Can we kick-start mining rehabilitation with cyanobacterial crusts?

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Abstract

A heavy mineral sand mine has commenced operations on the eastern edge of the Nullarbor Plain, South Australia. This area has low annual rainfall and frequent drought, resulting in challenges in relation to rehabilitation. The soil is fragile and prone to wind erosion during, and, following disturbance. Prior to disturbance, the soil surface is well stabilized by cyanobacterial soil crusts and chenopod dominated vegetation. The ecosystem benefits of cyanobacterial crusts include surface soil stabilisation and reduction in wind and water erosion, increased water infiltration, nitrogen and carbon fixation. Beginning the rehabilitation process with a cyanobacterial crust may therefore offer the soil protection, as well as the start of biological processes that survive harsh conditions due to their ability to deactivate and reactivate according to seasonal conditions. Using cyanobacteria as a kick-start for mining rehabilitation is not commonplace practice in the Australian rangelands. A new research program is underway with the University of Queensland to assess the potential for using components of the cyanobacterial soil crust to stabilise soil stockpiles and rehabilitated land surfaces.

Introduction

The Jacinth-Ambrosia (J-A) heavy mineral sand mine is located in two arid zone Regional Reserves on the eastern edge of the Nullarbor Plain, South Australia. Rainfall records from Maralinga, 100 km north-west of the mine, indicate a mean annual winter-dominated rainfall of 224 mm. Annual pan evaporation is ~ 2,340 mm, far in excess of rainfall. Temperatures range from a mean of 15.5℃ in winter to a mean of 34.8℃ in summer (BOM

2010). Highly erosive winds (>30 km/h) are common over summer, but also occur over winter, often accompanied by rainfall (Goode 2009).

The J-A mine has a lifespan of 10-15 years and is expected to impact an area of approximately 2,100 ha, with ore being excavated to a maximum depth of 45 m. Overburden and ore is mined using trucks, excavators and a dozer trap. A wet concentrating plant produces heavy mineral concentrate using gravity separation. The by-products (tailings) are returned to a tailings storage facility and the mining void as co-disposed sand and clay. The process water and therefore the tailings are hypersaline (~97 mS/cm) (Goode 2009). After 18-24 months the tailings will be directly returned to the previously mined landscape. An estimated 70% of the mining footprint will be rehabilitated using this method.

Prior to disturbance the landscape is dominated by open Myall (*Acacia papyrocarpa*) woodland with a chenopod shrubland understorey. The soil surface is well stabilised by cyanobacterial soil crusts. Cyanobacterial crusts are prolific in the local Nullarbor environment and they protect a topsoil that extremely fragile and prone to wind erosion both during and following disturbance.

Prior to mining a new area, particular care is taken with this topsoil layer, which contains all of the cyanobacterial crust and the majority of the vegetation seed bank. Topsoil (0-50 mm) is separately removed, transported and made into low stockpiles using carry graders (Fig. 1).

Fig.1. *Carry grader at J-A, top soil stripped in foreground*

Currently, soil surface stabilisation post mining disturbance is achieved through a combination of rain wash and the application of potable or treated waste water - creating a physicochemical crust. Large quantities of hypersaline process water or the finest fraction of the tailings by-product ('clay-fine sand mix') are also available for soil stabilisation; however their current use is restricted.

In-situ, the cyanobacterial soil crusts are critical structural and functional components of the ecosystem (Bowker 2007). Cyanobacteria are the primary colonisers, stabilisers and nitrogen fixers of the biological crust (Belnap and Lange 2003). Eldridge (1996) suggested that soil crust biota, particularly cyanobacteria, could have enormous potential for bioremediation of rangeland soils. Bowker (2007) suggested rehabilitation with biological soil crusts should be undertaken not merely to return the crust to an area, but more importantly to begin restoring ecosystem function to that area. Both papers indicate there is potential to improve future rehabilitation outcomes through choice of a soil stabilisation medium. Unlike water or commercial stabilisation products, a cyanobacterial soil crust could potentially provide soil protection and ecological processes and can deactivate and reactivate according to seasonal conditions.

As a result, a new research program has been initiated between the J-A mine and the University of Queensland, to investigate the ecosystem benefits of incorporating cyanobacterial crusts into future mine rehabilitation programs. The key goals of this research are to assess the potential for cyanobacterial crusts to contribute to mine rehabilitation through: (1) an improved understanding, followed by re-establishment, of the cyanobacterial crust landscape roles and arrangement (nitrogen and carbon cycling, water infiltration pathways, niches for vascular plant germination), (2) rapid and temporary soil stabilisation on soil stockpiles, (3) permanent and evolving soil stabilisation on rehabilitated soil surfaces, (4) a step-based approach to rehabilitation where the crust deactivates, not expires, during extended periods of drought and (5) re-establishment of a biodiverse ecosystem that includes cyanobacterial soil crusts.

Delivery mechanisms will be assessed to achieve these goals including; (a) inoculating cyanobacterial cultures with a variety of soil stabilisation media (water sources or clay/fine sand tails) and, (b) maximising the outcomes from scalping and direct return transfer of the cyanobacterial soil crusts. The overall aim is to establish techniques for cyanobacterial inoculation as the primary stabilisation means for both soil stockpiles and rehabilitated soil surfaces at the J-A mine.

Methods

A series of lab and field trials is planned to investigate the goals stated above. Two experimental sites have been established, the first to assess the dominant form of crust found within the mine lease. The other site is located at a nearby salt lake and is consistently exposed salinity and frequent disturbance via wind and water erosion.

These sites will be characterised using Landscape Function Analysis (Tongway and Hindley, 2004), crust diversity, biomass (chlorophyll *a* extraction), and plant available nitrogen.

Following the initial site characterisation, cyanobacterial soil crust samples will be collected and assessed in a lab trial comparing watering and soil disturbance treatments. Intact and disturbed crusts will be treated with the water sources available for rehabilitation on site - hypersaline water, treated effluent water and reverse osmosis water.

After analysis of the lab trial results the most promising treatments will be applied to a small-scale field trial, followed by larger scale field trials.

Discussion

Despite the lack of working examples in the Australian environment, some promising research has been conducted overseas. In Inner Mongolia, China, *Microcoleus vaginatus* was mass cultivated, inoculated onto a sand dune and irrigated, with crusts forming in 22 days that were able to resist wind and rainfall erosion (Chen *et al.* 2006). Another promising example from China showed that it is feasible to inoculate and cultivate artificial soil crusts by crushing and broadcast sowing the natural crust (Xiao *et al*. 2008).

In summary, developing techniques to establish cyanobacterial crusts as early colonisers of re-established soils has the potential to improve the speed and quality of rehabilitation outcomes. As a result of the Jacinth-Ambrosia and University of Queensland research program, it is expected that techniques for cyanobacterial soil crust establishment in an arid zone environment will be identified for initial broad scale field trials by winter 2011.

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