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The availability of second generation feedstocks for the treatment of acid mine drainage and to improve South Africa's bio-based economy

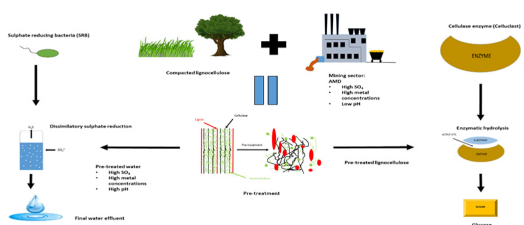
Dirk Karl Westensee [a,c,d], Karl Rumbold [a,c,d], Kevin G. Harding [b,c,d,*], Craig M. Sheridan [b,c,d], Lizelle D. van Dyk [b,c,d], Geoffrey S. Simate [b,c,d], Ferdinand Postma [b,c,d,e]

[a] School of Molecular and Cell Biology, East Campus, Biology Building, Room B220, University of the Witwatersrand, Johannesburg 2000, South Africa
[b] School of Chemical and Metallurgical Engineering, University of the Witwatersrand, Private Bag X3, WITS, Johannesburg 2050, South Africa
[c] Industrial and Mining Water Research Unit (IMWaRU), University of the Witwatersrand, Johannesburg 2000, South Africa
[d] Centre in Water Research and Development (CiWaRD), University of the Witwatersrand, Johannesburg 2000, South Africa
[e] Global Change Institute, University of the Witwatersrand, Johannesburg 2000, South Africa

HIGHLIGHTS

- South Africa has the potential to use invasive species as biomass feedstock.
- AMD can be used as resource for pre-treatment of 2nd generation biofuel feedstocks.
- Hydrolysed lignocellulosic biomass has the potential to produce fermentable sugars.
- Resulting biomass could also be suitable for commodity products.
- This could be a cost effective way to improve water quality and produce products.

GRAPHICAL ABSTRACT



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ABSTRACT

South Africa has a wide range of mining activities making mineral resources important economic commodities. However, the industry is responsible for several environmental impacts; one of which is acid mine drainage (AMD). Despite several years of research, attempts to prevent AMD generation have proven to be difficult. Therefore, treatment of the resulting drainage has been common practice over the years. One of the recommended treatment methods is the use of second generation feedstocks (lignocellulosic biomass). This biomass is also acknowledged to be an important feedstock for bio-refineries as it is abundant, has a high carbon content and is available at minimal cost. It can also potentially be converted to fermentable sugars (e.g. glucose) through different treatment steps, which could further yield other valuable commodities (cellulase, poly-β-hydroxybutyric acid (PHB) and penicillin V). It is estimated by a generic flowsheet model that 7 tons of grass biomass can produce 1400 kg of glucose which can subsequently produce 205 kg, 438 kg and 270 kg of cellulase, PHB and Penicillin V, respectively. In this paper we investigate the feasibility of grass as feedstock for AMD treatment and the subsequent conversion of this acid pre-treated grass into valuable bio-products.

1. Introduction

One of the most concerning environmental risks created by mining activities is acid mine drainage (AMD) (Johnson and Hallberg, 2005). AMD is a pollution problem around the world and results in polluted

* Corresponding author at: School of Chemical and Metallurgical Engineering, University of the Witwatersrand, Private Bag X3, WITS, Johannesburg 2050, South Africa.
E-mail address: kevin.harding@wits.ac.za (K.G. Harding).

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surface water. AMD is caused by the weathering of iron sulphide minerals. These synthesized iron sulfides (e.g. pyrite, pyrrhotite and mackinawite) containing minerals are exposed to oxygenated water (Yang et al., 2017). During the two-stage oxidation process, sulfuric acid and ferrous sulfate are produced which, subsequently, lead to the production of orange-red ferric hydroxide and more sulfuric acid (McCarthy, 2011).

AMD pollutes receiving aquifers and streams when discharged without treatment, causing serious environmental degradation. In view of the serious environmental degradation caused by untreated AMD, the use of active and passive treatment systems for the remediation have been researched extensively in recent years. Various viable systems have been identified and tested on lab and pilot scale for the prevention or clean-up of AMD (Johnson and Hallberg, 2005). However, the widespread use of these systems on a scale required by the coal and gold industries has not materialized (McCarthy, 2011). Reasons for this include the high capital and operational costs associated with most of these systems; especially active treatment systems. As a result, research on the viability of passive, low cost treatment systems is favoured (Ramla and Sheridan, 2015).

In the recent past, various natural substrates (e.g. compost, clay, limestone, cow manure, etc.) have been found to be useful for AMD remediation (Grubb et al., 2000). Among them, abundant cellulose rich waste products were found to be economically viable options for AMD remediation (Magowo, 2014; Ramla and Sheridan, 2015). Coincidentally, the same cellulose rich material has been identified as a feedstock for biofuel production. In fact, the current main driver for a bio-based economy is the production of biofuels from organic feedstocks.

The term bio-based economy (BBE) refers to biotechnological procedures that lead to an economic output. BBE can be defined as an economy where the basic building blocks for chemicals, materials and energy are derived from renewable biological resources (McCormick and Kautto, 2013). Biological resources would include animals, microbes, plants and minerals, which are exploited through technical and non-technical activities. The two main focus areas of industrial bio-based economies are industry development and sustainable environmental management with a delicate link between them.

In South Africa, one of Africa's largest economies, the establishment of a bio-based economy was identified as a strategic mechanism that would stimulate economic growth and diversify the country's revenue (Department of Science and Technology, 2013). Currently, South Africa wants its bio-based economy to make a significant contribution to the country's economy in terms of the gross domestic product (GDP) by 2030. Historically, South Africa relied on mining of precious metals as a significant income source. However, declines in the profitability of mines coupled with continued environmental degradation raised concerns over the long-term sustainability of mining operations in South Africa.

Additionally, it should be noted that the last few decades has seen an increase in the production of bioethanol and concerns over food security exists (first generation feedstocks). This has prompted research into the feasibility of using second generation feedstocks such as cellulosic plant material (e.g. woody crops, agricultural residues and grass) as raw materials for bio-chemical production as a replacement for first generation feedstocks sourced from edible crops (Pradhan and Mbohwa, 2014). In this regard, lignocellulose offers the greatest potential as a biomass source for bio-refinery use since it is abundant, is a large carbon source and is available at a minimal cost (De Jong et al., 2010; Van Zyl et al., 2011).

As already discussed, lignocellulose biomass has also been investigated thoroughly for the treatment of AMD such that various biological treatment systems, which include bioreactors and constructed wetlands, have used lignocellulosic material as a biological filter for AMD treatment (Magowo, 2014). When grass is used in AMD remediation, the AMD (dilute acid) hydrolyzes the grass altering the structure of the lignin and breaking down the other lignocellulose found in grass, releasing simpler carbohydrates (Vala and Tichagwa, 2013). This in turn makes the cellulosic material in the grass more accessible for additional hydrolysis and fermentation into value added products (e.g. glucose, cellulase, poly-β-hydroxybutyric acid (PHB) and penicillin V). Consequently combining AMD treatment and second generation lignocellulosic feedstocks, such as grass, could contribute to the SA bio-based economy through the development of a biofuel industry and improved environmental management. (See Fig. 1.)

In this paper, we discuss the potential sources of lignocellulose biomass, its availability in South Africa and how it can be used for the treatment of AMD. Furthermore, we elaborate on the possible production of value added products from monomeric sugars released from lignocellulosic biomass after pre-treatment with AMD and subsequent enzymatic hydrolysis steps.

2. Design summary

This novel technology would allow for the treatment of AMD using common waste organic material, whilst producing valuable products, fermented sugars and water. Various lignocellulose sources (roadside grass bales, sugarcane bagasse, woodchips etc.) together with AMD could be added together where pre-treatment will occur over an extending period.

Grass would then be removed and hydrolysed using a cellulase enzyme, Celluclast, to produce monomeric sugars of mainly glucose and xylose. From there, the fermented sugars could be extracted and sold as a commercial product.

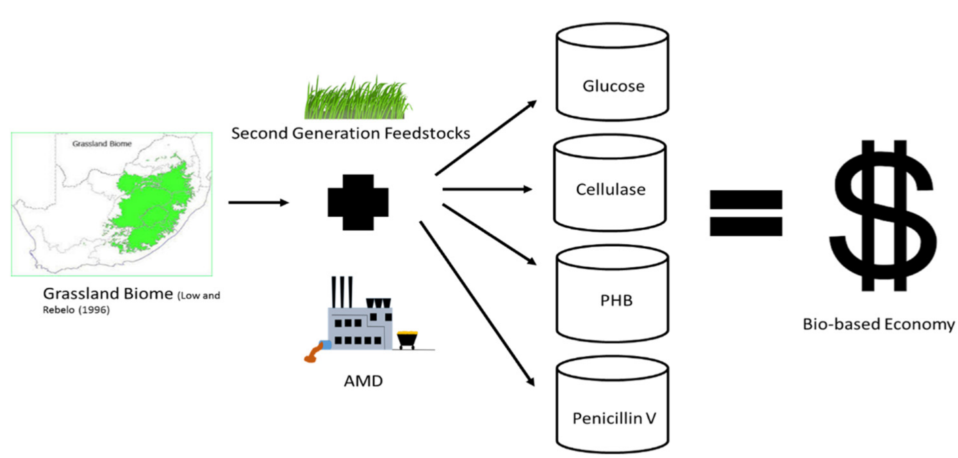

Fig. 1. Process flow for South African waste grasses to a potential bio-based economy.