Groundwater quality in the Murray irrigation districts

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- The quality of most deep groundwater supplies in the Murray irrigation districts is either marginal or poor for continuous irrigation and use of such water could lead to water infiltration problems
- Potential problems of deep groundwater are primarily due to salt content, sodium adsorption ratio, residual alkalinity or bicarbonates, and an unfavourable Mg:Ca ratio
- Further research is needed to evaluate models and guidelines that relate groundwater chemistry to its potential impact on soils, so safe recommendations for irrigation can be made

Use of groundwater for irrigation in NSW has increased considerably in the last decade. Many farmers of the Murray irrigation districts (MIDs), looking for alternative supplies to compensate for reduced availability of surface water, have invested significantly in bores to pump groundwater from shallow or deep aquifers.

Groundwater can be a significant source of soluble salts, which impact on sustainable agricultural productivity. To date, most assessments of groundwater quality for irrigation in the MIDs rely only on salinity, as measured by electrical conductivity (EC). For example, irrigators in the MIDs are issued licenses for installation of bore pumps provided the EC of the pumped water does not exceed 1.0 dS/m.

Salinity alone is an important parameter but it is only a partial measure to determine the suitability of water for continuous irrigation use. The nature and concentration of several important elements or the chemistry of soluble salts also need appropriate consideration, as discussed in the IREC *Farmers' Newsletter*, No. 169, pp 34–37, 'The importance of water quality for irrigation'.

In addition, current and widely used water quality guidelines (see list of further reading) are based on soils and farming systems very different to those of the MIDs. Irrigators are accessing the groundwater unaware of any potential problems for the long term sustainability and productivity of different soils and farming systems.

Hydro-geological background

The MIDs are situated in the eastern and central eastern region of the Murray geological basin, which largely underlies the valleys associated with the Murray, Murrumbidgee and Lachlan rivers. The soil formation processes in the basin are believed to have occurred some 65 million years ago. There are three main layers or hydro-geological formations in the basin which are important in terms of the aquifers supplying groundwater. In sequence from the surface, these are the Shepparton, Calivil and Olney (part of the Renmark group) formations.

Shallow groundwater

Shallow groundwater that is pumped in the MIDs occurs within the Shepparton formation, which extends from the ground surface to 80–90 m depth. Use of this groundwater is important for regulating watertable depths in high watertable areas of the MIDs.

Deep groundwater

Bore wells that are 70–140 m deep extract water from aquifers in the Calivil formation, which consists of sand and gravel layers between the clayey strata. The thickness of the Calivil formation is less in eastern parts of the MIDs. Underneath the Calivil formation, is the Olney formation made up of upper, middle and lower Renmark aquifers occurring 140–350 m below the ground surface.

Potential groundwater quality problems

Existing research information universally recognises four major problems related to marginal or poor quality groundwater for long term irrigation use. These are:

- salinity
- sodicity or sodicity-induced water infiltration decline
- specific-ion toxicities
- miscellaneous effects of certain ions on produce quality and irrigation infrastructure

These problems, discussed in the *Farmers' Newsletter*, No. 169, largely change soil characteristics to reduce the availability of irrigation and rainwater to crops. Therefore, groundwater quality is assessed by an understanding of the interactions of water quality parameters or water chemistry with physical and chemical properties of the soils, crops and their water requirements, climatic conditions, soil and water management practices, watertable depth and quality of groundwater in shallow watertable situations.

This article reports on an investigation evaluating the quality of deep groundwater, to understand what the potential long-term impacts of continuous use of this water may be on soils and agricultural productivity of the rice-based farming systems of the MIDs. The investigations on shallow groundwater will be reported in the Autumn 2006 edition of the *Farmers' Newsletter*.

Deep groundwater quality in the MIDs

Analytical results were obtained for water samples from 85 deep bore wells located throughout the MIDs. At the time of sampling, 30 of the bores were used for irrigation on private properties and the remaining 55 were installed by the former NSW Department of Land & Water Conservation (DLWC) for monitoring groundwater.

These bores extract water from either of the Calivil and Renmark aquifers or both. Deeper bore wells were more prevalent in the Berriquin district, probably due to an easily available low salinity aquifer with adequate water yields. Differences in water quality parameters between the two aquifers were not remarkable. There was also no relationship between water quality of deep bore wells and their geographic locations. Water quality of bores in the western MIDs was relatively lower than in the eastern MIDs, and private bore wells were generally better in quality than most investigation bores (Table 1), regardless of their geographic positions and aquifers. Water quality assessment was thus generalised across all sites, regardless of aquifer, ownership and geographic location.

Salinity

Variation in soluble salts as measured by EC of deep bore waters was very large. It varied from as low as 0.13 dS/m (good quality surface water) to as high as 51.5 dS/m (sea water). The EC of private bores in use for irrigation was much lower than the investigation bores (Table 1). Variation in EC between the Calivil and Renmark aquifers was not significant.

About 13% of the bore wells had water salinity within the safe limit, as determined by FAO standards (< 0.7 dS/m), 44% were marginal (0.7–3.0 dS/m), and the rest were unsuitable (>3 dS/m) for long term irrigation use due to their potential to salinise soils. Total concentration of sodium, magnesium, calcium and potassium in the groundwater showed a close relationship with EC of deep bore water samples (Figure 1), regardless of the source aquifer.

Table 1
Salinity (EC) and sodicity (SAR) readings of groundwater samples from private and investigation bore wells in the Murray irrigation districts

Aquifer	Private bore wells				Investigation bore wells			
	Range	Mean[1]	Median[2]	Sample no.	Range	Mean	Median	Sample no.
	EC, dS/m							
Calivil	0.26–4.79	1.60	1.15	10	0.13–51.50	6.70	3.10	28
Renmark	0.81–2.69	1.56	1.40	12	0.68–45.80	6.22	2.88	26
Mixed	0.51–8.24	1.92	1.32	8	–	1.98	–	1
	SAR							
Calivil	2.6–6.4	4.4±1.2	4.4	10	1.1–22.2	8.9±6.1	6.7	28
Renmark	3.7–8.7	5.7±1.7	5.6	12	0–25.2	10.2±5.2	9.3	26
Mixed	3.8–8.0	5.4±1.7	4.8	8	–	5.5	–	1

[1] The mean is the average result of all samples analysed
[2] The median is the mid-range value of all samples analysed

Table 2
Chemical parameters of groundwater samples from private and investigation bore wells in the Murray irrigation districts

Parameter	Private bore wells				Investigation bore wells			
	Range	Mean	Median	SD(±)	Range	Mean	Median	SD(±)
Sodium (%TCC)[1]	47.1–82.4	66.7	67.5	10.0	0.1–84.9	62.6	61.7	13.6
Magnesium (%TCC)[1]	14.0–39.5	25.0	23.9	6.9	9.3–40.0	28.5	28.9	12.7
Calcium (%TCC)[1]	1.1–16.2	7.6	7.5	3.8	2.0–16.2	7.9	7.8	4.0
Potassium (%TCC)[1]	0.0–1.9	0.7	0.6	0.6	0.0–2.4	1.0	0.7	0.8
Total cations (me/L)	1.7–69.2	11.3	8.5	–	0.02–508.5	54.1	22.1	–
Mg: Ca ratio	1.9–11.0	4.0	3.6	–	1.4–7.7	3.7	3.4	–
Bicarbonates (me/L)	1.0–3.5	2.5	2.5	–	0.5–7.3	3.7	3.3	–

[1] The percentage of the total cation concentration (TCC), ie Ca + Mg + Na + K in me/L

On the basis of the salinity results, groundwater irrigators of the MIDs should carefully assess the suitability of their groundwater supplies for continuous irrigation. Conjunctive use of deep groundwater and channel water, either by dilution or alternate irrigation, can help reduce potential salinity hazards, particularly with marginally saline groundwater. Decisions for continuous and conjunctive irrigation with groundwater must also consider the interaction of salinity levels with sodicity and other water quality parameters.

Sodicity

Deep groundwater supplies in the MIDS were found to have potential sodicity problems (Table 1). The SAR variation between the two aquifers was not significant. As mentioned earlier, 13% of deep bore supplies pose no salinity problem but 95% of these groundwater bore wells have SAR greater than 3, therefore the combined effect of the sodicity and salinity parameters needs appropriate consideration.

Sustained irrigation use of deep bore supplies for crops like rice on heavy textured soils can result in severe sodification of soils, as a significant majority of the bore wells had SAR greater than 3 and EC greater than 1.0 dS/m (Figure 2).

Sodification is the build-up of sodium in the soil, which leads to problems of dispersion and poor structure, and subsequent effects of poor water infiltration, poor water use efficiency of irrigation and rain water, crop emergence problems, and ultimately poor yields.

Unlike salinity, in which the salt in the irrigation water has a direct and predictable impact on the soil, potential sodicity problems from irrigating with sodic water are difficult to predict. The impact of sodic irrigation water will be determined by the chemistry of the soil and its interaction not only with the sodium in the water but also with other water quality parameters such as calcium, magnesium, bicarbonate, residual alkalinity, pH, and saturation index. Scientists are still trying to understand these interactions, let alone try and explain them to advisors and irrigators!

The level of bicarbonates, a measure of residual alkalinity, in all the groundwater samples is also of concern (Table 2) because their accumulation in the root zone causes precipitation of soluble and exchangeable calcium and/or magnesium. When precipitated, calcium and magnesium ions are inactive in the soil and cannot counteract the undesirable impact of sodium (ie the breakdown of soil aggregates or dispersion). The build-up of bicarbonates also increases the alkalinity or pH of groundwater and soil, which in turn also boosts the potential for soil sodicity problems.

The relationship between calcium and magnesium in the groundwater also needs due consideration when evaluating sodicity potential of groundwater for sustained irrigation. This is done by calculating a ratio between calcium and magnesium (Ca:Mg) or vice versa (Mg:Ca). One is the reciprocal of the other. The Mg:Ca ratio was calculated in this study as it was more than one in all the samples, ie Mg:Ca was greater than 1:1. Ideally, Mg:Ca ratio should have been less than 1:1 (or the Ca:Mg ratio should be greater than 1:1).

Excess magnesium relative to calcium in the soil induces loss of soil structure. Therefore irrigating with water with high magnesium relative to calcium can also lead to soil structure breakdown. The median (mid range) Mg:Ca ratio for private and investigation bore wells were 3.6 and 3.4, respectively, indicating that magnesium content of the water was three times higher than the calcium content, leading to he observation that most deep groundwater supplies are calcium deficient.

Calcium is the most important ion for effective binding of the soil particles into stable aggregates, a characteristic of good soil structure (which is why gypsum (calcium sulphate) is ideal as a soil amendment for poorly structured soils). Calcium and magnesium together accounted for about 20–35% of the total cations in deep groundwater samples. The relative concentration of calcium in all the samples was significantly lower than that of magnesium. The ideal balance between Ca, Mg and Na as determined by the SAR calculation should always be less than 3.

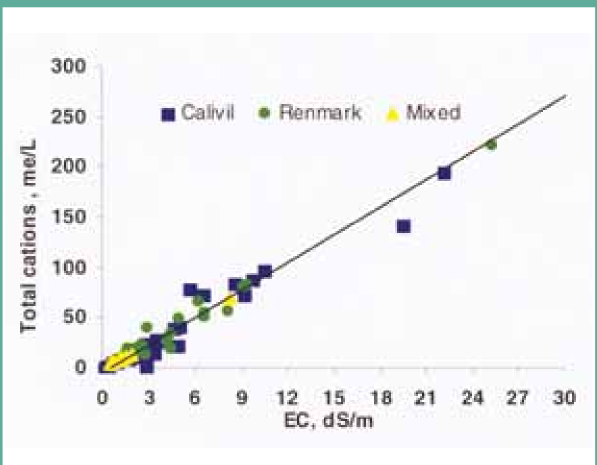

Figure 1 *A strong relationship was found between salinity (EC) and total concentration of important cations (total cations) in all deep groundwater samples, indicating similar water quality between the two aquifers and accurate predictability of cation concentrations based on water EC*

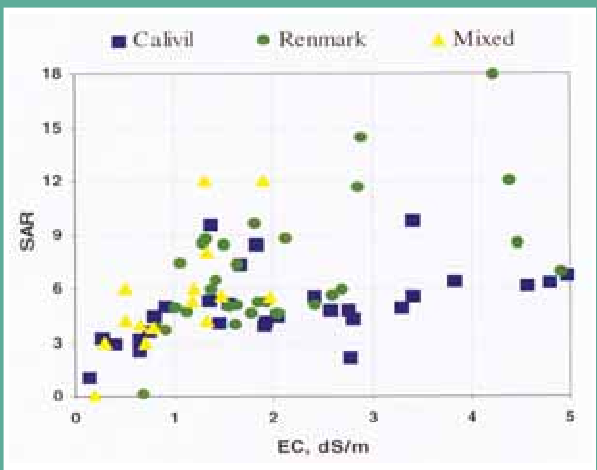

Figure 2 *A significant majority of the bore wells had sodicity (SAR) over 3, and salinity (EC) greater than 1 dS/m, indicating the potential of these waters to cause soil sodicity with continued irrigation*

The implications of sodicity related parameters (ie bicarbonates, calcium and magnesium) require further research as the occurrence of soil sodicity in the MIDs and sodification of good soils with irrigation farming is now a common observation especially in the western districts of the Murray Valley. Future research will help make decisions based on research experience on the Murray Valley soils, climate, and rice based farming systems. This can then be extrapolated to different irrigation areas of NSW.

Specific ion toxicities

Reduction in crop yields due to some ions in irrigation water occurs when such ions accumulate in plants to toxic concentrations. The intensity of such damage depends upon the sensitivity of various crops to different ions and their absorption. This type of damage can occur in the presence or absence of salinity and/or sodicity problems. However, specific ion toxicity can complicate the problems of salinity and/or sodicity. Chloride, sodium, boron and bicarbonate ions are capable of causing the toxicity problems.

The concentration of chloride and sodium was greater than 10 me/L in most samples. Use of such water for surface and sprinkler irrigation has the potential to cause toxicities to sodium or chloride sensitive crops. In all but the two investigation bore well samples, boron concentration was less than 0.1 mg/L, well below 0.7 mg/L considered safe. Specific ion toxicity due to high levels of chloride, sodium and bicarbonate in groundwater is usually corrected by applying a suitable amendment such as gypsum.

Miscellaneous problems

The presence of bicarbonates greater than 1.5 me/L in most bore well water samples makes their suitability marginal for sprinkler and other drip irrigation systems. In addition, total hardness of most water samples was either moderate or high. These parameters are known to induce clogging or deposition of materials in water pipes or the irrigation infrastructure.

Concentration of nitrates in all samples was less than 1.0 mg/L. One private bore well in the Berriquin district had 2.67 mg/L. Thus, there was no significant problem due to nitrates, which is considered safe below concentrations in irrigation water of 5.0 mg/L.

Impact on soils

Problems arising from continuous irrigation with deep aquifer groundwater will occur in heavy or clay soils before coarse textured soils because heavier soils have a greater capacity to accumulate salt, sodium and other ions.

Problems will also occur faster under rice crops than winter crops because of the greater opportunity for accumulation of salts in the root zone with ponding. For example, ponding of one hectare of rice crop using 15 ML water of 1.0 dS/m EC will add approximately 9.6 t of salt.

Marginal quality groundwater should be used for only infrequent irrigations. Its use in combination with good quality surface water, either by mixing or by alternate irrigations, may slow down the rate of occurrence of soil problems. It is important that soils irrigated with deep aquifer groundwater are periodically monitored for sodicity, cation proportions, pH and alkalinity. Similarly, the quality of bore water needs to be checked over time as significant changes may occur when pumping large volumes from deep aquifers.

The intensity and magnitude of the effect of water quality varies with the reactivity of chemical constituents present in the water, the physical and chemical properties of the soils, climatic conditions, irrigation management practices, crops and watertable depth. In addition, deep groundwater quality is not well defined in terms of suitability for irrigation and the consequences of its use are also not well understood.

Further research is needed to evaluate models and guidelines that relate soil chemistry and the physical processes important for safe use of saline and/or sodic groundwater for irrigation in southern NSW, and in the MIDs particularly. Having established guidelines based on this research, guidelines could be extrapolated to other irrigation areas of Australia.

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Further information

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Further reading

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