

ACIDITY NEUTRALISATION ASSESSMENT AND REMEDIATION OF A CONSTRUCTED WETLAND IN SUGARCANE LAND

By

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**KEYWORDS: Acidity Remediation, Constructed Wetland,
Rehabilitation for Sugarcane.**

Abstract

A CONSTRUCTED wetland of six level-terraced bays has been trialled for treating acidic sugarcane land drainage arising principally from the oxidation of acid sulfate soils. A concern has been that the cane land may have been permanently degraded for future cane production due to the accumulation of acidic metal contaminants (especially iron and aluminium) stemming from this remediation technique. The site is now being remediated so that it can be returned to cane production. Following initial measurements to establish the water quality and sediment characteristics in the wetland, assessment was made of the required acidity neutralisation by liming, and these results were compared with best management practices for acid sulfate soil drains of New South Wales cane areas. Lime application and its incorporation were accompanied by removal of constructed banks and re-levelling of the cane block. The ability of the constructed wetland to neutralise acidity has been reported previously. Further assessment of water quality following rainfall and acid drainage shows the inherent neutralising capability of constructed wetlands, as determined by changes to pH, electrical conductivity, dissolved oxygen, and metal concentrations. Total acidity of surface soils (0–50 mm) was measured as being comparable with drain sediment in acid sulfate soils. Lime application, its incorporation, and re-levelling of the wetland site are within the scope of standard farmland practices. This approximately 1.6 ha constructed wetland surface was only capable of treating ~10% of the total acidity discharge from the 100 ha cane farm. The adoption of this as standard practice in acidic sugarcane drainage treatment is therefore impracticable. However, the principles shown here have potential for application in management of vegetated drains. Results show that the land used for the constructed wetland has not been permanently damaged by this trialled acidity remediation device.

Introduction

Acid sulfate soils (ASS) underlie more than 50% of the estuary floodplains used for sugarcane production in New South Wales, Australia. The sub-tropical high rainfall of these lands requires major surface drainage systems with the soils supplying significant acidity to the drainage water.

Robert Quirk operates one farm (100 ha) on ASS, and this site over the past 20 years has been the subject of much research and trialling of best management practices to reduce acidity discharge. Dr Rosalind Green completed most of her doctoral studies on the Quirk farm and its

drainage system, trialling a number of potential acidity management techniques. An important outcome of Green’s research was that, although protonic acidity (H₃O⁺, as indicated by pH) is an important component of the drain water acidity, the main transported acidity component (>70%) is in the dissolved metals, particularly Aluminium (Al) and Iron (Fe) (see Figure 1).

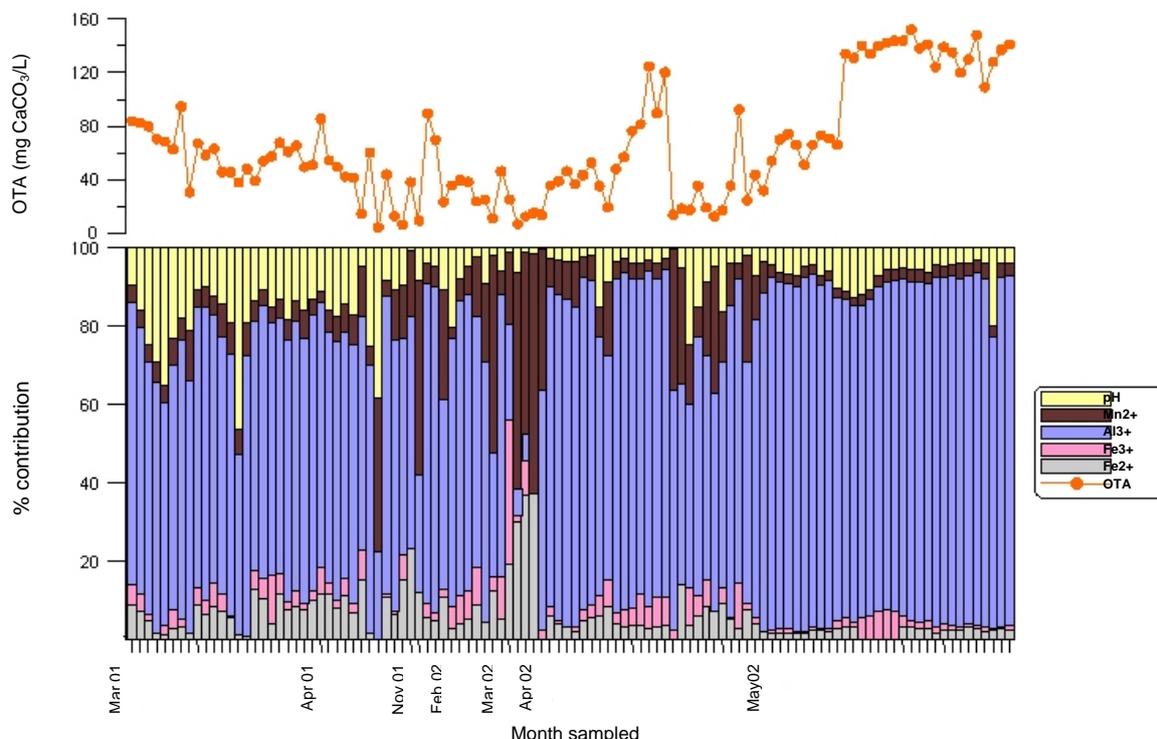


Fig. 1—Contribution of dissolved metals and protonic acidity (‘pH’) to Oxidised Titrable Acidity, OTA (from Green *et al.*, 2006; modified by A. Keene).

These dissolved metals hydrolyse and form acidity when they precipitate, particularly in downstream waters (simplified in Equ. 1 and 2).



Managing such acidity from sulfide minerals and their oxidation products is also a major environmental issue with many mine sites. One management technique used to reduce acid mine drainage (AMD) is with constructed wetlands.

Therefore, using funds from the Australian Sugar Research and Development Corporation, a wetland of 6-terraced bays (approx. 2 ha of land with 1.6 ha of wetland surface) was constructed in 2003/4 adjacent to the drainage outlet from the 100 ha Quirk farm. A proportion (about 10%) of the drainage discharge from the farm was pumped into the uppermost bay from which it gravitated back into the farm’s outlet drain.

Characteristics and performance of this wetland have previously been reported in Quirk *et al.* (2009). The wetland has completed its proposed tasks and is now being returned to its former cane production.

Two major issues of concern for the NSW sugar industry are: firstly, whether the precipitation of the acidity in the wetland would permanently damage the land for future cane production, and secondly, whether such a management technique might in the future be forced upon the industry.

April 2009 wetland operation and modifications

A major problem with operation and monitoring of water quality performance in the wetland has been the need to pump water into it from the farm's outlet drain after an appropriate amount of rain that promoted an acidity discharge event. Rainfall was often insufficient to retain water over the wetland surface, with sediments and any precipitated metals frequently drying out. At other times flooding from the adjacent Tweed River inundated the area under more than 1 m of floodwater. During periods of low rainfall, the farm's drain water was both too little and became too saline (electrical conductivity, EC > 3 dS/m) to allow pumping into the wetland. Controlled leakage into the farm's drain system is enabled from the adjacent semi-tidal McLeod's Creek (EC up to 20 dS/m) so that drain-bottom sediments do not dry out and oxidise. A large capacity electrical pump at the farm drain's outlet maintains the drain system water level sufficiently low to provide small rain event runoff storage but below that which would cause any lateral transfer of saline water under the cane crop. Generally, a rain event of about 35 mm is sufficient to fill the farm's drain system and initiate the automatic pump.

At the end of March 2009 about 120 mm of rain occurred followed by a further 300 mm during the first week of April (see Figure 2). An intensive final monitoring program between April 7 and 24 was therefore undertaken that included shifting the wetland inlet position from Bay #1 to Bay #3. Bays #1 and #2 were then allowed to commence drying and enable vegetation and sediment sampling as a prelude to trialling acidity neutralisation and wetland rehabilitation for cane production.

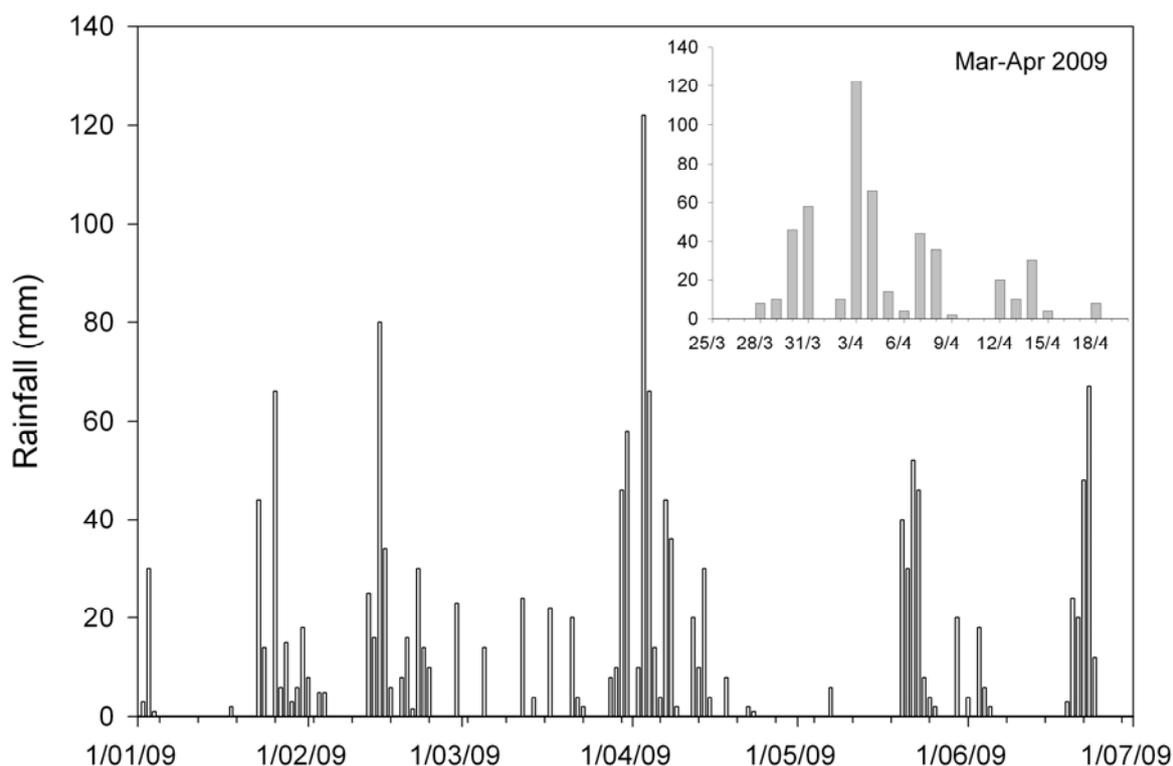


Fig. 2—Daily rainfall at site during 2009 with late March and April inset.

Water quality monitoring was completed across the wetland during the April study period. Initially, water quality in all wetland bays was measured (pH, EC, dissolved oxygen-DO or redox potential) but on April 10th the water inlet was transferred from Bay #1 into Bay #3 as mentioned above (see Figures 3 and 4). The effect of the initial large rainfall event is seen with the input water and down through the wetland, in values of high pH and low EC. The initiation and progress of acidic inputs through the wetland is seen in Figure 3.

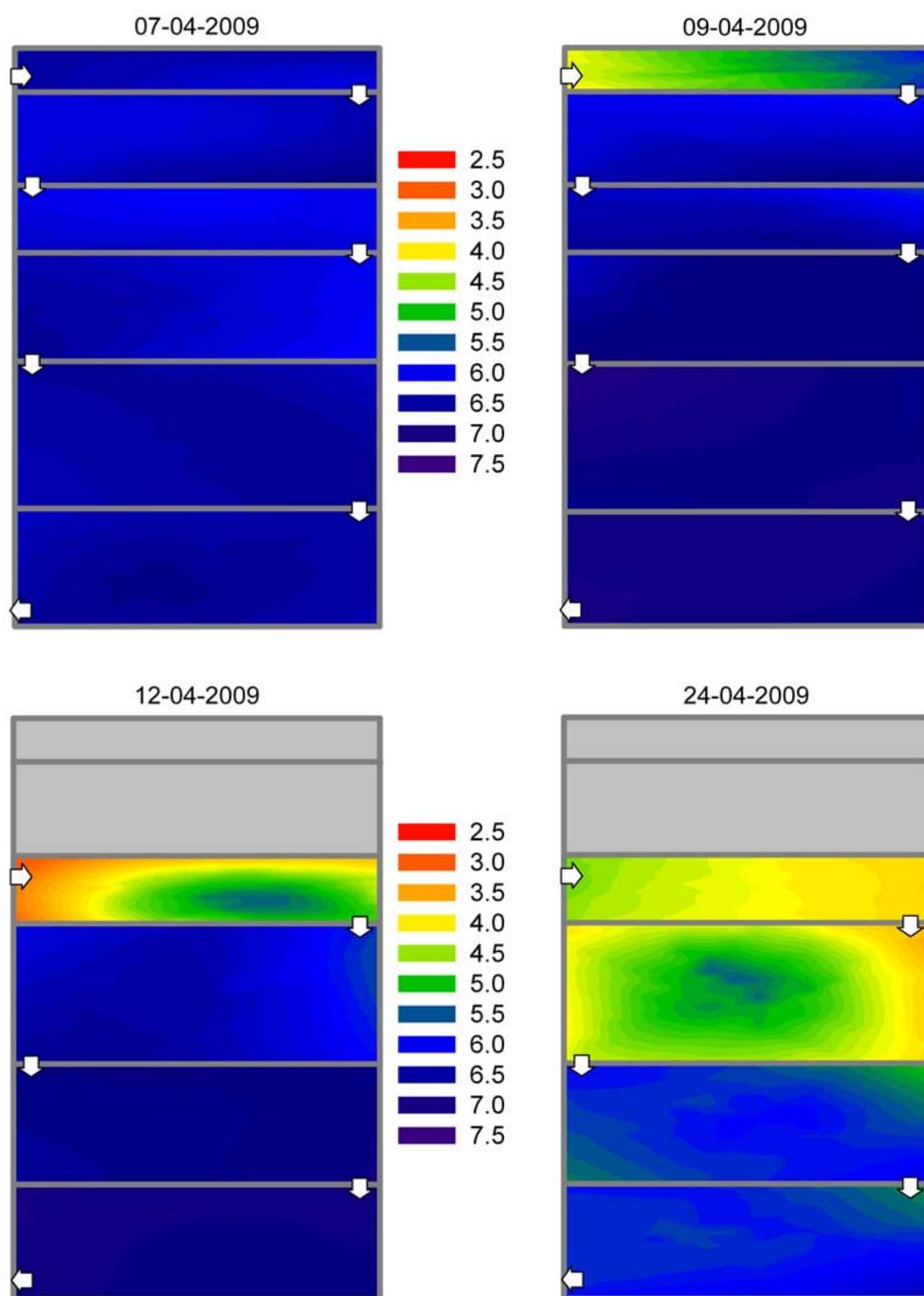


Fig. 3—Wetland water quality pH during April 2009 study period.

Towards the end of the study period, the input of less acidic (higher pH) and more brackish drain water (higher EC) can be seen.

Clearly, although acidic water was input continuously at about 100 L/min (there were some brief occasions when the pump stopped), as previously shown in Quirk *et al.* (2009), the wetland neutralised this acidity in the first one or two bays so that little of this acidity load exited from the wetland.

Red-brown iron precipitates on the wetland vegetation were obvious, particularly nearer the inlet points where initially reduced ferrous iron oxidised to ferric oxy-hydroxides (see Equ. 2).

The reduction of incoming dissolved sulfate to metal sulfide was seen in formation of black precipitates and objectionable odours, particularly after rain ceased and DO decreased over time.

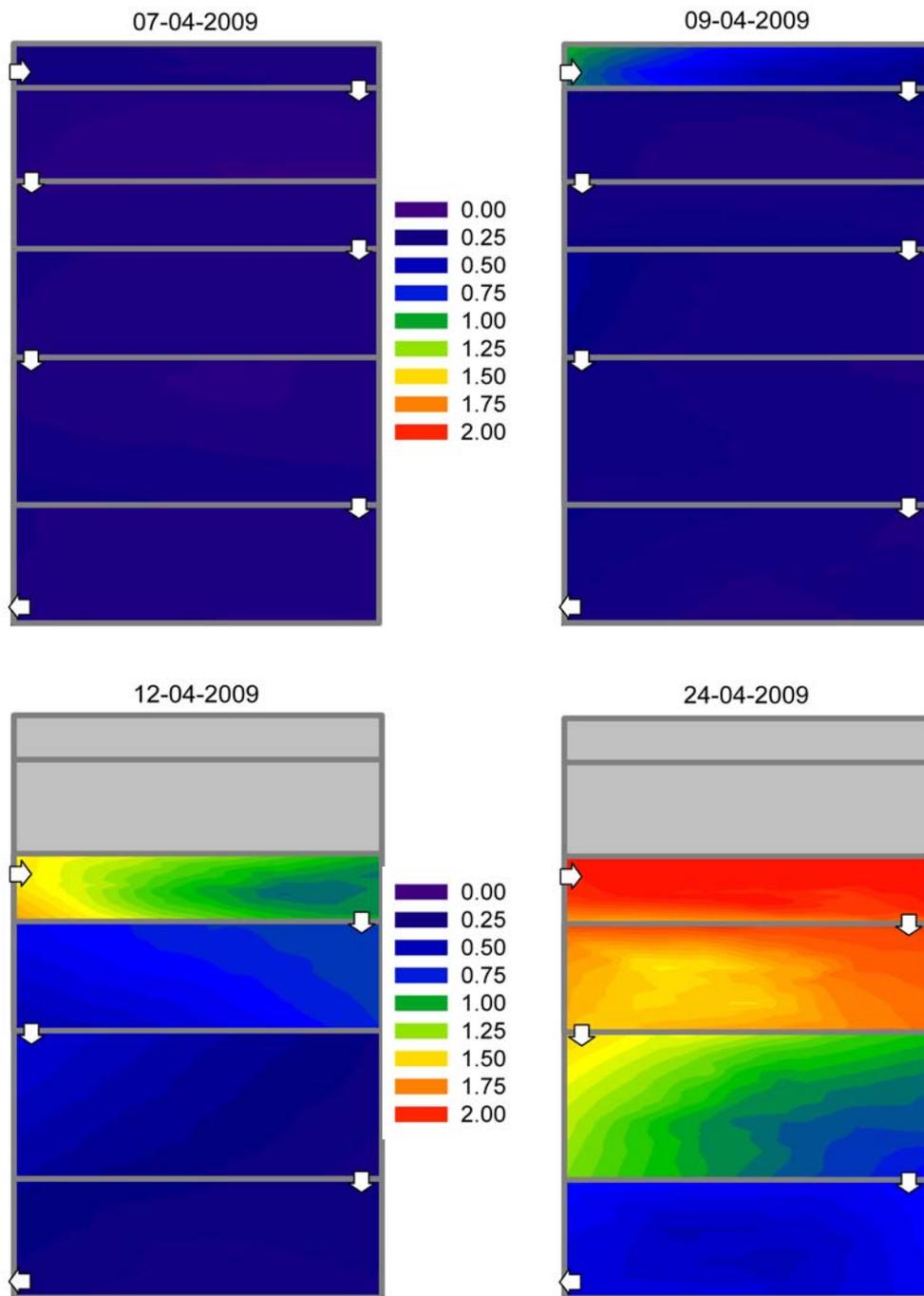


Fig. 4—Wetland water quality electrical conductivity (dS/m) during April 2009 study period.

Wetland vegetation sampling

Wetland vegetation was established by natural recruitment from apparently waterborne seeds. The main two species were couch grass (*Cynodon dactylon*) and common spike rush (probably *Eleocharis palustris*).

Both of these perennial, strongly rhizomatous species are native to Australia, although widespread elsewhere in the tropics and sub-tropics. A number of larger and woodier weed species established in the wetland over time, particularly on the wetland bay and perimeter banks. However, these weeds were controlled by weedicide wicking and spot spraying. The couch grass established best on the flat area of each bay while the *Eleocharis* tended to establish in the deeper water of the borrow-pits formed during bank construction (see Figure 5).

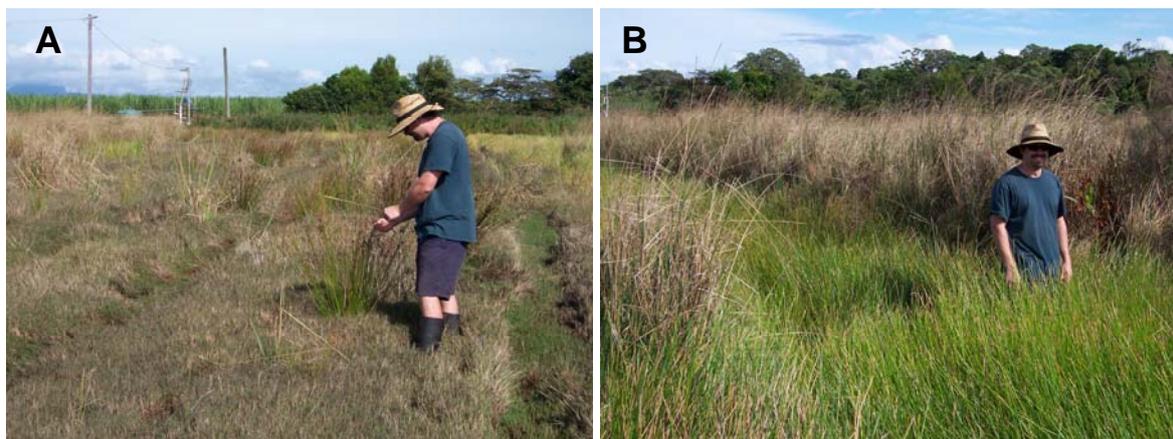


Fig. 5—Dr Kinsela standing among: (a) Couch Grass (*Cynodon dactylon*); (b) Common Spike Rush (*Eleocharis palustris*).

Total plant dry biomass samples of each of the two main species were taken from Bays #1 and #2. Three samples of each species were extracted using a spade, separating the root and shoot portions, bulking the sub-samples together, and oven-drying (85°C) and weighing. The total biomass of Couch was 3.17 kg/m² (about 32 t/ha, with approx. 60% shoot and 40% root): Eleocharis was 2.55 kg/m² (about 25 t/ha, with approx. 50% shoot and 50% root). These biomass yields are after more than 3 years growth; small by comparison to sugarcane and rather small by comparison to one-year irrigated pasture yields in Victoria, Australia (19–31 t/ha, shoot only; from Blaikie *et al.*, 2002).

Wetland soil samples and contained acidity measurement

Three surface soil samples (0–50 mm) were taken by core from each of Bays #1 and #2 after diversion of the water flow. Each sample was bulked from 3 sub-samples. The samples were dried, sieved and analysed at the Tweed Laboratory (Tweed Shire Council) using the standard acid sulfate soil analytical methods of Ahern *et al.* (2004). The measured pH (pH_{KCl}) and total existing acidity measured by titrating to end-point pH 5.5 in a 1M KCl soil extract ('TAA'), and the existing plus potential acidity with another such titrated extract, but additionally after oxidation with 30% hydrogen peroxide ('TPA'), are shown in Table 1. The peroxide treatment in TPA is intended to oxidise any sulfide minerals in the sample.

Table 1—Wetland surface soil (0–50 mm) acidity analyses. Values of TAA and TPA in mol H⁺/t dry soil.

Sample #	Bay #1				Bay #2			
	1	2	3	Mean (s.e.)	1	2	3	Mean (s.e.)
pH KCl	4.2	4.1	4.1	4.1	5.6	4.2	4.0	4.3
TAA	85	130	120	112 (16)	15	108	102	75 (35)
TPA	110	193	140	148 (30)	65	183	145	131 (47)

The overall mean TPA of 139 mol H⁺/t across Bays #1 and #2 equates to approx. 7 kg H₂SO₄/t soil. Assuming this represents the surface 0–50 mm of the total 1.6 ha of the wetland surface, and further that the soil bulk density is 1 t/m³, the measured acidity is the equivalent of approx. 5.6 tonnes of H₂SO₄ in the 1.6 ha. Each tonne of H₂SO₄ requires approx. 1 tonne of lime (CaCO₃) for acidity neutralisation. Using the common factor of safety of 1.5, neutralisation of the surface soil acidity, mostly sourced from inputs to the wetland, therefore, would require about 8.5

tonnes of lime (about 5.3 t/ha). This approximates the rate of lime normally applied by Robert Quirk (5 t/ha) with a plant cane crop to satisfy the NSW cane industry's Code of Best Management Practices (CBMP) for managing acid sulfate soils. Of course, the measured surface soil acidity was from those bays where most metal-sourced acidity would have been precipitated.

Application of constructed wetlands for acidity amelioration in sugarcane

It is clear from these results that, having limited the input of salt to the wetland, the inputs of acidity from the farm's drain water has not permanently damaged the soil and the land can easily be rehabilitated for cane production after adequate lime application, removal of terrace and perimeter bank by in-filling their adjacent borrow-pits, and re-establishing the laser-levelled drainage regime. The amount of acidity accumulated in the wetland over the 3 to 4 years of its intermittent operation probably had a significantly smaller effect than that of the land adjacent to cane field drains when they are cleaned and the drain sediments limed, spread, and incorporated into the cane field, as per the industry's CBMP.

This wetland already occupied about 2% of the farm's land area and only treated about 10% of the acid water discharge. On this basis, it might require a constructed wetland occupying up to 20% of a cane farm to treat all of the acidity discharge. Such a possible management tool is completely impracticable. However, there are still useful lessons that can be gained from this experiment, but these would require some shift in understanding and operation by cane farmers.

It is clear that acid water passing through vegetation stands has some of its acidity removed. Most drains in NSW cane lands have various vegetation growth, often including the main species (Couch and *Eleocharis*) identified in this wetland. In some instances, the water depth in the drain is too great for these species but there is a move being encouraged for farmers to use shallower drains.

On many occasions, farmers see the presence of any in-drain plant growth as deleterious to the passage of drainage water. Nevertheless, the drains are mostly required to remove water quickly under fairly high flow conditions.

At these times, the useful plant species we have identified are drowned-out and would cause little obstruction to flow. In the latter phase of a flood hydrograph, the flow rates are less and it is at this time that acidity discharge is greatest so the presence of in-drain plants would reduce acidity discharge. Any metal-sourced acidity precipitates would periodically be neutralised by liming during drain cleaning in accordance with industry's CBMP.

REFERENCES

- Ahern, C.R., McEnea, A.E. and Sullivan, L.A.** (2004). Acid Sulfate Soils Laboratory Method Guidelines. In: Queensland Acid Sulfate Soils Manual. Dept of Nat. Res's, Mines and Energy, Indooroopilly, Qld, Australia.
- Blaikie, S.J., Olsson, K.A., Hirth, J.R., Greenwood, K.L., Dellow, K.E. and Kelly, K.B.** (2002). Soil properties, root responses and production of irrigated pasture on a red-brown earth after subsoil modification. *Aust. J. Exp. Agric.*, 42(4): 453–463.
- Green, R., Waite, T.D., Melville, M.D. and Macdonald, B.C.T.** (2006). Characteristics of acidity in acid sulfate drainage waters, McLeods Creek, northeastern NSW, Australia. *Env. Chem.*, 3: 225–232.
- Quirk, R., Melville, M., Kinsela, A., Reynolds, J., Zwemer, T., Hancock, M., Macdonald, B. and White, I.** (2009). Treatment of drainage from acidic canelands using a constructed wetland. *Sugar Tech.*, 11(1): 73–76.

EVALUATION ET ASSAINISSEMENT DE L'ACIDITE PAR UN MARAIS ARTIFICIEL DANS DES TERRES A CANNE

Par

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**MOTS-CLÉS: Assainissement d'Acidité, Marais Artificiels,
Réhabilitation de la Canne à Sucre.**

Résumé

UN MARAIS artificiel de six niveaux en terrasses a été testé pour le traitement des drainages acides des terres de canne à sucre résultant principalement de l'oxydation des sols acides sulfatés. Une préoccupation a été que ces terres de canne ont été définitivement dégradées en raison de l'accumulation des contaminants métalliques acides (en particulier le fer et l'aluminium) découlant de cette technique d'assainissement. Le site a été maintenant assaini pour qu'il puisse être remis sous production cannière. Suite aux premières analyses pour établir la qualité de l'eau et les caractéristiques des sédiments dans le marais, la neutralisation de l'acidité existante par le chaulage a été évaluée, et les résultats ont été comparés avec les meilleures pratiques de gestion des sols sulfatés acides cultivés en canne dans la Nouvelle-Galles du Sud. L'application de chaux et son incorporation ont été accompagnées par l'élimination des marais construits et par un nivellement du bloc de canne. La capacité du marais artificiel pour neutraliser l'acidité ayant été démontrée précédemment, une évaluation plus approfondie de la qualité de l'eau après les pluies, et de drainage acide montre maintenant la capacité de neutralisation inhérente des zones humides artificielles, telles que indiquées par les changements de pH, de la conductivité, d'oxygène dissous, et par les concentrations des métaux. L'acidité totale des sols de surface (0–50 mm) était comparable à celle des sédiments dans l'eau de drainage des sols acides sulfatés. L'application de chaux, son incorporation, et le re-nivellement de la zone humide sont à la portée des pratiques agricoles standard. Ce marais d'environ 1.6 ha de surface a été capable de traiter seulement environ 10% de la décharge d'acidité totale provenant de 100 ha de canne. L'adoption de cette pratique comme un standard pour le traitement du drainage acide de canne à sucre n'est donc pas possible. Toutefois, les principes présentés ici ont un potentiel d'application dans la gestion de la végétation des drains. Les résultats montrent que les terres utilisées pour la construction des marais n'ont pas été endommagées de façon permanente par ce dispositif d'assainissement de l'acidité.

EVALUACIÓN DE NEUTRALIZACIÓN ÁCIDA Y REMEDIACIÓN DE UN HUMEDAL DE UNA PLANTACIÓN DE CAÑA DE AZÚCAR

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PALABRAS CLAVE: Acidez, Remediación, Humedal, Rehabilitación para Caña de Azúcar.

Resumen

SE CONSTRUYÓ un humedal de seis niveles en terrazas para drenaje de tierras plantadas con caña de azúcar, acidificadas principalmente por la oxidación de suelos con sulfatos ácidos. Surgió preocupación por degradación permanente del terreno, a causa de esta técnica de remediación, para la producción futura de caña de azúcar por la acumulación de contaminantes de metales ácidos (especialmente hierro y aluminio). Actualmente el lugar se encuentra bajo remediación para devolverlo a la producción de caña. Luego de mediciones iniciales para establecer la calidad del agua y las características de los sedimentos en el humedal, se evaluó el requerimiento de cal para la neutralización de la acidez y estos resultados se compararon con las mejores prácticas de manejo del drenaje de suelos con sulfatos ácidos del área cañera de Nueva Gales del Sur. Además de la aplicación de cal y su incorporación, se eliminaron los montículos formados y se niveló el lote. Previamente se ha reportado la capacidad de los humedales para neutralizar la acidez. Una evaluación más profunda de la calidad del agua después de la lluvia y del drenaje de ácidos, muestra la capacidad de neutralización de los humedales, lo cual se observa en cambios de pH, conductividad eléctrica, oxígeno disuelto y concentración de metales. La acidez total de la superficie de los suelos (0–50 mm) es comparable con el sedimento del drenaje de suelos con sulfatos ácidos. La aplicación de cal, su incorporación y la nivelación del humedal están contempladas entre las prácticas agrícolas estándar. En este caso, la superficie del humedal, de aproximadamente 1.6 ha, tuvo capacidad para tratar únicamente alrededor del 10% de la descarga ácida total de las 100 ha de la finca cañera. La adopción de ésta como una práctica estándar en el drenaje de ácidos es, por tanto, impráctica. Sin embargo, los principios mostrados en el presente trabajo tienen potencial aplicación en el manejo de drenaje de suelos anegados. Los resultados muestran que los terrenos utilizados no presentan degradación permanente a causa de la construcción de los humedales.