



WQPN 21, November 2006

Iron staining caused by irrigation systems

Purpose

Iron derived from groundwater delivered via irrigation systems can produce unsightly rust stains on buildings, paths, fences and plants in many areas, especially on the Perth coastal plain. It may also stain clothes washed in iron-rich water and plumbing fixtures such as basins and toilet bowls. These rust stains resist cleaning using soaps, detergents and bleach. This note discusses the causes, ways to minimise staining and measures that can be taken to remove the stains.

The Department of Water is responsible for managing and protecting the State's water resources. It is also a lead agency for water conservation and reuse. This note offers:

- the Department's current views on minimising and treating iron staining derived from groundwater irrigation; and
- guidance on acceptable practices used to protect the quality of Western Australian water resources.

This note provides a general guide on issues of environmental concern, and offers potential solutions based on professional judgement and precedent. The recommendations made do not override any statutory obligation or Government policy statement. Alternative practical environmental solutions to suit local conditions may be considered. Regulatory agencies should not use this note's recommendations without a site-specific assessment of any project's environmental risks. Any conditions set should consider the values of the surrounding environment, the safeguards in place, and take a precautionary approach. The note shall not be used as this Department's policy position on a specific matter, unless confirmed in writing.

Scope

This note applies to staining caused precipitation of iron hydroxide from iron-rich groundwater commonly associated with organic sediments, acidic conditions, absence of dissolved oxygen and/or microbiological activity (iron bacteria). The result is rusty staining (reddish-brown sometimes accompanied by multi-coloured streaks) on any structure or plant that is subject to irrigation spray over an extended period. Associated black staining may be caused by the presence of soil carbon or manganese oxide precipitate.

Causes and effects of iron staining

Iron is the metal that is most abundant on Earth and is therefore very prevalent in soils and groundwater. Dissolved iron occurs naturally in groundwater in concentrations of up to around 50 milligrams per litre. Iron salts become increasingly soluble as groundwater becomes more acidic. In anoxic and acidic groundwater (pH values below 5), iron concentrations of one to 20 milligrams per litre are common (usually as stable carbonates). Iron is normally found dissolved in groundwater in the reduced ferrous form (Fe^{2+}) and oxidises to relatively insoluble ferric form (Fe^{3+}) when the water pH is raised and with exposure to oxygen in the air.

When acidic iron-rich groundwater is extracted and mixes with air, carbon dioxide and hydrogen sulphide (rotten egg gas) is frequently released, the pH rises and the iron precipitates as ferric hydroxide (rust) on any flat surface where it rests as water evaporates. Over time this oxide coating builds up causing discolouration to light coloured surfaces.

Iron may also be present in groundwater in organic complex and slimy, but harmless, bacterial forms. These are unlikely to settle out, but may discolour water.

Iron deposits cause problems in irrigation systems, especially those that rely on small orifices for pressure control or delivery via water drippers, and may also affect heat transfer in hot water systems.

Iron staining is unsightly but shouldn't cause serious harm to plants, animals or humans or structural damage. With high concentrations of iron (more than 20 parts per million) some plants with heavy iron staining may experience a reduction in photosynthesis and vigour.

Areas where iron staining is likely

Acidic iron-rich groundwater is often found in the water-table close to present or past wetlands where organic carbon and sulphides are prevalent and the water table is shallow and contains little or no dissolved oxygen. Prior to drilling a well it is wise to check with neighbours to see if they have experienced iron problems with their bore water. Old or damaged galvanised steel pipe-work may add to iron staining problems as acidic waters attack pipe walls.

Testing for iron presence in groundwater

A simple means of determining if a problem is likely to arise from established bores and wells is to take a filtered sample of groundwater in a clear open topped glass jar, agitate the water and let it stand overnight. If the water becomes discoloured brown, a stain becomes obvious near the waterline or rusty sediment is produced, it is likely the irrigated water will stain light coloured masonry, fences or pavements over time.

There are chemical test strips available (eg LaMotte Company) and field reagent tests (eg Palintest comparators) that can give a reasonable estimate of iron concentration using a colour comparison chart. Chemical analyses of water samples performed by a laboratory accredited by the National Association of Testing Authorities can accurately confirm the concentration of iron present in groundwater. Suitable laboratories may be located under *Analysts* in the yellow pages telephone directory. Analyses of additional water quality attributes eg pH, dissolved oxygen, water (carbonate) hardness, manganese, silica and sulphur may also be necessary when considering water treatment options. Professional advice on water sampling, preservation and testing is generally necessary to ensure accurate results.

Waters with iron concentrations above one milligram/ litre (ie one part per million) are most likely to produce iron staining.

Recommendations

Minimising iron staining

1. It is best to draw water from a source that has a low iron concentration. These waters are normally neutral to alkaline and have some dissolved oxygen. Water in dams or surface waterways will rarely cause iron staining problems, as iron will normally drop out prior to water being extracted. Rainwater is also unlikely to exhibit iron staining problems, unless in contact with degraded steel tanks or pipe-work.
2. If irrigating with iron-rich groundwater, the system design should minimise spray onto paths, fences or buildings. Large droplet (low pressure) sprinklers should be used to limit overspray and water aeration. Alternatively initially painting surfaces a dark colour may make any staining less noticeable.
3. As soil strata are highly variable, groundwater at some depths may have less iron than at others. If iron staining is visible in the local area, there is a high risk that a standard bore will yield iron-rich groundwater. The bore driller should be asked if it is feasible to vary the drill depth and screen placement with an upper bentonite seal to minimise access of iron-rich water to the pump. Observation of the colour of soil encountered below the water table can assist the driller to set the optimum pump inlet screen level and avoid setting screens against organic-rich horizons. The national guidelines *Minimum construction requirements for water bores in Australia* provide useful advice on this topic.
4. The borehole should be chlorinated following construction to minimise transmission of iron bacteria affected material and drilling fluids.
5. Appropriate placement of borehole screens and seals will reduce the risk of groundwater cascading within the bores that can promote aeration and formation of iron precipitates and bacterial infestations.
6. If severe iron encrustation of bore screens occurs, it can generally be reduced by using hydrochloric or phosphoric acid dosing in combination with agitation, then pumping the bore water to waste until iron and acid concentrations are acceptable. Repeat treatments may be periodically required. For bores exhibiting signs bacterial infestation (often called *soft iron*), shock chlorination dosing at concentrations of 500 to 1000 milligrams/litre may provide an effective treatment. Leave the chlorinated bore unused for 24 to 48 hours, then pump the residue to a soak-pit.

Note:

- a. Pool test kits can be used to check water pH and chlorine concentration. Pool chlorine provides from 10 to 35 per cent free chlorine.
- b. Always ensure the selected bore screen treatment will not damage bore or pump components.

Treating extracted groundwater

7. Where treatment of bore water before use appears necessary, the choice of water treatment should consider the intended use of the groundwater. These uses may include animal water supplies, watering of gardens, lawn or crops; industrial process waters; flushing or bathing waters in residences; and fish, swimming or ornamental ponds.
8. Untreated groundwater drawn from the water table should not be used for human consumption as health problems may arise. The main health concern is disease from pathogenic microbes, however groundwater may also contain toxic substances which are difficult to detect such as fuel and pesticide residues, especially in areas where there is a history of human activity. Care also should be taken that any treatment chemicals do not harm the user during their application, or later when the waters are put to their intended purpose.
9. The following iron concentrations indicate groundwater suitability for various uses:

Use of water	Guideline value for iron (milligrams/ litre)	References
Aesthetic or recreation	0.3	2a
Aquaculture (fresh or marine)	Less than 10	2a
Drinking water or food processing	0.3 (based on aesthetic factors)	2c
Ecosystems (eg in ponds)	No recommendation	2a
Irrigated vegetation	10 (for applications under 20 years); 0.2 (long term)	2a
Industry (steam)	Range one to 0.01 (based on steam pressure)	2d
Industry (cooling)	<0.5	2d
Industry (textiles)	<0.1	2d
Stock drinking water	Not generally toxic	2a

Note: For References, see [Appendix A, Reference 2](#).

10. Groundwater that has a dissolved iron content of less than 25 milligrams per litre can be treated by speeding up the processes that happen in nature. Treatment involves dosing the groundwater with an alkali such as lime to raise its pH to between 6.5 and 7.5, then aerating the water by either pumping it into the air as a fountain or allowing it to cascade over a large surface such as baffle plates or rocks, then finally letting the water lie still for a period while the iron settles out as a sludge. This may be accomplished in a purpose-built tank or pond. An oxide-rich sludge will slowly build up in the treatment facility that will require occasional removal, then application to land or burial. The clarified water should be tested and confirmed as having an acceptable residual iron content.
11. Polyphosphate compounds added to cold iron-rich groundwater can be effective in coating iron, preventing its precipitation. This form of treatment is most effective with iron concentrations from one to three milligrams per litre and water pH in the range five to eight. However if water is heated in hot water systems, the poly-phosphate is converted to phosphate that allows the iron to drop out as a solid. Phosphate is a nutrient that promotes algae growth and therefore should not be added to systems where treated water discharge may harm waterways.

12. Sodium silicate (water glass) dosing can be effective for preventing iron precipitation for ferrous iron concentrations up to ten milligrams per litre. The silicate is normally applied as a liquid using a metering pump on the discharge side of the water bore, using measures that achieve effective mixing. This method may also be used to limit scale deposits in hot water systems.

A silicate dosing rate of approximately 75 milligrams per litre is recommended for iron-rich groundwater concentrations above 5 milligrams per litre. The sodium silicate is normally supplied as a concentrate and diluted to suit the application. The treatment forms a stable iron-silicate complex that resists iron precipitation.

Warning: Sodium silicate is caustic and will attack paint and metals, so care needs to be taken when handling the chemical. Wear protective equipment and flush any spillage with water immediately. Excessive use of sodium silicate may also add to water shedding problems with dispersive (clayey) soils.

13. Specialty water filters can be effective for iron concentrations up to five milligrams per litre at neutral pH (~seven). These rely on “water softening” chemical reactions (sodium ion exchange using coated resin beads or zeolite) to be effective. Such filters need backwashing and flushing of iron concentrates to waste to maintain effectiveness.

14. For iron concentrations below 15 milligrams per litre, an oxidising (catalyst) filter can also be effective. These consist of glauconite derived “green sand” pellets, or silica gel zeolite coated with manganese dioxide (MnO_2). The iron oxidises and precipitates as a solid.

Note: Iron bacteria may present clogging problems with filtration systems and water pH should be above seven. The dissolved oxygen concentration in the treated water may affect filter results. Filters have a specific operational life before they need to be regenerated or replaced. The chemical filters may be followed by a sand or fabric filter to remove any solid residues.

15. For high iron concentrations (between 10 and 50 milligrams per litre) or where a significant portion of the iron is an organic complex, it may be necessary to add alum ($Al_2(SO_4)_3$) to assist in iron floc formation, before filtering out the residue. Alternatively a solution of chlorine bleach ($NaOCl$), potassium permanganate ($KMnO_4$) or hydrogen peroxide (H_2O_2) may be added to iron-rich water. A retention time of about 20 minutes is needed to convert the iron into its insoluble ferric form, prior to the particles being removed using a sand or fabric filter. The oxidation process operates most effectively at a pH of seven to eight.

16. Water treatment residues should be removed from site for disposal at an approved location. Small quantities (ie less than one kilolitre) of residue may be allowed to soak into the ground, provided the disposal point is not within 100 metres of a water source or sensitive ecosystem, and offsite disposal is impractical.

Note: Water treatment residues should never be discharged into drains or surface waters.

Cleaning of discoloured paths and structures

17. There are a number of chemicals available from farm and chemical suppliers, pool shops and hardware stores that may be used to reduce or remove iron staining. The staining will be most easily removed from impervious surfaces (eg paintwork or hard rock), and most difficult to remove from porous surfaces (eg masonry and concrete), as the iron is likely to have formed in crevices below as well as on the surface.

Note: The following recommendations concerning chemical cleansers have been derived from a literature search on the topic. They have not been tested in practice by the Department of Water. The Department has reproduced this information in good faith, but provides no warranty as to the chemical's effectiveness, nor does it accept any responsibility for harm resulting from their application. The user should make appropriate investigations with product suppliers on the suitability and risks associated with the use of chemical cleansers in any specific situation.

18. Commercial cleansers suitable for removing rust (as well as calcium deposits) often contain phosphoric acid (tri-sodium phosphate), ammonium bifluoride ($\text{NH}_4 \text{HF}_2$) or oxalic acid ($\text{C}_2\text{H}_2\text{O}_4$) as a 12 per cent solution. Protective clothing, gloves, goggles, masks and footwear are essential as these chemicals can be corrosive and poisonous (if ingested or fumes inhaled). These cleansers dissolve the iron and are reported to be effective. For cleaning brickwork, a ten per cent hydrochloric acid solution may prove effective. The cleansers are soluble in water. Surface iron oxide may be removed from smooth surfaces by soaking a cloth in the cleaner and rubbing; and from rough surfaces by pouring on the cleanser, then scrubbing with a brush. Any residue should be flushed off the treated surface with a water jet.

Note: Care should be taken when applying these stain removers as they are often corrosive and may damage the surface being cleaned or sensitive areas on people handling the chemicals (eg the eyes). The product supplier's recommendations should be carefully followed for safety precautions. If oxalic acid is used, a respirator with carbon filter should also be used.

19. For situations where the iron has become ingrained in a porous surface such as masonry or concrete, it may be necessary to apply the sodium hydrosulphite solution ($\text{Na}_2\text{S}_2\text{O}_4$) as a poultice or paste. A sodium hydrosulphite paste can be made by mixing one part ammonium citrate or sodium citrate, six parts warm water and six parts glycerine. Initially wet the area, then apply and maintain a moist poultice for two to three days. Remove the poultice and flush with clean water. Repeat as necessary until level of staining is acceptable.
20. For outdoor situations as an alternative, mix a saturated solution of sodium hydrosulphite with Fuller's earth (an absorptive clay). Apply as a poultice for one or two days. Remove and flush well with clean water. Repeat as necessary until the desired result is obtained. This method is not suitable for enclosed situations (eg living areas) as the poultice gives off sulphur dioxide gas that can irritate the eyes and airways.
21. Where a resultant rough surface is not a problem eg paths and walls, rust coatings may be removed by high pressure water jetting or sand blasting.



More Information

We welcome your views on this note. Feedback provided on this topic is held on file No: **18587**.

This note will be updated periodically as new information is received or industry/activity standards change. Updates are placed on the department's internet site www.water.wa.gov.au select *Drinking water > Publications > Water Quality Protection Notes*.

To comment on this note or for more information, please contact the Water Source Protection Branch at our offices in Perth, phone (08) 6364 7600 (business hours), fax 6364 7601 or use *Contact us* at the department's internet site, citing the note topic and version.

In October 2005, the State Government announced the formation of the Department of Water. From January 2006, the Department of Water has assumed primary responsibility for managing the State's water resources. Once the Department of Water is legally established, it will replace many of the present functions of the present Water and Rivers Commission and operate in parallel (with separate powers) to the Department of Environment and Conservation. The custodian and recommendations made in this note will then change to match the assigned responsibilities of the Departments of Environment and Conservation or Water.

 Department of Water Department of Environment and Conservation		
www.water.wa.gov.au Telephone: (08) 6364 7600 Facsimile: (08) 6364 7601 Level 4, The Atrium 168 St Georges Terrace Perth Western Australia 6000	www.dec.wa.gov.au Telephone: (08) 6364 6500 Facsimile: (08) 6364 6525 Level 4, The Atrium 168 St Georges Terrace Perth Western Australia 6000	Swan Canning Cleanup Program www.swanrivertrust.wa.gov.au Telephone: (08) 9278 0900 Facsimile: (08) 9325 7149 Level 1, Hyatt Business Centre 20 Terrace Rd East Perth Western Australia 6004

Appendices

Appendix A - References and further reading

1. Chemistry Centre of Western Australia
Iron Staining (undated guidance paper).
see web page www.doir.wa.gov.au/ccwa/ for contact information.
2. Australian Government – National Water Quality Management Strategy
 - a. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, 2000;
 - b. *Australian Guidelines for Water Quality Monitoring and Reporting*, 2000;
see web page www.deh.gov.au/water/quality/nwqms/index.html.
 - c. *Australian Drinking Water Guidelines*, 2004;
see web page www.health.gov.au/nhmrc/publications/synopses/eh19syn.htm.
 - d. *Australian Water Quality Guidelines for Fresh and Marine Waters 1992*.
3. Standards Australia
AS 5667 Water Quality - Sampling.

4. Seelig, Derickson and Bergsrud, *Iron and manganese removal* North Dakota State University 1992; see www.ext.nodak.edu/extpubs/h2oqual/watsys/ae1030w.htm on 23/04/04.
5. Herman G.M., North *Iron and manganese in household water* HE –394, Carolina Cooperative Extension Service 1996; see web page www.bae.ncsu.edu/programs/extension/publicat/wqwm/he394.html.
6. Ramachandran and Beaudoin, Institute for Research in Construction (Canada) - Canadian Building digest CBD –153 *Removal of stains from concrete surfaces* 1972; see web page <http://irc.nrc-cnrc.gc.ca/cbd>.
7. Australian Government - Land and Water Biodiversity Committee
Minimum construction requirements for water bores in Australia, 2003
see web page www.iah.org.au/pdfs/mcrwba.pdf.
8. LaMotte Company
see internet site www.lamotte.com.
9. Palintest Ltd
see internet site www.palintest.com.
10. Varner, Skipton, DeLynn Hay, Jasa- University of Nebraska-Lincoln *Drinking water: Iron and Manganese*, 1996; see web page <http://ianrpubs.unl.edu/water/>.
11. Department of Water (Western Australia)
 - a. *Perth Groundwater Atlas* (current edition); see internet site www.water.wa.gov.au, select *Tools, systems and data > Perth Groundwater Atlas*
 - b. *Water Quality Protection Notes*
see web page <http://drinkingwater.water.wa.gov.au>, select *Water Quality Protection Notes*.

Appendix B - Statutory requirements and approvals covering this activity include:

What's regulated	Statute	Regulatory body/ agency
Licence to take surface water and groundwater	<i>Rights in Water and Irrigation Act 1914</i>	Department of Water – regional office
Storage of fuels, solvent, explosive and dangerous goods	<i>Explosive and Dangerous Goods Act 1961</i> and associated Regulations	Department of Consumer and Employment Protection
Community health issues	<i>Health Act 1911</i>	Local Government; Department of Health
Emergency response planning	<i>Fire and Emergency Services Authority of WA Act 1998</i>	Fire and Emergency Services Authority