Geochemical risks of saline acidic discharge from deep drains used to manage dryland salinity in Western Australia: overview

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Introduction

Salinisation due to rising watertables is a significant management issue in many parts of the Western Australian (WA) Wheatbelt and is expected to continue increasing in extent (Hatton et al. 2003). The primary cause in many parts of Australia is related to an increase in groundwater recharge following native vegetation clearance for annual crops and pastures. In valley floors of the Wheatbelt, there is increasing use of engineering methods such as deep (2–3 m) drains and groundwater pumping to manage rising groundwater and to protect low-lying land from salinisation or to rehabilitate marginally saline lands.

More than 3000 km of deep drains have already been constructed: most are less than 20 km long and discharge into saline lakes, creeklines and floodways. Although some drains discharge only during the initial dewatering of regolith profiles, others continue discharging for many years at rates of up to 10L/s. The interest in further expansion of drainage from individual properties to regional integrated drain systems has been met with concerns regarding the prospects of safe disposal of waters created by these schemes, particularly since some saline drain discharges are acidic (Ali et al. 2004). The occurrence of acidic groundwaters in the eastern Wheatbelt regions of WA (and Goldfields) has been known since the 1980s (Mann 1983). These waters were known to locally contain elevated concentrations of trace metals. The prospect of increased discharge of acidic groundwater to surface environments demands greater understanding of the distribution, origin of the acidity and the geochemical risks associated with draining and disposing of these waters.

We report on the results of a recent catchment-scale hydrogeochemical survey in the WA Wheatbelt including an evaluation of the geochemical risks to receiving environments. This survey was linked with targeted hydropedological investigations to identify key geochemical processes influencing risks within drains and receiving environments (Fitzpatrick et al. 2008).

Materials and methods

Samples were collected from more than 200 bores, 80 groundwater drains, 55 creeks/rivers (surface waters) and 90 lakes (drainage receiving and non-receiving) in the eastern WA Wheatbelt to assess the potential risks on receiving environments. Samples were collected from an area spanning 90 000 km2 comprising the inland reaches of the Avon catchment (east of the Meckering Line) and the southern part of the Yarra Yarra catchment. Multiple sampling events were carried out over three years (2004–06) to characterise a range of surface waterways (drains and creeklines) and lakes in different stages of drying (though most were in the final stages). Groundwater samples were obtained by low-flow pumping or hand-bailing the bores, and all others were grab samples of surface waters. On-site measurements of pH, EC, temperature and Eh were taken at most sites. Drain/creek flows were also estimated whenever possible. All samples were filtered in the field through 0.45 µm membrane filters and either acidified with ultrapure nitric acid or retained unacidified and stored at 5 degrees C, depending on the analysis performed. The concentrations of major and minor cations and sulfate were determined by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES), and trace elements by Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Anion analyses were completed using ion chromatography.

Results and discussion

More than 56% of the drains in the eastern Wheatbelt were found to have waters with pH < 5.5 with many discharging at between 0.5 and 4 L/s. The acidic waters contained high concentrations of iron and aluminium — exceeding 500 mg/L in some cases (Fig. 1). Manganese was also present, though typically in concentrations generally less than 6 mg/L.

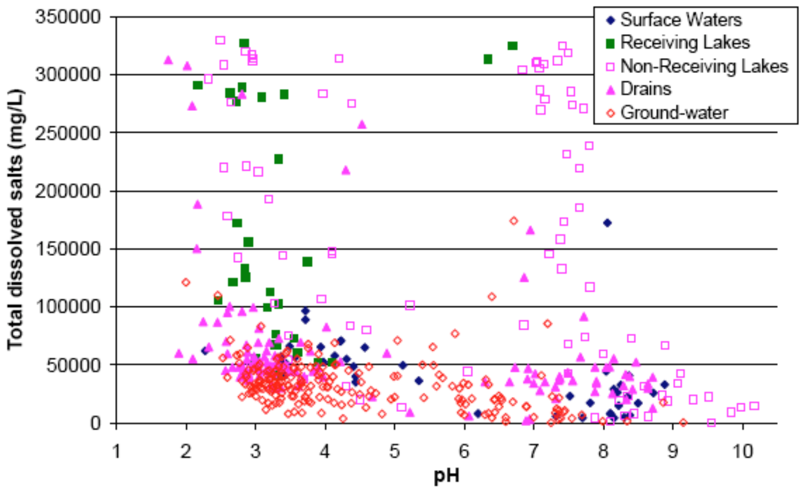

Figure 1 Total dissolved salt concentrations of waters in the WA Wheatbelt plotted against pH

The salinity of flowing drain waters ranged from 9200 mg total dissolved salts (TDS)/L to over 90 000 mg TDS/L for both alkaline and acidic drains (Fig. 1). Higher TDS concentrations were often due to increased evapoconcentration of salts in the drain during summer. Regional groundwaters in the area surveyed were generally less saline, generally ranging between 8000 and 65 000 mg /L TDS, with a tendency for alkaline groundwaters (>pH 6.5) to be less saline (Fig. 1). By contrast, the lakes contained waters up to 330 000 mg/L irrespective of pH. The ionic composition of all waters was dominated by Na and Cl (followed by Mg, Ca and SO4 2-) and broadly similar to that of evaporated seawater.

Groundwater pH across the eastern Wheatbelt ranged from highly acidic (pH < 3.5) to alkaline (> 7.5). Acidic groundwaters (pH < 5.5) frequently contained high concentrations of iron (45% exceeding 25 mg/L) and/or aluminium (66% exceeding 25 mg/L). The range in concentrations of these metals is similar to that in acidic drainage waters and was evidence that the chemistry of groundwater discharge significantly influences the acidity of waters in deep drains.

The concentrations of trace metals such as Cu, Cd, Zn, Ni, Pb and U in acidic drains broadly reflected those of the groundwaters, though there was a tendency for drainage waters to contain less Zn and Cu (Fig. 2). This highlights as ground-waters discharge and flow along drains there may be geochemical processes such as adsorption or precipitation retaining these elements. Despite this, trace metals such as Ni, Cu, Zn, U and Pb occurred in high concentrations in drainage waters, some exceeding 250 µg/L (particularly Zn, U and Pb). Other elements of environmental concern, such as Cd and As, were generally below detection limits within acidic drainage waters, though one sampled contained up to 5.1 µg Cd/L and another unrelated drain contained 40 µg As/L. Detailed analyses of the acidic drains, lakes and groundwaters also found that contained up to 10 mg/L of Ce and 3.8 mg/L of La , with generally lesser concentrations occurring in alkaline waters (generally < 0.1 mg/L). Most trace metals in alkaline drainage waters were below 20 µg/L, except for Zn and U (Fig. 2), which could occur in concentrations of up 300 ug/L. It is also noteworthy that there were some alkaline drains and groundwaters had concentrations of some trace metals similar to those in acid drains and groundwaters.

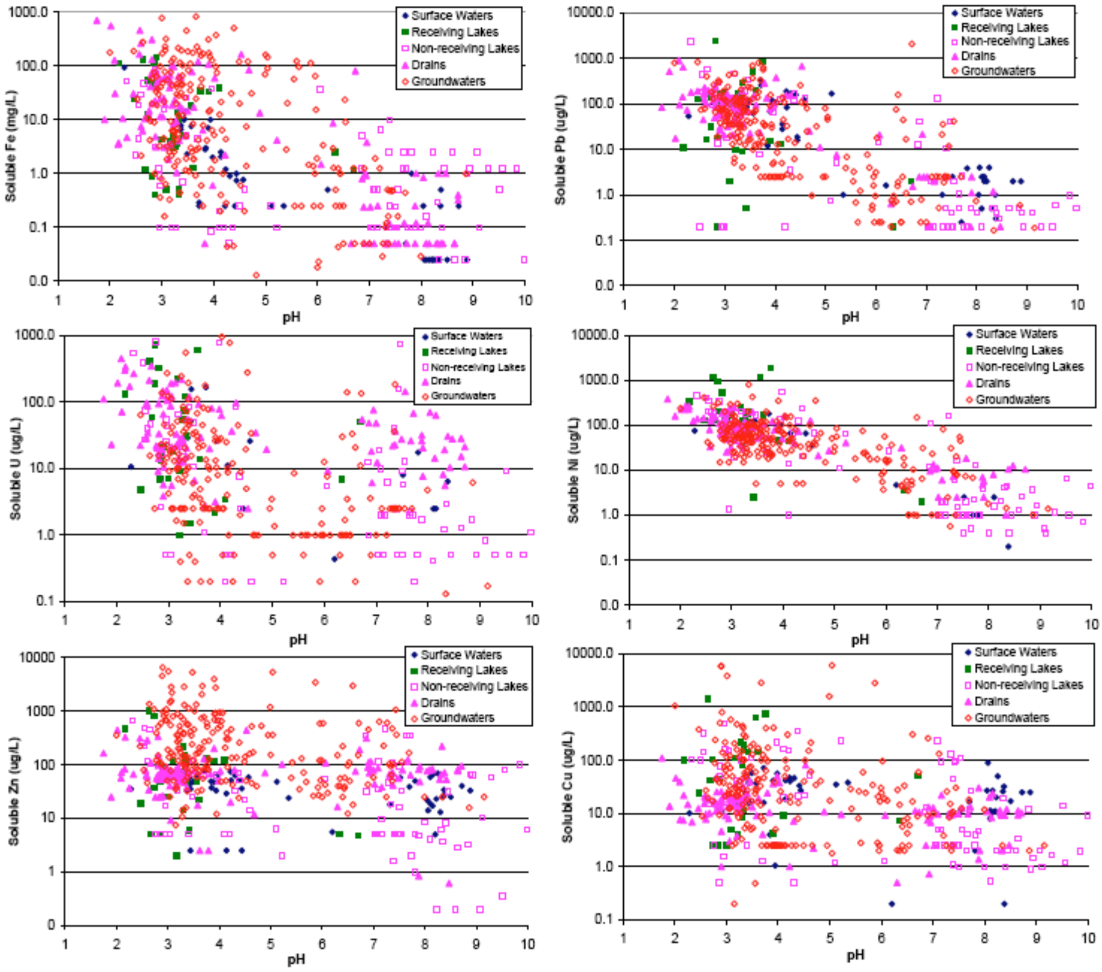

Figure 2 Major (Fe) and minor trace metal concentrations in waters in the eastern WA Wheatbelt distinguished by pH

A number of surface waters and lakes (both receiving and non-receiving) could contain concentrations of trace metals similar to those in drains (Fig. 2). High concentrations of trace metals such as Cu, Ni, Pb, U and Zn occurred in some lakes, often corresponding with high TDS concentrations (Fig. 1 and 2). This result was due to many lakes being in the advanced stages of drying at the time of sampling and indicated that evapoconcentration played a dominant role in influencing trace metal concentrations in the absence of any precipitation and/or adsorption mechanisms. Acidity was also present in some river and creek waters, though these were generally low discharges (mostly < 2 L/s) occurring as baseflows in creeks and some major floodways. Larger flows (more than 5000 L/s) in main channels of rivers were all alkaline.

The trace metals within drainage waters pose a risk to downstream environments through the acidity inherent within the waters and the potential for transport of trace metals. Allied research has highlighted that complex geochemical processes occur within acidic drains and receiving environments that concentrate acidity and trace metals (Fitzpatrick et al. 2008). Abundant iron precipitates and iron sulfide minerals in sediments of drains and some receiving environments provide opportunities for the removal of trace metals, but also the potential for future selective release. From an aquatic risk perspective, the metals Cd, As, Pb and possibly U present the greatest risks in terms of bioaccumulation in aquatic food-chains, should waters be discharged to lake environments where aquatic life can flourish during lake-filling events.

These investigations highlight the need to manage not only the impacts of rising saline groundwaters in the broad palaeodrainage systems of inland south-western WA but also the impacts of geochemical processes coupled with this discharge. In particular, both interventionist and non-interventionist management strategies need to consider the discharge of acidity and associated trace metals. Engineering options, such as deep drainage and groundwater pumping increases the expression and transport of acidity and trace metals in inland south-western WA. These will require management that may involve treatment (Degens & McIntosh 2008). Similarly, non-interventionist approaches including containing and adapting to salinity will need to consider managing acidity and trace metals due to regional ground-water discharge.

The existence of numerous 'naturally' acidic lakes unaffected by drainage discharge means that management of these will also need to be considered. Some lakes are likely to have been acidic prior to land-clearing. However, acidification of many non-receiving lakes is likely to have occurred due to increased regional discharge of acidic groundwaters to these environments brought about by past clearing of deep-rooted woody vegetation for agriculture in the WA Wheatbelt. Given that groundwater rise continues across the eastern Wheatbelt (Hatton et al. 2002), it is likely over the coming years that more lakes will be affected by acidity associated with rising groundwater. These 'naturally acidic' lakes often contain waters with trace metal concentrations similar to lakes affected by disposal of acidic drainage. Other investigations have also indicated that the sediments in these environments are geochemically similar (Shand & Degens 2008).

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