool for waste management. Some of the non-university participants have theoretical knowledge of biochar because it is associated with their occupation, with quite a few of the participants having practical experience with biochar. One of the participants produces and supplys biochar in a commercial capacity. The participants interviewed were:

- Anne Chisa from UKZN
- Nqobile Nkomo from UKZN
- Douw Harilal a horticulturalist
- Dave Still a civil engineer (worked on a biochar production project)
- Riaz Jogiat a manager of solid waste in the uMgungundlovu District Municipality
- Darryl Phillips from Adsorb Technologies (commercial biochar company)

"Schmidt and Wilson (Schmidt & Wilson, 2012) identified 55 uses of biochar while mentioning that these were not all the possible applications as more uses are being found through the conducting of research." Due to the versatility of biochar, there exist multiple uses of biochar that have been documented. In the interviews with participants, quite a few common well-known uses of biochar were mentioned. Some of the participants mentioned using the biochar for more specialised tasks, either relating to their research or the line of work. Listed below are some of the uses that the participants mentioned:

- As a soil amendment
- As an energy source
- For air purification
- For gas purification
- For deodorisation
- In water treatment (waste water and potable water)
- For carbon sequestration
- For heavy metal adsorption
- For waste management with urine diversion dry toilets (UDDT)

- As a feed supplement
- As a toxin adsorbent
- For water filtration in aquaponics and aquaculture systems

There obviously exist many more uses of biochar that are not listed here but these are the uses that the participants in the study were familiar with through their research and/or practical usage.

4.1 Potential sources of biochar feedstocks

"Sources of biomass can include, crop residues, forestry residues, agricultural animal wastes (biosolids), organic waste derived from municipal dump sites and organic wastes from production in the industrial sector (Iakovou et al., 2010 Toka, & Malamakis, 2010, p. 1860)"

The principal potential feedstocks discussed with participants were household waste and garden waste. However, with regard to other feedstocks in the Pietermaritzburg and Durban area, there is no shortage according to participants. Nonetheless, multiple participants stated that not everything organic will make a suitable feedstock for biochar production. Depending on the desired end result of using biochar, it is very important to choose the right feedstock so that the end product has the necessary characteristics that the manufacturer is trying to achieve. Participants however did outline a few feedstock sources that could be looked into:

- Human excreta and urine
- Green waste (garden refuse being just one)
- Black wattle (good for water-based application)
- Pine (good for soil application)
- Sugar cane residue
- Agricultural residue leftover from milling
- Alien vegetation (wattle, Port Jackson willow etc.)
- Furniture or pallet offcuts from manufacturing

Participant 5 did mention "The working for water programme is probably the largest generator of woody biomass for biochar production. As far as I am aware this function is outsourced to private contractors. An arrangement with the contractor to chip and deliver to a processing site is an option. Agricultural residue which is a bulk item can be loaded into huge trucks using farm mechanisation much like the sugar can farmers use."

4.1.1 Household waste

A large portion of household waste is organic which suggests the possibility and suitability of organic household waste as a potential feedstock for biochar. While all participants in the study were in agreement that it is possible to make biochar from household organic waste, more than half of the participants feel that it would not make a good feedstock for a multitude of reasons:

- A more appropriate destination is municipal refuse dumps that require waste streams like kitchen waste for anaerobic digestion to take place
- It would be better to compost rather than pyrolyse as KZN soils generally lack organic matter
- Considerable time and resources would be required to separate and dry the household waste and this may not be practically or economically feasible
- Due to the household waste being mixed, the end quality of the biochar would be variable and questionable, thus severely affecting potential end usage

According to Douw Harilal (horticuturalist) "I am of the view that organic household waste is better composted than pyrolysed. Soils particularly in KZN are extremely depleted of organic matter and are in most cases less than 5% whilst the optimum is in the order of 20%."

Some of the participants did think that it might be worth looking into but were of the mind that separation needs to happen beforehand and the mixture itself needs to be homogenous.

"By creating biochar production facilities, organic waste streams could be a sustainable feedstock too in the creation of biochar, on a larger scale, economies of scale could be achieved driving down costs and providing a clear advantage over traditional waste management methods due to the end benefits that could be attained (Montanarella & Lugato, 2013)."

4.1.2 Garden waste

"Conte et al. (2016, p. 417) outlines Leaves, flowers, vegetables, roots, pruning from trees, vines and bushes, clippings from nature conservation measures, hay and grass as a potential feedstock source."

When it comes to the suitability of garden refuse, opinion seems to be split. Whilst some of the participants agree that it is a viable feedstock provided there is enough woody material (minimal grass and leaves) and the feedstock is separated beforehand, other participants doubt the viability of using garden waste. The major concerns were that the end biochar product will

not have the necessary characteristics to achieve the result it was created for, the feedstock will be a mix of multiple sources instead of a single uniform feedstock which could lead to an uneven end product that cannot be properly assessed, especially if there is too much leaf and grass material which would lead to a high ash content and not enough carbon. If the biochar is being produced for a specific purpose, the nutrients and PH level of the feedstock should be assessed beforehand. Furthermore, the cost of such a project could exceed any benefits, an example being that if used as a soil amendment it may take years to see the full benefit, something which farmers would not be willing to do as they require more immediate results with less time and effort.

4.2 Contaminant removal

Removing contaminants from the feedstocks could prove difficult. A few participants suggested implementing a separation at source approach, involving asking people to separate their rubbish before it is dumped or collected. However, the concern was that most people would not be willing to do so unless their awareness was increased and there was an incentive provided through a partnership with local municipalities. Another approach mentioned by participants is to use the existing dumps that exclusively collect garden refuse, but to put more stringent measures in place and a better screening process. However, participants mentioned that the only way they see this happening is if a portion of the dump were privatised since the local municipality is incapable of handling such an endeavour alone. The privatisation would also allow for further operations on site for receiving and sorting the garden refuse which would make it much more suitable as a potential feedstock source. One participant was not in favour of using this material as biochar feedstock and instead suggested utilising a method called mycoremediation ("a form of bioremediation in which fungi are used to degrade or isolate contaminants in soil") to remove contaminants from a dump site. Such a method would work well with a large-scale composting site. Another method of removing contaminants would be to focus on screening the end product instead of the feedstock. This would involve maximising the expulsion of cellulose and hemicellulose while maximising the capture of lignin structures as carbon during the production method. This would create ash along with the end product and the ash and other contaminants smaller than the biochar would be filtered out.

4.3 Source separation

According to Participant 6 “it's not realistic to say that people are now going to put garden waste in a separate bag on their pavement. I mean, we can't even put plastic and paper in a separate bag”

According to the study participants, implementing a source separation approach may be possible but there are significant barriers. Some suggestions to implementing a source separation approach included:

- Focus on better management of existing garden refuse sites and open more with longer hours
- Approach supermarkets and produce stores and offer to collect the organic produce that is out of date or spoiled
- Start a campaign to educate and make people aware of recycling and separating their garbage; this should start from young kids in school so that a generational change takes place
- Incentivise recycling; for example, give discounts to people who recycle the majority of their rubbish

One of the participants did mention that socio economic demographics play a major role on waste management, as a thing like source separation would only work in elite areas where there is good waste management, unlike the majority of South Africa. The participant also mentioned that currently it would be better for municipalities to mix domestic waste with sewage sludge in order to produce a high-quality compost that could boost food production.

Another interesting point that was brought up was that in certain European countries, bins have RFID (Radio Frequency Identification Device) tags and measure the bin and send out an alert when full. Residents are billed per load and financial constraints are placed on those who do not separate and recycle garbage. The result has been 80-90% separation rates in those societies. However, it was suggested that such an approach will not work in South Africa as we do not have the infrastructure. Nonetheless, a view was that inspiration could still be drawn from this to devise solutions.

4.4 Drying feedstocks

According to participant 4” Drying it using mechanical means is quite costly because you need an energy source that you have to pay for. But it's fast. However, drying using airdrying or sun

drying or just spreading on maybe what you call this, slice drying beds and you allow it to dry naturally. It will be cheaper, but not very fast"

The easiest and cheapest method of drying feedstock, according to participants, involves sun drying or air drying. This would involve laying the feedstocks out on drying beds and waiting for them to dry naturally. However, this comes with its own problems, depending on the feedstock type, the drying time could vary and this would mean that the feedstock would need to be exposed for varying periods of time. Also, with a subtropical climate, this means that the chance of rain is always possible and thus a shelter or covering for the feedstock may be necessary. Drying large amounts of feedstock would mean a lot of space would be required to for drying beds which would be very costly and time consuming. Natural drying is suitable for small amounts of feedstocks but larger amounts may require other methods of drying. It is also important to remember that any method of drying that has an adverse environmental effect would defeat the objective of producing the biochar. An environmentally friendly method would be best. A few of the participants mentioned a method of drying that is efficient and cost effective. This method involves redirecting the heat from the pyrolysis process to drying; almost a circular economy approach. The pyrolysis process is an endothermic reaction and releases a pyrolysis gas. If this gas is burnt an exothermic reaction results. Therefore, by redirecting the heat from the pyrolysis process to drying new feedstocks a self-sustaining method of drying could be created and no excess energy would be lost.

"In order to reduce the costs associated with drying, it has been found that by integrating the drying process with production through the redirection of surplus heat or energy into the drying process, the cost of drying can be significantly reduced whilst at the same time increasing plant efficiency (Fagernäs et al., 2010, p. 1268)"

4.5 The biochar production process

4.5.1 Biochar kiln design

Participant 2 mentioned "I'm in the favour of engineered technology. Rather than basic technology, and it definitely influences the quality of biochar."

According to all participants the kiln design plays a major role in both the quality and the yield rate of the biochar end product. Temperature control is a major factor during the production process that has a direct impact on the biochar production. Ideally, a closed and insulated system is required so that manufacturers have full control over the manufacturing process. The kiln design also controls the level of pollutants being released during production, with poorly

designed kilns emitting much more pollution than properly designed and engineered ones. Engineered kilns have a major impact on the biochar quality and when non-engineered and untested kilns are used, it becomes harder to control all the variables during production. In turn, this leads to a lack of consistency in production.

4.5.2 Ideal feedstocks for production

A point stressed by all participants was that there is no one ideal feedstock for production, as feedstocks are chosen based on the end characteristics required of the biochar. However, participants did mention a few prime candidates:

- Woody biomass derived from alien vegetation
- By-product wood feedstocks that have high lignin composition
- Feedstock's with high nutritional capacities
- Feedstocks that when collected address existing problems
- Materials that require less preparation (dried or shredded materials)

Whilst participants mentioned that there is no one superior feedstock, there are feedstocks that are more suitable than others, based on their inherent characteristics, readiness for production and potential other uses. Chopping down trees to make biochar or using edible foods would be inadvisable as it makes no sense when they can be utilised more effectively elsewhere. The feedstock should be a by-product or a means of solving some problem for it to be worthwhile.

"The variety of sources and potential for conversion on a neutral CO_2 basis makes biochar an attractive product for soil amendment and other purposes (Song & Guo, 2012, p. 138)"

4.5.3 Feedstock preparation before production

"In order to achieve greater efficiency and overcome these constraints, a form of pre-processing is recommended where the biomass undergoes size reduction and densification which would allow for more efficient and easier transportation (Lin et al., 2016)."

Participants mentioned that it would be wiser and less labour intensive to use feedstocks that have already been semi prepared and require less labour. Examples of these include:

- Agricultural residue in the form of stover which will allow for better drying; if covered in black plastic it would solarise the process and make it more efficient
- Chipping and natural drying

- Utilising by-products such as woodchips and sawdust so minimal preparation is required
- Mixing more than one feedstock to achieve certain characteristics for your end product (whilst ensuring that the mixture is homogenous)

4.5.4 Production methods

"The conversion of biomass into biochar, biofuels and other bio-based end products occurs through a variety of thermochemical processing methods including pyrolysis, gasification, torrefaction and hydrothermal carbonization (HTC) and these processes happen under differing temperature ranges (Qambrani et al., 2017, p. 256)

The production method should be based on the scale of production and the resources at disposal. While some participants only have a theoretical knowledge of production, there seemed to be consensus amongst participants that the method of production should be based on what the producer is trying to achieve. One participant mentioned that during the course of her experimentation, she discovered that feedstocks charred at lower temperatures are good for agricultural purposes, whilst feedstocks charred at higher temperatures are better for carbon sequestration. Another participant mentioned using a better engineered approach for his large-scale production. This process involves using a combination of pyrolysis and gasification. Firstly, he pyrolyses his feedstock and then introduces steam to oxidise the biochar.

4.5.4.1 Personal low-tech kiln building

Participants had mixed reactions when it came to building a kiln for personal usage; something that could be built in someone's back yard. One participant mentioned building a furnace out of sheet metal with two chambers. Such a kiln would require some labour and plans can be found online. Another participant mentioned making a small unit with a few drums and a chimney. A low-cost, low-tech and rudimentary pyrolysis unit could be made with such an approach with, again plans to be found online. The easiest and most cost effective approach mentioned, involves a pit burning method, but the quality of such biochar would be low and it is not an environmentally advisable method.

According to Participant 5, a potential low tech kiln could be "a small unit fabricated from drums and a chimney or in a peri-urban or rural fire pit will be the most cost effective method. More recently, the use of rocket stoves is proving to popular as it uses twigs and small branches which in turn reduces the felling of mature trees and the end product is a quality biochar."

Some participants were of the opinion that the homemade approach is dangerous as the methods of production have not been properly researched. Scientifically endorsed research needs to be done into how acceptable the air emissions of these processes are and how acceptable the biochar quality is. The best method of production at home would be to buy an engineered kiln that could fit into your backyard. These usually are based on tried and tested designs and small quantities of acceptable quality biochar could be made.

4.5.4.2 Environmentally friendly production methods

The majority of participants claimed that most forms of pyrolysis and gasification are environmentally friendly as no emissions and smoke are released. Smoke may be initially released but that is rapidly curtailed. Several participants suggest that to be even more environmentally efficient, the excess energy and heat from the production should be redirected into a more useful avenue such as cooking, heating or drying the next lot of feedstock.

However, one participant, a trained engineer, stated that any non-engineered and untested approach cannot claim to be environmentally friendly until the production method has been assessed. He went on to explain that people often assume that because there is no smoke, there are no harmful gases being released but with low tech approaches this is unknown without the proper testing. Any gases need to be contained or redirected. The fire pit production method was cited as dangerous due to both emissions and the risk of wild fires.

4.6 Biochar characteristics and quality

Feedstocks and production have a definite impact on end quality and usage. The selection of both the biomass and the production process needs to be based on what the end product will be used for. Although chemically the biochar may look good, if the right feed wasn't used then it won't perform well. Pine, for example, makes a good quality biochar for use as a soil amendment, as an ingredient in animal feeds and for biological water treatment processes. Wattle is better for air and potable water treatment due to its absorption capabilities. The explanation provided, was that pinewood has a good structure and fibre content to allow for good microbial support while Blackwattle has a denser structure, hence is better for absorption. To get consistent quality, both the feed and production method need to be consistent, especially if there are plans for the biochar to be sold commercially.

4.7 Implementing a biochar supply chain

4.7.1 Existing large scale biochar supply chains

In the Pietermaritzburg and Durban regions there currently are no large scale biochar supply chains according to participants. The most likely reason for this being that companies haven't seen the monetary gain that can be achieved from such an endeavour. There are a few small operations such as:

- The St Lucia community project with items like pine cones being charred
- Adrian Padt of rocket technologies planning to make biochar using macadamia nut shells
- Kobus Venter who specialises in engineering kilns and makes a bit of biochar on the side
- Living Soil, that has members enthusiastic about biochar, produce on a small, decentralised scale

Outside the KwaZulu Natal region, quite a few companies produce biochar on a larger scale and, according to one participant, these include:

- Adsorb Technologies in Gauteng, that produce on a large scale and are linked to York Timbers with a capacity of about 20 tons per month
- Hive Carbon based in the UK but producing char in South Africa
- Nu Carbon in Sedgefield, (claim to have a capacity of 50 tons per month)
- Rotocarb in Clayville who make activated carbon from macadamia nut shells
- Senforesoil (make biochar enriched pellets)

4.7.2 Core factors to be considered when setting up a biochar supply chain

Participants itemised several factors to be considered when planning a biochar supply chain. With some overlap, these include:

- Sourcing and security of feedstocks (need a secure source)
- Drying cost, method and timespan
- Focus on low-cost production in order to gain market entry
- Energy usage and cost
- Site location and transport costs
- Compliant and economic technology
- Defined manufacturing processes

- Yield rate
- Target market of biochar product
- Environmental benefits of the biochar end product
- Packaging costs
- Customer attraction and retention

4.7.3 Considerations in developing a sustainable and environmentally friendly SC

Participants cited the following considerations:

- Production method shouldn't pollute the environment, testing of gases to ensure no pollution
- Transport costs and pollution from transport needs to be offset
- Utilisation of responsible feedstock sources such as alien vegetation and agricultural residues
- Using a closed loop production process so that excess heat and energy is utilised (redirected into heating or drying next feedstock lot)
- Location of production site should ideally be in same location as feedstock to minimise transport and handling costs whilst reducing pollution from transport

4.7.4 Biomass and logistical considerations

"A major factor that would influence transportation costs would be the concentration of biomass available in the immediate radius. A large concentration in a narrow radius could decrease costs substantially, meaning that the plant location is also of vital importance (Börjesson, 1996)."

With regard to transport considerations, the consensus of participants' opinions was that ideally the production site should be in the same location as the feedstock source in order to keep costs low. Failing this, the feedstock should at least be within a radius that transport costs would be economical. Transport considerations of the biochar product are less of an issue as the biochar takes up less space and has a higher storage density. If a plentiful source of biomass feedstock was found, a site could be set up within close proximity which would drastically reduce logistical considerations, some possible sources mentioned were:

- Working for Water programme

- Largescale biomass generation from alien vegetation, outsourced to private contractors so some sort of agreement would need to be struck between parties that is mutually beneficial
- Commercial forestry production sites. However, forestry companies may be unwilling to cooperate if there is extra labour or costs incurred on their side. May also be unwilling permit production on site as this may not align with their policies
- Agricultural industries; sugarcane waste, timber and pallet waste
- Certain semi-prepared feedstocks may be worth looking into

4.7.5 Collaboration opportunities with existing businesses and supply chains

Participants are of the view that many collaboration opportunities exist but working with any profit oriented, existing businesses will be an issue due to an unwillingness to get involved in a venture unless benefitting from the enterprise. Other avenues include:

- Community based small scale production where such an endeavour would lead to limited quantities of variable quality. An example being the St Lucia biochar project
- Integration into composting businesses by charging the biochar with nutrients beforehand and then selling both a fertilizer and biochar. Synergistic products that complement each other. Will see the benefit of the biochar more rapidly.
- Sewage sludge is an area the municipality is already struggling to handle. An example is the Urine Diversion Dry Toilet programme. The municipality has already partnered with organisations to find better avenues of disposing of the waste from these UDDTs and there is a major opportunity for collaboration as faecal sludge and urine are very high in nutrients. Urine has high nitrogen levels which would be beneficial to foster plant growth.
- The Umngeni water department has launched a programme where human faeces are treated. The faeces are de-pathogenised and a slurry mix is produced. Currently engaged in a joint research project with UKZN. Experiments have already been done on grass fertilisation with positive results. The department is now looking at mixing this slurry with other biomass sources to produce a fertiliser. In a project like this, the groundwork has already been done and there are opportunities for collaboration.

Participant 1 made an interesting point on collaboration, she stated that “Yeah, so, definitely, you need to be working with your policymakers, the people to make sure that this actually can happen. You need to be working with the communities to get them involved to see the benefits

of that, you also need to be working with your scientist again, and also the people who can market it”

4.7.6 Ideal method of producing biochar on a large scale

The best way of producing on a large scale according to participants who have experience in this area would be an industrially engineered approach. This would involve the creation of a large-scale pyrolysis or gasification unit where the entire process from beginning to end can be controlled, especially the temperature.

4.8 Commercial Applications

4.8.1 Why isn’t biochar more popular?

Currently, most of the agricultural sector is reliant on inorganic fertilisers and agrochemicals that do not work well with biochar. Farmers favour unsustainable methods that offer quick results because that is most financially beneficial to them at the time. However, there has been an increase in environmental and soil health awareness of late. As a result, biochar should eventually gain some popularity as a product that promotes soil health and allows for the proliferation of micro-organisms.

Biochar currently does not enjoy much industry support. Most of the support it does receive comes from a decentralised private sector. The most probable reason for this would be that companies and organisations do not see biochar as presently profitable. More skilled and educated people need to be involved in researching and promoting biochar for it to gain popularity, as currently it is being driven by enthusiasts who are using trial and error approaches. There needs to be more education and awareness on biochar so that it gains popularity and drives the industry forward.

Presently, most people are only interested in climate mitigation measures if they can gain some benefit. Incentives need to be provided for people to get involved in such programmes.

According to participant 3, a potential reason why biochar is not more utilised in the agricultural sector is “ it's not fully proven yet. So I mean, do you know of irrefutable scientific studies that say, you know, if you spend R50,000 per hectare, putting it into your, your farm, how long it will take to pay for that investment? That's what you've got to have. There's got to be a firm case for it. If you're saying, Well, we believe it's good for the soil good, but it's gonna take 50 years to to to pay off, you know, that that's hard for people, people don't have that kind of capital to wait that long”

4.8.2 Current large-scale sellers of high-quality biochar

The participants were not aware of any companies producing high quality biochar on a large scale. However, one participant did mention a few operations that are essentially the same as the existing supply chains mentioned above:

- Adsorb Technologies in Gauteng, produce on a large scale and are linked to York Timbers, capacity of about 20 tons per month, quality good enough for soil additive and animal feed
- Hive Carbon based in the UK producing char in South Africa
- Nu Carbon in Sedgefield (claim to have a capacity of 50 tons per month)
- Rotocarb in Clayville who make activated carbon from macadamia nut shells
- Senforesoil (make biochar enriched pellets)

4.8.3 Biochar certification or grading process

According to Particiant 2, “In South Africa, the institutions, although we've got them, their policing or their enforcement is quite weak (when it comes to biochar quality), I'm sure you know that from environmental laws and regulations, emissions and that sort of thing. So in my view, the weakness in our country has allowed biochar, let's say to be abused by those who are just trying to sell a byproduct alright into that space without going through the necessary certification, classification, quantification processes”

According to all participants, currently there is no grading process for biochar. In order for it to be sold commercially, the only qualification it needs is that it must not cause harm and this does not measure the actual quality. Potential quality indicators are the carbon content and the nutrients contained in the biochar. A similar format to compost could be followed where necessary information is displayed on packaging so consumers could buy the biochar product based on characteristics like physical, chemical and morphological properties.

4.8.4 Biochar characteristics and impact on price

The production process and feedstock quality definitely affect the characteristics of the biochar which then influences the price of the end product, according to the participants. However, as mentioned previously, no official grading system exists for biochar so the only way to inform consumers of quality and characteristics would be to display relevant information on the packaging. However, when compared to somewhere like America, biochar in South Africa is substantially cheaper since industries are not willing to pay a fair price. As a result, biochar

businesses may not prove viable or they may compromise the quality of their products to sell at a cheaper price

4.8.5 Commercial sectors most likely to benefit from the usage of biochar

Participants listed the following potential beneficiaries of biochar products:

- Commercial agriculture
- Commercial aquaculture and aquaponics
- Eskom and Sasol utilising biochar in their stack gas treatment systems
- Domestic gardens and nurseries collectively could make up a large market share, farmers may be unwilling to pay extra due to large quantities they would need but no such problem would exist if sold to private consumers
- Municipalities for landscaping gardens and improving public spaces
- Municipal waste and potable water treatment
- Companies could use it to reduce their carbon emissions, this would reduce carbon and short acting pollutants like methane and black carbon. Companies to gain a tax break from offsetting carbon emissions

All of these could have far reached positive effects, especially ones promoting soil health and environmental rehabilitation. However, one participant did mention that Eskom would need approximately 50 000 tonnes per annum of biochar for their stack gas treatment which is well above what is being produced in South Africa at the moment, especially good quality biochar.

4.8.6 Biochar as a feed supplement

“Biochar as an animal feed additive has been shown to provide numerous benefits to animals such as aiding in an increased feed intake and weight gain; a greater intake of nutrients; enhanced health levels; detoxification from pollutants, toxins and other contaminants; reduced methane emissions and a reduction in antibiotic residues (Man et al., 2021 Mo, & Wong, 2021, p. 13).”

Of all the participants interviewed, only a single participant had knowledge and experience when it came to producing and selling biochar as a feed supplement. According to the participant, his company is the only registered animal feed additive producer of biochar in South Africa. As an additive to animal feed, the aim of the biochar is to support microbes which contribute to better digestion in the animals. Biochar made as a feed additive or even a soil additive needs to have certain carbon to nitrogen ratios and certain carbon to hydrogen ratios.

What sets biochar apart from charcoal in this regard is that there are certain volatiles in charcoal that could be poisonous to soils and animals.

4.9 Regional applications

4.9.1 Potential biochar utilisation contributing to local communities in the Durban and Pietermaritzburg areas

Participants suggested several ways in which biochar utilisation would contribute to local communities in the Durban and Pietermaritzburg areas. These include:

- Small scale growers of fruit and vegetables
- A synergistic system where the biochar could be used in aquaculture and aquaponics systems which would then charge the biochar thus increasing value before being sold
- Vegetable and community gardens; the Department of Agriculture could experiment with and assess plant responses to biochar.
- Urine Diversion Dry Toilets; after creating the biochar with the feedstock from these systems, provide it back to the people in these areas for usage where it's needed most. An example being Kenya where biochar created from faecal sludge is used to cook or braai food.
- uMngeni water project that has created a depathogenised slurry that has shown excellent results when sprayed on grass seedlings; opportunity to partner and create biochar from slurry or charge biochar with slurry
- Divert waste from landfill; will be an attractive option in future
- Turning garden waste into biochar instead of it rotting and creating methane and occupying landfill sites

4.9.2 Alien vegetation as a potential feedstock in the Durban or Pietermaritzburg areas

Allien vegetation was cited as a good source of feedstock with government subsidies already in existence to remove and transport wattle trees. Currently there is a programme that turns some of the wattle into coffins for the poor. Creating furniture or biochar is better than drying and burning the feedstock, with better long-term benefits. There is other alien vegetation according to one of the participants but these species are probably unsuited for biochar production.

While the majority of the participants seemed to think that turning alien vegetation into biochar is a good idea, one of the participants did have concerns. This participant was supportive of the initiative but he was not supportive of deploying decentralised technology to create the biochar, as the quality of this biochar could prove rather poor. Biochar production, he considered, needs to be somewhat centralised to ensure a good quality and consistency. Furthermore, he was of the opinion that biochar should not be a primary focus and the wattle wood should be utilised for things such as furniture with only the by-product and twigs and branches being used for biochar production. Even with biochar made from wattle by-products and waste, the quality should be assessed before proceeding.

When asked about some of the most suitable sources of biomass for biochar production, participant 5 mentioned "Woody biomass especially that derived from alien vegetation removal is most appropriate as it addresses several environmental issues whilst yielding a valuable end product."

CHAPTER 5: DISCUSSION AND CONCLUSIONS

5.1 Introduction

Whilst the popularity of biochar has increased considerably in recent years, it still remains a somewhat unknown substance to the general public. Participants in the study only encountered biochar due to its relevance to their field of work, or in the case of university students, due to its relevance to their research. However, what was repeated during the course of the study is that biochar is a product with several potential uses and benefits and is a substance with potential worth pursuing.

During the course of the study it was found that there are multiple uses of biochar with the potential for more innovative ways of using biochar a good possibility. The uses of biochar that were described during the course of the study were:

- As a soil amendment

  Biochar is regarded as a valuable additive to soil due to its inherent characteristics. Unlike other organic compounds, biochar is highly stabilised and resistant to decay leading to a sustainable method of soil enhancement (as evidenced by Amazonian *Terra Preta*) and it also possesses the exceptional ability to retain nutrients that are essential to plant growth (Nanda et al., 2016 & Kozinski, 2016, p. 224)
- Energy source
- Air purification
- Gas purification
- De odourisation
- Water treatment (waste and potable water)
- Carbon Sequestration
- Heavy metal adsorption
- Waste management for Urine Diversion Dry Toilets (UDDT)
- Feed Supplement
- Toxic Adsorbent
- Water Filtration in aquaponics and aquaculture systems

With regard to the various uses of biochar, it should be noted that the majority of uses require a biochar of a certain quality possessing certain attributes. Potential exceptions being use as a soil amendment or energy source where, even with a poor quality product, some benefit may

be derived from the biochar. As described in the literature, other uses of biochar exist but during the course of this study these were the areas of use that were mentioned.

5.2 Potential feedstocks and usage

No shortage of potential feedstocks required to produce biochar were reported with regard to the Pietermaritzburg and Durban areas. However, feedstocks cannot be judged as suitable simply because they are made up of organic materials; there are multiple attributes that a feedstock should possess. These attributes should be based on what the biochar will be utilised for and what sort of qualities the biochar is required to have in order to achieve this end result. A few potential feedstocks that could be used to create biochar of a good quality that would have a good range of application were outlined and are listed in Table 5.1.

Table 5.1: Potential feedstocks and their applications after production

Feedstocks	Applications
Sewage Sludge	Biochar production has shown promise as a potential waste management solution with the resulting biochar making a good quality soil amendment due to the abundance of nutrients found in this feedstock.
Black Wattle	Would make a good quality biochar suitable for water based applications (water filtration or aquaponics). Due to its classification as invasive, collaboration opportunities exist with organisations like the WfW programme.
Pine	Would make a good quality biochar that would be best suited for soil application
Sugar Cane Residue	Extensive research has been conducted on biochar created from sugar cane residue. By using this residue the feedstock is already semi or fully prepared and could be used for biochar manufacture immediately. Furthermore the feedstock would most likely be of a consistent composition and quality leading to a consistent end product. The use of sugar cane residue as a feedstock also serves as a means of waste management.

Agricultural residues from milling	Depending on whether the residue is consistent or mixed, this could influence the end quality of the biochar and limit its possible uses. However, even if poor quality biochar is produced, it could still be used as a potential waste management method with the biochar used as a low grade soil amendment.
Alien vegetation	Biochar could serve as a good waste management solution and to control the spread of alien vegetation. Even a poor quality biochar could be used as a low quality soil amendment and this would still be better than simply burning the waste. The quality of the biochar would be based on the type of alien vegetation, whether multiple species are present in the feedstock and the consistency of the feedstock.
Furniture or pallet off-cuts	Depending on the type of off-cut, this would make a good feedstock as the feedstock would be prepared or semi prepared which would reduce the number of steps required before production. The end quality would rely on the feedstock type, whether it is a mix of sources and the production method.

Irrespective of the feedstocks or benefits mentioned above, any production of biochar would serve as a carbon sequestration tool in addition to the end benefit gained from the finished biochar product. However, keeping in mind the benefit of carbon sequestration, a proper, low environmental impact method of biochar production should be used in order to make a good quality biochar and to ensure that the benefit of biochar as a means of carbon sequestration is fully realised.

5.2.1 Household organic waste

The possibility of household rubbish being a potential feedstock for biochar production is something that may not be a viable option at present, for the following reasons:

- As an inconsistent feedstock, this would lead to a subpar quality biochar end product
- Easier and faster solutions such as composting exist for household organic waste compared to biochar production, which could also lead to a better end result compared to a low quality soil amendment

- The labour, time and resources required to separate and prepare the feedstock for production may outweigh any benefit that could be gained
- Organic waste is important for anaerobic digestion to take place in dumps and diverting it away from landfill could result in reduced benefits overall

As described, there are multiple barriers to using household organic waste as a biochar feedstock and unless ways are found around these then it is not a viable option at present.

5.2.2 Garden waste

Between garden and household waste garden refuse holds more promise as a potential feedstock. However, even this feedstock source has limitations that need to be overcome. Garden refuse could make a viable feedstock provided that the feedstock is assessed as suitable beforehand. The factors that may hinder its usage as a feedstock include:

- A high content of grass and leaves which would create too much of an ash content to be a viable feedstock
- A poor end quality biochar with any type of garden refuse used
- An inconsistent product due to a non-homogenous feedstock mix
- Garden refuse is usually made up of a variety of sources which makes it hard to attain the desired characteristics in the end product. Even if the quality is of a good standard, it may differ from what was intended, with its characteristics not suitable for the intended use
- It may be necessary to separate the feedstock beforehand which may prove too labour intensive and uneconomical

The usage of garden refuse as a feedstock would need to be properly investigated before implementation. The feedstock should be assessed before production begins to ensure that it will result in the desired quality end product. Furthermore, the fruits of such a project may only be seen well in the future as the most likely end usage of the biochar would be as a soil amendment. The benefits of which may take years to properly be realized.

5.3 Feedstock preparation

5.3.1 Contaminant removal

The biggest barrier to utilizing organic waste as a biochar feedstock is the removal of contaminants. This is a time consuming and costly task which can make it non-feasible. The only way of resolving this would be to take a proactive stance that would require implementing

specific measures to ensure that the feedstock that is received for biochar production requires minimal separation. However, this is an easier said than done task as it would require a high level of collaboration and participation. One potential method would be to implement an “at source” approach. However, unless there was some way to motivate people to do this through some sort of incentive, the chances of this succeeding on a large scale are unlikely.

With regard to the Durban and Pietermaritzburg areas, there are currently a number of dump sites specifically designated for garden refuse for residents in that area. However, contamination at these sites with non-organic waste occurs due to negligence or in some cases bribery to allow the site to be used as a common dumping ground. These dumping sites could be included in a collaboration project and achieve promising outcomes. The best chance for success with such a project would lie in creating a joint project between the public and private sector which would allow for on-site monitoring to prevent non-organic dumping. Furthermore, the project could lead to the development of an on-site biochar production plant.

The possibility of simply ignoring the separation process does exist. The process would involve pyrolysing everything, including the contaminants. Contaminants would turn to ash, depending on the production method, and the pyrolysed product could simply be sieved out at the end. By using this method, instead of measuring the quality of the feedstock, the biochar end product quality would be measured. However, with this approach there’s a strong possibility that the end product will be of a poor quality and time and resources will have been wasted. This is very much a trial and error approach to production. The method does hold credence as a waste management method if the production method is environmentally efficient and at worst the biochar end product was used as a low grade soil amendment.

5.3.2 Source separation

The barriers to implementing a source separation approach to waste are many. Lack of education and incentive being two of the biggest barriers. As mentioned previously, one of the easier approachess would be to use an existing garden refuse dumping site, since with a little fine tuning it would be a convenient site for separation and possibly production. The second method would be to provide an incentive to induce people to contribute to separation. A third method would be to partner with produce suppliers in the fruit and veg industry and form a collaboration that would allow for a biochar producer to collect produce that is out of date or spoiled. The methods mentioned previously are solutions that can be implemented in the short to medium term. Another more effective method would be to educate people on waste

management and the environment. However this is a long term approach that would only be successful if instilled in people from a young age.

Source separation in South Africa has little likelihood of being implemented due to poor infrastructure. However, it is important to understand that all areas in South Africa are not equal and that regions are influenced by certain socio economic demographics that may make it more or less likely for a source separation approach to be implemented.

A carrot or stick approach could also be utilised to incentivise residents to separate their waste. In some countries this is already being done and residents are charged more or less depending on whether their waste is separated. Once again there is little likelihood of such a management system being implemented in South Africa as the current infrastructure is unable to accommodate or manage such a system.

5.3.3 Drying of the feedstocks

Another barrier to biochar production is ensuring that the feedstock chosen for biochar production has minimal moisture in order to ensure a good quality biochar end product. When producing smaller quantities of biochar, the drying of the feedstock is easier to manage when compared to drying large quantities of feedstocks. Feedstock can go directly to drying if it is already in smaller pieces; examples are sawmill woodchips, sugar cane residue or human excreta, as these are already small enough to be dried. If the feedstock is larger it would most likely need to be reduced to smaller pieces in order to make the drying more efficient.

If a natural method of drying is used, this would require the feedstock to be spread out on drying beds and dried by the natural elements (sun and air). However this method of drying may take time depending on the type of feedstock and the process is subject to the weather. In rainy weather the feedstock would have to be covered with tarpaulins and this may prove inefficient, especially for larger quantities in terms of space and management. A potential solution would be to put up a drying shelter but again this may not be feasible, depending on the business model at hand.

There are multiple methods of drying. Mechanical methods using an industrial dryer may be effective but, if the drying method is not environmentally friendly, this may defeat the purpose of creating biochar in the first place.

Possibly the most cost effective and feasible solution for drying feedstocks would be to implement a circular economy approach to drying. The pyrolysis and gasification method of biochar production produces an excess of heat and gas and this could potentially be redirected

into a number of useful avenues, with one being drying the next batch of feedstock. This could result in a very efficient and feasible cycle of production.

5.4 The biochar production process

5.4.1 Biochar kiln design

The kin used in the production of biochar is pivotal to the end quality and even the yield of the biochar. Whilst homemade or low tech kilns do exist and can produce biochar. The quality, consistency and yield of the production with such kilns is not guaranteed. The chances of ending up with a low quality end product which would most likely only be suitable for use as a low grade soil amendment is the most likely scenario.

If a manufacturer wanted to produce a high quality biochar product, the most likely chance of success would be to procure a well designed and engineered kiln. With such a kiln the manufacturer has absolute control over the entire production process. The kiln would have to be properly closed and insulated with a built in temperature gauge and internal temperature control. Furthermore, a properly designed and engineered kiln would be more environmentally safe then a homemade kiln as the better control and closed system would prevent pollutants from escaping into the atmosphere. Such a kiln would be more essential for large scale production due to it being easier to manufacture a consistent product in consistent environment.

5.4.2 Ideal feedstocks for production and the preparation required

While it is true that there are some feedstocks more suited to use in the production of biochar than others, there exists no ideal feedstock per se, rather the feedstock utilised should be carefully chosen beforehand based on what characteristics the biochar end product is meant to have. There are some points that should be kept in mind when choosing a feedstock, these being:

- Using feedstocks that require minimal preparation (already shredded or dried materials)
- Using feedstocks that achieve two goals in that utilisation of the feedstock addresses an existing waste management requirement
- Using waste by-products instead of sourcing materials that could still be useful elsewhere (e.g. woodchips and sawdust)
- Using feedstocks that enable faster drying (e.g. agricultural residues such as stover)
- Mixing feedstocks into homogenous mixtures to acquire certain characteristics in the end biochar product.

In essence, it would be best to identify a feedstock, such as a suitable by-product, that provides the required characteristics whilst also coming in a semi prepared form requiring minimal preparation, is less labour intensive and is more efficiently converted to biochar

5.4.3 Production methods of biochar

The production methods used for the creation of biochar are completely dependent on what characteristics are required of the end biochar. Production of biochars at higher temperatures can drastically change the characteristics of the biochar and its suitable end usage. As described by one of the participants in this study, pyrolysing the feedstock at a lower temperature makes a better biochar for use as a soil amendment, whereas pyrolysing at a higher temperature leads to a better biochar for carbon sequestration purposes. Several variables need to be taken into consideration as certain production methods lead to biochar with a higher surface area and lower volatile content and vice versa.

5.4.4 Homemade kiln builds

The production of biochar in homemade kilns is common practice. Multiple plans and designs as well as instructional videos are available on the internet and claim to produce a mid to high quality biochar product. Such plans often involve the utilization of drums and sheet metal to create rudimentary biochar units complete with chambers and a chimney. However, there are certain risks and limitations involved with the manufacture of homemade or small-scale kilns.

Perhaps the most important factor to consider with homemade kilns is the safety factor as pyrolysis units often build up pressure that may potentially be dangerous. The chance of accidents happening is greater with a non-engineered kiln. Another major factor that biochar producers of the engineered approach have mentioned is the lack of certified test results of small-scale kilns. The claim of these kilns being environmentally friendly is for the most part unfounded and the same could be said for the biochar end product. Since there are no quality testing systems in place to assess the grade or quality of the biochar produced, this may undermine the effort and end result of the small scale production process.

However, there is the opportunity to make biochar on a small scale for personal use or potentially for a small business such as a nursery as there are several kiln producers who have designed and engineered miniature kilns that allow for small batch production with all the necessary controls of a pyrolysis unit in place. One example of this is kilns built by Vuthisa technology. They are small and mobile while still enabling proper pyrolysis to take place.

5.4.5 The environmental impact of biochar production

Provided that a proper pyrolysis or gasification unit is utilised, the production of biochar is an environmentally friendly process as a minimal amount of smoke and emissions are released. Most producers of biochar who produce on an industrial scale will often test the emissions released from the chamber during production to ensure there are no harmful emissions. A further step could be taken by using a circular economy approach method and redirecting the heat and excess energy into other useful avenues so that no wastage occurs either. The role of biochar in carbon sequestration, its potential role in alien vegetation control, the utilisation of waste streams as a feedstock and the contribution of biochar to depleted soils all have a positive impact on the environment.

5.4.6 Achieving the correct quality and characteristics of the biochar end product

As mentioned previously, in order to ensure that the end product is of a good quality and able to achieve the task it was created for, the starting point would be to select a good feedstock. Once again, this emphasises the importance of a customised approach that best produces the biochar required for a particular application. Not only are certain feedstocks better suited for certain tasks but the production process itself should be customised to achieve the end goal of the biochar produced. Suitable feedstock examples previously cited include:

- Pine biochar being used for soil, animal feeds and biological water treatment
- Wattle being well suited for air and potable water treatment due to its absorption capabilities

Pine wood has a structure that allows for the ample formation of capillaries during the production process due to its high fibre content. The residual capillaries in biochar promote the growth of microbes which is extremely beneficial to the soil. To speed up the growth of these microbes, the biochar could be charged by mixing it with a sewage sludge or organic fertilizer that enables the benefits of the biochar to be realised at an earlier stage. Black wattle on the other hand has a denser structure making it useful for adsorption of, for example, minerals or even toxins.

5.5 Implementing a biochar supply chain

Currently, no biochar supply chains on an industrial or commercial scale exist in the KZN region. However, there are a few experts in the field who have made considerable progress in the field over the last few years and are currently working towards scaling up production and

potentially commercialising it at a later date. The biochar projects currently in operation have, for the most part, been implemented in order to address a particular need and to gain further insights into biochar. An example is a community project in St Lucia where pine cones are used as a feedstock for biochar production. This project is still in the pilot phase with the hopes of ramping up production if a good quality biochar can be created from these pine cones. The University of KwaZulu Natal has initiated numerous projects over the years where biochar was created from a number of feedstocks, including black soldier fly larvae and faecal sludge. Once again, none of these projects were implemented on a large scale and were more for research purposes. On the other hand, there are a few companies in South Africa producing biochar on an industrial scale and they are selling this biochar commercially.

In the implementation of a biochar supply chain, certain core functions need to be planned and researched. These are discussed in the following sections.

5.5.1 A secure feedstock source

Finding a secure feedstock for large scale biochar production could be a potentially arduous task as there are multiple factors to consider. The first factor would be finding a feedstock with the desired characteristics that would be present in the end product. The feedstock would need to be easily accessible and a constant supply would need to be present. If the feedstock chosen also solves an already existing problem at hand this would be all the better (alien vegetation or removal of unwanted residues). An example being the Working for Water programme that has projects that involve the removal of alien vegetation from certain areas in South Arica or possibly sawmills, sugarcane mills, forestry operations or pallet manufacturers where organic residues are plentiful.

5.5.2 Drying and preparation of the feedstock

Ideally the feedstock chosen should require a minimal level of preparation as the drying and preparing of the feedstock could be a harder task than the actual production process if a lot of preparation is required. Feedstocks that are large in size and mass would be hard to transport, reduce and thereafter dry which would not be feasible for the implementation of a biochar supply chain. A semi prepared feedstock such as waste from a sawmill, forestry operation or possibly items like the shells from nuts would be ideal as this would require minimal chipping, be easier to transport and would dry at a much faster rate.

5.5.3 Site location and transport costs

The site location should be carefully chosen as transporting large quantities of feedstock to a secondary location would be time consuming, costly and bad for the environment if heavy machinery such as trucks were to be utilized. A scenario where the feedstock preparation and biochar production site were on the same lot as the feedstock source or in close proximity would be the best approach as this would eliminate the need for transportation and lead to a more efficient cycle of production. The transportation for the feedstock source is likely to be a more arduous task than the transportation of the end product. This is due to feedstock being bulkier and heavier, especially if it is not at least semi processed or prepared. Residues or by-products would be easier to transport but it would still be advisable to have production on the same site as the source or at least in close proximity as additional transporting would be a costly, labour intensive and time consuming exercise. Transporting the finished product on the other hand would be a lot easier due to it being a lot more condensed and light compared to the feedstock before production.

5.5.4 Equipment considerations

Depending on the feedstock chosen and the site of production, the equipment requirements will be directly influenced by these previous factors. If a production site different from the feedstock source was chosen, this would require the feedstock to be transported to the production location in question and this would require heavy machinery such as tractors or perhaps trucks based on the size and quantity of the feedstock. If a feedstock in a solid non-reduced form were chosen, such as tree logs, this would require the feedstock to be reduced in size with perhaps the only way being through the use of a chipper. Furthermore, the feedstock would have to be dried before production and this may require a drier if the quantity of feedstock was large.

Thus, a previously emphasised point needs to be kept in mind when designing a biochar supply chain; if the machinery and energy cost outweigh whatever environmental and/or commercial benefit that could be gained from the end biochar product, there is no future in continuing. The point being that at every step of implementation, all factors such as the feedstock source, the location and the energy requirements should be considered so that minimal equipment, labour and effort is required before the production process actually begins.

5.5.5 The production process

In the implementation of a biochar supply chain, the only way to get a consistent biochar quality with a consistent yield on a large scale would be to have large pyrolysis units engineered

specifically for that production. These pyrolysis units could even be customised for a specific feedstock so that the biochar could be created efficiently on a large scale. Furthermore, with a consistent quality and yield rate the opportunity for commercial application increases.

5.5.6 Quality verification

Depending on the type and consistency of the feedstock used, along with the production conditions, the end product quality of the biochar can vary. It is therefore imperative that quality verification is conducted on the biochar before any distribution takes pace. This will ensure that the biochar is effective in its application and the end customers are satisfied with the product

5.5.7 Cost to the environment

If a careful approach is taken at every step, then the cost to the environment is minimal and the benefits of the end product should outweigh whatever impact the production may have had on the environment. The first step would be to ensure a feedstock source that is environmentally responsible and is not using a material that may be redirected to a more useful task. The transport emissions and whatever emissions are generated during the preparation of the feedstock would need to be offset, with the ideal scenario being to do the production on the same site as the source of the feedstock. It is also important to test the emission levels from the production process on a regular basis and not to just simply take it at face value that it is a clean production system. In order to be more economical and efficient, the excess heat from the production should be redirected to the drying of the next feedstock lot or some similar activity instead of wasted. The end biochar product is a lot more condensed and light, making it easier to transport. The transportation of the end product would be a lot less costly than the feedstock and should be offset by the benefits gained from the biochar production and end usage.

5.5.8 Customer attraction and retention

At present the customer base for biochar in the KZN region is a narrow niche market that is most probably buying on a small to medium scale. In order to attract and retain customers the customer base would need to grow in the long term and this can only be done through education. Whilst the popularity of biochar has seen steady growth in recent years, it is still a relatively unknown product to the majority of consumers. By educating the consumer and highlighting the benefits and uses of biochar, this customer base can be grown.

The agricultural benefits gained from biochar are an attractive feature yet this may not appeal to the common farmer as the positive results to be gained from biochar may not be realized for

years to come. Farmers would most likely look toward readily available fertilisers as these are tried and tested and will yield results in the shorter term. A way to make the biochar more appealing to certain agricultural markets would be to supplement it with a charger such as an organic fertilizer which would help the consumer see more immediate results and help the biochar reach a stage where it could improve soil health at a faster rate.

There are other market segments that could also be targeted, such as the animal farming sector, the water treatment sector and possibly even the energy sector. The biochar product would have to be customized for each segment. However, in recent years a lot of research has been done in these areas to show the potential applications and benefits to be gained from biochar usage and whilst the extent of such a market in the KZN region is unknown, it is a growing market segment if one has to look at it on a Global or even South African scale.

What this tells us is that while the commercial sale of biochar may take some work, there are plenty of opportunities to be explored in this regard. There is a distinct lack of accessibility for the existing untapped market segments and these market segments could be grown through education and awareness and eventually creating a substantial need.

5.5.9 Flow of what a biochar supply chain would look like

Figure 5.1 illustrates the envisioned biochar supply chain.

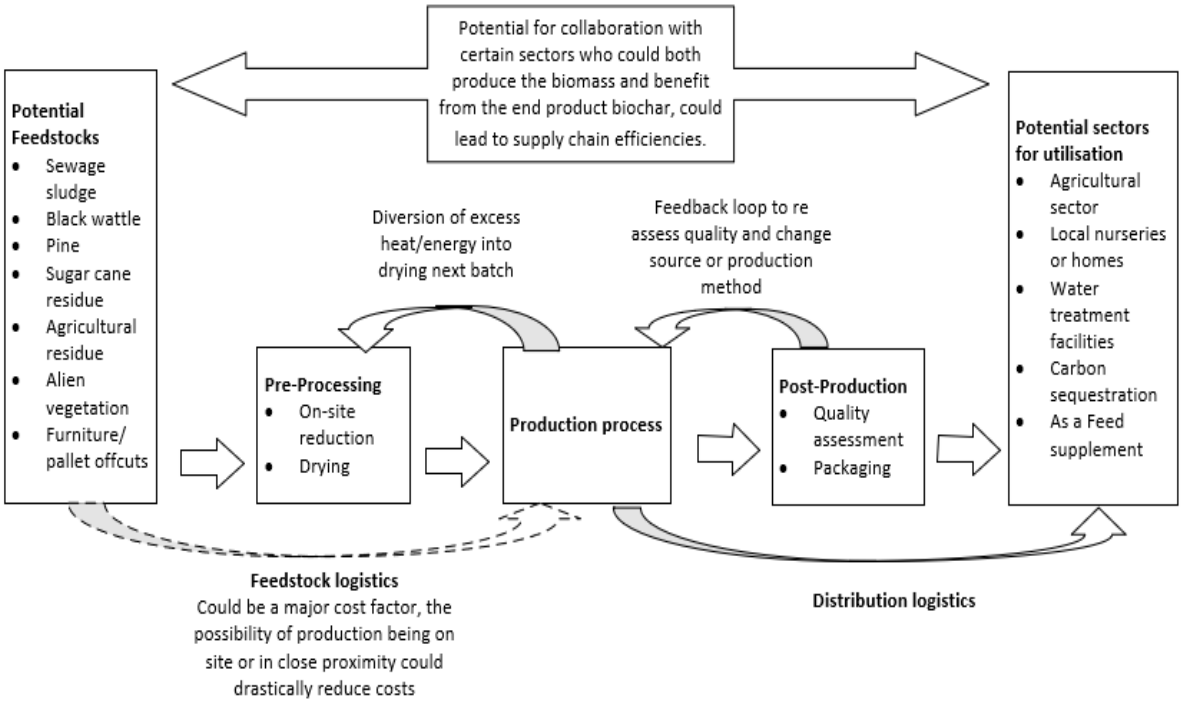

Figure 5.1 An envisioned biochar supply chain with a loop for diverting excess energy and heat to the drying of the next biomass batch

5.6 Collaborative efforts with existing businesses and supply chains

Many opportunities exist for collaboration in the production of biochar. There are many sectors and businesses that produce a valuable feedstock by-product but often dispose of it due to finding no value for it. However, if a collaborative relationship could be made with these businesses, there are many opportunities for growth, but this may be easier said than done because most businesses in the commercial sector would be unwilling to join a collaborative effort unless there was some immediate benefit to them, be it monetary or in the form of providing a valuable service.

Most biochar projects that could be launched via a collaborative effort may require time and effort to gain traction and to attain sufficient scale for these businesses to see the benefits that would eventually be realized. The benefits that could potentially be gained include:

- A cost saving waste management system that redirects waste from landfill
- Monetary opportunities to be realised if the biochar production business is able to reach a large enough scale to produce industrially and sell to the different market segments
- A positive business image in terms of environmental rehabilitation and sustainability due to redirecting waste from landfill and investing in a product with multiple positive environmental implications
- A positive community or local image due to job creation and investing in the environment

The advantages for collaboration are many, but businesses would have to be enticed to get involved. This may take some time and effort but be worth pursuing for the benefits that can be reaped. Sectors to pursue include.

- Agricultural industry (residues from milling or the shells from farmers who harvest nuts)
- Forestry industry (residue or offcuts from a forestry operation)
- Timber mills, furniture operations or pallet manufacturers (sawdust residue or wood offcuts)
- Sanitation industry (faecal sludge rich in nutrients and makes a good biochar feedstock)
- Fresh produce suppliers (large quantities of spoilt goods that require disposal)

The challenge arises with the need to be selective in choosing of the feedstock. Choice is based on the end biochar characteristics to be achieved and the supplier of this feedstock would have

to know beforehand about the parameters of supply. An example being if the residue or by-product of a single type is required then it cannot be contaminated and this would be the only waste a manufacturer would be able to 'dispose' of. This may require the collaborative partner to modify operations for the biochar manufacturer which would most probably be a non-feasible option for that supplier. So as can be seen, whilst the opportunities for collaboration are plenty so too are the barriers. A manufacturer of biochar would need to come to a mutually beneficial relationship with feedstock suppliers so that they are willing to partner and supply the required feedstock for the operation.

A potential solution or benefit would lie in having a production site in close proximity to the feedstock source with an agreement in place with the business to "dump" certain wastes that are of a certain grade or quality at the production site. This would be beneficial to businesses as it would require less effort than the usual avenues of waste disposal and may save them time and money in the process. Having the production facility on the same site as the feedstock source would be the most practical scenario but businesses would most probably not allow it if it hindered their operations or they had to change their setups. The ideal scenario would be to be as close as possible to get the benefits of minimal transportation requirements.

Collaboration after production is also a possibility. One such scenario would be to approach businesses in the composting industry with the offer of a mutually beneficial business relationship. A good quality biochar produced for the purpose of being an agricultural amendment would still take time for microbial support to develop in the capillaries once added into the soil. By collaborating with a compost producer, the biochar could be mixed with a compost and sold as a package product. The benefit of this would be that the biochar would be charged beforehand and would accelerate the formation of microbial support whilst providing customers with more immediate results. Biochar could usually take anywhere from 6 to 12 months to provide benefit but by charging it, the benefits could be seen in the span of a month or two with the end results being healthier soil for an indefinite period of time. Composting on its own over time could lead to a depletion of nutrients from the soil but by utilizing it with biochar this could be mitigated and would instead improve soil quality over time.

5.7 Collaborative efforts with environmental organizations or municipalities

The possibility of implementing a biochar supply chain with existing organization's or with municipalities would have less barriers to entry and have a greater environmental impact due

to the feedstock coming from areas where innovative waste redirection solutions are always sought after. Examples of these would include:

5.7.1 Municipal faecal waste management programs

Currently the Msunduzi and Ethekwini municipalities are struggling with waste management in rural areas. As a result, multiple projects have been launched, such as the Urine Diversion Dry toilets. The design of this toilet ensures that urine and faecal waste are separated before entering a pit which is more sanitary as it allows for the faecal matter to dry more easily and thereafter be disposed of or redirected in an appropriate fashion. The dry faecal matter would make a good feedstock as it is high in nutrients and would require minimal preparation. If a collaboration with such a project was launched, the possibility of creating small batch production sites across multiple locations at the site of the feedstocks exists. This would provide an on-site sustainable feedstock source that would solve a waste management issue at the same time. The end product could be redirected into different avenues with some of it being sold commercially and some being redirected into these rural communities as an agricultural amendment or fuel source for cooking.

5.7.2 uMngeni water programme

The uMngeni water programme is already involved in a human faeces treatment programme where the faeces are de-pathogenised and the remaining slurry mix used in a number of ways. So far testing has been done by using this mix straight on grass with positive results achieved. Currently they are looking at mixing it with other biomass sources to create a fertilizer. The opportunity exists here for such a mix to be used as either a feedstock or if not a feedstock then a charging mechanism for the biochar end product

5.7.3 The working for water programme

The working for water programme currently focuses on the removal of invasive alien vegetation in South Africa. Through this programme a constant source of biomass is provided with a large portion of it simply being disposed of. There are some projects that utilise these plants in a more useful avenue such as one that uses the wood from invasive trees to make affordable coffins for the poor. In the same regard some of these trees could be used as feedstock for biochar production, a perfect example being black wattle that would make biochar product with good adsorption capabilities

5.8 The slow adoption of biochar as a product

At this point in time, it is hard to say that biochar is a new discovery as it has been around for more than half a century. Why then is it still a relatively unknown product to the masses and has not been adopted in sectors like the agricultural sector where the most benefit could be gained? The most likely answer to this question has to do with the fact that biochar as a product is not meant for short term results such as fertilisers. Currently the farming sector is heavily reliant on inorganic fertilisers and agrochemicals which provide short term results. These fertilisers and agrochemicals may not mesh well with biochar due to its adsorbent capabilities and may even cause a crop decline in the short run due to biochar binding some of the nutrients meant for plants or possibly even binding agrochemicals and having adverse effects on plant growth.

However, in the long term, with proper maintenance, biochar is a much more sustainable method to promote healthy soil and farming if properly implemented and maintained. The ability to charge biochar to speed up its results may prove to make it a more attractive choice for some farmers, especially in areas where soils have been heavily depleted of nutrients and the soil health is of a poor quality.

The other barrier to usage would be the high cost of adoption in the farming sector. Considering that farms are usually many hectares in size the cost of biochar application to soil may be astronomical and the average farmer would be very hesitant to invest in such a costly product that they have never used before. However in the climate of increased environmental and soil awareness, there will be some that look toward biochar as a solution due to its ability to have a positive impact on soil health.

Most other uses of biochar have shown to be promising but are still in the research and experimentation stage for the time being. This is not necessarily a bad thing because it means that the traction toward biochar is growing as more research is done and more is learnt about it. The popularity of biochar is steadily growing although it may be some time before it becomes mainstream. With climate mitigation awareness increasing, there are multiple avenues of research opening and biochar is one of them.

5.9 Biochar certification or grading process

At present biochar has no set grading system. This may be a too complicated to implement as there are too many variables to consider to simply give biochar a grade. The only way to measure the quality or rather characteristics is to do an analysis of the end product and assess

whether it is of a good enough quality and possesses the desired characteristics to achieve what it was created for. A way to do this would be similar to how compost has its chemical make up declared on the packaging. So too must biochar, if not on the packaging then an analysis document that serves as proof of its quality and characteristics. Parameters that could be measured include:

- The carbon content
- The nutrient content (N,P, K)
- Physical properties (surface area, etc.)
- Other chemical composition
- Morphological properties
- Recommended areas of use

5.10 Biochar as a potential product for the commercial market

As mentioned before the market for biochar is currently a narrow niche market but it is also an untapped market full of opportunity. At present soil health and environmental wellness are two major areas of concern to be concentrated on and with the current world climate, many more consumers are becoming more conscious of their environmental impacts and are looking for ways to offset them. This number may be small at present but it has been gaining traction and biochar presents the opportunity to fulfil a gap in this market. These consumers may include individuals in a domestic household, farm owners or perhaps even large scale industrial factories looking to offset their carbon footprints. Areas where biochar could be used in a commercial capacity include:

5.10.1 The agricultural sector

As mentioned before biochar as a soil amendment is a proven way to revitalise the soil and promote microbial support leading to long term sustainable farming practices and more bountiful yields. The farming sector in particular could benefit from such a product.

5.10.2 Nurseries or home use

The home gardening and nurseries sector may appear an insignificant market but as a collective this market can grow to be quite large. Nurseries have already been known to use biochar as a soil amendment to promote the healthy growth of their plants. By supplying a good grade of biochar to nurseries for resale this could potentially turn into a lucrative business as domestic gardeners often look to nurseries for advice and inspiration. This method would serve as both

a practical demonstration of biochars potential to the public as well as lead to word of mouth marketing through the nurseries' staff or owners.

5.10.3 The treatment of water

Many studies have been conducted on biochar's capability as a water filtration medium. This could be waste water where biochar could be used to filter out the pollutants from the water or it may even be in an aquaponics system where the biochar would serve as a tool to optimise quality by absorbing nitrates and other pollutants whilst at the same time maintaining the nutrients level in the water to foster plant growth. In the KZN area where the treatment of waste water is a struggle, biochar could be one of many potential solutions to help in the treatment and filtration of this waste water. As such, the potential for a collaboration with municipalities does exist for the treatment of waste water.

5.10.4 Biochars potential to offset carbon emissions

If companies involved in the industrial sector produce an organic by-product, this may be redirected away from landfill to biochar production. This could be seen as a method of offsetting their carbon footprint and possibly leading to tax breaks depending on the scale of the operation. The creation of biochar can actually be considered a carbon negative process if the biochar is produced from a feedstock that would usually be considered as waste under normal circumstances. Instead of the feedstock rotting and creating methane or being burnt and producing black carbon, it would instead be transformed into a product that represents sequestered carbon and provides multiple other benefits for the environment. By outlining the potential incentive of a tax break from biochar production, companies may be more willing to get involved in collaborative projects to produce biochar or may even produce it on their own.

The second half of the incentive would be the profit creation. If the biochar created from the by-product is of an adequate quality, it could be sold to certain markets which would in turn produce a profit.

5.10.5 Biochar as an animal feed supplement

In order for biochar to be used as an animal feed additive, the quality has to be optimum with the correct carbon to nitrogen and carbon to hydrogen ratios. Biochar as a feed additive is still a relatively new area of research that has gained popularity in recent times. The purpose of biochar ingestion being to promote healthy digestion in the animals through microbial support by the biochar. Of course testing would be required to test the viability and benefit of the end

product but if successful there are major opportunities for business growth since it is a relatively new product and not many entrants have entered the market as yet.

5.11 Local applications of biochar

Of the multiple opportunities where biochar can be utilised, there are many opportunities for implementation in local areas. Biochar does not necessarily have to be applied on a large scale to benefit the environment or serve as an alternate form of waste management. Due to the nature of the product its holds a lot of capability to help communities and local municipalities whilst at the same time redirecting waste from landfill and sequestering carbon. By implementing it on a smaller scale in local communities through community or municipal projects or by even selling it to local nurseries, this could lead to biochar awareness whilst at the same time benefitting the environment and people. Some ways that biochar could be of benefit include:

5.11.1 Biochar production as a waste management method in rural areas

Top-lit updraft gasifiers serve as a great way of waste disposal through heat generation for cooking. These gasifiers could be regarded as low tech biochar kilns that could create a biochar by-product of lesser quality. By using a feedstock such as faecal waste from a Urine Diversion Dry toilet in these rocket stoves, locals would have fuel for cooking and the remaining by-product after cooking would be biochar. This biochar could then be used in local gardens and would boost soil health to give crops of greater yield. These gasifiers are low tech and easily operable. The size and cost of these stoves would make them perfect for a decentralised personal biochar operation where the biochar serves as only an added by-product and not the core function of the stove.

Even if a centralised approach were used, a biochar operation could be set up in a rural area where biochar could be made from the faecal waste of UDDTs. This would involve having the production site in a location that makes it easy to collect the faecal waste from the surrounding areas and then producing the biochar in an engineered kiln. The size of the operation would depend on the availability of feedstock in the area and the benefits of such a project could be two pronged. It would serve as a waste management method for the community and the biochar produced could be redistributed to locals in the community with gardens and the rest being sold to consumers in the commercial sector. There is a good likelihood that the biochar end product would be of a consistent quality and of a good grade due to high nutrient levels available in faecal waste which would allow the biochar to be sold for a good margin and to a wider consumer base.

5.11.2 Alien vegetation

South Africa has many alien plant species that are a threat to the indigenous vegetation of the country. The KwaZulu Natal area has multiple species with some of these being good potential feedstock sources. In the fight to remove these invasive species, considerable waste is generated with the majority of this waste being incinerated. Whilst not all this vegetation will make a good feedstock due to the lack of a high enough fibre content, some species would make for a good feedstock from which a high quality biochar can be made. One example being black wattle. Whilst the tree in its entirety may not be a feasible option for a feedstock, if the wattle is initially used for something like furniture production, the offcuts or by-product would make an ideal feedstock due to it being semi prepared for production and solving a waste management problem by diverting the waste away from usual disposal methods.

5.12 Limitations of the study:

- A few of the participants had never actually produced biochar but were chosen due to their knowledge of it and its relation to their field of expertise; this could impact the veracity of the study.
- No regional costings or figures were found that could be used as a base for a feasibility study
- Different feedstocks produce varying qualities of biochar but from the research gathered, the conclusion was reached that any biochar created from organic waste that is not properly separated and filtered would be substandard and only fit for use as a low grade soil amendment; this was not tested in a field study
- Biochar is still an ongoing object of study for researchers and not everything is known about the benefits as well as potential downsides to biochar use that may be found in the future
- After extensive investigations, no medium to large scale commercial biochar operations were identified in the KZN region so all information regarding this scale of operation was not based on data from the Pietermaritzburg region but from the whole of South Africa
- From the available literature, very few papers have done any in-depth review of the commercial applications of biochar

5.13 Potential future areas of research

- The quality differentiation between biochar produced in an engineered kiln vs a homemade kiln
- Other than biochar production, what operations could be implemented to redirect waste from landfill looking at the same potential feedstock sources identified for biochar production
- Potential businesses that could be run in collaboration with a biochar production plant to produce a more attractive and lucrative business model
- Businesses that could be partnered with to source biomass in order to redirect waste from landfill for the production of biomass or even some other sort of waste redirection with products such as bricks made from rubble or manure
- How to incentivise households to separate waste at home which would allow for more opportunities to redistribute waste to other transformative projects leading South Africa to a more circular economy approach when it comes to waste management.
- An in depth study of the state of the commercial biochar industry in South Africa

5.14 Conclusion

The biomass feedstocks in the Pietermaritzburg and surrounding areas are plentiful, so the production of high quality biochar is a definite possibility. However, the existence of the feedstock alone is not a guarantee of a feasible biochar production operation as multiple factors have to be considered. Most importantly, it does not make sense to source a feedstock that could still be utilised elsewhere, such as in the production of furniture or similar, as this would defeat the purpose of biochar production as a means of redirecting waste from landfill and as a tool for environmental rehabilitation. The other reason why non-processed feedstocks in a semi-solid form would not make good feedstock is that the required preparation would be too labour intensive and costly, and the preparation and drying time would be a major consideration. There are biochar by-product feedstocks that require a minimum of preparation and labour and these include:

- Agricultural residues such as stover or sugarcane residue remaining after crushing
- Algae
- Forestry residues from logging and forestry thinning as well as the clearing of alien vegetation

- By-products from manufacturing plants such as sawmills, paper production factories or pallet manufacturers
- Nut shell by-products such as macadamia or pecan nut shells
- Household or municipal waste streams that require minimal separation and have attributes suited to biochar production (e.g. faecal sludge and garden refuse)

Once a feedstock is chosen, a production method should be chosen to suit the required characteristics of the biochar to be produced. For a high quality, consistent product where all parameters of the production can be measured and controlled, a suitably designed and engineered kiln or pyrolysis unit should be used. This is of particular importance if intending to produce on an industrial scale and even on a smaller commercial scale. Whilst many lower technology kilns, that could be self-manufactured, exist, the issue with these is that they would not be able to produce biochar on a large scale with a consistent quality. There are too many variables that affect the end result. Furthermore, if the biochar production chamber is not properly insulated and controlled, the yield rate will be reduced and this inefficient will result in more of the feedstock turning to ash.

The implementation of a biochar supply chain in the Pietermaritzburg area would be a challenging task to undertake and the potential benefits could be outweighed as a result of multiple factors. A public dumpsite was initially considered as a potential location for biochar production whilst diverting waste from landfill. This would be convenient as feedstock could be sourced and production could be done in close proximity. However, after due consideration this was ruled as a non-viable option, the concerns being:

- If household or garden waste was going to be a feedstock, the separation would be too time consuming and labour intensive
- There would be very little control over the feedstock and it would most likely comprise a mixture from multiple sources instead of a uniform feedstock for each production lot. This would result in a non-homogenous feedstock which would impact both production efficiency and biochar quality
- Any biochar created from these feedstocks would most likely be only fit for use as a low grade soil amendment and the limited benefits would compromise sustainability of the project

- There are alternative methods of re-diverting these wastes from landfill that would have a greater effect in the short term and would be much easier to implement and be more effective
- Organic waste is a necessary component for landfills where anaerobic digestion takes place

Ultimately, it was concluded that biochar production should only be considered as a potential waste management solution where there are relative, measurable benefits to be gained. Such a project requires a more uniform feedstock and this feedstock should have the attributes to make a high quality end product that could be used in a number of ways. Even more beneficial would be biochar production that solved a waste management problem and benefitted people in the surrounding area. For example, the co-processing of faecal sludge in rural areas would be advantageous as the biochar product would be high in nutrients and require minimal production preparation. If the end product was good quality, a certain amount could be reserved for the local community's use and the remainder sold for profit as an additional incentive.

To be sustainable, biochar should not be produced for the sake of producing biochar but rather an economically viable plan should be designed. The plan should take into account every process in the entire supply chain from feedstock sourcing, to transportation, to the actual production and finally to the intended end product use. Presently, there is little evidence of biochar supply chains in KZN and even in the rest of South Africa. The principal reason for this is the lack of incentives to encourage individuals and commercial enterprises to get involved. However, in recent years some companies and institutions have started to show an increased interest in biochar as awareness of its potential applications and capabilities has begun to grow. Currently, the consumer base for biochar is a narrow niche but it is growing as the range of potential benefits and uses of biochar increases. Entering into a commercial biochar producing supply chain at the present time may prove advantageous as it is currently and unsaturated market with very few of the existing operations in South Africa producing on a large scale. New entrants to a biochar producing supply chain could provide a much needed product for environmental rehabilitation and other uses whilst benefitting from potentially viable enterprises, if implemented properly.

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APPENDICES

Appendix A: New England Road landfill dump schedule for the month of May 2019

Waste Description	**Total weight for the month (kg)**
Builders Rubble	918 060
Bulk Food Waste	5 480
Domestic Waste For Council	2 487 760
Finely Divided Excavated Material	84 200
Free Cover Material	3 467 620
Free Garden Refuse	42 480
Garden Refuse	698 060
Illegal Dumping	216 800
Industrial Darvil	18 620
Industrial Waste By Council	79 860
Mixed/General Domestic Waste	3 081 690
Saw Dust	19 320

Source: (Timol, 2019, p. Appendix E)

Appendix B: Interview informed consent

CONSENT TO PARTICIPATE

I ……. have been informed about the study entitled "Developing an organic waste processing supply chain to produce biochar: A Pietermaritzburg field study" by Abdullah Timol.

I understand the purpose and procedures of the study.

I have been given an opportunity to ask questions about the study and have had answers to my satisfaction.

I declare that my participation in this study is entirely voluntary and that I may withdraw at any time without affecting any of the benefits that I usually am entitled to.

If I have any further questions/concerns or queries related to the study I understand that I may contact the researcher at 082 968 5330 or alternately at abdullahtimol@gmail.com.

If I have any questions or concerns about my rights as a study participant, or if I am concerned about an aspect of the study or the researchers then I may contact:

HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION
Research Office, Westville Campus
Govan Mbeki Building
Private Bag X 54001
Durban
4000
KwaZulu-Natal, SOUTH AFRICA
Tel: 27 31 2604557 - Fax: 27 31 2604609
Email: HSSREC@ukzn.ac.za

Additional consent, where applicable

I hereby provide consent to:

Audio-record my interview / focus group discussion YES / NO

_____ _____
Signature of Participant **Date**

_____ _____
Signature of Witness **Date**
(Where applicable)

_____ _____
Signature of Translator **Date**
(Where applicable)

Appendix C: Semi-structured interview questions

Semi-Structured interview questions

Name:

Occupation:

1. How did you get exposed to biochar and what is your current experience with it?
2. In your opinion, while biochar has many uses, what are some of areas that it can be best applied in?
3. Biochar Feedstocks
   3.1. Some of the potential feedstocks that could be utilised in the Pietermaritzburg/Durban region
   3.2. Would household organic rubbish make a viable feedstock, elaborate on the suitability of such a feedstock?
   3.3. Would garden refuse collected from residential areas make a viable feedstock, elaborate on the suitability of such a feedstock?
   3.4. What are some issues that could be experienced by using these types of feedstocks?
   3.5. Feedstock contamination could be time consuming and costly, even municipal garden refuse dump sites are often found to be highly contaminated. Are there any ways to reduce contamination or even ways of separation after contamination?
   3.6. What would it take to implement a separation at source approach to feedstock collection?
   3.7. Ideally, you'd want dry feedstocks for biochar production what is the best way to ensure that feedstocks are dry, letting them dry naturally, using a dryer, finding quick drying feedstocks etc?

4. Biochar Production Process
   4.1. To what extent does the design of the biochar Kiln affect quality and/or yield rates of the end product?
   4.2. Are certain feedstocks superior to others when it comes to the production process? please elaborate!
   4.3. Are there any methods of preparing feedstocks beforehand in order to increase the efficiency of the production process? To what extent could preparing feedstocks beforehand affect the end product quality/yield?

4.4. There exist may forms of biochar production including pyrolysis, gasification, pit burning etc. Are certain methods of production superior to others when it comes to quality and volume?

4.5. What would be the simplest method of producing biochar for someone wishing to produce it for personal usage? A method that allows them to do it in their very own back yard

4.6. Are certain forms of production more environmentally friendly than others? Please elaborate! Looking at this aspect, should any production methods of biochar be avoided for environmental reasons?

4.7. Biochar produced using different feedstocks often end up with different characteristics, do these characteristics affect quality and if so, what are some of these characteristics?

5. Implementing a Biochar Supply Chain

5.1. To the best of you knowledge, are there any existing large scale biochar supply chains in the Pietermaritzburg and Durban region? Could you name a few and if not, do any major reasons exist for this?

5.2. What would be the core functionalities to consider when implementing a biochar supply chain?

5.3. Considering that one of the major uses of biochar is as a carbon sequestration tool, what considerations need to be taken into account when implementing a biochar supply chain in order to ensure that the supply chain itself is environmentally friendly and uses sustainable practises?

5.4. What would be a few large-scale sources of attaining biomass for biochar production and what sort of logistical considerations should be taken into account when moving these feedstocks?

5.5. Instead of starting an entirely new supply chain for a biochar business, would it be possible to integrate existing business services such as gardening services or other waste management services into a biochar supply chain? If this were possible, what level of collaboration would be required between these parties?

5.6. If a large-scale biochar supply chain was created, what would be the ideal large-scale production method that is financially viable to create biochar.

6. Commercial Applications

    6.1. Biochar is a product with a large range of capabilities in many sectors, the potential for biochar can almost be considered limitless. With its large range of abilities including climate change mitigation, why isn't biochar more popular?

    6.2. Many gardening businesses sell biochar on a small scale to be used as a soil amendment, to the best of your knowledge are there any other sellers of biochar who sell it on a large scale with the quality of the biochar being good enough to use as more than just a soil amendment?

    6.3. From preliminary research, there doesn't seem to be any classification or grading on the differences in biochar quality, does such a classification or grading system exist? If such a thing as different grades of biochar does exist, are there any price differences between these different quality biochar products?

    6.4. Certain feedstocks used during the biochar production process often give the biochar end product different characteristics, could some of these characteristics affect the price of the biochar product? Please elaborate!

    6.5. Considering biochar from a commercial perspective, which sectors would best benefit from the usage of biochar? Which sectors are most likely to buy biochar?

    6.6. One of the uses of biochar is a feedstock supplement, can any biochar product be used as feedstock or does the biochar need to be of a certain quality or have certain characteristics?

7. Regional Applications

    7.1. Looking at local regional zones such as PMB or DBN, what are some areas that biochar could be utilised in in order to better local communities etc?

    7.2. Alien vegetation has been suggested to be an ideal feedstock for biochar production. What are your thoughts on this? Specifically looking at the Durban/Pietermaritzburg area as well as the existence of alien vegetation in this specific region, certain municipal reserves and areas have been known to have issues with alien vegetation

Appendix D: Interview 1 transcript

Anne Chisa

SPEAKERS

Abdullah Timol, Anne Chisa

Abdullah

So I'm looking at the PMB and Durban are, looking at potential sources of organic biomass that can be used to make biochar, something like a biochar Supply chain.

Anne Chisa

Oh ok, Have you spoken to Nqobile already, I know that's her area of expertise.

Abdullah

I spoke to her yesterday

Anne Chisa

Okay cool, when the world reopens, we are wanting to work in the eThekwini site as well, sort of the informal settlement, the rural areas. Cos in essence what my research is, the problem rather is food that is being farmed in these rural areas get transported to these urban areas, so like your Durban city center or even your surrounding informal settlements. So, when the food gets transported there's something called nutrient that happens in the soil, it creates problems with soil productivity and whatnot in these rural urban areas. And then at the same time in your more informal settlements, they don't have adequate sanitation provisions in terms of your formal toilets so there's a whole lot of human waste generated. So, these urban areas are what they call nutrient sinks, so you have all of this excreta with the potential nutrients to be converted into these human waste products. So now it creates an opportunity to create the waste-based products. So you know this cos of the work Chris is doing, the PRG now known as the Wash RND center, they've had success growing crops. So, my project because I'm part of another project called wood rights. The whole essence is trying to look at ecological restoration using trees, so now we trying to see if using the similar principle in terms of growing crops that's already been achieved by many researchers. Can these waste-based products be used to grow tree seedlings that can be used in the rural areas where these soil fertility problems happened? So using specific types of trees that can help with nitrogen fixation. At the same time, it can provide opportunities for the communities for them to have a source of income and

maybe fruit trees in the form of food provision. So that's where the circularity of it is going, but its still in its infancy. Okay I feel like I'm talking too much

Abdullah

No, you making some very interesting points, I've come across similar research but not the same thing by other researchers

Anne

Yeah, that's the beauty of it, we all have the same goal, even with me, the only difference, the novelty is I'm doing trees instead of like crops. So I'm also trying to look at all of these other people who I'm sure you've interviewed. So obviously they are a couple years ahead of me in terms of their research, they have a bit more experience. So I'm really excited in terms of the collaboration.

Abdullah

Are you by any chance also going to be a part of Mr Dave Stills project?
Anne

No, I've read about him a bit because of the work that PID's doing, but they use sludge, they don't convert it, they just take it from the pit and then what they call entrenchment which is directly putting it into the soils but then that's got some problems because it affects the ground water and then its got some pathogen things going on. So we want to process it and then take it to the trees. So I haven't dealt with him but maybe in the future because I've seen some of the work they are doing and they've had a lot of success in terms of their research.

Abdulla

So that's good, let me get down to the questions, so some of them can be a bit technical so if you just want to pass then that's fine. So what is your current experience with biochar and how did you come across it

Anne

Its very minimal, I just know its one of the processes that can be used for soil amendments.

Abdullah

So what I'll do is focus more on the other aspects such as the biomass feedstock collection and the appropriateness of specific feedstocks to be used in the production process

Anne

Ok

Abdulah

So you said you only know of its application as a a soil amendment right?

Anne

Yes

Abdullah

So, looking at the PMB and Durban area, what do you think are some of the major sources of biomass or organic waste that could be put to better use in any endeavour?

Anne

So, you mean in terms of the human excreta being produced?

Abdullah

Sure, that's one of them!

Anne

So, in my understanding of it, the human excreta and urine could potentially be used as a product for fertilizing soil, that's as far as I know.

Abdullah

Do you think something like household rubbish for example might hold potential value to be used in the same regard?

Anne

Of course. Traditionally we know that how your composts are made, using fruits and vegetables from the house and I think there's great potential in that, and it will also minimize waste generated at landfills so instead of putting everything in a bin and letting the rubbish truck collect everything, I think if we separate your organic waste and find ways to incorporate it such as compost, it would be really, really good, it would minimize the use of synthetic fertilizers and its more of a healthier opportunity. In that way things are re used and recycled and it's not waste, and in the end its more sustainable in the long run actually.

Abdullah

So in the same regard would garden refuse be the same?

Anne

Yes

Abdullah

So, looking at for example household and garden refuse, what are some issues you forsee if we had to use these as potential feedstocks, what are some issues you could see in the collection of these materials.

Anne

Well, the first thing would be people's willingness to participate, they might be excited in the first couple of months "oh yeah, I'm recycling", but the commitment needs to be there, it requires a lot of commitment on their part instead of dumping it and making it someone else's problem, there needs to be some sort of incentive that needs to be created to get more people to be interested because people would automatically find it troublesome and want to make it someone else's problem. And also another thing is the acceptance mainly from the people, are they willing to to do this because some of them work, they don't have the time to tend to their gardens and do all of these things on their own. So for me I think the big problem would be peoples willingness to participate in this so that it becomes a norm. because obviously it isn't right now, so how can we get people to see the value in doing this.

Abdullah

Okay, so looking at the same point, let's say we get people involved. Or even if we look at already existing dump sites. If we look at the organic waste, there exist certain dump sites that are supposed to be only for garden refuse. But tt the end of the day if you go to those dump site, you'll find a lot of non-organic stuff mixed in with that even though its supposed to be just organic garden refuse. So what do you think is a possible way to reduce contamination and separate contaminants from this organic waste

Anne Chisa 00:01

Yeah, I expected that, people are lazy and will dump it anyways. So I think there's that whole thing where, when you recycle for recycling, I think plastic and glasses and what not, they give pople money to make sure that they collect purely what needs to be collected. So I think as

much as it sounds like why do we need to pay people for that….. And also, maybe employ people to make sure that whatever gets dumped is just the organic matter. And also inform people I didn't even know that they were just, I didn't know that there's specific places purely for dumping organic matter. I know that these different places were dumping your, you know, your papers and whatnot. So maybe informing people that, hey, there's a place for you to do this. If you don't, let's say for example, you live in a flat, and you don't have a garden. So you can collect your organic waste, and there's a place here, you can dump it. So I think we need more work needs to be informing public public awareness. And I want to say fines if people dump the wrong thing, but I don't think that's a good point, I think we first need to make it seem cool, maybe make more awareness, maybe advertisement, whatever, so that people are aware that you can actually do this. And there's places for people to do this. And maybe there's some sort of incentive, if you do this, if you maybe go in and put X amount of kgs, you get X amount of money, something or you get a food voucher, or you know, maybe get other corporations to work together for like a food voucher, like a big food chain. I don't know checkers, say if if people go in and dump organic matter, they get 200 rand off buying from checkers, something like that, so that we can engage the public, I think that will be really exciting. And we'll get people motivated to do things such as that.

Abdullah Timol 01:42

Speaking of the one point said, employ people to make sure that other people don't dump anything non organic. There are actually already people that are supposed to be doing that. But if you just give them like a 10 rand, or something, they just allow you to dump whatever you wanted. So its a very vicious circle

Anne Chisa 02:11

Yeah, obviously, everybody obviously always has a price, which is unfortunate. But I think instead of policing people, I think we need to make it more exciting, make it attractive to be more concious about being sustainable. I think the image in terms of sustainability is not the same. I'm thinking of other countries, I don't know if it was Ireland, or somewhere in your European countries, they get incentives to be more sustainable, you know, governments here they talk about all of these plans and all of these policies, but why should I do it? Why bother, you know, so make it more attractive to the consumer so that he doesn't even have to pay somebody to dump his inorganic matter or organic waste, so that it can actually make him want to dump purely organic matter, because theres something that he's going to get in return. It's

unfortunate, that's how we are as human beings, but I think that's the only way to just make it more attractive, personally.

Abdullah Timol 03:22

So this question is kinda in the same regard, like, you know, if you had to implement a separated source approach, or other than the incentive approach, can you think of any other methods that might work.

Anne Chisa 03:47

other than incenctives? Yeah. Again, public awareness, education. Why are we actually doing this? Why is it important? Yeah, starting it at a young age, working with your school, so that the kids are aware because, you know, kids, when they listen at school, they're the ones who tell the parents like, nooo, at school we learned this we should be doing this. So theres that, even in your workplaces, maybe start putting it in there to create some sort of habit. Because, you know, people do eats bananas and apples at work, and they get thrown away in the same bin as your papers and whatnot. So I think it's a culture change. It needs to be culturally normal all around, apart from the things other than that over can't think of anything.

Abdullah Timol 04:50

So you wouldn't know anything about the kilns, right? No, I don't know. Um, okay. So looking research, you said you were currently researching the usage of human excreta and urine . So could you tell me that what sort of characteristics do human excreta and urine have that would be beneficial, or would have adverse effects it put into the soil.

Anne Chisa 05:23

Okay, well with urine as far as I know, urine contains your nitrogen and your phosphorus. Already, so when you wee, the nitrogen that's in the urine, it's not in a state that is available to the plants. So they need to change it, I can't remember the chemistry of it, they need to convert it into ammonium, I think that's what the plant can uptake. And then through other process called struvite, de hydrous, yeah, struvite dehydration they are able to create to get perspiration, they're able to get phosphorus, so NPK and some other minor micro nutrients that are beneficial to the plants, such as your magnesium and whatnot. And then so that's from your urine, then your, your actual poo contains, it's got organic matter which can be used as a soil amendment to kind of make the soil better. So I'm sure with other people who you've spoken to, they've got different sanitation systems to so source seperate these things such as your urine diversion

toilets, which separates the feces and the urine so that you're able to, to collect the urine in one particular space. And the nice thing that it's designed where, in a manner that is similar to the human bodies. So in the front, there's the urine part where the urine gets collected, and then obviously at the back, that's where the feces gets collected. So with that, they're able to collect it and then theres work that's being done, where they then use these different technologies such as your precipitation, alkaline de hydrations, all of this stuff to convert it to..., chemical engineers rather convert it to so that it's safe for.... to be applied for crops or flowers or whatever you growing. Of course, the problem is that people always, there's that whole thing like is it really safe, because nowadays, people are drinking a lot of..., people are consuming and drinking a lot of not healthy things. So people are having a lot of medications. So pharmaceuticals I know, I don't know, if you've spoken to her Sharon, she's doing a lot of work on that she's working on on the pharmaceuticals because people take a lot of medications. And obviously, we don't want that to go directly into the soil. So to try and make it more safe , theres different protocols that have been put forward by the World Health Organization. So that this urine is safe because I even know that with some of the urine they make sure that it sits for, I think six weeks or something before it can be used. So the problem is that people just think of it like ewww that's disgusting, but they really make sure that once it gets..., during all of these processes and I'm sure with biochar, you also know that it's it goes through like an incineration process. So like even the feces, there's no way that these pathogens or whatever can survive to make it safe. So I think people are not well aware that there's a lot of things that go through to make sure that these, either your biochar or there's something else called ladeppa pellets, latrine derived I think pellets. I think that's the word. So there's a lot of different things that go through to make these products safe for use and there's a whole protocol that's actually put in place.

Abdullah Timol 09:46

So you're saying that for the most part, it is safe to put these things into soil after Because the thing is I was talking To Sharon. And they say that while they think it's safe. At the end of the day, there hasn't been a lot of research into it. So biocharcan survive in the soil for millenniums. So they don't know the long term effect that it has on the soil. So that's the area of concern at the moment.

Anne Chisa 10:30

Yeah, because I think the research is still pretty new. So yeah, I think the more you go in, the more, you can find some faults. Trying so far to try and make it safe. Like I said, I'm not 100%

familiar in terms of biochar . But in terms of the, the urine based fertilizers, for example, in Sweden, they already, they've developed a product called oreen, which they are actually using commercially, the Swedish Federal Bureau of like health or something like that. They've given the go ahead for people to actually use it. Initially, it was only used for flowers, because obviously, that wasn't for human consumption. But I think it passed all of the the tests needed so that they can actually use it to grow soils. Here in South Africa, the research, it's still research, it hasn't been taken up that that they can put it to make use, there's still a lot of engagement that needs to work with the stakeholders and the different types of governments and you have people like Sharon, who works with runways where they try and work with farmers, and you've got other people PRG where they also try to work. So it's still in it hasn't been implemented. It's still at its research base. Like they're people who are saying, hey, look, it's working. Hey, look, it's working. But I think the policy and implementation and the public perceptions is still a problem. And I think there's still a lot more work that needs to be done before I think he answered Africa, we can say, we are actually using these waste based fertilizers as an alternative to commercial products.

Abdullah Timol 12:32

So I'm not sure what other forms of organic wastes you've worked with or come across. But from my understanding, using different types of biomass feedstocks. For anything, for fertilizer, or even biochar production, you end up with different characteristics in your end product. So, how great an impact do these characteristics have on the quality of the End product? Is it like a major thing? Or is it minor? coul you Tell me about that.

Anne Chisa 13:19

Okay, I will try and see...i know for example, like with, you know, what you said about how there's there's different nutrient quantities in the in these products? So, um, I don't know how to answer that. Okay. I'm trying to say how I'm gonna answer this. But I am not 100 percent. Well, I am sort of, but I can't tell you in terms of quantities. So I was actually reading a paper where in the Philippines and Burkina Faso, they were using these waste based fertilizer, your urine based fertilizers to grow, I think it was vegetables, maize, and they saw a success like even if you apply these products, again, I can't give you the quantities. I can't tell you off the top of my head right now. But yeah, but it gives you the same even sometimes greater yield than using your normal quantities of your synthetic or rather commonly used fertilizers. So you're able, and also with these urine products, you're able to concentrate it so that the more

urine and the more, there's a project, there's a product or a process rather called alkaline dehydration process. So basically it's where they take the water out of the urine so that all that is left is the the nitrogen and they using different pH levels. I can't remember the science yet exactly. But yeah, that's what they do. And then in that process, they take out the water so you can apply more, more urine, and then you dehydrate it to take out the water and then all you're going to be left with is a concentrated amount of nitrogen source, which is better than what is currently on the market. So when you're using this alternative, again, I can't give you the quantities. It's more efficient than using what's currently being used, because some of these are blended fertilizers. And even if it's just purely your, your nitrogen source, for example. It's, it's expensive. So yeah, this is a cheap alternative. And it's it's got a greater concentration. Depending on the process it went through. I hope that answers the question.

Abdullah Timol 16:23

It gave me some insights. Um, you mentioned the dehydration process for urine. Do you Anything about the process itself.

Anne Chisa 16:34

I know how it's done, but I can't tell you in terms of... Yeah, so basically they collect the urine umm I'm going to try, because like I said, this is also new to me. So I'm going to try and see if I can simplify it. So they collect the urine. And like, obviously, we all know that your urine is made up of water, right. But I think like 90% of it is actually this ammonia that is actually available in the soil, but they have to remove all of the water. And then what you're left with is like a, I think it's like a powder. And also with that, the urine in its form, it's got to have very high acidic Ph. So they have to put it in a they have to increase the pH rather. So it's got a low pH because it's acidic. So they have to increase the pH so that it's more alkaline to be used. So hence why it's called alkaline dehydration process. And then they keep on adding urine to make it more concentrated. So the more urine they add, so they dehydrate it, increase the pH and then you get a specific amount of products such as your your nitrogen, so they're going to add in some more. And then the more urine that they add and the more that they dehydrate and increase the pH then you're able to have this concentrated form of ammonia, I think which is, which is the one that's available for plant uptake. Because you can't just go pee on a on a plant now and then think that the plant will take that pee? No. It needs to go through this process so that it can be dehydrated and the pH can be increased so that it's more alkaline and not too acidic. Yeah, so that's the very layman's terms of it. But I'm sure you can Google it. It's called

alkaline dehydration process. It's very interesting. And I know it in it's baby baby form. I'm probably maybe missing some some steps. But yeah, that's the that's the short story of it.

Abdullah Timol 19:01

I'm actually a bit more interested in what they are the methods they use to extract the, you know, to dehydrate the actual thing, like how they extract the water.

Anne Chisa 19:14

Yeah, no, it's a process. It's very interesting. For me when I was reading it, and it involves a lot of chemistry, because there's something called you raise in the urine that they needed to .... It's some some enzyme like there's a lot of science in it. But I was telling you in a very like, diluted way of how it actually happens, but I think you can Google it and there's a lot of work it's pretty, pretty exciting. And they do something similar and I think it's struvite precipitation. Now this is what they do to to to get phosphorus where they kind of make the urine like a precipitate also chemistry and Then you get this end product called strew vide, which is a source of phosphorus, which is also needed for plant uptake. So, yeah, there's, there's a lot of interesting things that these chemical engineers are doing.

Abdullah Timol 20:20

Okay, this question, I think we kind of already went over it, but can you think of a few large scale sources of attaining organic waste or biomass. And what consideration may need to be taken to attain this with?

Anne Chisa 20:47

Yeah, they need large scale collection of this waste. Yeah, um, yeah. So in essence, in eThekwini, what they currently doing from these urine diversion toilets or UDP is that they experimented with and they give they gave to some of the residences and the informal settlements is that they had employed people from the water and sanitation, people who'd come around and empty out these toilets rather. And then also, they also gave an incentive for the public to collect the urine and go give it into them so that they can get money. So yeah, it requires a whole system, a chain, that it requires involvement, I think of your local municipalities, the communities, and then with that it needs to have a place in terms of where it's going to go. So it requires your scientists, your different types of scientists. And then it also requires people who are able to sell this as a product to manufacture it. So I think, I think that's what needs to happen. Yeah.

Abdullah Timol 22:07

And that actually ties into my next question, you already touched on it a little bit. So so. So this is a very generalized question. So looking at, you know, biochar production, and the uses of biochar using, you know, the use as asoil amendment. So what other departments or sectors could form a collaboration with biochar production and would be able to benefit from it in the end?

Anne Chisa 22:42

Yeah, so, definitely, you need to be working with your policymakers, the people to make sure that this actually can happen. You need to be working with the communities to get them involved to see the benefits of that, you also need to be working with your scientist again, and also the people who can market it, I don't know... sell it. To make it. Yeah. So that I think, I don't know, in your supply chain. There needs to be a chain of people in this and I think that's the beauty of how research is actually going now that it's not just scientists working by themselves, but they need all of these people for this product to work. So you need your your your policymakers and your families. I mean, sorry, your communities.

Abdullah Timol 23:43

Okay, so this here, as you said, it's no longer just about the scientists, its involving a lot of other sectors now. So I'm looking at maybe the commercial sector, looking at products such as biochar, or even the fertilizer that you are trying to create the urine and fecal matter fertilizer. Why do you think these things are still such an unknown, why do you think no one knows about this? why do you think no one's using them

Anne Chisa 24:18

Yeah, because the thing is, people know about this, well, they used to know about it, like when you think about it, like when I think about in terms of composting, it's something that we were doing in the past, you know, but because of the movement in terms of all of these urban areas, people have kind of let go of their indigenous knowledge. And now you've got these big companies who are pushing the agenda of chemical fertilizers. And although now we are starting to see like, Hey, this is actually not sustainable. But we're realizing but it's actually quicker. So it's just, I think there needs to be worked on in terms of like your, your general media in terms of communicating the science better. Apart from this, I'm an avid science communicator. I'm very passionate about making the science that we do, or rather the research that we have scientists do known but in a way that people who are not doing the science can be

aware of it instead of just only publishing in journals and stuff like that. So taking it back to the people putting it out there. So I think there needs to be more of that. And for me, personally how I've been doing it is I have my own podcast where I interview different scientists, and they talk about the different research. So going back to the point of this stuff, there needs to be more communication in terms of general media, in terms of these things. We used to do it, like in China, heck here in Africa we were doing it, before all these synthetic fertilizers came in, before these governments allowed for these synthetic fertilizers to come in. Of course, now it's a little bit more difficult because our waste is no longer 100% organic, like I said, initially that its got a lot more things now which you can just take it and put it on the soil needs to go through a process. But I think deep in our hearts We all know , we are aware that this is something that can work but we just haven't been told it just isn't out there. So there needs to be more work in terms of putting the work out there and it can be with the responsibilities of the scientists themselves communicating science better, it can be the responsibilities of the the, waht you call these people, the policymakers, or I don't know just your normal media to be like, hey, there's this product and when this product comes out, advertise it, work with people who are PR people, I don't know.... marketing. People who can brand it, instead of just saying oh no, this is just a scientific product that we developed, people actually want this stuff people are more aware, they want to be more sustainable. And also, with that being said, make it not so expensive, that it can only be for a select few of people, you know, where if you want to be sustainable, then it's like, it's way more expensive than your synthetic fertilizers. Of course, the general population is not able to, to afford that. So it's those type of things that I think needs to be done.

Abdullah Timol 28:01

You, um, you told me about your podcast. Did you interview Shannon on the podcast?

Anne Chisa 28:09

Yes, I did. She was my first one. Before I knew what I was doing.

Abdullah Timol 28:17

I think I listened to some of that podcast.

Anne Chisa 28:24

Oh, okay. Yeah, I didn't know you listen. Yeah. I interviewed Sharon was my first ever guest before I even knew what I was doing. So, yeah, yeah, she she was my first case. And she was

part of the inspiration behind it, because I found what she was doing so fascinating. But people didn't know that there this work. And that was even before I started, I think that was even before I started working on it. But you know, we just all had this, like, it was a running joke that I know, you guys are working on shit, you know, but like, that's all people would say. But we didn't know that it's actually this important work, for example.

Abdullah Timol 29:06

That's pretty awesome hey, So you've talked about how most companies just sell the synthetic fertilizer and organic ones, the ones that are companies do sell or the companies that do exist and sell this are often overpriced. Um, can you tell me any companies that you know of, that sells the, you know, the fully organic fertilizers.

Anne Chisa 29:37

I know of one product. I don't know if it's..., that's the one that I told you about in Sweden. I think they sell it It's called oreen?. I don't know where it's sold 100% but it's not sold here in South Africa. It's not available here in the South African market. I think in terms of , That's the only one that I know locally. I'm not 100% sure. But I mean, well, yeah, I do know theres TWK, they sell organic sort of organic compost, they sell compost. Or even what you call this this gardening shop called Black, is it black Woods? somewhere near the mall. They also sell some sort of organic compost as well. I don't know the product names. I do not know, but I know that they do that.

Abdullah Timol 30:58

Okay. Okay, this is probably my last question. But we're talking about feedstocks. One of the largest feedstock that's a big problem is currently alien vegetation in KZN, do you know anything about any species of alien vegetation around the PMB or Durban that may make a good possible good organic feedstock

Anne Chisa 31:34

Oh, I, I don't but that's very interesting, if there is, I don't I don't know about that research. But that's very interesting if they is.

Abdullah Timol 31:48

I think that's all for me, actually.

Anne Chisa 31:50

Okay, cool. Okay, thank you very much. I mean, I hope it was helpful.

Abdullah Timol 31:58

It was, it gave me a lot of things to look into.

Anne Chisa 32:01

yeah, definitely. look into that alkaline dehydration. It's very interesting. Cool. It's got a lot of chemistry, but I think if you read past it, yeah..

Abdullah Timol 32:49

Thanks, again, very appreciated.

Anne Chisa 32:53

You're welcome and all the best with your research.Thank you. Okay. Bye

Appendix E: Interview 2 transcript

Darryl Adsorb

SPEAKERS

Darryl, Abdullah Timol

Abdullah Timol 00:08

Hi Abdullah

Darryl 00:09

Hi Darryl How are you

Abdullah Timol 00:10

I'm good, yourself? You don't mind if I record this do you.

Darryl 00:14

Go for it, no issues.

Abdullah Timol 00:16

Okay, so let me just tell you a little bit about what I'm doing. So I did my honors in Supply Chain Management on a biochar research project. It was more about, like an intro into biochar, how it's made, the uses the benefits, and so on and so forth. So for my Masters, I'm doing something a little bit similar, but going a little bit more into detail. Tracing the logistics supply chain from feedstock sourcing to distribution and potential commercial uses. So, basically, that's my interview. Can you tell me a little bit about your company?

Darryl 00:38

Yeah, let me start there. For whatever reason, let me just try once more. my mic didn't work. There we go. Alright. So Adsorb has been going for about 11 years now.

Abdullah Timol 00:47

Could you just wait, I'm hearing a little background interference.

Darryl 00:49

Okay, how's that sound? Better? I was moving. Alright. So we started, I come from a activated carbon background. In the previous company I worked for where I was the general manager, we specialized in activated carbon servicing and processing, including something called

reactivation. So any big use of activated carbon via the waterworks, or a sugar refinery or something to that effect, when you use even gold, when you use activated carbon at scale, you normally use it in the granular form, and you reactivate it once it's spent so that you don't have to buy virgin carbon all the time. Alright, so that was our background. And we there were two things that we learned in that process. How to reactivate carbons, and really, it's thermal reactivation using steam. So it was how to reactivate how to handle produce a gas. And how to activate carbonsas well. That's part of the game. And then in 2000, basically in 90 that's in 2004. We were approached to start carbonizing and just give me two seconds, I'm going to, Can I pause you for just a bit, I've just got a call. Let me just chase them away and then I'll continue We can start recording again. Okay, excellent. Okay, so, we then in 2004 began the process of making biochar from waste wood residues. So that was started in 2004. And let's say that the company involved Thermix, worked with a waste company from the UK, called castle environmental, that's where we cut our teeth in carbonizing, pyrolyzing making biochars. Alright. So, sadly the company made a play with George sawmill, right. And at the time, I felt that the contractor risks were too hard. So I actually left Thermix and actually started up Adsorb, almost in, not direct competition, we carried on really consulting in the activated carbon space. And then I led the development of a biocharring technology, alright, which we launched in 2012. And then, that was on grape waste, so we actually charred grape waste into biochar. It was motivated primarily as a potential fuel swap from coal to charred grape grape skin pellets by the end customer. But I saw greater potential in the biochar. But in 2012, the biochar market was underdeveloped. And there was no real interest. And you may have noted in your own research that, you know, it's an emerging market, and actually only in the last two or three years has there been really a lets say an expansion of that market. Anyway, because there was no real demand for grape biochar. And they found that the fuel characteristics of the biochar are poor. They gave us the ability to upgrade the, let's say, the pyrolyzing machine, the furnace to activation, so we incorporated steam injection, into the process and started activating. And we then targeted wood activating wood carbons, and we succeeded in doing that. And that basically gave lets say myself the ability to make any quality of carbon from a biochar to a high activity carbon. Alright, and depending on what the market wanted, then we finished that in 2014. But at that stage, there was the let's say, the great waste processor had got to a state where you know, they found this a distraction to their core business. They said, Listen, guys, you come back with a full blown proposal, if you want to buy this tech back, didn't have the ability didn't really have the market. And for the last, let's say, five to six years. Alright, I've been working on the biochar market, developing the products, alright, and working

out what the market needs in the biochar stroke activated carbon space, so in the last five years we've learned a huge amount. In 2016. We entered into a joint venture discussion with York timbers and York is the largest sawmill in the country in sabi. They process 700,000 tons of logs per annum and they generate 350,000 tons of wood waste per annum. They burn a large portion of that wood waste to generate steam for their process. So let's say they burn 100,000 tons of wood per annum and in doing that, they generate a very carbonaceous fly ash and we had a look at the carbonaceous fly ash. It's got about 60 to 70% carboning, biochar, let's call it that. And we said, well, there's a very nice and easy way to enter the biochar market without having to install a whole lot of furnaces and capex and that sort of thing. So we entered into a joint venture with them in 2017. And for the last four, four years, we've been developing the biochar sort of space and market and products, so that we can now expand that emerging market, so that's where we are at the moment. We currently supply roughly 20 to 30 tonnes per month of biochar and activated carbon to the South African market. In terms of applications that we service, it ranges from soil, and growing media's. We registered our carbon with DAF at the time, now it's got a different name, I can't remember what the department's name is. So it's a registered fertilizer, it falls under class three, which is class three bio fertilizers. So although it's got no nutrients, it supports microbes, and therefore it goes into the bio fertilizer space. So i believe we've got the only registered lets say biochar or activated carbon or soil carbon, let's just call it soil carbon. For ease of a better word. And then we also registered the same soil carbon as an animal feed additive, and we secure that registration so we believe we've got the only animal feed additive registration in the country. And then we've developed applications in air purification. So carbon is used or activated carbon is used to remove mercury from coal flu gas, and dioxins and furans from incineration, flue gas. So dioxins and furans. being chlorinated compounds, through a thermal destruction process, like incineration. We also service the water industry. Unfortunately, the carbon has a surface area of between 500 and 600 square meters per gram, and it falls below the threshold for SANS for water, potable water grade carbons, so we are not allowed to sell it into the potable water space, because of that SAN specification of minimum 600 square meters per gram. But we are allowed to sell it into the raw water space or wastewater space. We do sell small volumes. We've been working with the water research commission, we've been in a development research project funded by them and the UN, where we put carbon into various environments and utilize the biological support mechanisms. So it's called biological activated carbon. And we working on a number of initiatives with them, but the majority, 95% of our carbon, alright, goes into either

soil applications or animal feed applications. Okay. So that is a summary, if you can lead the discussion!

Abdullah Timol 13:29

No problem, does that mean that you guys are selling a pretty high grade biochar if you're able to sell it as a feed supplement? I've come across alot of it but no one seems to be able to use it as a feed supplement so far.

Darryl 13:46

Okay, so biochar, by its true definition is a char applied to the soil or charcoal applied to the soil by its definition. Okay. Unfortunately, that means you can actually take a fuel charcoal alright and put it in the ground and claim that it's biochar. Unfortunately, a fuel charcoal is not appropriate for soil. Okay, In my view, alright, and I'll tell you and I'll give you my reason. So a fuel charcoal is designed to trap as much of the volatiles on the carbon as possible. Those volatiles are a range of a huge range of, of, let's say hydrocarbons. And some of those hydrocarbons are poisonous to the soil and to animals as an example. So eating charcoal alright especially, purposely made fuel charcoal that you would want to use on your Braai. Okay, or using it for the soil is not actually appropriate. That's my view. I know that there was quite a bit of work done by Stellenbosch University in the soil division. Dr. Elsa hardy where bio chars have certain carbon to nitrogen ratios and certain carbon to hydrogen ratios where they then use a another classification to work out. Is it a good or bad biochar? Alright, so, yeah, and I think there are institutions around the world lets say the European biochar Commission and the the Institute for IBI. International biochar initiative alright and other entities that have come up with specifications for what is a biochar? When does it become biochar. So there's quite a big difference between what these institutions certify as biochar versus the classic definition of charcoal applied to the soil. If we talk institutions, and I think this is really important. In South Africa, the institutions, although we've got them, their policing or their enforcement is quite weak, I'm sure you know that from environmental laws and regulations, emissions and that sort of thing. So in, in my view, the weakness in our country has allowed biochar, let's say to be abused by those who are just trying to sell a byproduct alright into that space without going through the necessary certification, classification, quantification processes. So if you talk to multiple lets say farmers out there that have tried biochar, generally biochar has got a very bad name in this country, if you talk to the the wider community about biochar, they'll say it doesn't work, alright. My view is that they've actually been exposed to bad biochars alright. And even

some of the research done by some of the universities has been done on poorly classified or poorly manufactured biochar and I include in that some of the work done at Stellenbosch university, I know that Porch or NMU has also done quite a bit of research, but I mean to give you an example, NMU has been looking at chars made from tires and claiming that that char can be used as a fertilizer and other processes. Yeah, I have huge reservations that a char from let's say, quite a hazardous waste like a tire, Okay, can be used sort of successfully in a soil or even animal feed environment.

Abdullah Timol 17:57

I wasn't aware that non organic substances can be used

Darryl 18:03

So some people have put tire charts, you'll know that when you pyrolyze tires, there's quite a bit of char that is produced, Alright, in that process. Now, some people have sold that into the, lets say the soil space, and damaged the reputation of something called biochar. Yes, applying a char into the soil can be claimed to be a biochar, but not from a hazardous waste source.

Abdullah Timol 18:37

Okay, so when I started this study, I kind of generalized it to the KZN Region, you know, Pietermaritzburg, Durban but I found there's not alot of experts around here. I wasn't getting the information I wanted. So I'm trying to widen my search. So that's why I sought you out

Darryl 18:55

Fantastic. Abdullah, maybe just to share with you so what we said as a business, let's say, in 2014, and said, Okay, how are we going to? How are we going to develop this market? How do we assist the South African biochar market development. We said, okay, we know that there's a huge question mark, as to what is a good quality and a bad quality biochar? Okay, well, there was a big question mark at the time. And we know that there are different technologies, you get charcoaling technologies, the standard retorts that make fuel charcoal and you get sophisticated technologies that make lets say activated carbon and we said, let's make the best biochar we can make without having to, so that was our goal, how can we make the best biochar? Okay, and what I mean by best is how do we get the volatile component out of it, okay, so that it cannot act as a poison to the soil or to animals or to any environment. So that was our strategy, we said Okay, if we if we don't know what's good, let just make the best possible biochar. So that's where we started. And we said, okay, with our technology on the

grape way side, we managed to get volatiles below a threshold of let's say, 3%. And we said, Okay, there we go, let's call that our base, okay, for high grade Biochar, or high quality biochar. And on that basis, when we later engaged YORK, we said okay YORK, what is the volatile content, and we found that their volatile contents were also in the 3% range. Alright, and we said, lovely, now we've got a source of, high grade or high quality biochar, let's develop on the back of that. So we then went into greenhouse trials, we went into animal feed trials, and we did all sorts of things. Alright, And the result of all that work? Basically, everyone raves about that carbon, right? The question now is, if you were to decrease the quality, where is the limit to a biochar that delivers value? We sitting on the one side where we saying, we can't afford to take that risk of giving any of our customers a lower quality biochar, alright, without any evidence that it is as good as the high quality one, so we just err on the side of caution, and we now supply high grade biochar to our customer base.

Abdullah Timol 21:41

Interestingly, One of the questions I have in my interview is,does there exist a rating, a you know, a quality rating system for bochar, and from what I've found, no one seems to have one and from what I've been told, basically, you need to take into a lab and get it tested to see what's in it and then only you can decide the quality of the biochar. So basically what you do is you measure how much volatiles are in the biochar and then looking at that you decide on the quality of the biochar.

Darryl 22:19

Yeah, so that's exactly, that's my key focus. I'm less worried about the ash alright in the biochar. Alright, so Ash is inherent in the wood. All right, and you know, the ash is not necessarily hazardous. You do get, obviously, concentrations of various metals, depending on where the biomass was grown. But to give you an example, in sabie, it's a boron rich the soil, so you get a higher concentration of boron, alright, but not to a level that causes a problem. But you're 100%, right, there's no, there's no certification process, other than All right, that qualifies the biochar to be fit for use, okay. And I think that's where we've struggled as a country or as a market is that the enforcement of that registrations is ultimately what is needed. Alright. So if someone is going to make a biochar, they must take it through the registration process to confirm that it's not detrimental. Because that's what that does. They actually don't necessarily go, if you make a claim, they will then have to, you have to show them why you making that claim. But if you make no claim, and you say, yeah, here is a animal feed additive, or if you

say here is a soil editor. As long as you're not making a claim, then the requirement for registration is that it is not proven or shown to be detrimental. Alright, I think that's key. All right. So it's not it's not necessarily about looking at the chemical makeup of the carbon, or the biochar. it's all about have you proven that it's not detrimental?

Abdullah Timol 24:19

So let me just start going through the questionnaire I do have

Darryl 24:25

Okay, go for it. All right. Let me try and answer as best I can.

Abdullah Timol 24:29

So you mentioned that the areas that you focus on is as a feed supplement and as a soil amendment. Um, can you think of any other areas where it can be best applied?

Darryl 24:46

Yes. Okay. So I've mentioned air purification or air treatment, so gas purification or gas treatment. Okay. If you want me to expand, so I've mentioned It's mercury removal from stack gases. It's dioxin and Furin removal, also incineration of stack gases. And then deodorization. Alright, so odor removal, so landfills and anything that has odor emissions. And used in that case as almost an activated carbon or an economic adsorbent Alright, then in addition to that, if we then go to the water treatment market or the water market, it's used for water treatment both raw water both wastewater and potable water, but there is a constraint that if the surface area is not above 600, in South Africa, it does not fulfill the sand specification for safe drinking water. But in the US that specification is 500. So it does, depends on your on your surface area.

Abdullah Timol 26:11

Okay, so, before I go forward can I just ask a question um, what in your opinion sets high quality biochar, What sets it apart from activated carbon?

Darryl 26:27

Alright, so, yeah, so, what sets high quality biochar from activated carbon? It's actually I believe it's the other way around. So bio char, high quality biochar firstly has a very low volatile content. Okay, and that's what defines it to be a high quality biochar. What defines an activated carbon to be better than then a biochar is the surface area. Alright, so the more surface area you put on it, the greater the value of that biochar and it tends towards activated carbon. Can

activated carbon be used as a biochar. Possibly? there's a question mark there that you don't want super absorption capacity. You want, let's say, medium absorption capacity. So we believe biochar sits in the range of 400 square meters per gram to 600 square meters per gram, and activated carbon sits 600 and above 600 to 1000.

Abdullah Timol 27:30

So its the absorption capabilities that's the main area.

Darryl 27:38

Yeah, that's the main area that defines a good carbon from biochar.

Abdullah Timol 27:43

Okay. Okay, so feedstocks You said you guys are using wood, Wood residue?

Darryl 27:52

Yes, we use wood residues, correct. And at the moment, we've registered two products on pine. So our preference is for Pinewood versus, let's say in the biochar space. And there's a very good reason for it, is that the the structure, the fiber, the woodfibre structure of pine wood is we believe better suited to microbial support. Okay, and we believe most biochars, their true function, alright, in the soil is water retention, and microbial support. And that also goes into the animal feed sort of area as well. It's the microbial support function that delivers value. If you now take a different species of wood, let's go to the extreme blackwattle. It's wood fiber structure is very different to pine and doesn't create a very good microbiol support structure, its more Dense. In black wattle, for example. That type of structure is very useful in water and air treatment. So where you're not looking for biological lets say performance and you're looking for for absorption performance, blackwattle would be preferred.

Abdullah Timol 29:23

Basically depending on what you want the biohcar to be used...

Darryl 29:27

Its the application. So my preference for water treatment is black wattle, and my preference for soil is pine. And then I did say we did make a grape biochar, a grape skin biochar so completely different from wood in 2012. Although chemically it looked fantastic. You know, it had lots of potassium obviously, because it comes from the grape skin. Testwork or research done by Stellenbosch University didn't seem to demonstrate any value in the soil applications. So it was

an interesting, interesting result. So this idea that any anything can make a good biochar, you know, any biomass can make a good biochar , although chemically it looked wonderful, in performance or in delivery, it didn't seem to do much. T That's actually a part of my study. Yeah, so although there are claims that you can use grasses and all sorts of other things, we've just found that the wood based carbons have been preferable and, and it's not proven, but when we look at it, we believe it's the biological structure, a structure that or the support structure that is key, alright to the performance of a biochar in the soil as an example. And hence pine is is favored. And it also explains why grape skins which had very little carbon or biological support structure in it seemed to do very little.

Abdullah Timol 31:21

And then, looking at what you said, part of my study involved looking at things like, you know, household organic waste, and garden refuse and so on. So if you had to look at these, you couldn't tell what quality biochar you'd get with it, unless you looked at them individually.... the feedstock itself.

Darryl 31:46

Correct. It's not that it won't be good, it's that we just have no knowledge. Alright. Same with I suppose with grape. At least grape skins as an example, was submitted to research, let's say institutions and work was done on it. Okay, was the protocols and the methods and the research actually relevant? big question mark. Alright. So yeah, so sadly, because these are all emerging products, there is very little information available on their performance, although there's what I call a tremendous amount of gray literature on the internet and everywhere, a lot of research. Alright, that claims performance from any, any biomass species, so personally, the farmers that have used or let's say, real farmers that have gone out and done commercial farming on carbon enriched fertilizers or deployment of our carbon, have come back with some incredible productivity results. But again, it's gray, it's not scientific.

Abdullah Timol 32:59

Okay, so looking at your feed stocks, I'm sure you don't really have a lot of contamination in your feed stocks, Because you're getting it straight from the woodmill. But if you have to get a source from let's say, a contaminated source, can you think of a way to remove the contamination in a non costly non labor intensive way?

Darryl 33:30

Okay, so then lets just look at the process, it depends on obviously the process but we do receive from YORK a contaminated carbon, it's got let's say 30% ash in it alright. So, we have come up with procedures to remove ash okay from carbon and increase the carbon content, very important and that is obviously relevant to any biocharring process or even a combustion process. There's the risk that you concentrate ash, so we we've developed a low cost way of removing it. In terms of other contaminants what do you have in mind in other contaminants metal or something like that.

Abdullah Timol 34:18

So, a large portion of my study was you know, looking at any biomass not a specific one. So, basically....

Darryl 34:31

So you have multiple species present and grass and sand.?Okay, so let's, let's, let's look at the, the broader application once you've consumed let's say, the sawmill residues as an example. Yeah, so my take on that is as follows ,we know that let's say the leaf cellulaose part okay,Will not deliver great biochar at the end of the day. That's what we learned from grape skins as an example. Okay, So the more lignin you've got, the better the quality of your carbon. So, essentially, the way to try and to control that is to develop a charring process that maximizes the expulsion of cellulose and hemicellulose and maximizes the capture of lignin structures to carbon. In expelling the cellulose and hemicellulose you're going to create ash. Alright, because you're going to basically gasify it and leave the behind the ash component, we have a low cost way of removing that ash. And it's size specific. So any inherent ash soil or whatever, generally is smaller then the carbon structure that is produced and you can remove it by way of screening.

Abdullah Timol 36:11

And if you were using a, a feedstock that, you know, has a bit of dampness in it, how would you go about drying it? In the same way, some way that is ...?

Darryl 36:29

Economical?

Abdullah Timol 36:30

Yeah

Darryl 36:31

Okay, so yeah, so that's something, so that's something that's very important. The technology we've developed, obviously, is a, it's a hybrid of pyrolysis, gasification and activation. And, when you look at, although pyrolysis to get it to its, is an endothermic reaction. If you burn the pyrolysis gas, the total process is actually exothermic. So you have the ability to be self sustaining. When, obviously, the first step in pyrolysis is the drying step, which is what you referring to. And that drying step depending on the moisture content, freshly cut wood normally has a lets say a 50% moisture content. And we've found that we can, we've shown and we've got an energy balance to show that even at 50%, you'll remain exothermic. So you've got the potential to have a self sustaining process. Now the question is, how do you deploy the pyrolysis gas alright to to energize the drying stage? Alright, and we believe, what we do is we we don't try and capture the pyrolysis gas and make it into a fuel or whatever else, we incinerated it instead, and we use that energy to do the drying and the pyrolyzing. So, yeah, we believe that there is a mechanism of producing biochar sustainably using its own energy content,

Abdullah Timol 38:12

So like a circular economy approach?

Darryl 38:15

Yeah, well, if you just look at biochar, alright, or let's say biomass, okay, and you know take a block approach, and you make biochar, okay, we believe that the energy or alright of making that biochar, well theres excess energy. So as long as you you make use of the excess energy alright, then you can be a self sustaining process. So wet wood we've got no problem we can process wet wood in our system, and there are other systems that can also do the same. Alright, so does that make sense to you?the energy of the biomass, including how much drying energy is required. To make biochar you will see that there is a net energy loss. There's a an energy release. Alright, and as long as you are able to take advantage of the energy release, alright, then you can create a self sustaining system.

Abdullah Timol 39:19

So a lot of what I was looking into was, you know, the production process and from the research I found it's like a lot of differing opinions, some say that you can make it in your backyard some say you know, you need a proper pyrolysis, gasification unit to make usable biocahr. So,

in your opinion what, to what extent does the design of the kiln affect the quality and yield rates of the end product?

Darryl 39:51

Okay. All right. So I think, yeah, I'm in the favor of engineered technology. Rather than basic technology, and it definitely influences the quality of biochar.there are two sort of issues with basic technology. One is that it's uncontrolled, right? Yes, it's designed to, let's say, gasify, pyrolyze gasify, burn the biomass. Alright. And to make the biochar, but the quality is obviously dependent on human intervention. All right, all the time. temperature, alright, residence time. And yeah, and obviously, the drying and how to utilize the energy release. So, in a basic, you get things like Kon tiki kilns, three drum retorts, open flame kilns that are being lets say promoted for biochar production, at a decentralized scale. The two issues with that is that the quality is going to be variable. It's just, it's human nature that you can't repeat the same thing over and over again. And then if the quality is variable, how do you know that the performance is going to be acceptable? Is it going to be damaging? Okay, as I've indicated, if there's a high volatile content, it can be actually negative. Or it can be what's the right word that's used? detrimental! Okay. And the cost of doing that analysis is relatively high for such a small volume. So yeah, there's going to be a huge variability in quality and performance. All right, related to that. The second issue with some of those kilns is that they generate an air emission, and a air emission that is not aligned to our air emission regulations and specifications even though people claim it is. So yes, it may be smokeless alright. But what is in that smokeless flue gas can be very detrimental to the environment. So you may be creating a biochar product that is, and theres a big question mark is positive to the soil environment but at the expense of the air environment around you. So our strategy is the engineered approach, but I am an engineer by training, it is to engineer it to the best of your ability to create a system that one produces a consistent biochar to the spec that you want it. Alright, and that's through using refractories, and controls to make sure that the process is controlled all Alright, that residence time is fixed, alright, and in control, that temperatures is fixed and in control. Alright. And very importantly, at the end of that, that the air emission that is generated is below, let's say air regulations, alright? So you're not compromising the air. In addition, it generates a huge amount of energy. All right, and that energy in theory shouldn't be wasted, it should be recovered rather than just wasted. So all our our plants that we design, have energy recovery built into them to make either factory steam or to make power.

Abdullah Timol 43:39

Okay, so I'm just going to combine two questions into one at this point because they are similar in nature, but the feedstock that you are using for the production,it doesn't matter what you use, and what you're trying to achieve. Are there some feedstocks that are easier to use, you know, because of how they can be prepared beforehand, or how they'd react during the production that make them more suitable than other feedstocks.

Darryl 44:11

Alright, so yeah, so the first thing we target are feedstocks that are byproducts, Rather than primary products, okay. So we target wood, and we don't want to compete with either lets say structural timber or food, for example, we don't want to compete for that resource. We want to use a byproduct so thats the first sort of question there, and also make sure that the whole process is viable. So the making of biochar needs to be viable. So if you compete for the primary source, let's say the tree alright that's problematic, it's going to be very difficult to be viable to make activated carbon or biochar. But if you if you purely compete with the byproduct, well then then you've got an economic equation that works. In terms of that raw material, you're looking for high lignin. Okay, that's what you're after. You're looking for lignin sources. So you've got a preference for lignin and then depending on the application as I mentioned, pine is preferred for soil and animal feeds and what we call biological water treatment systems. And then lets say wattle or other species are targeted for potable, for absorption applications. And that would be air and potable water treatment. Than answer your question.

Abdullah Timol 45:53

Yes, ok you said your method of production is a combination of pyrolysis and gasification? Is that right?

Darryl 46:06

Yeah, it's a combination of pyrolysis and activation. And activation could be classified as a as a gasification process. So understand when you make chocolate, let's just quickly give you my sort of take on it. When you make charcoal, the cellulose and hemicellulose alright is basically paralyzed. Okay, in the process of breaking down the cellulose and hemicellulose. It's pyrolysis basically breaks the long chain organics. Alright, and it breaks that organic down, down, down, and you end up with charr. It's called amorphus charr. All right. That amorphus charr basically lies on the surface of the carbonized lignin. All right, so the lignin converts to skeletal carbon. Alright, very highly structured. But then around that lignan skeletal structure, you get

something called amorphus charr from the celulose and hemicelulose. Okay, that's pyrolysis. Okay? When you send the steam in, the steam selectively oxidizes the charr, not the skeleton, okay, and then creates the surface area. Alright, so that's how you get rid of that charr. And sometimes that charr can be in volatiles, when we talk about let's say fuel charcoals. Sometimes, the surface can trap oils and tars. Okay, that's the white smoke when you light a fire. It's like oils and tars that are the residual from the the pyrolysis or the pyrolyzing of the cellulose and hemicellulose.

Abdullah Timol 48:02

So, obviously, you've mentioned that you are a fan of the engineering approach when it comes to producing biochar. So what is your opinion on people producing it for personal usage? You know, is it possible to make a biochar that's good enough to actually to actually be considered as Biochar andnot charcoal? Using a low tech environment for production?

Darryl 48:29

Yeah. So my view is until the low tech developers have proven scientifically, that the air emission is acceptable, and that the charr produced is beneficial, that should not be supported. I don't have a problem supporting it. But it needs to be needs to be better researched and developed until theres evidence of a positive outcome, not a negative outcome

Abdullah Timol 49:04

A controlled environment where you can actually test the outcome?

Darryl 49:10

Correct, Yes. So in that field that all these organizations from WWF, to let's say, the endangered wildlife fund to the UN, to all the entities that are promoting sort of bio charring let's say programs, their efforts need to be on the biocharring technology, and validating All right, that it is safe and fit for purpose, not where we are at the moment where they are validating the role of progress. So their efforts are possibly flawed, because what they're trying to do is promote let's say rural and decentralized production of biochar, but without having actually looked at the life cycle, and performing complete lifecycle analysis around that proposed approach.

Abdullah Timol 50:14

So, obviously, initially my study was confined to PMB and Durban but I'm not finding a lot of info here. So to the best of your knowledge Can you think of any existing large scale biochar supply chains in South Africa?

Darryl 50:32

So we have, probably one of the largest! Adsorb has the largest one. All right, and as I mentioned, it's linked to york timbers. So york timbers is the manufacturer, it comes from woodfired boiler fly ash. Alright, so that's important, okay. Then as adsorb, we have ambition of building our first let's say, active biochar activation plant, Diamond stutterheim outside East London and that will be on sawmill residues alright. And who else is producing? Thers some recent entrance, okay, theres hive carbon, alright, have you come across hive energy, a renewable energy company, global, based out of the UK, they have developed something called high carbon in South Africa. And since January this year, they have been building bio charring technology units in PE, Alright, and establishing it. So we engaging them with, none of their biochars have been approved yet for use. We have a currently a capacity of typically 20 tons per month of biochar. They claim they've got a capacity of 200 tons per month of biochar. Oh, there's also Nu Carbon. There's Nu carbon in Sedgefield. Alright. They claim they've got a biocharring capacity of 50 tons per month, but I've never come across their products in the market and never evaluated them. But I have met them at expos and workshops and that sort of thing. There is another carbon Luke Boshier from Sen Foray in the southern cape. Its not Sutherland, they are south of Cape Town. And they produce a biochar enriched pellet, so it's got manures and other things. So it's a biochar enriched product, and they supposedly have a capacity of 50 tons per month. But there are a lot of people that claim that unless you produce that. You do have a company called Rotocarb that makes macadamia nut activated carbon. Okay, so high quality activated carbon from macadamia nut shells, and their operation is in Levubu. But they don't pursue the biochar market. they pursue the activated carbon market. Okay. There was others out there, but they've all fallen by the wayside. So there was carbon innovations. There was a company is in Hembelay energy that produced a char but they've moved towards the wood vinegar aspects. So when you paralyze wood, the gas that's produced can be can actually be made into wood vinegar. And the primary market for wood vinegar is by understanding a biodegradable plastics. But again, I've never seen any sort of commercial sort of application of their technology.

Abdullah Timol 54:50

I've come across a horticulturalist who is working with business trying to make biochar and wood vinegar for commercial application, but as far as we're still in the testing phase.

Darryl 55:04

So yeah, I would say our company, Adsorb is leading the biochar supply chain, we've got the most developed and the most stable supply chain, and it's sitting at 20 tons per month. it should be much more, it should be 200 or 300 tonnes, but we have to build charring capacity, which is what we currently trying to work on.

Abdullah Timol 55:38

Okay, so as someone who claims to be leading the biochar supply chain in South Africa, what do you think are the core functions that you need to consider when implementing a biochar supply chain

Darryl 55:57

Okay, firstly. Yeah, so the raw material source, what raw material source and the stability of that, okay, and the security of that. Its one of the reasons why we tend to go towards formalise saw milling. Because that's a very secure source. And it has a defined lifespan, typically supported by forests, commercial forest. Next is the tech, what tech you're going to deploy. Right, And will it be compliant? And will it be obviously economic? Then it's what what applications your biochar are going to service? Because that's going to define what process and lets say the whole manufacturing? And I think that's Yeah, I would say probably, that's the key. And obviously, security of those customers, how big are they? What are the actual off takes? Are they secure? You know, so those are the considerations.

Abdullah Timol 57:09

So considering that one of the major uses of biochar is as a carbon sequestration tool, what considerations do you think should be taken into account before you even think of implementing the biochar supply chain?

Darryl 57:27

Yeah, so on the sequestration side, that there has been enormous progress, to try and register the, let's say, the sequestration and in the form of a credit, so that supports the commercial elements of the supply chain. At this stage, it would seem that the user, the farmer, as an example, who actually performs the sequestration, is able to register the credit through a new carbon sequestration program. But there is potential for the manufacturer. So that gives the the ability for the manufacturer to charge a higher price based on the end customer securing a sequestration credit, there is potential for the manufacturer to try and better register the credit

but a lot more difficult because they have to prove that it goes into the sequestration markets, it's much easier to inflate the price relative to the credit that the farmer will secure rather than the manufacturer. Try and secure the credit

Abdullah Timol 58:50

So looking at attaining a sustainable feedstock for your biochar business, obviously, you have to look at where you can get the sustainable source that's large scale. And also, what logistical considerations need to be taken into account. And is it possible to integrate existing businesses into a biocharsupply chain? Like you said, you're using residue from a wood sawmill so that will be one example. Can you think of any others?

Darryl 59:25

Okay, yes. Okay. So let's just discuss that. One, moving wood, all right. The transport costs , your transport economies of moving wood are high. location is towards the wood or the biomass. Okay, so you've got an economic radius, let's say 50 kilometers or 100 kilometers from where you can source the woods. So that's one of the considerations. Moving the higher value carbon product gets easier, once it's been halved, at least half or sometimes sorry, the density has been either doubled, Or if you start pulverizing into powders which is part of the application, you can get a four or five times reduction in volume. So it's much more cost effective to move the carbon than it is to move the wood. So manufacturing needs to be located closer to the source of wood, and secure, and carbon can be moved to where it's needed.

Abdullah Timol 1:00:41

You answered that already. So looking at the commercial applications of biochar, was that something that your business is doing at the moment? Why do you think biocahr not more popular? It has a lot of capabilities, there's a lot of potential, why is it not gaining traction? Why is it taking so long to take off?

Darryl 1:01:13

So I think there are a couple of reasons, One reason, there's been very little state support or the industry. So it's been done privately. And so that's one of one of the reasons, the primary driver has been to make money out of out of waste products. So it's been driven from a need to find those solutions. And that's lets say caused or limited the development. If it was driven from the other way, here are the products, how do we make them? That would be a lot easier. Alright, so very little state support, very little, llets say institutional support from universities and

academic institutions. What else? Then there's the charcoal industry has inherently been lower skilled and this is a sophisticated product. Okay. So, the majority of biochar or development has been from unskilled or low skilled charcoal and background rather than being pulled from higher skilled lets say agricultural market, does make sense your, it needs engineering, it needs a higher level of sophistication for it for it to be successful.

Abdullah Timol 1:03:10

Okay, so currently, there's, you know, a lot of people are selling biochar. If you look at, you know, nurseries, gardening centers, what do you think of the quality of these biochar? is it questionable?

Darryl 1:03:25

I would say all questionable. Yeah. Okay, if it doesn't have a DAFF registration number, it's questionable. And so, should be registered as a fertilizer if it's being sold in a retail environment.

Abdullah Timol 1:03:51

So the production and the quality of the biochar end product is obviously going to, is obviously going to influence the price of the end product. Yes. Can you give me like an example of or just an idea of how much a high quality biochar is going to cost in your company for example

Darryl 1:04:18

Okay, so we biochar currently is being sold at 14 Rand a kilogram, which equates to let's say $1 a Kilo in the South African market, the same biochar is being sold for $4 a kilo in the US market. So the the issue that South Africans face is that the willingness to pay fair value for biochar from the South African market has been low. The appetite to pay has been low, and that's compromised the ability to lets say put up the capacity at the scale that's required. And that the sophistication required. Okay. So the tendency has been for low tech solutions to make lets say biochar at six Rand a kilogram as an example. But that has been unsustainable, causing many of those lower tech companies to go under or to fold alright. Or to produce a lower quality biochar that compromises the market.

Abdullah Timol 1:05:44

So within your company as an example, again, what are some of the biggest buyers of biochar? Who's going to benefit the most? Obviously, there's like farmers and maybe the water industry. Can you elaborate on that

Darryl 1:06:03

Okay, and I can answer that. So it's a broad market. Alright. And the, so who's going to benefit, the farmer will ultimately, the end user, the farmer will be the main benefactor. And, but obviously, the entire supply chain will benefit including the fertilizer manufacturers that incorporate carbon into that so they will. Yeah, if you can make an example a higher activity, biochar. Then there is interest from our lets say large industry like Eskom or Sasol to deploy those biochars in their stack gas treatment systems, and they will ultimately lets say deliver an air emission that is safer for the general population. So I would say that South Africa or the country as a whole will benefit. If you're deploying biochar into the soil, then the soils of South Africa will increase in value. If you're deploying biochar into air treatment or lets say gas treatment, the air quality will be superior and those who benefit is actually the population of South Africa.

Abdullah Timol 1:07:38

A Domino process that will benefit everyone.

Darryl 1:07:43

To give you an idea, just an idea, the estimate quantity that Eskom requires per annum for their coal fired power stations is 50,000 tonnes of carbon.So a biochar equivalent, a high activity biochar. We only making at the moment 200 tons per annum.

Abdullah Timol 1:08:15

Okay, and then this is my last question. So, a lot of the people I've interviewed that have mentioned alien vegetation as being, you know, a good biochar feedstock because, you know, you're solving a problem while making biochar from it, but obviously, you've mentioned that unless you know what the feedstock is and you know what quality of biochar is coming out at the end, you can't say whether it is a good feedstock. So what are your thoughts on using alien vegetation?

Darryl 1:08:54

I'm very involved and I'm supportive of these initiatives, I'm not supportive of deploying decentralized technology to to make the biochar as I've mentioned, theres two issues one, the quality of the biochar, is it going to be been detrimental or beneficial. Okay, big question mark. And it will certainly be detrimental to our environment. So I'm supportive of a more centralized approach, I don't want it highly centralized. I consider lets say co op scale, to be applicable.

Where you bring the alien invasive vegetation into, let's say, a co op, scaled lets say entity. I would like to see primary use of the alien invasive before it goes into the biocharring space. So if there's a mechanism of making furniture or if there's a mechanism of making a primary product, alright from the wood, it would be great. So that you you try and use, let's say, the the less valuable portion be at the twigs, the branches, the whatever in the biocharring space. And then in terms of application more than likely they are question marks about how valuable it is, right? As a buyer, we really don't know there needs to be much more work. But what we can say is, if you take those multiple species alright, and you activate them as high as you can and take them into the water industry space then it doesn't matter. Alright. So that would be the goal to take it into water treatment, where the as I mentioned, the microbial support function is less of a consideration. But if the biochar produced in that operation goes back to the land to support an agricultural activity, be it forestry, be it crops, be a farming, food, whatever, and is shown to be beneficial, well then that makes a very neat lifecycle sort of approach. Okay, I think that's all for me. That was my last question. Well, Abdullah, you've got got a lot of work. You've got a lot of thinking to do. Yeah. But if there's anything further, let me know I've given you a hopefully honest, candid sort of responses. And yeah, I'd like to try and support you as much as possible.

Abdullah Timol 1:11:41

Thank you so much. I've received like some really, really good information today. A lot of new angles I need to look into so thank you so much testing.

Darryl 1:11:49

Brilliant. And plese, if you need anything further, let me know. Thanks Abdullah, have a good day. Just Cheers.

Appendix F: Interview 3 transcript

Dave Still

SPEAKERS

Dave Still, Abdullah Timol

Abdullah Timol 00:01

Okay, so you don't mind if I record the interview do you?

Dave Still 00:05

That's fine. Yeah. Okay. So, I'm sure you have an idea of what I'm doing. Last year, I looked into biochar to see if it could be used as a possible solution to waste management. specifically looking at the Pietermaritzburg dump. So I'm just expanding on that a little bit to see how a biochar supply chain would look. I'm looking at possible feedstocks sources in the Pietermaritzburg and Durban are. Okay, so let me just get started. Okay, so you are a civil help engineer am I right? Civil Engineer. Yeah. And a lot of my work is in , environmental engineering, water, sanitation, that sort of thing.

Abdullah Timol 01:07

And how exactly did you get exposed to biochar? What's your experiences with it?

01:18

Well, because I do quite a bit of my work is in what's called fecal sludge management, which is the disposal of sludge from onsite sanitation. People in that world, you know, one of the things that they look at quite a bit is pyrolysis and biochar of as one disposal mechanism.

Abdullah Timol 01:47

And looking at biochar, what do you think, You know, there's a lot of uses, what do you think are some of the best areas that it could be applied in, in your opinion?

Dave Still 02:03

Best uses for biocahr

Abdullah Timol 02:05

Yeah, best areas it could be applied in

Dave Still 02:07

Where you apply the actual biochar product or the areas for making biochar? Sorry, what do you mean? You're looking at a landfill site. So you're looking at landfills? You say you're looking at landfill or a way of getting rid of organic waste at the landfill? Is that what you mean by an area? Or are you talking about what happens to the product that you produce?

Abdullah Timol 02:42

I think what happens to the product you produce, where can you use it?

Dave Still 02:49

Yeah, well, look, it's It is believed to improve soil fertility. Um, you know, you've probably read quite a bit about it. I've read a bit, probably not as much as you I'm sure not as much as you. And it does seem to me that maybe the some of the claims that are made biochar might be a little bit inflated. You know, we've read about the Terra preta and the Amazon. And that's, that's very impressive. But is that maybe something that's more than just standard biochar? Or was that an effect that was achieved over a very long period of time? You know, like, hundreds of years. So, you know, what I've seen, you know, looking at the cost of producing both the cost of biochar and the cost of putting it into soil. Is the productivity increase enough to pay for that? I don't know. I know that some people are very passionate about it. So maybe there's a market with people who just you know, want to believe in the concept, who want to do organic farming, and they say, well, that's the way to go. So. But if you had to go to a big commercial farm and say, you know, I'm going to spend 100,000 Rand a hectare, putting biochar he'd say look, I think so. So, yeah, Look, you've got landfill waste. The products being thrown away anyway. So it's good, it's a way of producing something useful with the waste, extending the life of the landfill, and having a product that's useful, but now, what can you sell that for? And that's, that's a question. I'm sure there is a good niche market for it. I don't know. I don't know how that translates into, to scale above market.

Abdullah Timol 04:42

What about using other areas, such as waste water, as you said, would the benefits of doing that outweigh the costs of it, just the fact that you cleaning water with it

Dave Still 05:02

Are you talking about the activated carbon kind of thing?

Abdullah Timol 05:06

Yeah

Dave Still 05:06

Where you actually it is a filter medium. Yep. Yeah, that definitely has potential. I don't know whether the, the specification for making that, you know, is that very different from if you're just planning to put it in the soil, then obviously your specification would be a bit more broad. If you're going to use it for filter medium, it's got to be made to quite a very specific specification. So I don't know how that affects the manufacturing process or the feedstock maybe then you can only use certain feedstocks.

Abdullah Timol 05:45

Okay, and as I said, I was looking at landfills. Um, do you think that organic rubbish you know, from a household. Do you think that's a viable feedstock?

Dave Still 06:02

Yep. Could that be used as a feedstock?

Abdullah Timol 06:10

Yeah.

Dave Still 06:13

I don't think kitchen waste I think that would be too wet. And definitely garden waste, no question about that. Kitchen waste I would be doubtful. I would rather go for a composting process with that, you know, to beneficiate that. I mean you're aware that one of the significant costs with biochar production is getting the feedstock dry enough, if you have to spend a lot of energy reducing its moisture content and drying it before you pyrolyze it then makes it more expensive. So with the example I was looking at, a big part of the operation was going to be getting the feedstock dry before you could actually put it into kilns.

Abdullah Timol 07:08

So you said garden refuse would probably be a better fit so yeah,

Dave Still 07:13

Garden refuse I'm sure yeah, definitely. But you'd want to get some, you want to get enough woody garden refuse,not just all grass and leaves because grass and leaves I don't think are going to give you such great biochar

Abdullah Timol 07:31

And then looking at a feedstock like garden refuse do you see any issues other than the drying that you mentioned

Dave Still 07:50

Garden refuse, after garden refuse I missed you. What did you say?

Abdullah Timol 07:54

Do you see any other issues other than the drying process that you mentioned?

Dave Still 08:08

Well, yeah, it would depend on the on the mix of the garden refuse, you know, how leafy You know what, what sort of carbon percentage is in there. You don't want to just produce powder orash, I think you want to produce something that's got a bit more structure to it. So, you know, if you're paralyzing wood chip, you're going to get a better result than paralyzing grass.

Abdullah Timol 08:38

Can you think of any other feedstocks that would produce a good quality biochar? That is maybe more accessible?

Dave Still 08:57

Well look, the sludge, as I said, the sludge you get from a wastewater treatment plant, not Darvell. But a place like howick, because that's a different process. That would be worth. You know, I think if one used it as a mix, you know, as we had in our proposal, we'll use that in a mix with your wood chip. The nice thing is, then you're getting I mean, it does have to be dry enough, but you're getting a bit of NPK coming through there, which is good. And when I did my proposal, it looked to me like the in in the biochar was still quite low. And to really make it a useful product for agriculture. I thought it would be a good idea to add some urea because that's the most important thing that the farmers need is nitrogen. Now that might then affect the market because then it's not fully organic anymore. You've mixed in urea, although urea is a natural substance. So I don't know if that would affect the marketability and the price, but it would certainly improve the usefulness. The other thing is wood ash, you know with your biochar, you are usingwood as a fuel. So the wood that, that you burn to drive the process, the waste product from that is wood ash, which has value. That's got potassium in it. And so I would, you know, my thinking was, you could mix that wood ash into the final product, instead of throwing it away.

Abdullah Timol 10:40

Just looking at the dumps, even if you look at the garden refuse, not even looking at the main dumps, in Pietermaritzburg, we have dedicated dumps for garden refuse, but even though we have these they still get contaminated with a lot of non organic things. Could you think of any ways that could be used to reduce this contamination?

Dave Still 11:13

How does that happen? I mean, are they bringing bags of garden waste with a little bit of trash inside and then just poor control? I mean, it shouldn't be strict. I mean, these garden centers all have attendants there. And they're meant to see what's coming in. I think just better management. I mean, it's not like people are paid for bringing stuff. So they don't care. Yeah. I guess a bit of better awareness, both of the public, better awareness of the managers to why it matters. At the moment, nobody's doing anything was at worse. They probably say, well look its all gonna... it all ends up in the landfill Anyway, we separate it at a garden site. And then it all goes... correct me if I'm wrong, but it all gets thrown away in the landfill site anyway. So people probably say, Well, what does it matter? It doesn't matter. Now, if there was something useful being done, people knew what was being done, and it was good education, maybe some posters? Hey, guys, this is fantastic. Do you know what's happening to your garden waste and stuff in the news, then maybe people would be more motivated to to do it properly and the operator, maybe even the attendants sitting there thinking, Well, you know, it doesn't actually matter. It's all gonna go into landfill sites. So who cares? So if he knew that something good was being done with it, then maybe he would get off his chair and go and see what they doing!

Abdullah Timol 12:47

That's actually a major issue. Because usually, if you just give them something, I've seen it, and they're like, dump whatever you want inside.

Dave Still 13:00

You mean, there's a little bit of a backhand, a bit a bit of bribery and corruption there. Yeah. So then to help with that. If they were audited, you know, like spot checks, a manager comes along and has a look at what's in the in the skips. And if you find that the skips have got the wrong stuff in, then that attendant should be disciplined, you know, like disciplanary, you know, warnings, fired, penalties, whatever. but probably there's not much management going on there.

Abdullah Timol 13:32

And in the same regard, if you have to look at a separate, if you have to look at in the same regard, you know, separation, what would you think it would take to implement a separate at source approach instead? Do you think this is in any way possible?

Dave Still 14:04

Well, having the garden site is meant to be a kind of separation, I don't think.... it's not realistic to say that people are now going to put garden waste in a separate bag on their pavement. I mean, we can't even put plastic and paper in a separate bag. So the garden sites are a good thing, they should be, I think they probably should be a few more of them. They seem to be a bit few and far between. Maybe they could have longer hours. So if if you had a more successful sort of profitable process processing this waste that might then Provide a revenue stream which could pay for better collection services. More garden centres, longer hours

Abdullah Timol 15:07

Earlier on you mentioned, that the biggest problem with collecting the feedstock is the drying of the feedstock, looking at this, what do you think would be the best way to dry your feedstock if you have to look at cost, effectiveness, efficiency?

Dave Still 15:40

Well, depends wha the feedstock is. A fairly cheap drying mechanism is just a drying bed, but that can be exposed to rain unless you have a removable cover that you use. The then there's quite a lot of waste heat in the biochar process, in the kilns. So, if you cycle some of that waste heat into drying tunnels, you can use the waste heat to dry the feedstock as a preparation stage. Okay, if you use that waste heat, take that that will help.

Abdullah Timol 16:22

Okay, so you've done some work on kilns?

Dave Still 16:29

No, I mean, I just spoke to people who had and learned quite a lot from them. So you've spoke to the Vuthisa guy, what was his name?

Abdullah Timol 16:45

Kobus Venter

Dave Still 16:51

Yeah. So you know, I've spoken with him quite a bit and learned from him, and then also, Oliver in East London. They did, they did some work, they built some kilns there and did some work there. So I learned a bit from them as well.

Abdullah Timol 17:06

Okay, from what you got, the kiln design itself, does it have a major impact on the quality and the rate of baiser.

Dave Still 17:25

Yeah, cuz you've got to have ...temperature control is important. And and then the way you recycle heat between kilns is important. And what else? If you, if the design includes insulation, then that improves the energy efficiency and the control. But look, I'm not I'm not an expert on that hey

Abdullah Timol 18:05

This is also slightly related to the production process... other than the drying process, can you think of any other way of preparing the feedstocks beforehand that may help with the production process?

Dave Still 18:43

Maybe hand picking because if there's any trash in it like plastic, you need to have somebody spreading it out and picking out the trash.

Abdullah Timol 18:51

Oh, sorry. I just went offline for a bit, can you just repeat that?

Dave Still 19:07

Abdullah this line is very poor hey.

Abdullah Timol 19:10

Yeah, let me just try switching my connection. Can you hear me? Okay, I'm just going to have my video I think I have a very poor line

Dave Still 19:35

The picture picture quality has improved a bit. yeah, I'll off my video as well. I think that might be using up some bandwidth

Abdullah Timol 19:48

So we're talking about methods of preparation beforehand.

Dave Still 20:06

You're disappearing again, can't hear you. do you want to just try and finish up with a WhatsApp call?

Abdullah Timol 20:17

Let me just try one more time to reset my connection. Can you hear me?

Dave Still 20:38

Okay. yeah

Abdullah Timol 20:44

Okay, we're talking about preparing feedstocks before hand

Dave Still 20:53

yeah. I was saying chipping. some form of chipping is a good thing. And then just see if it's come from.... depending on where the waste source is, you probably have to have just a labor intensive process, just picking out any non organic waste.

Abdullah Timol 21:29

As you said, you haven't really looked too much into price or production. But have you come across any types of production, simple enough, very low tech that can be done in the backyard or somewhere

Dave Still 21:49

You mean like literally in any neighborhood yard. Yeah, well look the kind of kilns that kobus produces one can do that on a much smaller scale. So one could make that with some drums. But you'd get quite a small quantity of biochar. But, yeah, I know there are people who make small production. So it is possible , one does need you know, you need the fuel. And theres quite a lot of setting up and finishing up. So it's quite, it's quite a labor intensive process. So I don't know how motivated people would be to do it on a very small scale.

Abdullah Timol 22:52

Okay. And then how environmentally friendly is this production process you're talking about?

Dave Still 23:12

Well, you see, you're generating a bit of a bit of smoke, but that's mainly in the beginning until you've capped it off. I don't think it's too bad. There are people who, you know, if you will read up some of the discussion that making biochar is a way of capturing carbon where it doesn't break down further, where you now put it in the soil and it's, it's in a kind of a state that it's not going to degrade so that you've sequestrated carbon, so, maybe that's a good thing. I don't know, you know, in the broad scheme of things with the kind of carbon problems we have I don't know whether it's significant, but there are people who claim thats a benefit

Abdullah Timol 24:07

And looking at, you mentioned this a bit before but in order to get biochar to do certain things or depending on what you plan to use it for your end use, you need to have a certain feedstock quality and you have to be careful in the way you produce it. To what extent do you think the production process and the feedstock process affect the end quality and the characteristics that the end biochar has

Dave Still 24:44

If you want to have a consistent product, you've got to have consistency in your feed and your method, otherwise your customers won't know what they're getting. And the other thing is, I mean, I presume you're aware too. You want to sell this product officially, not just you know, your backyard, you're going to have to go through some kind of approval process. So people actually know what they're getting. So that will require some form of certification. It may depend on what you sell it as, if you sell it as like a fertilizer, then definitely because thats governed by an act, if you saying it's a kind of a glorified compost, you know, a conditioner, maybe that's not too much. But if you want to get a reasonably good price for it, and it would be advantageous to get it properly certified.

Abdullah Timol 25:40

Do you know how you would go about getting it certified? You know, who would certify such a thing?

Dave Still 25:49

I think you would have to send your product to, there'll be a running through the Agricultural Research council, there'll be some process. I haven't had to do that. I mean, I haven't done enough, if we ha done that biochar project, if I'd been involved, that was one of the areas that

we had an assigned budget to was to do that whole process. Hans Salisbury, he um, he can give you the name of this. I forget the act. I think it's 1947. But there's a fertilizers Act, which has the process, which I'm sure you can read up on it quite easily

Abdullah Timol 26:33

And then this year is more along the supply chain side. But can you think of any existing biochar projects or supply chains, around the Durban or Pietermaritzburg area?

Dave Still 26:51

No, no, I don't think there is you know, Kobus makes a bit now and again and hefinds a market for that. There is a crowd, is it called Living soil? There are people here that sort of have, you know, like a biochar interest group. So if you investigate there I think you might find some people who are selling it, but I don't think there's anything happening at much scale. I think there's, there's probably a gap in that, probably if more people are interested in the product then it's available.

Abdullah Timol 27:34

And then if we you have to consider implementing it biochar supply chain, what would be the core functions of the supply chain?

Dave Still 27:55

Well, Imean you're trying to produce a product at the best cost you can to get it to the market efficiently and find buyers and satisfy the demand and grow the demand.

Abdullah Timol 28:25

Okay, so you said that, biochar, one of the thing that environmentalist often look at is its ability to sequestrate carbon. If you had to look at this, if you had to look at biochar production for an environmental use, do you think any considerations need to be taken when actually producing the biochar, like sustainability and environmental awareness.

Dave Still 29:08

Well, it will come down you know, sustainability is a cost issue. And so if one really looked at that carbon thing in detail, you'd have to say how much carbon are you burning, you know, with trucks driving around collecting feedstock in order to produce the carbon in the biochar that gets sequestrated. So if you're spending, if you're using more carbon than the carbon you sequestrate, you haven't, you haven't really made a contribution. But then that should probably

come out in your financial feasibility, if you're spending too much on collection. Then it probably isn't going to be economical, the product you produce. So the optimal is where you've got a waste product, at the landfill site, the waste is coming there anyway. So, if you were a biochar operator who built a plant next to the waste filled site, the landfill site, your collection cost is nearly zero because they're bringing it there anyway, that would be optimal.

Abdullah Timol 30:33

Other than looking at a landfill site, Can you think of any large scale sources of biomass that could be used for production?

Dave Still 30:47

Well, in agriculture, theres's, you know, with the sugarcane industry they have, they have waste, I think some of it gets composted and used as you know, on lands so there might be some potential there. I don't know about the timber industry, you know, they don't have, they have a little bit of timber waste. I don't know if it's worth setting up biochar. Mobile plants when they, you know, when they cut it timber at the end of the growth cycle to to process all the stuff that can't go to the mill. So there may be some potential there. You know, the people who make pellets, you know, you see piles and piles of wood chips in certain places like that you wonder if they shouldn't, if they couldn't produce biochar. Some of those places are in the midlands,you might have seen them... near the highway

Abdullah Timol 31:53

Okay, so do you think any? Okay, so, this question actually ties into the question I just asked, but do you think that these businesses that you mentioned, you know, the sugarcane industry or the pellet industry, could they be tied into a biochar production line somehow? And what sort of collaboration would be needed to make such a thing happen?

Dave Still 32:24

Well, it would have to be, it would have to be more advantageous than what they're doing at present. So you'd have to say, Well, what are you doing with that waste at the moment? Does that have any value to you? If you can offer them greater value or save them costs, then they'd be willing, if you're actually going to cause them cost, they're not going to be willing.

Abdullah Timol 32:52

Okay. So my next question has to do with commercial applications of biochar. So, biochar itself has a lot of capabilities and a lot of potential. So, looking at all this, why isn't biochar more popular than it is. Why haven't a lot of people heard of it?

Dave Still 33:30

Well, I don't think it's.... it's not fully proven yet. So I mean, do you know of irrefutable scientific studies that say, you know, if you spend 50,000 Rand per hectre, putting it into your, your farm, how long it will take to pay for that investment? That's what you've got to have. There's got to be a firm case for it. If you're saying, Well, we believe it's good for the soil good, but it's gonna take 50 years to to to pay off, you know, that that's hard for people, people don't have that kind of capital to wait that long. So I think it's partly that and then maybe just, maybe just people aren't aware of it. You know, there's definitely a niche in the environmental world where people are very passionate about biochar, but I guess the general public are not that aware of it.

Abdullah Timol 34:48

So, do you know of any producers of biochar that sell biochar on a large scale, where it could be used as more More than just a soil amendment.

Dave Still 35:05

Do I know of any what?

Abdullah Timol 35:07

Any companies or businesses that sell biochar, where the biochar is of good enough quality that it could be used as something other than a soil amendment?

Dave Still 35:23

Well, Kobus.. you know, he knows who those people are around here. I know you, you've talked to him as well. I can't remember the name of it, it was livingsocial, something like that. And there are certainly I mean, there's, one can see on the internet, that there are companies in the US and UK that do these things. So you can buy your biochar online and they'll mail it to you. I don't think there's anything like that in South Africa.

Abdullah Timol 35:55

Okay. So you mentioned earlier on that, in order to assess the quality of your biochar you need to get it assessed? Um, do you know if any grading or classification of biochar exists at this current moment? Because I haven't found anything

Dave Still 36:22

Um, I think biochar. I don't know of any formal system. I do know that. You know, one of the aspects that they rate biochar on is what is the carbon content? So depending on your feedstock, you might end up with a greater or lesser carbon content and the higher the carbon content, the sort of higher the quality of the biochar.

Abdullah Timol 36:49

Okay. So, we said early on that biochar is limited by the end product, the uses of it. do you think that the quality of the biochar, how big of an impact does it have on the price if you have to sell it commercially?

Dave Still 37:27

It would make an impact. But it's like, you know, when you sell fertilizer, you're paying for NPK, you know, so the more grams of NPK you have per kilogram, and the more you're prepared to pay for it, or should be. They put that on a table, you buy fertilizer, and there's always a table on the packet which says this is the percentages of N and P and K. Now biochar, you could do you know, if it's properly assessed and tested and marketed, you could have something similar and, and the more NPK and carbon that you have, you could justify a high price. That's what you'd have to do. But you'd have to be able to have quality information and be able to back that up.

Abdullah Timol 38:24

considering buying from a commercial perspective, which sectors are most likely to benefit from its usage other than the farming sector?

Dave Still 38:40

Just domestic gardens. I think that's quite a big market. Well, certainly the bigger towns, so nurseries. In fact, that might be one of the best markets because when people go to a nursery the financial calculations are very different from a farmer who's buying truckloads you know, if somebody is buying a bag or two, you know, an extra 10 Rand or whatever is nothing. But if you buying truckloads then a few percent makes a huge difference to the cost. So and then you know, the municipalities doing landscaping or gardens you know, improving public spaces

they might be prepared to use a bit and as you say, the water treatment industry with high quality activated carbon, that's another market, people pay a lot for activated carbon. That's that's quite an expensive product. So if you're producing something of that quality, there's quite a high price.

Abdullah Timol 39:42

So I'm not sure if you know about biochar being used as a feed supplement.

Dave Still 39:50

A feed supplement? to what animals?

Abdullah Timol 39:55

Okay, I haven't come across anything specific but I've seen it being used just for farm animals. I think sheep

Dave Still 40:03

So why would they eat biochar? What does that do for them?

Abdullah Timol 40:09

I think it's supposed to increase or improve the digestion or something somehow?

Dave Still 40:15

Well, if that's real then that would be a market. But I mean, these things need to be proven. You know, you can't just have somebody writing an article in internet saying he thinks this is the case. So if you know you have serious scientific studies that properly conducted that demonstrate that then that's great.

Abdullah Timol 40:32

I'm almost done. Just two more questions. So looking at Pietermartizburg and Durban. can you think of a areas specific to Pietermaritzburg and Durban, that biochar could be utilized to contribute to local communities?

Dave Still 40:57

Look, you've got as I said, you got your garden market in your urban area, you've gota lot of vegetable gardens, community gardens. And so things could be done, you know, with assisting them with biochar. The department of agriculture might want to do that where they plough in

some bio char, but then they should monitor the results to see if it helped. There's lots of lots of gardens around the town.

Abdullah Timol 41:31

My last question was to do with alien vegetation. Um, so PMB and Durban have a lot of alien vegetation. Do you think it would be possible to use this alien vegetation to produce biochar? Do you think it would make a good feedstock?

Dave Still 41:52

Well wattle certainly Yes, there is a certain amount of wattle that needs to be managed or thinned or just to be removed so wattle no question. Bugwheat which there's lots and lots of bugwheat and lots of lantana. I don't think that would make very high quality. But I think you'd certainly be worth trying because a lot of it then you would want to have fairly mobile biochar units that could be set up in a field rather than having to truck the waist all the way to a central place. Maybe you know, I definitely think that would be worth looking at. Because otherwise what happens is you cut down lots of bugweed and looks unsightly, eventually it will rot but it's a bit of a mess.

Abdullah Timol 42:40

So that's it from me.

Dave Still 42:43

All right. Good. good luck with that.

Abdullah Timol 42:51

Thanks.

Appendix G: Interview 4 transcript

Nqobile

SPEAKERS

Abdullah Timol, Nqobile

Abdullah Timol 00:03

Do you mind if I record the session?

Nqobile 00:21

No.

Abdullah Timol 00:30

Alright. So shall we start! okay, just making sure I'm you're doing a PhD in agriculture right So how did you get exposed to by Biochar and what's your current experience with it

Nqobile 02:06

Initially I I was interested in excreta derived materials, for my honours I worked with urine. For my masters now. I wanted it to be more like something, a material that has phospurous. So, that's when I read on the types of materials that can be used to make biochar, I read there were woody materials that can be used, crop residues and invasive plants. And also I saw that fecal matter is one of the materials that can be used for pyrolysis. Then it so happend that that I dealt with the guys from Agro protein, a company in Cape Town, where they were feeding fecal matter from UDT's, urine diversion toilets, black soldier fly lavae. So, the whole idea was to feed the larvae, and the larvae with their feeding they convert the organic material into protien and then the larvae you can use it as animal feed and also the residue that remains behind, they didn't just want it to go to waste so they decided to use it as a feedstock for pyrolysis

Abdullah Timol 04:03

very interesting

Nqobile 04:04

Actually, they didn't know the initial. So, it was a kind of a preliminary study to get the optimum pyrolysis condition with regards to temperature and residence time. So, that was pyrolysis chapter, where I had to pyrolyze that residue. Residue basically consists of ipartly digested material because they see that sometimes the liver remains in the residue and also it's

picked up from the larvae itself. So, it's got residual nutrients and it also got residual pathogens because its derived from toiler and it also because we discovered that people throw things in the pit, in the UDT. It separates urine and feaces but we discovered that people don't use it solely for that, they throw in plenty of things, batteries, you can even find razor blades, guns, human hair. So even on the analysis their were heavy metals and stuff so pyralyzing that residue want to see the biochar also characterized into the physical characteristics, chemical characteristics and see how it compares to biochar pyrolyzed from woody materials and other materials

Abdullah Timol 05:53

So, this urine diversion dry toilet, is that something different from a pit latrine?

Nqobile 06:02

Yes, it's different from a pit latrine, a pit latrine has one one pit. So in a pit pit latrine, you're putting everything, your urine and your fecal matter in one pit. But the urine diversion dry toilet, it separates at the source. So as you pee the Pee goes in a different pit and the fecal matter goes in a separate pit. Mainly they did it to prevent cross contamination because urine mostly doesn't contain the total elements, your E. Colli, your fecal coliforms, then your total coliforms so you urine is a bit pure frome seperating and collecting just urine and that's the one that Sharon uses, a more pure form. Andthen the fecal matter is also collected seperately. So a pit latrine has one pit while a UDT has 2.

Abdullah Timol 07:15

And just to clarify that the company talking about what did you say the name was agro protein

Nqobile 07:26

yes

Abdullah Timol 08:51

So we're talking about agro protein.

Nqobile 10:27

So agro protein is, is kind of the sister company to biocide. Agro Protein is based in Cape Town, they feed the black soldier fly to.... their feedstock is just waste from restuarants. So they wanted to extend it to fecal matter, that's when they moved it to a Isipingo in Durban. So theirs Agro Protien on top and then theirs biocycle. The company I was working closely with

was bio cycle, the one in Durban. That's where they fed the black soldier fly lavae to the Fecal Matter and then I collected the residue from there.

Abdullah Timol 11:25

Okay, interesting. Then moving on to the next question. So, in your opinion, while biochar has many uses, what are the some of the best uses that it can be applied to? What are some of the best areas that can be applied?

Nqobile 11:50

I think biochar depending on the feedstock that you used can be useful, it can be used for different applications for instance, when it is used as, when the feedstock is originating from woody material it doesn't have much nutrients. So, it can be used as a soil amendment because of the properties such as its high porosity, its high surface area. So, when you put it in the soil, it can be a soil amendment in the sense that it helps hold your water for sandy soils, improve structure. It's also for carbon sequestration and also because of the high carbon it can also also release carbon into the soil and because of the high porosity it can accomodate microbes. And then when it's used, when feedstock is originating from animal manure, or human feaces, like I did, I discovered that after pyrolyzing it, the phosphorus content, so it can actually be used as a phosphorus source. So it has more fertilizer value when it's feedstock is of manure origin compared to woody material and plant material. And maybe residue from maybe maize stock or rice stock.

Abdullah Timol 13:51

He says it has more agricultural value when it comes from a manure source basically.

Nqobile 13:58

Yes, theres more agricultural value. And sometimes I've read articles that say it can, it can be used also to absorb certain elements such as physical Hello. And also it can be used to the soil science department here they've been using it to... they put it in heavy metal contaminated sites, especially those contaminated by cadmium. And then it's able to absorb the cadmium and then they're able to reclaim those contaminated souls and then they're able to use it for plant production and stuff. and then for me, to furhter my study, I used it as a bulking agent for composting. So because as you pyrolyze you increase the C02 ratio. Whatever method you are pyrolyzing by you increase the pH and also you're increasing the porosity of the resulting biochar. So, you can see that composting with biochar you have synergism, when you add

biochar and your feedstock for compost and you put them together and you initiate the composting process, the end core compost is of higher value compared to a compost that is composted without biochar with reference to nutrients, with reference to pH and also with reference to time that we take to finish the composting process, with reference to time that you take to reach thermophelic temperature, with reference to the actual thermophilic temperature you reach to kill pathogens. So that was the second phase of my experiment where I core composted using the biochar. So biochar can also be used as a bulking agent for the composting process.

Abdullah Timol 16:55

Okay. So just want to clarify you said it's superior than using just like compost or something on its own. If you bulk the biochar, if you use it as a bulking agent. But I was doing research and a lot of farmers don't like using biochar because they say it's for the long term basically, and they want to see short term gains. So even when using it as a bulking agent, you know, you're using manures to supplemental the biochar maybe maybe. Is it still a long term? Do you see the effects immediately like the normal compost or is it for the long term?

Nqobile 18:06

I saw the effects. It depends with how much biochar you put, because I told you when you put biochar, even when you combined it with chemical commercial fertilizers, if you put it at the higher application rate, there's a tendency to lock your nutrients. In the first planting season. You actually maybe find a lower yield compared to either you positive control or it can be comparable even to your negative control because the nutrients are locked. But then they say when you're using biochar, it's preferable to use it at less than 10% weight for weight. For every 10 grams of biochar you are left with 100 grams. So for me, I use 4% weight for weight, I used four grams of biochar for every 100 grams of my feedstock for composting. So, actually, when I was going through literature, I read that biochar is good to be used alone or in combination with other fertilizer sources for which it proved that it's, it has had positive, negative and sometimes neutral responses. Also, depending on the type of so that you're using.

Abdullah Timol 19:49

So looking at biochar feedstocks, what do you think are of the best potential feedstocks that can be found just looking Maybe at the Durban or Pietermaritzburg area?

Nqobile 00:04

Durban and Pietermaritzburg?

Abdullah Timol 00:07

Yeah

Nqobile 00:13

There's a lot of sugar cane that's grown here. So you can use sugar cane. The remains of sugarcane the after milling.

Abdullah Timol 00:30

Ok. Do you know if theres a lot of alien veg

Nqobile 00:35

Yes, I talked to someone who pyrolyzed invasive plants, I think it was lantana camara. There is quite a lot of lantana.

Abdullah Timol 00:47

I'll look into that. Okay, so you basically use a very specific feedstock when you made your biochar for your experiment. What do you think would be the possibility of using maybe organic household rubbish as a potential feedstock?

Nqobile 01:17

I beg your pardon?

Abdullah Timol 01:21

If you had to use organic household rubbish as a potential feedstock, you think it would work? organic household waste

Nqobile 01:39

I think it would work but it would need to be to be separated, I think like if it's going to be fruits and fruits are put on their own. And then because people tend to, for kitchen waste, their remains for food like rice and chicken and what not? unless before pyrolysis, unless you're going to mix it all and make it into a homogeneous mixture. So that you won't have patches of, these nutrients, a lot of nutrients here, there is not much nutrients here. There's a... I don't know if you understand what I'm saying. So for instance, for instance, what they do in in Cape Town because they use kitchen waste, like they collect from restaurants, everything that gets thrown

into the bins. So they actually have the best state where they separate, they remove the bones and everything and then they they mix everything together to make sure that they have a homogeneous mixture. Before they feed to the black soldier fly lava witch I would think would be the same thing when you're looking into pyrolysis that you also mix everything together homogeneously before you try to take it to the pyrolysis process.

Abdullah Timol 03:27

Okay, so so on a similar note, um, what do you think the suitability of using let's say garden refuse collected from residential areas?

Nqobile 03:49

Yeah, it is suitable is suitable.

Abdullah Timol 03:58

Okay. Do you see any problems with choosing something like that? any issues that might arise

Nqobile 04:08

from using garden waste? Maybe accessing it. As long as you have the means to access it. Because also one of the one of the things I always question about the our biochar, I'm saying our biochar that it's it's not needed in so much quantities. In as much as after pyrolyzing, you reduce the yield to maybe up to let's say, for example, If you use 300 degrees at two hours, you reduce the yield to maybe 60%, 55 maybe 60%. But you don't use a lot of biochar in the field. So, yes, so, that will come back to how much feedstock you will need for a particular purpose. For instance, you want it for an experiment or for putting in the field, how much you would want to apply in the field. And with it is how much feedstock then you want for the pyrolysis process, considering that if you're using garden refuse, it has got no nutrient value, actually. So if you're going to put your biochar you're gonna treat it with an external fertilizer source, an organic source or an inorganic source. Okay, because now you're biochar will be acting as an amendment, more of a soil amendment and less of something that adds nutrients to the soil, but something that holds the nutrients and releases them slowly, for instance, when applied in soil such that the nutrients don't get leached. For instance nitrates, they don't get leaked easily. So, it's just there to, to absorb your nutrients and release them slowly to match the crop, as the crop grows and it needs nutrients, the biochar shall be releasing them slowly and as they are released it with enough nutrients that the plants at thus preventing loss, however, not necessarily meaning that the biochar is getting the nutrients. So I always I always have a question also on

that, that in as much as we say biochar is a nice thing, but how often are we gonna put it in the soil? Because also, they say it takes several years to be great, or even up to millennia?

Abdullah Timol 07:36

Sharon was also having the same concerns. She mentioned the exact same thing. She said that we haven't really seen the effects of the long term. You know, what long term impacts it has on soil. So at this point, you know, it's hard to see what it's going to do in the future. Okay, so you kind of mentioned this, but using, I think you already answered this. issues that could be experienced by using these feedstocks. Oh, yeah, I'm just you know, looking at how school and and gathering. I think you're the sound is the sound is okay. Now Hello. Hello. Hello. Hello. Hi. Can you hear me now?

Nqobile 09:16

Can you hear me as I tried to move and thinking maybe its my side

Abdullah Timol 09:23

hi. Can you hear me now?

Nqobile 09:28

Yes, I can hear you.

Abdullah Timol 09:30

Okay, so lets hope it's a bit of a better connection. So I was just about to ask you with regard to using garden and household rubbish. As I asked in a previous question. Um, you said it impacts the quality of the biochar. You can't just use it. After producing it you can't just use it on anything.

Nqobile 09:58

I was saying that I think there is need for, for consistency. if you had to use the household one, it has to be properly mixed, so that there's homogenity. And for instance, for instance, I was thinking that if I, if I collect, if I collect from one house or from one household today, and then I collect, like make biochar and collect from the same household next week, it might not be the same in terms of characteristics. Because these people have eaten different meals maybe. Okay, but then maybe to just go down you would have to just initially characterize your feedstock before pyrolysis so that you can always have something to fall back on, that it was household feedstock, however, it had different characteristics. And I'm sure there are ranges that either

way I have never seen I've never searched literature for the ranges for household feedstock, ranges for for the characterization of nutrients or for pH and all those things. But I'm pretty sure there is the range within which they all fall, but it will just be different. Just taking feedstock from from one household will be different from the feedstock from the next house . Just depending on different people who would eat different things.

Abdullah Timol 11:53

Okay. So as you said that, because, you know, things are going to be different from week to week from household to household, there's no consistency. There's also a lot of chance for contamination, so nothing is consistent at all. Do you think there's a way of reducing contamination or maybe even separating the feedstock at source, do you think such a way exists? Maybe?

Nqobile 12:36

Yes, I would think that the best way would be source separation. So if you're having fruit peels and fruits residue in this plastic, we first categorize the waste and then we say this is the plastic bag for fruits this is for what...,this is for what....etc. according to the criteria that you throw in. Just like the way we do inorganic and organic, so maybe that will be something kind of similar to that. Because I've seen that some people when they pyrolize they go to... there was a paper I was reading I think it's from Kenya, they go to the vegetable market. And they pick all the the tomatoes, the almost rotting tomatoes, the peeled banana peels, the pits of the apple and then they mix them together. So it's more like it's only fruit that they're using in their feedstock. So when it's now household, it's a combination of the fruits and the food and some other things that are not even food that will need to be separated.

Abdullah Timol 14:21

Oh, yeah, I can guess what some of those things are. Okay, so the next question. So during biocharproduction. Ideally, you'd want a feedstock that's dry, completely dry. So what do you think is the best way to dry feedstocks?

Nqobile 14:44

Okay, I think now it would, it will depend. Drying it using mechanical means is quite costly because you need an energy source that you have to pay for. But it's fast. However, drying using airdrying or sun drying or just spreading on maybe what you call this, slice drying beds and you allow it to dry naturally. It will be cheaper, but not very fast. Sometimes you don't get

a very dry material comparable to where you can control that time drying it using this temperature in the temperature is evenly distributed throughout your feedstock, you know that your feedstock has been subjected to the very same conditions and its dried very evenly. Okay. And also, when you're looking at quantities, if you've got large quantities, the mechanical way will be the better option to take because it won't be tedious, but if you've got just a few samples, you can just air them and you're good to go.

Abdullah Timol 16:21

When you say mechanical, what do you mean like a dryer, a giant dryer?

Nqobile 16:27

Yes. So, I saw this one in bio cycle they had a rotary, like a kind of like a rotary like a drum you see where It would rotate and they would force air into and then it would roll like this. and then they had an inlet and an outlet valve. So the inlet valve would flow in the and then the rotary rotates, and then the outlet valve will blow out the air from the other end. They did it at I think 200 degrees and they had a heated residue that was really dry, the moisture was reduced from 55 to 5%. Yeah, it was very, very dry. And the temperature was also quite high. So my main worry also was because of those items we are likely to lose nitrogen since the feedstock was of fecal origin, they may be some nitrogen that could be lost....

Abdullah Timol 18:00

Oh, I've never considered that. In thedrying process, you could lose nutrients

Nqobile 18:08

If its of nitrogen origin, your volatiles that can volatilize at a temperature less than the temperature that you're using it will all go. So even if you find that if you analyze your feedstock before drying, the nutrients in total will be higher than your total in effect, right? Because some of the end nutrients would have been volatilized

Abdullah Timol 18:34

Okay, let's look at the biochar production process. So, to what extent do you think does the design of the kiln in itself affect the quality and yield rate of the biochar?

Nqobile 18:55

the kil? I've never used a kiln. Are you referring to the one that you can control the temparature or just the kiln where you can put firewood on the ends and then you close it and you put the feedstock in the middle of it.

Abdullah Timol 19:20

Lets talk about what you familiar with.

Nqobile 19:25

For mine, I had to... It's just a furnace that I had to manipulate to produce biochar. It's not like the pyrolyzer because for a pyrolyzer you'd have the place where you put your your feedstock and then you switch you switch it on, and then you have somewhere to collect your gases, you have a condenser, and you have your tars dripping out. So its a whole closed system to prevent your pollution. You prevent evaporation of your vapors and everything. So for me, I just had to use a, what do you call it? a furnace, a muffle furnace. Yes, with crucibles. So I could control, I could control the temperature, I could set the temperature, if I wanted to be it 300 degrees, I could set it to be 300 degrees. And also to make sure that the temperature, because this set temperature was the temperature I could view from the outside, when I could also insert a thermocouple inside, close it and make sure that inside it's also really 300 degrees. But it didn't have a system where it could collect the, because when you pyrolyzing they are those, the soot that comes out, I just had to open the what do you call this, I've forgotten the name of it, the one that takes the soot outside, I just had to open that extract the soot outside, which was not very environmentally okay, because for pyrolysis, you just have to make sure that everything is contained, and you're not even causing pollution. So I just had to manipulate the muffle furnace that way, because there was no proper muffle there was no proper pyrolyzer. However, for the kiln, the kilns there was a first option for me to use a kiln at the farm. However, I did not like that idea because I wanted to use different temperatures 300, 400 and 500 degrees. So using that kiln you had to put firewood on the outside on the outer part and put your feedstock inside and then close. So you had actually no control over the temperature itself. So that was my main challenge that if I wanted to, how would I differentiate between 300, 400 and 500 using that kiln, but at least for this one, I could set the temperature and make sure that it's at 300 or 400 and 500. So could I ask how did the quality of the biochar turn out in the furnace Okay, so in the furnace, I pyrolyzed at 300 degrees, 400 degrees and 500 degrees. So at 300 degrees. At all temperatures, I found out that increasing the residence time resulted in the burning of the biochar. Maybe for me, it was because of, it was mainly because of the residual

larvae that had proteins and fatty and oil. So I thought that it heated up faster. However at 300 it pyrolyzed optimally at 60 minutes, then at 400 at 45 minutes and 500 at 30 minutes. Which was a lesser time compared to pyrolysis that I see in literature for other feedstock where pyrolysis goes up to two hours, some pyrolyze for even more than two hours.

Abdullah Timol 23:53

And do you think that doing this in the furnace at such a short time, do you think it affected the yield by a lot?

Nqobile 24:10

Yes, it did. Because most of the most of the material that was supposed to be converted to biochar actually got converted to ash, ash has a lower bulk density than biochar. So, it ultimately resulted in a very low yield. And they say that everything thats ash is not considered biochar. Actually they say if your biochar, actually they say if your biochar has an ash content of I've forgotten. the percentage that they say your biochar should have an ash content of what for it to be biochar. If the ash content of your biochar is more than that, then it's not biochar. Its something else I don't know what that will be.

Abdullah Timol 25:03

So you're seeing us feed stock rally as your.... I mean, you use the soldier ant larvae as ur feedstock. Am I right?

Nqobile 25:16

So it was residue from the decomposition of fecal matter from New UDT toilets by black soldier fly, can I type it for you? Residue from the decomposition of fecal matter from UDT tech by black soldier fly larvae

Abdullah Timol 26:48

So I wanted to ask. So you use this as a feedstock obviously, because you obviously want certain characteristics to be in your biochar.

Nqobile 27:01

And also this was this was marrying to, to the overall objective of bio cycle, and they wanted to close the whole loop. Because the problem here was, the whole problem was when we collect this, this fecal matter from the UDT, what can we do with it? We can feed it to the black soldier

fly lava, okay, when we feed it, but then there's a residue that's left behind, we can't just dump it anywhere. what can we further do with it? That's where I came in.

Abdullah Timol 27:41

Okay. So do you think that certain feed stocks, you know, looking at characteristics and whatnot, does it depend on what you want from your biochar? Or do you think that just you know, at the end of the day, certain feedstocks are just completely superior to other feed stocks?

Nqobile 28:06

I think certain feedstocks are superior to other feedstocks because of the inherent characteristics. For instance, woody materials, they there's no way they're gonna have a nutritional value. And then I just wanted to add, theres is also a lady doing her biochar on potato peels from those people who do chips. So when they peel the potato peels, theythrow it away. So she took those and dried and she made biochar from there as well, from the potato peels. And I thought, mostly she she did that because it's more like, it's the same thing. It's just potato peels. It's not mixed with anything else. It's just potato.

Abdullah Timol 29:12

Okay. So you mentioned that in order to ensure like, preparing your feedstock, you know before production, the two things you mentioned was source separation and drying. Can you think of anything else that could be done to a feedstock that will better prepare it for the production process

Nqobile 29:42

For the production process. Okay. I'll talk of mine. I'll talk of mine. To be used for agricultural purposes, and For the purposes that I wanted to initiate my composting process, I wanted my feedstock for composting. This is now feedstock for composting, to have an initial cpn ratio of at leats one. So I saw that after pyrolyzing my biochar didn't even go up to 10 as to one. Why, because fecal matter doesn't have carbon compared to woody material, which has got carbon. So I was thinking that maybe it was going to be a wise idea to mix certain ratios of the residue, and a woody residue, for instance, sawdust, and then mix them together, crush and mix them together before pyrolyzing just to boost the cpn ratio. But I think it now goes to what you want to use your biochar for. So you can mix... For me at the end of it, yeah, you can mix 2 feedstocks, depending on what you want to achieve, to see if I mix in the ratio one is to one of this, this this feed stock has got this advantages but it's lacking on this, can I counter

disadvantages with this feedstock? and can my resulting biochar have that advantage without compromising the other things that I want in my end result. And then you can maybe compare it with the residues that are pyolyzed alone without additions and also when they are added in different ratios.

Abdullah Timol 32:12

So the next question I wanted to Ask was, so you've used as you said, a furnace to produce your biochar, but as you said theres many methods. Theres pyrolysis, gasification or even pit burning. Do you think that any single method is superior to other like maybe pyrolysis is the best or...

Nqobile 32:48

Okay when you say pyrolysis, do you mean fast pyrolysis, slow pyrolysis, hydrothermal carbonization? For pyrolysis, I saw theres slow pyrolysis and fast pyrolysis and then there's that one called hydrothermal carbonization, the one that they normally used for for making material with very high surface area to be used as an adsorbent.

Abdullah Timol 33:20

I haven't heard of hydrocarbon carbinization. Okay. So are you saying that the production method is dependent on what you want from the feedstock?

Nqobile 33:40

Yes, I think it depends to what you want your biochar, what properties you want your biochar to have. For instance, I think I'm biased because I'm an agricultural person, I've seen that by feedstocks produced at low temperatures are more important, not important but more suitable for agricultural purposes. The ones produced at higher temperatures are more suitable for carbon sequestration, especially, especially if they're, if let's say, of animal origin. chicken manure, pig manure, if you pyrolize maybe at 300 degrees for two hours. It's more beneficial for agricultural production, for the addition of nutrients and so forth. With all the other advantages of porosity, high pH if added to lessen the acidic soil, Improving the soil structure, offering habitats for microbes. But if if you pyrolize at high temperatures that the woody material is more important for your carbon sequestration.

Abdullah Timol 35:13

Okay, it just depends on what you're trying to achieve at the end of the day. okay, so the next question is, let's say someone decides they want to use biochar at their house, at their backyard, what they think would be the simplest method to produce biochar. Regardless of quality...

Nqobile 35:48

To use already made biochar? No, the simplest method to make biochar using whatever feedstock is available to you Oh, to make biochar? They can make a little furnace. Where, maybe they can take, I tried to make one for myself, but I wasn't successful, where you can buy like a, like a sheet of steel. And put a smaller one inside of a bigger one. So the outer, the space between the inner and the outer one is the space where you put your, your heating material, for instance, if you have wood or anything, and then the inner material is where you put your feed stock. Okay, so you just put one inside of the other, you put the material that you're gonna use, you're ignited to reach a certain temperature. And then at the bottom here, you close, and then you put your feedstock and then you close again, like a mini kiln.

Abdullah Timol 37:20

Okay, I think I know what you're talking about.

Nqobile 37:22

I don't know if that makes sense.

Abdullah Timol 37:24

It makes sense. I was looking into that.

Nqobile 37:26

But you also you also have to have a little hole to allow the, what you call it, the smoke to come out. Okay. But in as much as pyrolysis is a process that doesn't need oxygen or limited oxygen, I wouldn't know how you would manipulate that to prevent backflow of air, prevent everything to just burn up. So like in like a mini, like a mini kiln, where you have a bigger outer sheet thats circular like this. And then you put a smaller one inside, the space on the outer one provides you with heat, heating from the outside going inwards

Abdullah Timol 38:22

I was actually thinking of making one like that, iwith drums, putting a small one inside a big one

Nqobile 38:29

Okay, I can send you an image of one that we have here at the farm. It's actually like a drum like this, do you know a drum? Yes, like a What can I say? Like those big drums, they had that drum and the smaller drum inside. So the space between the bigger drum and the smaller drum, that's where they put the firewood. The one that I said I can't use it because I can't control the temperature, thats where they put the wood, they ignited the wood and then they they close the top and theres an outlet valve that allows the allows the smoke to come out and theres a space they can continuously feed more firewood if the firewood is getting finished, you can continuously feed in and close it up. So this inner part is not exposed to air, only the outer part is the one that's exposed to air and then they close the the outer part. So everything that happens, and also my concern was that so if its heating from the outside going inwards, Will I not have that situation where my outer part gets heated more than the inner part because there is no equal distribution of heat. Because we are not constantly checking this thing. So material that was where it was, its going to be where it was until the process finishes. But I felt like there are some places where the heat is hitting more than some places, for instance, the middle part. Look, I thought it was going to receive less, less heat. But I think I can send you that that document also, where they made that kiln there at the farm there. The guys from engineering,

Abdullah Timol 40:26

that will be great. And in the same regard them Do you think that certain methods are more environmentally friendly than others?

Nqobile 40:38

Yes, yes. Yes, definitely. I really, I really beg to to say that the method that allows air to just...., because initially also when I wanted to go to pyrolysis in PRG , the technician, they actually asked me that, how are we gonna get rid of the gases that are going to be produced? Because it's, we need to know where the gasses are going. So there is also a video I watched on YouTube, the video from lemon, where you demonstrate the pyrolysis process with HIS student. His is actually a very closed system where there are no fumes anywhere. So the contents, the liquid condenses, collects into a jar that they collect and then.... Yes, it's really closed. There are no loop holes. So now, if the gases just go away, we don't know what's in those gases. Where do they end up, if people inhale them. What's going to happen to them? In as much as you can have protective clothing, these gasses are going into the air, they get transported over long distances.

Abdullah Timol 42:23

So you think that using like, let's say that drum you're talking about. You can't release gasses. At a simple Look, it might look environmentally friendly, at the end of the day, you don't know, what gases are coming out of it?

Nqobile 42:42

Yes, but someone was saying that as long as you do it in an open space, like the farm, like an industrial area, so I think they were taking advantage of that. At the end of the day, they are just humans everywhere. So whatever.

Abdullah Timol 43:05

open area Yeah, I'm gonna ignore the next question because pretty much went over it. It's just using different feedstocks, you end up with different characteristics. So I think as you said that depends on what you're looking for. You can manipulate the end results by mixing it stocks or using a different method of production and so on.

Nqobile 43:36

Okay

Abdullah Timol 43:45

To the best of your knowledge in let's say, in PMB and Durban. Do you know of any local companies producing biochar. There is one, I've forgotten its name? Not Vuthisa by any chance?

Nqobile 44:10

Yes. Yeah, thats the one I actually wanted to use their kilns. I know they've got kilns. But Ibut I think there were some problems accessing it and stuff.

Abdullah Timol 44:31

Yeah, I actually interviewed the guy last year. I think he makes like very, very awesome kilns but he puts a lot of work in so it can be a bit pricey. Okay, you said that the companies you're talking about, agro protein and other one, those are based in Cape Town.

Nqobile 45:03

Agro Protien is based in Cape Town, Bio Cycle was here in Durban, but apparently they closed. they are no longer operational. But Agro protein is still operating.

Abdullah Timol 45:20

Okay. Are you part of the project with Mr. Dav Still?

Nqobile 45:32

The Vulindlelar one? Yeah. not really

Abdullah Timol 45:44

I plan on interviewing him also. So I just wanted to get some information on that also .

Nqobile 45:53

The person who is in direct contact with him is Sharon.

Abdullah Timol 45:56

Yeah, she told me about that. So I got some good information from her on that. When implementing a biochar supply chain? Um, what would be some of the core functions to consider? you know, the most important areas to consider?

Nqobile 46:29

Yeah, I think you'd consider the source your source of your feed stock. And then you'd consider transport costs, how it would cost what it would cost you to transport the feedstock from wherever you're taking it. Where you are accessing it. And then other costs, like feed productions like drying. And, what do you call this thing? For instance, if you're using a, if you're using it a furnace, how much energy are you putting intothe pyrolysis process itself?

Abdullah Timol 47:24

you need to get more than you use? Okay, I'm looking at the next question. Considering that, you know, biochar, one of the major uses of it is as a carbon sequestration tool, what considerations need to be taken into account when implementing a supply chain to ensure that the supply chain itself is environmentally friendly?

Nqobile 48:04

Thats questions of supply chain? My, my, my economics background is very poor. Can you please repeat the question?

Abdullah Timol 48:18

Okay, I'm sorry, can you just give me a minute? Just want to tell this guy to give me some quiet. Thank you. I am back. Okay. So the question I was asking was that if you implementing

a biochar production line essentially. Considering that, you know, one of the major uses of HR is as a carbon sequestration tool, what considerations need to be taken to ensure that it's environmentally friendly, the production itself?

Nqobile 49:16

Okay, so I think like I said, you need to make sure that the, the way you produce the biochar itself doesn't pollute the environment in any way. Because we are trying to use the end product to fix the problem. But at the same time, I think we shouldn't, the process itself shouldn't pollute the environment. We shouldn't produce greenhouse gases through the process of biochar protection. We shouldn't solve a problem by creating another problem.

Abdullah Timol 50:00

Okay, so attaining, feedstocks or biomass, what do you think are a few large scale sources that could be used as a few large scale sources of this feedstocks?

Nqobile 50:25

Sorry

Abdullah Timol 50:26

Um, what do you think are a few biomass feedstocks, that a large scale that there's a lot of

Nqobile 50:42

Sugar cane. maize stocks, invasive plants, sewage sludge. Sewage sludge, I really feel sewage sludge is a problem. Because especially now that where it used to be dumped off, the land there, it's getting full and actually the municipalities are facing challenges of how to get rid of this large quantities of sewage sludge, and we can see that that they're even trying to come up with these decentralized wastewater treatment plants like ways of like the UDT's that don't use the, the centralized system, but Sewage sludge is also one of the major feats took that can be used for the pyrolysis process. But in as much as I say that the bulkiness of, or the abundance of a feed stock, I always I'm always coming back to this. Does the bulkness, we need to be careful, we going to be getting feedstock in bulk, which means we're going to produce the biochar also in bulk. Are we going to use the biochar in bulk

Abdullah Timol 52:29

And also the transportation of all these bulk feedstocks, they might cause harm to the environment as well if you're not careful.

Nqobile 52:39

Yes, especially if the feedstock is like of fecal origin, where you are really concerned about, about pathogens and stuff like that.

Abdullah Timol 53:02

Next question. Um, do you think that any existing sectors or businesses can integrate biochar production into you know..., instead of starting an entire new biochar production line of business, do you think that it's possible to integrate biochar production into other businesses or sectors?

Nqobile 53:32

Yeah, I think so. You can integrate it into composting. You can, I don't know if it's possible to make biochar fertilizer, like mixing biochar with a source of fertilizer in making a fertilizer that is good both biochar and the fertilizer. So at the end of the day, we're looking at putting it as a fertilizer and at the same time using it as a soil amendment.

Abdullah Timol 54:22

So you said integrate composting into a biochar fertilizer, do you think is possible

Nqobile 54:30

There is what they say. When when I was going through my my literature review, they were saying the benefits of using biochar on its own compared to let's say, let's say you've got biochar. So you use biochar on its own and you use a compost on its own, the benefits are exceeded by using a composted biochar compost or adding biochar in compost separately. They say, taking biochar and adding it to your composting feedstock before initiating the composting process actually has advantages like in terms of physical chemical characteristics of the finished compost compared to taking biochar and your compost and separating them, after you've already composted already on its own biochar on its own, and then you combine and then you put it in the soil. So essentially just charge the biochar with the compost. Yeah, charging the biochar with compost, they were saying that they are synergistic. Theres synergism when you're are doing the composting process, initiating it with biochar. The biochar is advantages that it gets from the compost, and the composted advantages that it gets from the biochar, the composting process on its own, you shorten the composting period, because your compost pile heats up faster and at a higher thermophilic temperature, so you're gonna finish

your composting over a shorter period of time than the normal composting process. So you're gonna be moving more batches over a shorter period of time. So those kind of things.

Abdullah Timol 56:40

Okay. So the project that you're working on, you know, what? urine, urine diversion, dry toilets? So your'e saying that the municipality are having trouble dealing with this? So so you want to turn this into biochar as a way of producing biochar and dealing with this problem. what is the level of collaboration that is required between you know, the parties producing the biochar and the government in such an endeavor?

Nqobile 57:25

For me, because this is a private company. It didn't involve the municipality., the only thing that they had was that the municipality already had failed, because the municipality built these toilets without a plan of how they were going to empty these toilets. So people started just to say, when they pit gets full, they will just dig another pit on the side and drag that dirt or fecal matter into the next hole so that it creates space, until they can't create space anymore. And when these people approached them, they were more than happy to say you can take our poop and do whatever with it. But I'm not quite sure if there's any, any collaboration with the government.

Abdullah Timol 58:29

So if biochar is being produced on a massive scale, and what would you think would be the most, you know, effective, and financially viable method of production that can be used to create it on such a large scale?

Nqobile 58:47

The most financially?

Abdullah Timol 58:50

Financially viable method of production to produce biochar on a large scale Oh, its alright if you don't have experience in that sector?

Nqobile 59:14

I don't know.

Abdullah Timol 59:17

That's fine. Okay, so let's look at the next question. So this question, yeah, it says your own personal opinion, right. So biochar, it has a large range of capabilities and can be used in many, many sectors including climate change mitigation. So why isn't biochar more popular thing? Why has so many people not heard of biochar?

Nqobile 59:54

I think it's lack of education on the subject itself. Because obviously, people can see that climate change is there and it's real. But I think it's just lack of education on on the, on the subject. And as well as is I think we as scientists, when we do our scientific work, we do biochar or whatever.. And then we do our experiments over three years, and we see that it has reduced the production of greenhouse gases and then it's all scientific, and no one interprets this things. The ordinary people to the ordinary layman. Its just all science and all science, nobody actually goes to look at them. If I'm not doing biochar, I won't go look for anything. So I think there is need for more education on these topics and more discussions and to get people engaged and to get them to talk about this things. Get them or them to ask questions and let the people who have done the research answer them, answer those questions. I think maybe it will help in making this biochar popular, but I it seems like maybe from the academic point of view, I've seen that it's becoming more popular.

Abdullah Timol 1:01:56

Okay. It's becoming popular maybe but at a very slow rate.

Nqobile 1:02:11

Yes and I think also the other thing is the concern of saying like what I'm saying, I'm also doing bicochar but I'm concerned that if you continuously pump the soil with biochar taking into consideration that we say it takes millions of years to degrade in the Soil, does it accumulate in the soil? Does it break down to tiny tiny particles? If this breaks down does it get transported by water, verticaly, lateraly, does it ended up getting deposited into the seas? What effect does it have in the seas, on on the seabed? Like so, will it settle as sediment? will it be in suspension in the water? What effect does it have on the aquatic life? What effect does it have on the soil and the microbe population

Abdullah Timol 1:03:15

A lot of unanswered questions that need to be looked at?

Nqobile 1:03:20

Yes. So before it even becomes that popular, I think people already have a question as to we are putting it where is it going? Like I had a conversation with a guy from chemistry, where he was saying that biochar is used to, adsorb, adsorb what do you call this, let's say for instance, if it absorbs heavy chemicals, and I'm thinking so if it adsorbs heavy chemicals from the soil, or whereever, are you going to take the little pieces of biochar that is adsorbed and what are you gonna do with it, because it's now absorbed something? So it's now like a compound? So what are you gonna do with the biochar that has absorbed whatever. He said, maybe incinerate it. So I didn't quite get like we how are we going to end up with? Yeah, we have made. We have taken the straw that's accumulating in the fields. And we made the biochar, we've solved this problem. And we found a use for it, but at the end how are we going to? We also have a problem of heavy metals. So we have used it Yes, it's fine, but how you gonna dispose off that which has attached to the biochar in a sustainable way? I think maybe that's the questions that don't have answers.

Abdullah Timol 1:04:59

Okay, to the best of your knowledge, do you know any companies selling biochar on a large scale? Or just selling biochar? Maybe?

Nqobile 1:05:20

I didn't come prepared for this.

Abdullah Timol 1:05:25

To the best of your knowledge, as I said, it's okay. If you can't think of anything.

Nqobile 1:05:32

I know, but I forgot them.

Abdullah Timol 1:05:35

That's fine. So this question here I was going to ask, but I'm not sure if it's appropriate anymore because as you said, biochar produce for its characteristics, you know, you manipulate the production. Do you know if any classification. Do you know if any classification or grading exists for different types and qualities of biochar? Any way to grade or classify already produced biochar?

Nqobile 1:06:32

No.I haven't come across that, I have just come across the general classification of physical, chemical and morphological. Not the one that I've seen for sewage sludge where they say there's grade a or grade B. No, I haven't seen, I haven't come across that.

Abdullah Timol 1:07:00

So, do you think that the biochar produced to get different characteristics? If you had to sell this biochar, let's say you know, if you produced it specifically for a certain task, do you think this would affect the cost of it, if it had to be sold?

Nqobile 1:07:26

If you produce it for a particular purpose, would it be sold at a different cost? Yeah, Yes, I think so. Because it will go down to the pyrolysis process, of course, if you use a higher temperature, it would mean you would have invested more and more of your energy and I think it would cost more and also it will depend on your feedstock, how you got it and how much you got it for, but most I think most importantly in the production process, if you produce it at a higher temperature, it will cost more than the one produced at a lower temparature

Abdullah Timol 1:08:20

considering biochar from a commercial perspective, which sectors do you think can most benefit from biochar

Nqobile 1:08:30

Agriculture sector.

Abdullah Timol 1:08:39

Okay. So, one of the uses of biochar is a feed supplement. To what extent can feedstock products be used as a feed supplement and what quality and characteristics are required

Nqobile 1:08:57

As a feed supplement. A supplement to feed animals? Like using biochar as a feed for animals.

Abdullah Timol 1:09:10

They mix it with you know, with the animals feed with the grains or whatever, and apparently it's supposed to help promote healthier digestion and things for the animal.

Nqobile 1:09:25

I have never heard of that.

Abdullah Timol 1:09:29

I also don't know much about it, but I came across it a few times during my lit review,

Nqobile 1:09:34

okay, okay. Yeah, I had never heard of that. But it sounds interesting. I'll also look it up.

Abdullah Timol 1:09:40

The one guy I was talking to actually told me it could help with human digestion even though I don't want to try that.

Nqobile 1:09:51

Okay, but it is possible because it's just charcoal like. Actually Some people eat charcoal if they have stomach problems. At home, My mom used to tell us to eat charcoal if your stomach is hurting,

Abdullah Timol 1:10:09

maybe its like the same thing, you know? Yeah. So I'm looking at that. Okay, we're almost at the end, there's two more questions. I'm looking at regions such as PMB and DBN. Other than the UDT toilets? Can you think of any other place it can be utilized to help local communities? How can biochar be used to help local communities? Other than, you know, the UDT that you've already mentioned?

Nqobile 1:11:16

No, maybe not actually helping them in the sense of taking the poop from their toilets. But then providing it back to them as an agricultural amendment for farmers with poor soils, the ones that that want to improve their soils and the ones that can't afford it..., that have got problems with enriching soils and if you use fertilizers efficiently then maybe just plowing it back into the soils or thinking of using it as a fuel but then in South Africa most people have electricity almost all the time. So it wouldn't count. Maybe in rural areas it might work Yeah, maybe. Yeah, maybe where there is no electricity. But yeah, maybe where there is no electricity. Like I've seen in Kenya. They actually use this this to braai, even to cook a whole meal with the briquettes made from from biochar from fecal sludge. so yeah.

Abdullah Timol 1:12:34

Okay, and then the last one. Okay, I think you've already talked somewhat about this. What are your thoughts on using alien vegetation as a potential feedstock? And then do you know of any

specific alien vegetation species? The potential of you using alien vegetation as a feedstock, specifically in the Dbn or PMB area?

Nqobile 1:13:10

I think it's quite, it's quite a good initiative, because it's a problem on its own. And we've seen the municipality trying to send people to clear it off but before you know it, it's back again. So if there is way that it can be used is as a feedstock for the pyrolysis process and where the biochar can actually be used for a good cause. I think it's a good way for solving a problem that we already have. Because at the end of the day, we need the, I think, most of the time when they cut down those alien what what, they allow them to dry and burn, which actually causes pollution. So if there is a way that we can use them to provide a product that can be used in a positive way, that's actually a good thing. We have a problem and we're solving a problem and also solving a problem rather than just burning it in just just emitting smoke into the air pollutants into the air.

Abdullah Timol 1:14:34

Okay. I think that's the end of the interview.

Nqobile 1:14:47

I'm sorry, I couldn't answer the supply chain questions.

Abdullah Timol 1:14:54

I got a lot of insights from the production side. So that's awesome. Yeah,

Nqobile 1:14:59

I think also the production side is really where my strengths are as I really did the production

Abdullah Timol 1:15:09

thank you very much for your time. Thank you for your time. I'm going to email to you the informed consent . Alright, thank you and have a great day.

Nqobile 1:15:38

Okay and if it so happens that I forget to send you this kiln please do remind me, also if I just come across some nice articles I also send them to you. Bye

Appendix H: Interview 5 transcript

Name :Douw Harilal

Occupation: Horticulturist

5. How did you get exposed to biochar and what is your current experience with it?
   I was introduced to biochar by my friend and mentor Richard Pocock. My first experience was to use it in a small aquaponics system to filter the recirculated water and then use the biochar that was charged with the organics into soil to encourage and sustain the growth of micro- organisms that are vital to soil health.
6. In your opinion, while biochar has many uses, what are some of the areas that it can be best applied in?
   Water filtration in aquaponics and aquaculture systems, in soils to provide a structure to protect soil micro-organisms from extremes of temperature and desiccation and hereby ensure proliferation of beneficial micro-organisms.
7. Biochar Feedstocks
   3.8. What are some of the potential feedstocks that could be utilised in the Pietermaritzburg/Durban region?
   Any agricultural residue in the form of maize/sorghum and other crop stover. nut shells, corn cobs,
   woody material from management of alien vegetation especially but not limited to wattle, port Jackson willow, off cuts from furniture and pallet manufacturers.
   in all instances it is crucial to endure that the feedstock is not contaminated in any especially with chemicals and paint.
   3.9.What is your opinion of using household organic rubbish as a feedstock? Please, elaborate on the suitability of this as a feedstock
   I am of the view that organic household waste is better composted than pyrolysed. . Soils particularly in KZN are extremely depleted of organic matter and are in most cases less than 5% whilst the optimum is in the order of 20%.
   composting also lends itself to coping with the huge volumes of solid waste generated by households and industry in a manner that cannot be matched by pyrolysis. .
   3.10. What is your opinion of using of using garden refuse collected from residential areas as a feedstock, elaborate on the suitability of such a feedstock? Please, elaborate on the suitability of this as a feedstock.

Here again, composting is the favoured option for reasons stated above.

Further, feedstock should as far as possible be homogenous to ensure a uniform biochar that has he required characteristics to perform as water filters, restructuring of soils by protecting and encouraging the proliferation of soil micro- organisms that are vital to soil health.

3.11. What are some issues that could be experienced by using these types of feedstocks?

Feedstocks that are homogenous result in biochar of a quality that can be assessed critically.

Randomly collected material lacks homogeneity and will result in a sub- standard biochar.

3.12. Feedstock contamination could be time consuming and costly, even municipal garden refuse dump sites are often found to be highly contaminated. Please describe ways to reduce contamination and ways of separating contaminants.

This is indeed a huge problem.

Mycoremediation is a low tech method of safely breaking down contaminants especially those of a chemical nature.

Paul Stamets and Tradd Cotter are two world renowned mycologists who are in the forefront of mycoremediation.

Mycoremediation works to remediate polluted water, soils and woody biomass.

The process of mycoremediation works best with large scale composting of municipal refuse.

3.13. What would it take to implement a separation at source approach to feedstock collection?

This is an ideal scenario that will work in the elite areas of the country and is directly related to the socio economic demographics of the country.

Waste collection in most parts of the country is tardy at best and non-existent at worse.

A potential solution lies in co-composting domestic waste with sewage sludge that produces a high quality compost that is effectively utilised to boost food production.

This approach is being used in Switzerland and is worth investigating as separation at source will only address the problem on a miniscule scale.

3.14. Ideally, you'd want dry feedstocks for biochar production. What is the best way to ensure that feedstocks are dry? Let them dry naturally, use a dryer, find quick drying feedstocks, other approaches?

Feedstocks of different types need to be treated differently.

Agricultural residue like stover is fairly quick to dry by leaving it on the field to dry.

Using energy to dry biomass cannot be justified unless the energy/heat source is from a cooling process and will be exhausted into the atmosphere. Chipping woody biomass is an option as it allows for the material to be sun dried more efficiently.

8. Biochar Production Process

7.3.To what extent does the design of the biochar Kiln affect quality and/or yield rates of the end product?

Kiln design is important and is directly related to scale. More importantly, temperature is the factor that determines the quality of end product.

Kiln designs that allow for the collection of the liquid wood smoke adds another dimension to collect a by-product that can be used in agriculture to enhance crop protection and yields and as a wood preservative.

7.4. What feedstocks are superior to others when it comes to the production process? Please elaborate!

Woody biomass especially that derived from alien vegetation removal is most appropriate as it addresses several environmental issues whilst yielding a valuable end product.

Heat generated from woody biomass that has to be pyrolised for extended periods is a valuable source of heat energy to dry additional batches of biomass for pyrolysis, heating of water for community use, heat source for community cooking.

7.5. What methods of preparing feedstocks beforehand may increase the efficiency of the production process? To what extent could preparing feedstocks beforehand affect the end product quality/yield?

Agricultural residue in the form of stover is best allowed to dry on the fields after harvest. Drying can be expedited by covering the residue with black plastic to solarise thereby using the sun's energy for drying.

As explained above, chipping of woody biomass and allowing it to sun dry is a

very efficient way of pre-treating material.

If the heat energy from pyrolysis is not being used to cook meals or heat water, it can also be used to dry biomass.

7.6. There exist many forms of biochar production, including pyrolysis, gasification, pit burning, etc. What methods of production are superior to others when it comes to quality and volume?

The choice of method will depend on scale and available resources. Both pyrolysis and gasification are suitable options for bio char production on a large scale.

Pit burning is a low tech low cost method that is usually used in rural areas as it literally involves the digging of a hole to carry out the process.

All processes need to be carefully managed to ensure that fires are properly contained and does not spread to property thereby causing damage.

7.7. What would be the simplest method of producing biochar for someone wishing to produce it for personal usage? (a method that allows them to do it in their very own back yard)

a small unit fabricated from drums and a chimney or in a peri-urban or rural fire pit will be the most cost effective method.

more recently, the use of rocket stoves is proving to popular as it uses twigs and small branches which in turn reduces the felling of mature trees.and the end product is a quality biochar.

7.8. What methods of production are more environmentally friendly than others?

Pyrolysis or gasification are the most environmentally friendly options as the heat generated can be used for heating of water, cooking food, drying biomass or heating greenhouses.

The use of rocket stoves for cooking is also a viable option especially in areas that are off the grid. The use of twigs and small branches is a further advantage as it reduces the need to fell large trees for firewood.

Furthermore, what biochar production methods should be avoided for environmental reasons? Please elaborate.

Fire pits are a low tech method to produce biochar but can become a hazard if the fire is not managed and burns out of control with the potential to destroy physical structures or veld and forests.

7.9. Biochar produced using different feedstocks often ends up with different characteristics. To what extent do these characteristics affect quality and what are some of these characteristics?

I will send you a reference to a company are involved in a community biochar project using different feedstocks. They have sent the liquid smoke for analysis and I am sure that will share the results with you.

(Krishen Moodliar 0837888269 who will put you in touch with his son in law who manages the community biochar project)

8. Implementing a Biochar Supply Chain

8.1. To the best of your knowledge, what are the existing large scale biochar supply chains in the Pietermaritzburg and Durban region? If there aren't any, please explain why not?

No large scale supply exist in Pietermaritzburg and Durban although this may change in the near future with Adrian Padt who is planning to turn macadamia nut shells into biochar.

8.2. What would be the core functions to consider when implementing a biochar supply chain?

reliability of supply, quality of the biochar, packaging, cost, quantity

8.3. Considering that one of the major uses of biochar is as a carbon sequestration tool, what considerations need to be taken into account when implementing a biochar supply chain in order to ensure that the supply chain itself is environmentally friendly and uses sustainable practises?

As explained above, industrial scale production should focus on agricultural residue like corn cobs, stover, macadamia nut shells and more importantly biomass from alien vegetation control.

Production methods that operate on a closed loop basis are a prerequisite for industrial scale production namely gasifiers and pyrolisers where the heat energy can be used for water heating, cooking food, drying biomass and heating greenhouses.

Production of biochar close to the source of raw materials and creating a demand in the same area optimises on transport and handling.

8.4. What would be a few large-scale sources of attaining biomass for biochar production and what sort of logistical considerations should be taken into account when moving these feedstocks?

The working for water programme is probably the largest generator of woody biomass for biochar production. As far as I am aware this function is outsourced to private contractors. An arrangement with the contractor to chip and deliver to a processing site is an option. Agricultural residue which is a bulk item can be loaded into huge trucks using farm mechanisation much like the sugar can farmers use.

8.5. Instead of starting an entirely new supply chain for a biochar business, to what extent would it be possible to integrate existing business services such as gardening services or other waste management services into a biochar supply chain? If this were possible, what level of collaboration would be required between these parties?

Community based small scale production is definitely an option to produce limited quantities of biochar of varying qualities based on feed stock availability. Also refer to the St Lucia community project where items like pine cones which have no other value is easily sourced for biochar.

8.6. If a large-scale biochar supply chain was created, what would be the ideal, financially viable, large-scale production method to create biochar.

Refer to Adrian Padt as he has already fabricated the units for industrial scale production and has the financials at hand.

9. Commercial Applications

9.1. Biochar is a product with a large range of capabilities in many sectors; the potential for biochar can almost be considered limitless. With its large range of abilities including climate change mitigation, why isn't biochar more popular?

The short answer is that chemically intensive farming with inorganic fertilizers and agro chemicals do not work well in conjunction with biochar. The move to regenerative agriculture will see an increase in the uptake of biochar as it is now becoming abundantly clear that a living healthy soil is the basis of a stable food production system and biochar is a crucial part of soil health as it protects soil micro-organism and allows them to proliferate.

9.2. Many gardening businesses sell biochar on a small scale to be used as a soil amendment. To the best of your knowledge, what other sellers of biochar sell it on a large scale where the quality of the biochar is good enough to use as more than just a soil amendment?

There are no large scale producers of biochar that I am aware of. Adrian Padt may

shed more light on this issue with his planned production. Other options for high quality biochar utilisation includes filtration of water especially in aquaponics and aquaculture. This is a value add process as it pre-charges the biochar with organic nutrients which sustains soil microbial life and also prevents the biochar from drawing down nitrogen from the soil in the first year or two if it is introduced into the soil uncharged.

From preliminary research, there doesn't seem to be any classification or grading on the differences in biochar quality. If a classification or grading system does exist, please explain it? Also, if there are price differences between different quality biochar products, what are they?

I am not aware of any classification or grading system .suggest that you contact the St Lucia community project to shed more light on this aspect

9.3. Certain feedstocks used during the biochar production process often give the biochar end product different characteristics. If some of these characteristics affect the price of the biochar product, please elaborate!

ditto as above

9.4. Considering biochar from a commercial perspective, which sectors would best benefit from the usage of biochar? Which sectors are most likely to buy biochar?

commercial agricultural and commercial aquaculture and aquaponics operations

9.5. One of the uses of biochar is as a feed supplement. To what extent can any biochar product be used as a feed supplement and what quality or characteristics are required?

i am aware of the use of biochar as a feed supplement but do not have enough knowledge to comment further.

10. Regional Applications

10.1. Looking at local regional zones such as PMB or DBN, what are some areas that biochar could be utilised in in order to better contribute to local communities?

the areas that will benefit most are the small scale growers of fruit and vegetable and aquaculture and aquaponics operations and the opportunity to maximise the synergy so that the aquaculture/aquaponics operations can charge the biochar before selling if off to the crop farmers.

10.2. Alien vegetation has been suggested to be an ideal feedstock for biochar production. Alien vegetation in the Durban/Pietermaritzburg area, in certain municipal reserves and other spaces is known to be a problem. What are your

thoughts on using alien vegetation as a potential feedstock in these specific regions?

As explained elsewhere in this questionnaire the use of alien vegetation is a win-win option but this needs a well- planned strategy to ensure a steady supply of feedstock. Preparation of the feedstock and the potential of using mobile gasification/pyrolysis equipment to create biochar on harvest sites.

Appendix I: Interview 6 transcript

Riaz Jogiat

Sun, 8/15 2:27PM • 1:04:54

SUMMARY KEYWORDS

biochar, waste, people, garden, feedstocks, pay, create, collect, carbon, materials, produce, carbon tax, money, rand, soil, planting, producer, urine, farmers, buy

SPEAKERS

Riaz, Abdullah Timol

Abdullah Timol 00:02

My first question would be, how did you first come across biochar? And what's your current experience with it?

Riaz 00:12

I read an article many years ago which indicated that the whole issue of organic materials in our society and how we use it, and it touched on things from the waste of livestock to biological, I mean, plant,green, wood, all sorts of organic products that that are capable of being used as a renewable source of energy. So the end product can be energy instead of it being buried in the ground to form fossil fuels and greenhouse gases and all that. So yeah, I heard about it, and I read something about it. And this is very much, what I say is just the surface level knowledge of it presented in a way that we can make wise use of scarce resources.

Abdullah Timol 01:28

In your opinion, what are some of the best areas that biochar can be applied in?

Riaz 01:37

In our context now? So typically, your most basic form of biochar would allow you to create heat energy. Right? I'm presuming the costs of of that and benefits are better than electricity. And my view, without knowing very much details would be that it would help at a household level of energy. Possibly you know, small scale. I don't know about large scale use. I mean, I don't even I'm not even sure. What is the applications that people now use it for? I'm just referring to the very basic things and I can see there being a need. But it also has to make a business case that's about money to people who are going to use it beyond the environment.

Because it's to many many people which would find it cheaper. What benefits do they have? Yeah.

Abdullah Timol 03:05

Okay, and then the Okay, so you have a basic knowledge. But do you think that any kind of organic waste could be used, for example, household rubbish with this be a suitable source.

Riaz 03:22

Look, lets put it this way. Currently, as you know, municipal solid waste that waste that municipalities are supposed to collect, they do collect or fail to collect, or whatever ends up on their landfills, 40 to 50% of them in the developing world, in our types of climates, is organic. So, and it has to be because we need food to eat and most of what we do is with organic Compendium, and half of our things are organic. So now we're gonna have to work out. We've got lignin, which we've got garden waste, hard green waste. And then we've got every type of organic waste from animal carcasses to manure or to whatever is produced agriculturally, restaurants or towns, so food, food and primarily food primarily, this food and garden. Now, food waste in my view, and I'm not a chemist or chemical engineer, but what I've read, food waste is probably better dealt with if it cannot be eaten any more and through anaerobic digestion to produce gas and also produce a digester. Which is the equivalent of fertilizer. The garden waste is definitely an area that's challenging because we've got residents to generate lignin waste garden waste. I've got all sorts of other producers, and your typical low cost solution like composting, from what I'm told by the industry, it is not, It's not viable commercially. Unless there's a subsidy involved. So if you just took all this garden waste made compost with it, the price that compost is which just the soil or conditioner, you might even lose money. so there definitely is a need for solutions in greenwaste, the green waste plant, forestry garden, that is beyond composting because composting operations require to be part of a company that is also doing fertilizer, and all of that so they can use it as a byproduct for something else that has higher value. So I'd say definitely. In the in the, currently we take garden waste green waste, we put it in the landfill, it rots, releases methane then when it's old enough it burns and produces black carbon. So definitely there is, there are solutions that are required as to how do you obtain the maximum economic, social and environmental value from green waste? anaerobic digesters, they factories that you have to feed and the one day they'll be here and hopefully be run well, and all our quick digesting organics can go in those digesters, because it needs that kind of thing. What's your view now in terms of that issue?

Abdullah Timol 07:09

Of which should the anaerobic digestion?

Riaz 07:12

No, no, no. Yeah. What you asked me I also just want to know from having your your your view on that all that that's me.

Abdullah Timol 07:20

Using household and Garden refuse?

Riaz 07:23

Yeah,

Abdullah Timol 07:25

From what I researched and from the people I've spoke to, they say that it's viable. But at the end of the day, you don't know what quality biochar you're going to get. And if it's a low quality biochar, it's going to be limited, the application is going to be very limited, most likely to soil supplements, you won't be able to use it for you know, as an energy source or something because for those types you require a high quality biochar product, it is viable, but very limited prospects with the biochar product you do manage to get at the end of it.

Riaz 08:08

So from the basic process, it's the same problem with that type of material but, but the reality goes our soil needs conditioning, because of what it goes through. Again, the argument is another biochemical fertilizer one time on organic fertilizer, that's called phosphorus, nitrogen and all these other things, and sort out my production and the soil rather than investing in this unless you're giving it to me for free, I don't want it. Okay, and then many people also just take the manure off from animals and utilize that as a soil conditioner, and maybe even chemical fertilizer. So biochar has to compete against a situation where if I got 10,000 cows, then I don't need and I'm also planting vegetables and all that I don't really need your thing. I'm saying that the issue comes about using those type of fertilizers. Eventually, they strip the soil of all its nutrients. I agree, but for farmers, that's farming now. He's worried about putting phosphorus and nitrogen in the soil. So that come this season he's gonna make money. When it's cash, the market system bosses you to just find the lowest cost of doing these things. So I agree that they have to use more sustainable practices but.... I was just making the comment that in the space

that we play, the product to be viable has to compete with the fact that that farmer For example, He got free, organic fertilizer, but he also got back pathogens and bacteria and problematic things and all that they've been allowed in to the environment, they created eutrophication . They're the staff wards of oxygen, they do all harmful things. But in order for you to tell me to use biochar, it must be cheap. And it must compete against things that are... and the farmer don't see it as free, he feeds the cow or pig, the pig manure, He takes it and he applies it to the ground. Like, it's like he's doing a circular. Yeah, yes. Yeah. So I don't know...that's the challenge. So we have a garden waste. And now Yeah, okay, so no, that's fine. Let's proceed. Let's go to the next question.

Abdullah Timol 10:49

I think we already touched on the issues with the experience when using the feedstocks. So....

Riaz 10:58

I'll give you an example man, I don't know if it'll help you. I was in the Netherlands for two weeks about seven years ago, to study anaerobic digestion in plants, how they work, because I think it is a very important treatment option right. Now, when I landed there, I asked the guys that I met how this thing works. They said, okay, all the farmers and remember, the Dutch are the second largest exporter of agricultural products in the world. And they the size of kwazulu Natal. So intensive farming happens, so I asked them, how this thing works. So okay, first story, is every farmer has to register every cow, pig, sheep, whatever wild animal livestock he got. And the government will then work out based on his land, how much of manure he must deliver to an anaerobic digester plant, for him to get some sort of farming subsidy. And so they compel farmers, they, if you've got 1000 or 100 calves, you're only allowed to keep 20% of their shit, because if you keep more, you're going to pollute the water table. So the other 80%, you have to show proof that you sent it to your nearest anaerobic digestion facility, which is in private hands. Then the AD guy says, Well, you had that system, and then you had middlemen starting to enter now to buy up the farmers waste, and then supply it to people because you need continuous supply. If you don't have supply, the whole thing will stop. It's a facility, you stop it, it will take you six months to reproduce the gas again. So now what had been highlighted to me is that if you want to use materials in the economy, you have to have, you have to regulate and incentivize the value chain in order to maximize the value of the product you're creating. And it's crude, the ad's is in the Netherlands, the guy told me 10 years ago, they had 600. When I went there, they had 120, I asked him why he closed, he says because Germany is offering

higher prices for the shit that the farmers got. So now they exporting it to Germany because there's nothing wrong with that. That's their neighborhoods, its a train away. I just wanted to say, the kind of regimes that are required to, add value to things, the whole value chain has to be understood, incentivized, regulated, and you have to get the whole, all the players to see why they have to be involved in an activity. And because it's a market activity, as soon as an alternative opens up. So Germany starts offering 10 euros a ton for manure, because they got 10,000 anaerobic digesters. And then the guy in the Netherlands is taking this thing to Germany, because this other guy has given him two euros. Now. So what I'm saying is that the product has to survive in in the economy, it has to, you know, has to have a well thought out...you have to create a value chain, and you have to show how these things can survive. And in South Africa, we haven't embraced many of the technologies in the world, I'd say 20 years behind, from what I've seen, and so we don't have many examples that you can then say, Let's follow this. Let's do this. The uptake of solar energy is a classic example amongst normal South Africans, so no, I've stopped it. I just wanted to make that point at least Yeah.

Abdullah Timol 14:54

Okay, so I know we spoke about how would it be possible to use on things like household or garden refuse. So looking at municipal, maybe even the garden refuse dumps, you know, like the one we have in Pietermaritzburg, even those are highly contaminated, because those would be great feedstocks. But at the end of the day, they get contaminated a lot, even though they're only supposed to be for garden refuse, are there any ways to reduce this contamination.

Riaz 15:26

Look I'd say that garden waste, in my view, from what I've seen on landfill sites in the district are mixed and contaminated because the guys are burying everything, right, they stupid. And then in other places where it's a drop off site, like a garden refuse drop off site, or wherever, you're probably gonna get, and its regulated. So there's somebody there to make sure what you're throwing, there is a degree of it. I mean, it's it's not as highly contaminated as it is, you know, it seems. But if you had a facility, like they do these garden refuse sites, which the city got no money to run and they look broken, they they should be closed down the way they look, they look dangerous. If you were to have a private party that says I'm gonna license and build a big one at my cost, and all I want is people to drop it off there and I'm gonna run it, you'll get clean garden waste. Remembering that if you view you're probably going to appeal to people whose property is larger than whatever, you know, some middle class upper working class

upper class people who themselves they drive it or they pay people, they now insist you send it to that to Abdullah because he's making biochar, rather than sending it to.... So it is possible to increase the cleanliness level as long as you show that this is part of a project. And remembering most people will take the garden waste themselves to a garden waste facility, the municapality doesn't collect it. So you could in a place like this. Have a private party, obtain a license to store garden waste in an appropriate place with all the environmental authorizations. And you will get very clean waste because people bring them themselves or their garden contractors. You know, the contractors, and you can create incentives. I mean, the city could say look no more garden waste..., the new strategy, the National waste management strategy. It was released in October last year. It talks decisively although it's talked before that in five years, there must be 45% diversion of waste materials from landfill. The easiest one if I had that challenge, and I do in an indirect way would be to ban garden waste from landfills. But then the facilities must exist to update these. If the facilities exist, they have to be built by the private sector if you expect a Broken municipality like msunduzi who can't fix portholes to go and even Umgungundlove to go so far as to even support somebody to even do composting. And I did environmental authorization, I mean the municipality here we started one to do composting, we had to stop because it was on Msunduzi land, they said we don't want to do composting, we want to burn it in on facility that somebody showed us, we said fine. 10 years later there is no composting all the garden waste is gone. So the Law, the new waste management strategy, and the norms and standards are going to slowly force society to no longer take garden waste, food waste, electronic waste packaging waste, the electric bulbs, you know those Bulbs , you're not going to be allowed to take it there. But what happens in a third world is you'll dump it somewhere. What we're hoping to do is government will build certain facilities, a broken government so it will take longer, but also the private sector if they are allowed to play their role in the materials economy. If there's a business case for biochar, abusiness case for anaerobic digestion, a business case for whatever reuse of material or processing, then the waste streams available. I mean, if I was running New England Road, I will gladly say, if there's 20,000 tonnes of garden waste, it's not allowed here and you got a license for it. Please take it to away. And it's your business now, you know what I'm saying, its not mine. It's done in other parts of the world, where garden waste is clean. Food waste is collected from hotels and the street, you can force people to change their ways. Waste is a lot about behavioral science, how do you get human beings to change the behavior so we create a more sustainable system and realize that everything we consider waste is actually is still a material, it's still a resource, and has a further role to play because we've got finite resources.

And we don't have infinite thing. So I am of the view that you can clean it up. It's already largely cleaned in the way people bring it, and you can get citizens, if it's not too far to drop these off in a clean place. Absolutely. If you told people I'm making biochar and I'm where Msunduzi is, nearby in the garden sites, people bring it to you. Plus you give them a discount of 10% to rebuy the thing in order to incentivize the cycle.

Abdullah Timol 20:38

So in the same regard, if you were to try to implement separation at source approach, um, that would also be more of a behavioral science thing.

Riaz 20:49

Yeah, look in Europe, where they..., okay, look, there are three countries in Europe that use pay as you throw. So they managed to put RFID radio frequency, you know, I mean, what this chip snap, they put two chips in a bin. And normally we just pick up because it shows it's full, you know, in most of the advanced world. In three countries, they got pay as you go systems where, depending on the thing where it weighs either the truck is weighing it or the chip is weighing it, whatever. You want to pay as you throw, right. Those societies have separation rates at 80 to 90%, because you're forcing people and you imposing a financial sanction. So people will do very well. In societies where they are no pay as you throw, but they are well organized source separation. So they got different bins, they got a vehicle that can collect the paper, plastic, cardboard glass and put it one place and drop separately, and then take your filthy waste and put it in another place. In Europe, In Western Europe, the highest source separation rates are between 50 to 60%. Now, I'm talking about wood source separation. In societies where they provide clockwork, they will come collect your red bin, green bin, blue bin and white bin.... whatever color bin and they won't steal your bin. you know what I mean, and they leave your bins and all. There It's 50 because people say fu*# this, I got no time to separate nothing. I'm busy. I'm busy, and there's no incentive for me. I've got two bins by my house, and this already irritates me, because all I want to do is take everything and put it in that big wheely bin, and send it of... Even though I work in waste. I've got no time in my life to do certain things. Behavioural issues, we are talking about openly. I must be prepared ..., my wife wouldn't allow three bins. Okay. She's say you mad. So at a practical level, middle class people in Europe, Currently we don't reach fifty. Here most separation schemes have failed. The most classic example is the thieving in ethekwini municipality. When I talk about that orange bags thing. Ethekwini was supposed to give four bags to 1 million houses, which was 4 million bags

a month and fifty million a year. They only gave all the middle class areas where people were participating to make it seem as if this thing worked. And the other 80% of the bags were, were said to be given to the to other people, you were paid for it, but they were never given. I'm saying to that when Zandile Gumede fell, they all charged for two issues. One is this plastic bag story where we paid one rand for 50 million bags for five years or whatever, but only 20% were delivered. And the manufacturer knew you only had to make 20% and they chowed all the rest of the money because the other 80% of the people even though you told them you got orange bags you giving them or you never gave them. In fact, all they care about is putting the waste outside and the municipality must come collect, you know, the typical attitude. So even the largest one which we invested the most money, well that one ended in corruption. My view on source separation is that Yeah, given that we only got a small middle class, you got a very small footprint of a number of those people that gonna do separation, only half of them may do it, or less. Then as you go into the majority of households which are working class unemployed, you're going to have to incentivize them financially as to why they should do this. You'd have to tell them Okay, uncle, if you do that your waste bill is 50%. And if we charge you 120 rand if that person who's collecting tells us you do give a blue bag, you will only pay 50 rand. you have to create incentives that matter to people. Even the wealthy, if you tell them hey, you know what, if you're only gonna pay half the waste, I might start doing it too. Because now you take it hundred rand less from me. Or, you're charging me hundred rand more. You know what I mean, so you have to, you know, I was reading an article that says that you have to look at the waste as from a behavioral scientist, as a behavioral scientist would use it. You know, from that perspective, how it's created, who uses it, how they throw it, what then happens? So it's that that kind of thing. Yeah, I don't know. So it's possible. But it has to be incentivized, regulated, well resourced, well financed, or else it won't work. In Germany, the guy that I worked with, because we worked with the international guys, he was saying to me, that his waist bill for the month is an equivalent of a 1000 Rand a month. Right? And now obviously, he said to me, You must consider I live in Berlin, my per capita income compared to yours is vastly different. But he says to me, it's significant that I have to pay 1000 whatever he said, 1000 rand a month, like you know. So he said, to me, that's the cost of the system. And we want that system be cause we want to live in a clean place. I said, you know, people would never paid 1000 rand here, because they won't get a clean system firstly, right. And secondly, they don't have the money to pay it, even if you could be believed that you're going to create a clean system. So these systems, they cost money to advance in order of treatment and

processing. And often we don't have the subsidies in places government to fund them so that they become commercially viable.

Abdullah Timol 27:01

So you'll have to create value.

Riaz 27:03

Otherwise, nobody's interested, and they're not interested, you won't get it happening.

Abdullah Timol 27:09

Okay, so looking at all this feedstock, let's say if you manage to collect some, you know, feedstocks, if you manage to find a source, you'd ideally one something dry. How to ensure that feedstocks are drier, if you had to do it on a large scale, would it be viable to let them dry naturally, or use a dryer? or...

Riaz 27:32

look, we subtropical climate, right. So that means for six months of the year, we get rain. And you don't know how and when it's coming and what story and all that. Like this year, we had record rainfall in terms of the last three, four years. Now, ideally, look, it's a business decision, if you got money to spend to create sheltered, if you've got money to spend to create a place where all the wood and all these things can dry naturally, you know, per square meter costs if you've got that kind of resources. And if it makes sense for you to dry it naturally under those conditions versus buying equipment to dry it, then look, I'm saying that the capital cost of buying the equipment to dry the waste might be create more economic value, Then you leaving it to dry naturally in a covered environment For 30 days. You might try everything in one hour and treat it and create the product in one day. Whereas here you might have to wait 30 days before it dries. And then if you build those things and the weather situation, we in the middle of constant rainfall for 10 days, then you want to have space to store these things. Eventually, if its largescale, so from what I seen in Europe, they build industrial factories. So you want to produce something, whatever type of factory you need to build, you're gonna have to build it because in that society, you have to be capital intensive, you have to be efficient, and its cost per unit. How much money can you make. So it goes back to that story, you'll have to make choices around how you're setting up the operation in order to get your return on investment. So if you've got money and time to waste you can have a 20 year return on investment. If you've got no time to waste, you're going to have a five year return on investment by

mechanizing processes. That won't work. Think about it. Msunduzi says they get 20,000 tonnes per annum of garden waste wood more of it in summer. So say we were to assume it's 2000 tons a month straight for the whole year. If it takes 30 days to dry, in summer, when you have the most amount of production, you then need space for 1000 tons of garden waste. You might say, you know, you'll chip it, so then the volume is gonna be smaller, but then you need to have a chipping operation. I mean, you might have to have. So I'm saying it's gonna be all based on the return on investment, when can that happen? and under what conditions does it happen and which are the most sustainable conditions and which are also forward looking? So your competition don't come samsh you. you know what I mean?

Abdullah Timol 30:40

So basically, to run a project like this, it'd have to, you'd have to be able to make a profit somewhere.

Riaz 30:47

Yeah, not somewhere. If the bank is giving you money, say you went to the development bank, Standard Bank, net bank, whoever, whichever even if you went to a funder, they'll say, Fine, Mr. Timol, I'll lend you 30 million Rand, when are you going to return the money? When are you going to start being able to show a return on investment and pay me back my loan? That's first and then when you gonna make a profit? You have to pay my loan, and you have to make a profit. And so when you then thinking about this product, you're going to have to think about it as the things you're looking at. Exactly The business plan, the technology, the return on the unit costs of producing, what you're producing, and the time that it takes and the markets that you can then play in.

Abdullah Timol 31:34

So you'd say that something like this would have to be run by someone in the private sector, it's not going to work.

Riaz 31:40

No. government can't run potholes. If government can't fix potholes then they can't run this. No, it will be a disaster. There'll be fires, it won't work, it will collapse. There has to be a profit motive. I think the materials economy, they commodities, and if they're not run, in terms of how the market works and if then not run by entrepreneurs trying to make a profit. It won't work. Yeah, it'll fail.

Abdullah Timol 32:06

Okay, so what do you know about the biochar production process?

Riaz 32:12

Very limited knowledge. Yeah, very limited. It's not mainstream in the sense that Yeah, biochar it's like, yeah. Oh, I'm not sure why I never even dug more. It probably seemed unfeasible to me. Something about it seemed unfeasible. So I would have said anaerobic. Like my view, anaerobic digestion is a technology you have to have for the treatment of materials, and then whatever other technologies for plastics and so on.... the issue of feedstock for biochar is which technology is going to give you the highest economic, social and environmental returns.

Abdullah Timol 33:02

What I'm gonna do with this is I'm just gonna go over a question if you want to pass just pass, right. So, you know, about the design of page Shopkins affecting quality and you it's not good. Do you think that any feedstocks are superior to others, if it comes to production?

Riaz 33:30

Well, the global experience right of, biochar whatever that is, is clearly pointing to what materials have the most value versus other materials. So I think that it's already known what materials you need and which ones are most suitable. And answering your question, then, it is possible to get these materials in the condition that you require, provided a business case can be made with the people who are the producers of these materials that you want. A value chain can be created.

Abdullah Timol 34:09

And then do you know of any ways that that potential feedstocks could be prepared beforehand that may increase production yield and efficiency?

Riaz 34:25

Look, all I know is that if you want any feedstock for any manufacturing process, it has to be produced and extracted. Now, who are the people who are extracting and producing the feedstock that you want? You can? What are you saying again? Sorry, the last part of that question

Abdullah Timol 34:49

Could you increase...

Riaz 34:52

oh yeah, you can increase the quality of the product and the efficiency of the livestock provided that your value chain incentivizes the producer to bring it to you in the condition you want. So for example, I'm using a stupid example. Coca Cola is now going again with the deposit refund scheme. They were trying it out in parts of South Africa. When I was young, which was 30 years ago, when I was 10 years old, we used to collect all the glass bottles we found in sight and take it to the shop and get money. Now coke is introducing that for its bottles, it's plastic bottles, but the money is gonna come when you buy a new coke. So we're gonna give you a deposit then when you buy the new two liter you get the R6 of or something. Right now what I'm trying to hint at is that if you want something, you must offer something else.

Abdullah Timol 35:43

So you'd have to create value again,

Riaz 35:45

Yes, and feedstocks..... What are the most desired feedstocks for biochar?

Abdullah Timol 35:53

you'd want something compact, something that can dry easily something you can, you know, put in the kilns easily... So most people they look at stuff like wood chips from a saw mill, sawdust, then they try acorns, you know, but it's most probably a uniform feedstock. You don't want too much things in the mix otherwise...

Riaz 36:17

Yeah, but now in this district Umgungundlovu, right? The 9000 square kilometers in size that it is, 24% of it, if I'm not mistaken, is under commercial plantation forestry. So a quarter of this land so 2000 or 1800 square kilometers, I've got this somewhere, it was inthe environmental management plan They did. It's under agricultural plantation. So we have one of the largest commercial forestry operations here. We have a few sawmills. So we have primary producers of the scheme. And I'm sure that your researchers want to talk to the SAPPIES, Monies, all these people that own all these forests around here, to ask them the potential about biochar because remember, they planting this thing, they preparing it for these paper millls. They also

have headaches with sawdust they also have headaches with chips they also have headaches with all these things. So what I'm trying to say is that provided the correct incentive is created for the producer of the of the material you want, you can get it. But if he is putting it back into the paper mill to burn that papermill. Like someone I'm now recalling telling me, then he is not going to give you. There is a lot of these people, they co generate heat by burning the sawdust. That's what I understand that someone was telling me that No, no, they reduce it because they burn the chips or whatever they call it. And then they keep the sawdust because that's not useful. For burning

Abdullah Timol 38:01

So you have to know anything about ....we've already covered that one, most of production in this section was covered. Let's move on to the biochar supply chain. To the best of your knowledge. Do you know of any existing largescalee biochar supply chains in the Umgungundlovu and eThekweni areas?

Riaz 38:35

supply chains that are already existing and supplying some producer some manufacturer? No, although there are. They're not lined up to my knowledge.

Abdullah Timol 38:51

And then the reasoning would be that they haven't seen value in creating these.

Riaz 38:58

Nobody showed them how to make money. Or there are other ways of making money.

bdullah Timol 39:07

If you had to implement a biochar supply chain, if you're looking at collecting the feedstocks, production. Thereafter putting it to use, what would be the core functions you'd want to consider if you implemented a biochar supply chain.

Riaz 39:26

The core functions of what? the municipality? the enterprise?

Abdullah Timol 39:31

The enterprise lets say, what its core function would be. Yes, if it was trying to implement a biochar supply chain.

Riaz 39:43

It would be obvious to produce biochar and sell it and make a profit and show people the environmental benefit the climate change mitigating impact of it. It could also look at the carbon taxes that are now approved. And say, we gonna do this, this qualifies as a mitigation of carbon. Because remember, there's a huge playground. I don't know if they link but with carbon tax, if you can't pay, then you must show where you offset it. So it's legal now. And I think this year is the first year that I think Eskom and I don't know who will have to pay, they're gonna send it to farmers and sappy and whoever and whoever, meaning if you create carbon as a direct result of your operations, then you must pay the tax and or you must offset by involving yourself in projects that produce carbon. Now, does black biochar qualifiers, as a technology thats mitigating the production of co2 or other greenhouse gases

Abdullah Timol 40:53

It does. One of the major uses of biochar, is obviously probably depending on the quality. If you put it in the soil, it becomes a carbon sequestration tool.

Riaz 41:04

as you can measure it and international. So is there any carbon trading program in Europe, that includes I'm sorry, include biochar?

Abdullah Timol 41:15

And there's quite a few companies that you know, that...

Riaz 41:23

are trading carbon credits because you're offsetting in biochar? Yeah.

Abdullah Timol 41:29

There's a lot of uses for biochar. Some of the one of the main ones as I'm seeing is a carbon sequestration tool. Another one would be another one would be using it in water purification, you know, if you put it in the water, it acts as an absorbent and it removes all the toxins.

Riaz 41:50

Okay, so now, it's like, this is new to me now. Now, because I don't worry about things, I just worry about few things that are in fornt of me. Therefore, the carbon tax is now working in South Africa, it's gonna take five years to evolve until all the direct producers of carbon are involved, but they can offset the tax they owe by investing in offset projects. So I think that

you have to look at how the carbon tax, the carbon trading system, which is what we have. They saying that you pay the tax or you offset and invest in the green economy. So one of the leverages that you have in this context is the carbon tax in South Africa. And the fact that you have an option that provides sequestration of carbon. And remember, also you have to prove and how long it's gonna stay there. Because remember, this argument replant trees and it'll pull out all the carbon, so plant trees everywhere, and they started planting trees everywhere, only to realize that some trees, sequestrate carbon better than other trees, and some trees then take water away from ahabitat, so you shouldn't be planting it. So it's very robust, you're going to have to show that I paid you to sequestrate carbon and you've done it for 20 years. Yeah, so I'm saying that the carbon trading scheme, the carbon tax creates excellent leverages to create a value chain. The offset part

Abdullah Timol 43:23

Alright, I see what you're saying. You have to find how you're going to get value at the end of it.

Riaz 43:31

So SAS will have to pay 10 million, say 1 billion. If they show that they gave you and 10 other people 10 million Rand to start one business and this is how much yall offset they pay less tax or get tax breaks. And government is prepared for the carbon tax to be recyclable, a tax that's recycling, so they're not going to increase the corporate tax rate they rather have the carbon tax force you to change your behavior rather than tax you further. So they're prepared to forego income and charge you the carbon tax but they want to forego, they're not going to still now..... you know, you're a commerce student. They prepared to have the carbon tax be a recycling form of tax. If you know what I mean, where it's fine. We just want you to change your behavior. You don't have to pay more tax, if you can come out of it with all these other things. We're very happy.

Abdullah Timol 44:32

So the more environmentally friendly you are, the less you're going to pay basically.

Riaz 44:36

Yeah. So they're saying hey, go invest in all these things. We don't want to punish you. We want you to recycle your your investments, your money. Yeah.

Abdullah Timol 44:48

So let's say if you're using by biochar, if you're producing it to be a tool to use for environmental rehabilitation. If you Decide to to set up a biochar supply chain and use biochar. Would there be any environmental ramifications if you're not responsible in collecting the feedstocks and stuff?

Riaz 45:20

Yeah, I mean, they'll only allow you to, they'll only allow it to be used in remediation of land, soil, water, if the product can do what it says it can do. So I think that the product will have to at least have some sort of proven way of doing things.

Abdullah Timol 45:47

Okay, so I think we went over this already. But just to recap, what would be a few large scale sources, you know, major, major sources of biomass that you could attain for biochar production? And what sort of logistical considerations need to be taken into account if you decide to use this biomass sources?

Riaz 46:12

Yeah, well look, in our context, it would mean thatyou will have to, if you're looking for wood chips, or dust, and all of that, you'll have to be looking at your commercial forestry production areas, and how they if they're not already involved in any form of treating their.... because remember they too leave it on the ground to rot and naturally condition the soil. Now, it firstly with the producer, he might have to change some of the operating protocols to give you the feedstock, right, and that there may incur additional costs or time or whatever, then if you were to collect all this, you would need your biochar facility to be near your producers, you can't have your facility in Durban and expect the materials to be in howick and moii river and all those areas. So definitely, with the cost of diesel and transporting all these things, you either, if there's a large commercial forest, if you can make the biochar in that plantation, if there's enough supply there, if you can make it right there and supply those people, it will be number one, because you cutting out transport, everything is on site. But if you're taking small quantities to a central location, there will be huge transport issues huge. How do you collect, who's gonna pay? so I would say that a large scale operation should ideally, it's probably an ideal situation, if you can be on site where the producer is making this thing, you can probably cut out transport costs, the product might even be used directly where it's produced.

Abdullah Timol 48:09

So when was it last year I was speaking to someone that told me about a biochar project that was going to happen in Mkondeni using waste from pit latrines I think, I'm not sure if that's happening. So something like that, they were gonna do it on sire, you know, close to the where the waste is collected from.

Riaz 48:35

And is human feces suitable for biochar?

Abdullah Timol 48:41

I think you might be limited in your usage, but they .....

Riaz 48:49

Cos I was working on a project with some people from the UKZN Faculty of Agriculture. And their interest was in separating urine from feces because urine has higher nitrogen phosphate etc levels than feces. And if you separate the urine, they call it the urine diversion toilets, then you deny the feces moisture and the feces will decompose quicker in the pit so you don't have to collect it. But primarily they were looking for urine because urine has higher concentrations of nitrogen. You know the NPK? nitrogen, phosphate and all that. urine is better. And if you collect the urine and you clean out the pathogens, you have concentrated form of NPK. So I know that work is continuing on that particular project to try and get urine. That's number one. Number two, I think Umngeni water is interested in providing, treated humans feces. So it's now pasteurized. There's no pathogens, its depathegenised slurry, right. They're now working on a project with UKZN and those people that plant grass, you know where the wastewater works are? At the bottom the near the landfill site? There's a Darvel waste waterworks. Yeah, you won't see it from the highway. But if you go past the landfill site, you'll see this big thing that's the wastewater works in maritzburg. Right. Now, what has happened there is because they used to spraying slurry on the land, a lawn company started planting their seedlings in this land. And it proved to be highly successful. Right. And so now they're in the process of experimenting with providing. Depathegenised, so its got no pathogens, they're going to provide you with that slurry. Instead of spraying it, they're gonna provide that lawn company with the slurry. And they're going to try and mix it with other organics to produce the fertilizer. Okay, so I can hook you up to people you can speak to, they trying to talk to me, but I've got so much work to do, I don't want to get involved. And also on umgeni water is quite capable of sorting things out, they are a world class organization, if you're involved with them,

they can do it. So that project is alive, but they're looking at urine first. And then secondly, taking the wastewater works, the slurry that's got no pathogens, and then using it to create a slurry with other materials. Okay.

Abdullah Timol 51:44

So, speaking of this, then you would say that, looking at all of these kinds of new existing programs, it would be possible to somehow integrate a biochar supply chain into the these instead of starting at one from scratch.

Riaz 52:00

Yeah, definitely. Definitely. Definitely. And what's good about this grss thing is that they using treated human feces to grow grass. Because if you ask people, whether they'll eat food where they use the treated human feces, they'll tell you no. I might say no too even though I understand science and know it happens anyway. I will say no, my wife will definitely say no. And I wouldn't eat that food. So growing grass is probably better. For the application and use of human feces, and urine .Growing grass and trees will make people happy. You can tell them you're gonna make food from it, they won't eat the food.

Abdullah Timol 52:43

Yeah, probably not. Yeah. Okay. So looking at commercial applications. So it's biochar has a large range of capabilities in many sectors. With its capabilities for climate mitigation, why do think something like biochar isn't more popular than it is.

Riaz 53:07

Okay. I think Firstly, lots of climate mitigating things are not popular. If you tell people, no, don't burn fires, don't put you aircorn on all the time. And all the classic things that are easy for people to do people are not interested, right? The world must sort itself out. Now, if you're telling people that it's a climate mitigating tool, ordinary people, yeah, you'll have to show them how they benefit financially or environmentally from it. But then it can only be, we don't have many climate mitigating things that we're doing anyway. So if you had to look at the mitigation, hey, it's Elon Musk and the cars, they doing it at at a high level. At a city level, we don't even do basic things to mitigate climate change. Like solar is not widely used. Electric cars might take longer here, a whole host of things. So if you worried about it, I will, from where I sit, I wouldn't be stressed because people are not taking decisions based on climate mitigation. There isn't enough incentives yet for them to do that. It might happen in the future. I think it's certainly

will. But for now, I think biochar is a bit harder, its because so you tell me buy a LED light, its cheaper, it'll give you a longer life and you will be contributing less carbon, I'll buy that light, if you tell me please separate your food like this... and then you put it out there and someone will collect it, and then they'll make it into something. And if the supply chain don't work, I'll tell you to f*ck off. Its was wasting my time now, made me separate all these things. But no one collected it. It's easier to go buy a bulb or to buy your product in the shop, then for me to be participating in this thing. So what I'm saying is that there aren't many climate mitigating solutions that are already in play, the popular easy to win low hanging fruit, even those don't work. Because we are too used to take and make waste, you know that world of extract and make a problem and that's the world's problem. So, biochar is not as popular but then not many of the popular ones are being implemented anyway. Even though it is so easy to do. I must have 200,000 to put solar on my roof and then I don't have to worry about them. I'll get my pay back in 10 years time. I won't do it because I've got 200,000 I'll buy a car. Yeah, and then I pay Msunduzi for electricity, even though I know they unreliable. So I'm saying the easy to do things, solar power, collecting water from the garden instead of using clean water. Very few people are involved in all those things.

Abdullah Timol 56:04

They want immediate gratification.

Riaz 56:06

Yeah, So now your biochar is complicated. I'll buy the product from you after you made it don't involve me at least. As a citizen maybe i'll buy it from you

Abdullah Timol 56:22

Have you come across anyone selling biochar for higher quality?

Riaz 56:28

No.

Abdullah Timol 56:40

So considering biochar from a commercial perspective, if you have to look at the many uses. So as a soil amendment, potentially treating wastewater or absorbing chemical toxins from the soil, which sectors would most benefit from something like biochar?

Riaz 57:08

Agriculture, definitely. And people who are producing huge amounts of carbon and need offsetting opportunities like. So its agriculture and then your highest emitters of carbon, because you can use carbon emission. So I think it's the carbon, the need for us to reduce the amount of carbon and even short, they call it short acting pollutants, like methane, black carbon, all those things. So I think that that whole economy that's developing as well as agriculture are sectors that need biochar.

Abdullah Timol 57:52

One question, I wanted to ask you this earlier, but I forgot. You said that waste it needs anaerobic digestion process right. So would you say that biochar can't really be considered as an alternate waste management solution to biomass streams like garden waste

Riaz 58:21

Look, anaerobic digestion doesn't want garden waste because they take too long to break down into gas.

Abdullah Timol 58:28

So it could be a possible replacements for waste management.

Riaz 58:35

Yeah, you see we're struggling with a solution for garden waste, definitely. Because if you build an anaerobic digestion, you want abatoir waste you want manure, you want blood, you want food waste, quick breaking things, whereas garden waste and all take too long. You're gonna have to pretreat them and even then to the amount of methane and carbon and all that that you need ..... so ad is ideal for food, garden waste and greenwates forestry waste. Biochar is perfect. .

Abdullah Timol 59:10

And then I'm looking at some local regions in the Pietermaritzburg, Durban area. Can you think of any specific communities, areas of possible projects, where biochar can be used to make a difference.

Riaz 59:31

Yeah, I would think that project that's happening looking at Umngeni water, what they called? Greenlawn, that one. And then the municipalities are going to be in the future required to divert

all garden waste from landfill, and biochar is going to be a very attractive option. Because it might have more uses than investing... cos if you build composting facility we just gonna get soil conditioner, whereas biochar, we might start with the soil conditioner, but you could add modular units to to reach higher quality of products at the same facility. So we could start off just producing the same thing as compost. But in terms of biochar technologies, we could then add them on modularly on the same site people to produce more valuable products for the economy. And for garden waste, you see, I told them just cut the waste and make firewood. So all the big trees and all that can be made into firewood, make firewood and in winter, people can sell it. Now, if you think of garden waste in those crude terms, where we'll take it and burn it again and create carbon, biochar is a better option. Okay, I mean, so we were saying, okay, you can't use all the garden ways to compost, then whatever remains, we'll have to make firewood. Now environmentally, it's insane isn't we're taking wood to burn the thing and produce carbon and black carbon. If we can produce biochar from the same thing, it's a much better option. Environmentally, economically and socially.

Abdullah Timol 1:01:16

So looking at some. Also, this is also a localized question, you know, looking at PMB. From what research I've seen, there is quite a bit of alien vegetation around. Is this like a major issue? And could it be used as a potential issue?

Riaz 1:01:40

Huge Issue! I mean, the amount of alien vegetation is frightening in the open spaces that we own. And I know that people used to clear alien vegetation tried coffins. And I'm told it works. And in coffins, yeah. So they're chopping all these big wattle trees and wattle, black wattle. So say there's like two or three indigenous trees, you have to chop down there. Now what they were doing is somewhere I don't know where that project is, but they were taking the wood and making coffins. Because the wood, wood could land cheaper than pine, because now you have government subsidizing the chopping of the tree cleaning of the tree, even the delivery too. So then it made sense for a supply chain. And they made cheap coffins, maybe for poppers or for poorer people, but it then means that the same thing can happen with biochar.

Abdullah Timol 1:02:38

So there's a lot of scope here. So this was actually my last question, I'm done.

Riaz 1:02:49

Okay, now, as I said, I'm very interested in it because it is a waste management strategy. But like all the strategies, there has to be a business case, you know, and the more independent they are of subsidy... they may initially have to subsidize everything to create the economy. But the quicker you can pull it off, and it can stand alone as a treatment that makes its own profit, attracts people to participate in its value chain. It'll work better. Like paper, like SAPPI I mean, like this packaging Mondi, they put all their efforts into getting paper back because its cheaper for them to get paper back then to produce new paper and they make more money out of it. In the same way, one has to develop models like that, that do that same thing that show how you need to start collecting these things, because it's the business case.

Abdullah Timol 1:03:51

Kind of like a circular economy approach

Riaz 1:03:55

And if you look at the National waste management strategy, the November one, it's actually saying we take the Ellen MacArthur Foundation, quite a leading foundation in terms of the circular economy. Helping many cities, they have a right approach and so it openly embraces the circular economy, Ellen MacArthur. Also you must use international practices, or international case studies of biochar to show what is achieved elsewhere because we are behind times in South Africa. Yeah, and lots of examples globally of successful projects. Okay, okay. All the best Yeah, man contact me. No problem.

Abdullah Timol 1:04:39

Thanks so much for everything

Appendix J: Ethical Clearance Approval

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

30 October 2020

Mr Abdullah Timol (214551355)
School Of Man Info Tech &Gov
Pietermaritzburg Campus

Dear Mr Timol,

Protocol reference number: HSSREC/00001926/2020
Project title: Developing an organic waste processing supply chain to produce biochar: A Pietermaritzburg field Study
Degree: Masters

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 06 September 2020 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted FULL APPROVAL on the following condition:

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

This approval is valid until 30 October 2021.
To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

All research conducted during the COVID-19 period must adhere to the national and UKZN guidelines.

HSSREC is registered with the South African National Research Ethics Council (REC-040414-040).

Yours sincerely,

[redacted]

Professor Dipane Hlalele (Chair)

/dd

Appendix K: Amended Title Letter

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

15 September 2022

Abdullah Timol (214551355)
School of Management, IT & Governance
Pietermaritzburg Campus

Dear A Timol,

Protocol reference number: HSSREC/00001926/2020
Original title: Developing an organic waste processing supply chain to produce biochar: A Pietermaritzburg field Study
Amended title: Exploring the biochar supply chain to determine the potential for biochar production in KwaZulu-Natal
Degree: Masters

Approval Notification – Amendment Application

This letter serves to notify you that your application and request for an amendment received on 08 September 2022 has now been approved as follows:

- Change in title

Any alterations to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form; Title of the Project, Location of the Study must be reviewed and approved through an amendment /modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

HSSREC is registered with the South African National Research Ethics Council (REC-040414-040).

Best wishes for the successful completion of your research protocol.

Yours faithfully

[redacted]

.....
Professor Dipane Hlalele (Chair)

/ms