EFFECT OF DIFFERENT STOCKPILING PROCEDURES ON TOPSOIL CHARACTERISTICS IN OPEN CUT COAL MINE REHABILITATION IN THE HUNTER VALLEY, NEW SOUTH WALES

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ABSTRACT

There are currently 17 open cut coal mines in the Hunter Valley (New South Wales, Australia) that produce 58 Mt/annum of coal for export and domestic use. Mines are legislatively required to rehabilitate land on completion of mining operations. The most common rehabilitation objective in the Hunter Valley is to return mined land to pasture ecosystems for low intensity cattle grazing. Topsoil management is an important factor in determining the long-term success of rehabilitation and sustainable post-mining landuse. However, topsoil in the Hunter Valley is often scarce and of poor quality, in terms of its physical, chemical and biological properties. Current Department of Infrastructure, Planning and Natural Resources (DIPNR) guidelines recommend that if storage of topsoil is needed stockpiles should be constructed to a height of less than 3 m. However, no studies in the Hunter Valley have directly assessed the effect of stockpile height and age on soil quality. When compared to smaller stockpiles, larger stockpiles lead to the disturbance of smaller areas of land, and a decreased cost of construction and management. The major objective of this study was to examine the effect of increasing stockpile heights and age on the physical, chemical and biological components of topsoil used to rehabilitate open cut coal mines in the Hunter Valley.

A preliminary survey of topsoil stockpile characteristics in the Hunter Valley and Bowen Basin (Queensland, Australia) was undertaken. One hundred and fifty soil samples were collected from 25 stockpiles and two depths (0-20 and 80-100 cm) at 12 mines in the Hunter Valley. Information on stockpiles in the Bowen Basin was collected through a questionnaire with detailed information obtained from seven mines and 60 stockpiles. Topsoil stockpiles in the Hunter Valley were younger, taller but were of lower volume than those in the Bowen Basin, indicating the unique nature of topsoil management in the Hunter Valley. Soil parameters differed significantly across the 12 mine sites indicative of the variable soil types within the Hunter Valley, ranging from loamy sand to clay loam soil types. Height and age of stockpiles did not significantly affect the majority of investigated parameters. Microbial respiration was maximal in moderately aged stockpiles and subsequently decreased in older stockpiles as the anaerobic zone became more extensive. Nitrate-N, ammonium-N and exchangeable cation levels were significantly higher in the 80-100 cm than the 0-20 cm depth class, indicative of leaching over time. Microbial respiration was positively correlated with vegetation cover emphasising the benefits of seeding stockpiles after construction.

A field trial was established at three mine sites (Bengalla, Cheshunt and Mt Arthur Coal) investigating the effect of stockpile height (2, 4 and 6 m) and age (0, 6, 12, 18 and 30 months) on physical, chemical and biological aspects of the topsoil. Soil samples were collected at different depths, depending on the height of the stockpile. During the stockpile construction, many soil parameters (e.g. microbial respiration, total N and soil organic carbon) decreased by up to 50%,

indicating that deterioration of soil quality is rapid and initially independent of stockpiling. Multivariate analysis indicated that site was the most significant factor differentiating between topsoil characteristics. Within each site, age of stockpiles was the most significant factor affecting soil parameters. For example, microbial respiration decreased over time, while species richness and seed density in the topsoil seed store increased over time as vegetation established and set seed. The 2 m stockpiles had greater levels of soil organic carbon and nitrate-N indicating maintenance of soil quality, while ammonium-N was greater in the 6 m stockpile due to ammonification occurring under anaerobic conditions. Nitrate-N, ammonium-N, electrical conductivity, available P and some exchangeable cations increased with depth as a result of leaching, although an accumulation at the base of the taller stockpiles meant that nutrients were not lost completely. Deterioration of soil quality during stockpiling was greater for the clay loam soils at Mt Arthur Coal, compared to the loam and sandy loam soils at Bengalla and Cheshunt respectively. For example, at Mt Arthur Coal but not the other two mines, nitrate-N decreased and ammonium-N increased with depth indicative of the formation of anaerobic zones. Overall, stockpiling topsoil under the relatively dry conditions experienced during this study had a relatively minor impact on soil quality, particularly when compared to the initially large impact of handling topsoil with heavy machinery.

A glasshouse trial was undertaken to investigate physical, chemical and biological ameliorants that could be utilised to address decreases in soil quality following stockpiling. A total of 72 treatments were investigated, namely six stockpile attributes (two ages by three heights), two physical (gypsum and control), three chemical (inorganic, organic and control) and two biological ameliorants (fresh topsoil and control), with four replicates. Monitored for 12 weeks all ameliorants affected some of the chemical and biological parameters that were assessed. Gypsum application decreased pH and increased Ca and was recommended for mine sites with alkaline and/or sodic topsoil. Organic fertiliser (biosolids) generally increased chemical and biological parameters to a greater extent than the inorganic treatment (Diammonium Phosphate - DAP). The addition of fresh topsoil increased plant biomass, species richness and vegetation cover, but not microbial respiration.

A field rehabilitation trial, based on the results of the glasshouse trial, was established at three mine sites (Bengalla, Cheshunt and Mt Arthur Coal) to investigate the effects of different chemical (inorganic, organic and control) and biological (fresh topsoil, biological inoculum and control) amelioration techniques on topsoil from stockpiles of different height (2, 4 and 6 m) and age (18 and 30 months). Increased rainfall following the second (30 month) compared to the first (18 month) spread influenced the quality of the rehabilitation more than the age of the stockpiled soil. Height of stockpiles had little influence on soil quality in the rehabilitation areas, suggesting those parameters that did deteriorate as stockpile height increased can be rectified by soil mixing

and oxidation during the respreading process. Application of biosolids increased chemical (e.g. total and available N and P) and some biological (e.g. biomass, microbial respiration and cover) soil parameters to a greater extent than inorganic fertiliser (DAP), supporting the results from the glasshouse trial. Organic fertilisers should be encouraged in mine site rehabilitation in the Hunter Valley because they provide key limiting nutrients, organic matter and rapid soil stabilisation. Addition of fresh topsoil as a biological ameliorant did not significantly increase microbial respiration, however the majority of other biological measures did increase. The microbial liquid inoculum did not increase the majority of the biological parameters and is not recommended for use without further refinement.

The results from the four experimental chapters were synthesised into a height by age standardised matrix based on overall chemical and biological soil quality. The matrix exemplified the differences in soil types, with soils with higher clay content requiring greater amelioration for shorter stockpiles more rapidly than sandier soils. A range of management recommendations relating to topsoil stockpiling and subsequent rehabilitation were made for open cut coal mining in the Hunter Valley, these include; the construction of lower stockpiles for shorter periods should be considered for mines with high clay content soils than those mines with sandier soils. Free draining shaped stockpiles prevent anaerobic zones forming – preventing erosion and encourage water run-off. Maintain seeding of stockpiles including nitrogen fixing species and grasses such as lucernes, cloves and medics. A high level of ammonium nitrogen is a recommended indicator for anaerobic zones and when respreading topsoil the aerobic and anaerobic zones formed should be mixed to avoid concentration or dilution of chemical or biological parameters. In summary, it was concluded that topsoil stockpiles in the Hunter Valley could be constructed to a height greater than the DIPNR guideline of 3 m as long as the potential greater levels of amelioration required in rehabilitated areas was recognised.

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