Report

Cement Concrete & Aggregates Australia

Use of Recycled Water in Concrete Production

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CEMENT CONCRETE
& AGGREGATES AUSTRALIA

Contents

1 INTRODUCTION

With the current water shortage in Australia, there is a need as well as opportunities to look for alternative sources of water for use in concrete production. Water authorities are increasing the supply of recycled water as 'greywater' for domestic use and as 'reclaimed water' for agricultural and industrial needs. They also encourage sewer mining by the private sector. In addition, it is possible to reuse higher proportions of wash water as well as combined wash water and slurries from concrete production operation (CPO) which will move the concrete industry toward zero-discharge facilities.

This report presents current information on the quality of concrete mixing water in terms of: mandatory limits and guidelines on impurities, as well as permissible performance variations stipulated in leading National and International Standards; and the impact of CPO water on concrete performance. New sources of reclaimed water which are or will be available for industrial usage are identified in terms of quality and impact on Occupational Health and Safety (OH&S). Based on this review, new opportunities and gaps in knowledge will be identified.

2 OBJECTIVES

The objectives of this study are to:

- compile guidelines on quality of water suitable for making concrete in terms of the presence and limits on impurities;
- review the reuse of water from concrete production operation (CPO);
- review alternative sources of water supply, quality and impact on OH&S.

3 METHODOLOGY

This report has been compiled from technical literature and information provided by local water authorities. Suggested limits on impurities in mixing water and their effect on setting time and strength are based on a literature review of current standards which allow a variation in initial and final setting times and strength of the concrete. Guidelines on the possible effects of other impurities on concrete are compiled from published information. OH&S considerations when using recycled water is based on information available from authorities such as EPA Victoria, NSW Health Department and Queensland EPA.

4 TERMINOLOGY

Terminology used in this report has been specifically adopted from the water industry and internationally-recognised concrete standards such as EN 1008, ASTM C1602and AS 1379. The term *reclaimed water* is used to describe water recycled by the water industry, whereas terms such as *wash water* and *slurry water* are used to describe recycled water recovered from CPO.

Potable water – water suitable for human consumption.

Recycled water – water recovered from CPO or water generated from sewage, greywater or stormwater systems and treated to a standard that is appropriate for its intended use.

Reclaimed water – treated recycled water supplied by the water authorities for domestic, agricultural and industrial usage.

Greywater – wastewater from hand basins, showers, baths, laundries and kitchens. Greywater is often contaminated with human faeces, dirt and other materials but to a lesser extent than blackwater and is therefore less infectious.

Blackwater – wastewater generated from toilets and bidets which is heavily and directly contaminated with human faeces and/or urine and may contain contaminated solid material, such as toilet paper. This wastewater is highly infectious.

Sewage – a combination of both blackwater and greywater. Also highly infectious.

Water from concrete production operations (CPO) – water recovered from processes of hydraulic cement concrete production that includes wash water from mixers or water that was part of a concrete mixture; water collected in a basin as a result of storm water runoff at a concrete production facility; or water that contains quantities of concrete ingredients.

Wash water – clarified water recovered from washing mixers.

Slurry or sludge water – a mixture of slurry or sludge, collected from sediments, and clear water recovered from waste water storage system from CPO.

Combined water – a mixture of two or more sources of water blended together, before or during introduction into the mixture, for use as mixing water in the production of concrete.

Sewer mining or water mining – the process of tapping directly into a sewer (either before or after a sewage treatment plant) and extracting wastewater for treatment and reuse as recycled water. Some sewer mining by-products may be returned into the sewerage system.

BOD (Biochemical Oxygen Demand) – a measure of the quantity of oxygen used in the biochemical oxidation of organic matter in a period of 5 days under specified conditions.

E. coli (Escherichia coli) – A type of thermo-tolerant Coliform bacteria, nearly always present in the gut of humans and other warm-blooded animals. E. coli is now generally regarded as the most specific indicator of faecal contamination, and therefore the most important indicator for public health.

Hydraulic stabilising admixtures (HSA) – extended set retarding admixtures used in managing returned concrete and water from concrete production.

Impurities – soluble and insoluble (solid) materials that exist in water which may or may not be deleterious to the quality of concrete produced using the water.

NTU (Nephelometric Turbidity Unit) – units of measure of the turbidity of water due to suspended, colloidal and particulate matter, measured using an apparatus called a nephelometer.

5 ACCEPTABLE MIXING WATER

The principal considerations on the quality of mixing water are those related to the effect on *workability, strength* and *durability*. In addition, health issues related to the safe handling of such water must be considered. The suitability of water can be identified from past service records or tested to performance limits such as setting times and compressive strength. Limits are placed on the contribution of mixing water to the total alkalis, chloride and sulfate of all concrete ingredients in order to control the durability of the concrete. Biological treatment and pathogen reduction are used to ensure safety in handling reclaimed water.

There is limited information on the quality of water which is acceptable for use as concrete mixing water. The allowable impurities in concrete mixing water are compiled from earlier literature such as Abrams[2], Steinour[3], Kuhl[4] and Neville[5]. Some of these limits are reflected in current standards which allow the use of recycled water or CPO water. Recent literature such as Lobo and Mullings[6] and Cebeci and Saatci[7] focused on the use of CPO and partially treated sewage water.

5.1 Guideline on Limits of Impurities

Steinour[3] found the following:

- Natural fresh water rarely contains more than 2000 ppm (0.2%) of dissolved solids, and is generally suitable as mixing water.
- Water contaminated with industrial wastes, but free of *suspended solids*, appear also to be generally suitable at low concentrations.
- Much larger contents of the *impurities*, in natural water, can be tolerated except for the *alkali carbonates* and *bicarbonates* which may have significant effects even at 2000 ppm.
- Other *inorganic impurities*, of possible industrial origin, ones that may be detrimental at moderate concentrations are the *sulfides, iodates, phosphates, arsenates, borates*, and compounds of *lead, zinc, copper, tin* and *manganese*.
- *Organic solutes* are also suspect, especially sugars.
- Seawater, although it contains 3.5% of dissolved solids, produces concrete with good early strength, but often somewhat lower later strength. Risk of corrosion of embedded metals limits the use of seawater in reinforced concrete.

No general summary or tabulation in terms of maximum limits on impurities was attempted by Steinour[3] as he considered the information to be inadequate. For the most part, the data were only strength data. Effect on un-investigated properties such as workability, long-time volume stability, and tendency to effloresce were unknown. Ryan and Samarin[8] summarised the general effects of *impurities* in mixing water on concrete properties as shown in **Table 1**.

Netterberg[9] reported that, on the whole, the deleterious salts present in construction water are likely to be sodium chloride (NaCl), sodium sulfate (Na_2SO_4) and magnesium sulfate ($MgSO_4$), less often sodium bicarbonate ($NaHCO_3$) and sodium carbonate (Na_2CO_3) and rarely calcium chloride ($CaCl_2$), and magnesium chloride ($MgCl_2$) and nitrates.

TABLE 1 Effects of impurities in mixing water on some properties of concrete *(Ryan and Samarin[8])*

Impurity	Effect
Oil, fat or detergents	Air entraining possible
Calcium chloride and some other calcium salts	Probability of set acceleration
Sugar, salt or zinc, lead, and a range of other inorganic and organic materials	Probability of set retardation
Chloride ions	Strong probability of steel corrosion

5.1.1 Mandatory limits and guide on questionable amount of impurities

Despite the limitation on these findings, mandatory limits of chemical and total solids in concrete mixing water compiled from the reported literature, National and International Standards are listed in **Table 2**. A general guide on questionable amount of impurities in concrete mixing water is provided in **Table 3**. It can be used as the basis for the selection of acceptable mixing water.

TABLE 2 Mandatory chemical and other limit for concrete mixing water

Chemical	**Limit** ppm*	**Test method**	**Notes** (References)
Chloride Cl	500 1,000	ASTM D512	Prestressed concrete/grout, reinforced concrete.
Sulfate SO_4	3,000	ASTM D516	EN 1008 limit. Water with higher salt contents has been used satisfactorily. (Building Research Station).
Alkalies, as (Na_2O + 0.658 K_2O)	1,500	ASTM C114 or EN 196-21	Total sodium and potassium ions, computed as Na_2O_{eq}, from all ingredients is limited to 2.8 kg/m^3 of concrete to safeguard potential alkali-aggregate reaction if used with reactive aggregate.
Total solids	50,000	ASTM C1603	ASTM C94[11] optional requirement. See section 5.4.2 for possible use of water with solids exceeding the limit.
Harmful substances Sugars Phosphate, P_2O_3 Nitrates, NO_3^- Lead, Pb^{2+} Zinc, Zn^{2+}	 100 100 500 100 100	 AS 1141.35 Local Standard ISO 7890-1 ASTM D3559 ASTM D1691	AS 1379 and EN 1008 requirements. In the first instance, qualitative tests may be carried out. If the qualitative tests show a positive results, either the quantity of the substance shall be determined or tests for setting time and compressive strength shall be performed.
pH	>5.0	AS 1580.505.1	AS 1379 requirement.
Oil and grease	<50	APHA 5520**	AS 1379 requirement.

Standard test methods cited in this table are:

ASTM D512 – Test Methods for Chloride Ion in Water

ASTM D516 – Test Methods for Sulfate Ion in Water

ASTM C114 or EN 196-21 – Test Methods for Chemical Analysis of Hydraulic Cement

AS 1141.35 – Methods for sampling and testing aggregates – Sugar

ISO 7890-3 – Water quality – Determination of nitrate – Part 3: Spectrometric method using sulfosalicylic acid

ASTM D3559 – Test Method for Lead in Water

ASTM D1691 – Test Methods for Zinc in Water

AS 1580.505.1 – Paints and related materials – Methods of test – pH of water-based paints.

1ppm=1mg/L, 0.1%=1000ppm

***Standard methods for the examination of water and waste water, 18th edition, American Public Health Association 1992.*

5.1.2 Water testing standards and scheme

The test methods specified in AS 1379, ASTM C94 or EN 1008, are given in **Table 2**. In the first instance, qualitative tests may be carried out (Annex B in EN 1008). For the harmful substances, if the qualitative tests show a positive result, it is required that either the quantity of the substance be determined or tests for setting time and compressive strength be performed.

TABLE 3 General guide on type and amount of impurities in concrete mixing water

Impurities	**Limit**	**Notes** (References)
Dissolved solids	2000 ppm	Testing to BS 3148* if limit is exceeded.
	1000 ppm	Testing if alkali carbonate or bicarbonate is present.
Na_2CO_3 or $NaHCO_3$ or sum of the two	2000 ppm	Large amount of Na_2CO_3 can cause quick set, and $NaHCO_3$ can accelerate or retard setting. Testing if they exceed 1000 ppm (Steinour[3]).
$Ca(HCO_3)_2$ and $Mg(HCO_3)_2$	400 ppm	Calcium and magnesium carbonates have low solubility and can be disregarded, but not their bicarbonates (Steinour[3]).
Other common salts		
$NaNO_3$ and KNO_3	No limit available	Sodium and potassium nitrates gave strengths little inferior to those obtained with sodium chloride (Steinour[3]).
$MgSO_4$ and $MgCl_2$	4% of the negative ion	Magnesium sulfate and magnesium chloride at solution concentrations up to 4% of the negative ion, showed as good strength as control (Steinour[3]).
$CaSO_4$	No limit available	Water saturated with calcium sulfate is satisfactory for the liquid phase in cement paste which is normally saturated or even super-saturated with this compound. (See SO_3 limit in AS 1379).
$Ca(NO_3)_2$	1.7% wt of cement	Calcium nitrate added at 1.7% wt of cement accelerates setting with 10% strength reduction.
Na_2SO_4, $MgCl_2$, $MgSO_4$ and $CaCl_2$	10,000 ppm	A 1% joint concentration of these common ions, exclusive of carbonate and bicarbonate, could be present without much effect on strength (Steinour[3]).
Total impurities	5,000–10,000 ppm	If water lacks service record, then ensure durability by testing for volume stability and long-term strength in wet and dry storage (Steinour[3]).
Ferrous sulfate ($FeSO_4$)	No limit available	In mix water at negative ion % of 0.5, 1, 2, and 4 wt % of water showed 28 days and 3 years tensile strengths exceeding control by 10–15%.
Ferric sulfate $Fe_2(SO_4)_3{\cdot}7H_2O$ and ferrous sulfate.	No limit available	At 2 wt % of cement, similar or better strength than control at 3–28 days. Some retardation but satisfactory setting times (Steinour[3]).
pH	6.0–8.0	No significant effect (Neville 1995[5])

continues

TABLE 3 *continued*

Impurities	**Limit**	**Notes** (References)
H_2SO_4	6250 ppm	Spent plating bath water which was high in iron sulfate and contained 6250 ppm H_2SO_4 gave borderline strength results (Abrams[2]). Contribution made to the SO_3 content may upset the optimum gypsum content in cement.
HCl	10,150 ppm	Normal setting, superior 7- and 28-day strengths (Steinour[3]).
CO_2	No limit available	Free carbon dioxide in solution constitutes reserve acidity which is drawn into action as hydrogen ion reacts. Uncontaminated natural waters seldom exceed 10 ppm.
NaOH	(2.0% wt) (0.65% wt)	Significant strength reduction. Reduce effectiveness of Ca_2SO_4 as retarder.
KOH	(1.2% wt)	
Mineral oil	No limit given	Large % of petroleum ´fluid residual oil’ emulsified so well with cement paste as to disappear completely. 10% in concrete resulted in 25–35% strength reduction. 2.5% may cause 8 and 20% reduction in wet-cured and air-cured strength respectively.
Chlorides of tin, manganese, zinc, copper and lead (nitrate).	2% of $CaCl_2$* wt of cement (*equimolecular quantity)	Of the five salts, the last three were the most active. Zinc and copper chlorides retarded so greatly that no strength was achieved. The action of lead nitrate was completely destructive.
Sodium salts of iodate, phosphate, arsenate, and borate		Significant reduction of initial strength. More information reported by Steinour[3].
Chlorides or nitrate (where solubility is low) of lithium, barium, iron, sodium, strontium, potassium, nickel, ammonium, cadmium, cobalt, magnesium, aluminium, calcium and chromium, and other sodium salts of fluoride, peroxide, chromate, chloride, hydrosulfite, bichromate, bromide, thiosulfate, sulfite, sulfate, chlorate, perchlorate, nitrate, aluminate, iodate, nitrite, silcofluoride produced no pronounced detrimental effect at high concentrations and may be presumed to be relatively safe in smaller concentrations such as might be encountered in industrial contaminated mix water (Kuhl [4])		
Zinc oxide	0.01% wt of cement	No significant effect but 0.1% strongly retarded setting and lowered strength. More information reported by Steinour[3].
Sodium sulfite	0.01–0.1%	Reduction in early strength. Higher dose gave detrimental effect on strength development.
Ammonium ion	No specific limit	Ammonium chloride increased strength. 0.4, 0.8 and higher % by weight of water of ammonium nitrate gave same strength as with similar % of NaCl.
Algae	To be tested	May result in air entrainment. See BS 3148*.
Organic acids		Humic acid or other organic acids may adversely affect the hardening of concrete (Neville[5]).
Sugar Oil and grease	< 100 mg/L < 50 mg/L	AS 1379.

continues

TABLE 3 *continued*

Impurities	**Limit**	**Notes** (References)
Sucrose	500 ppm	0.03-0.06 wt % of cement retarded setting but increased strength, 0.1% severely retarded setting but increased strength, 0.15% caused quick setting and lowered 7-day strength & similar or lower 28-day strength. (Steinour[3]).
Tannic acid	(0.5% wt of water)	No effect on strength but may well have a considerable effect on setting time (Steinour[3]).
Silt or suspended clay particles	2000 ppm (turbidity)	USBR Concrete Manual**. Much higher amounts can be tolerated as far as the effect on strength is concerned (Abrams[2]).

* BS 3148 *Methods of test for water for making concrete*

** US Bureau of Reclamation *Concrete Manual.*

5.2 Current Standards

The use of water and recycled water for the production of new concrete is covered in National Standards such as:

- AS 1379—1997 *Specification and supply of concrete*
- ASTM C94—05 *Specification for Ready Mixed Concrete,* which refers to ASTM C1602 – 06 *Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete*
- EN 1008—2002 *Mixing water for concrete – Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete.*

The most common performance criteria for mixing water are in terms of relative strength and setting time, whereas prescriptive limits are usually given in terms of chloride, sulfate and suspended solid contents. These criteria are compared and summarised in **Table 4**.

AS 1379 stipulates that mixing water shall be drawn from a source of acceptable quality. Water recycled from mixer washout operations may be used as mixing water if it is stored such as to prevent contamination by matter deleterious to concrete and the water drawn from the storage outlet is of *acceptable quality*. Acceptable quality is identified from past service records or tested to requirements in Tables 3 and 4 in the Standard. Table 3 covers performance requirements on 7-day and 28-day compressive strength and initial setting time. Table 4 limits the maximum concentration of sugar, oil and grease and pH.

ASTM C94 stipulates that mixing water comprises water and ice added to the batch, water occurring as surface moisture on the aggregates and, in the case of truck mixers, any wash water retained in the drum for use in the next batch of concrete. Water shall conform to ASTM C1602 which defines sources of water and provides requirements and testing frequencies for qualifying individual or combined water sources. In any case where the requirements of the purchaser differ from the specifications, the purchaser's specification shall govern. ASTM C94 permits the use of non-potable water or water from CPO in any proportions to the limits qualified to meet the requirements and optional limits summarised in **Table 4**. The levels of impurities permitted in the wash water should be below the maximum concentration criteria

TABLE 4 Main criteria of EN 1008, ASTM C94 and AS 1379 for the assessment of mixing water

Parameter	EN 1008	ASTM C94	AS 1379
Cl^- content	≤500 mg/L (prestressed concrete/grout) ≤1000 mg/L (reinforced concrete) ≤4500 mg/L (without reinforcement)	Optional requirement: ≤500 ppm (prestressed concrete or bridge decks) ≤1000 mg/L (reinforced concrete)	Specified as a total limit for concrete. Acid-soluble chloride ion content shall not exceed 0.8 kg/m^3
SO_4^{2-} content	≤2000 mg/L (otherwise, water fit for use in certain cases only*)	Optional requirement: Sulfate as SO_4 ≤3000 ppm	Specified as a total limit for concrete. Acid-soluble sulfate-ion content, reported as SO_3, shall not exceed 50 g/kg of cement.
Suspended solid matter	Recommendation: ≤1% of the total amount of aggregate in concrete	Optional requirement: Total solids by mass ≤50,000 ppm	Not specified.
Other impurities and harmful contaminants	Preliminary inspections for oils and fats, detergents, colour, odour, acids and humic matter (see Table 1 of Standard). Alkali as Na_2O_{eq} † < 1500 mg/L* Sugars < 100 mg/L Phosphate, P_2O_3 < 100 mg/L Nitrates, NO_3^- ≤500 mg/L Lead, Pb^{2+} ≤100 mg/L Zinc, Zn^{2+} ≤100 mg/L	Optional requirement: Alkalies as Na_2O_{eq} ≤600 ppm. Density as QC tool for combined water.	Sugar < 100 mg/L Oil and grease < 50 mg/L pH > 5.0
Comparative samples strength	The mean 7-day and 28-day compressive strength of the mortar or concrete samples prepared with wash water must be at least 90% of the mean strength of the control samples (prepared with distilled or tap water)	The mean 7-day compressive strength of the mortar or concrete samples prepared with the water must be at least 90% of the mean strength of the control samples (prepared with distilled or potable water).	7-day and 28-day compressive strength of concrete made with water from a source with no service record must be at least 90% of the mean strength of the control samples (prepared with water from a stable reticulated drinking water supply).
Setting times	Initial set ≥1 h and final set ≤12 h with both not differing by more than 25% from control.	From 1:00 hr earlier to 1½ hrs later than control.	Initial set from 60 min earlier to 90 min later than control sample time.

**ie the final assessment depends on an assessment of each individual case and/or the comparative concrete test*

† Na_2O_{eq} is $Na_2O + 0.658\ K_2O$

as follows: chloride as Cl^-(500 ppm), sulfate as SO_4 (3000 ppm), alkalies as Na_2O equivalent (600 ppm), and total solids (50,000 ppm). The PCA[12] also permits the use of wash water from mixing concrete with a tolerance of up to 50,000 ppm of total solids. Annex A1 in ASTM C1602 provides a guide for the comparison between two concrete mixtures necessary for compliance with, while Appendix X1 gives guidance for testing frequency as related to water sources used in mixing water.

EN 1008 specifies the requirements for water suitable for making concrete conforming to EN 206-1 and describes methods for assessing its suitability. The Standard considers the use of potable water, water recovered from processes in the concrete industry, water from underground sources, natural surface and industrial waste water for reinforced concrete, and seawater or brackish water for concrete without reinforcement or other embedded metal, but considers sewage water to be not suitable for use in concrete. The requirements for water are summarised in **Table 4** comprising preliminary assessment, chemical properties, and setting time and strength. Appendix A provides specific requirements for the use of water recovered from processes in the concrete industry.

5.3 Water in Leading Road Authorities' Concrete Specifications

Leading road authorities such as the Roads and Traffic Authority of New South Wales (B80 specification), Queensland Department of Main Roads (Standard Concrete Specification MRS11.70) and VicRoads (Specification for Structural Concrete) refer to the requirements of AS 1379 for mixing water. VicRoads also limits the chloride and chlorine content to 0.03% of the water.

5.4 Water from Concrete Production Operations (CPO)

There are a number of studies on the possible use of CPO water: as clarified wash water (partial recycled wash water) or slurry water (complete recycled water). A complete recycling of wash water and slurry for concrete making is part of the industry's move toward zero-discharge facilities. Studies by the NRMCA in the US and at the University of Toronto (Canada) on recycled water in ready mixed concrete operations were reported by Lobo and Mullings[6]. Other studies in Taiwan, Thailand, Italy and the USA were reported by Su et al, Chatveera et al, Sandrolini and Franzoniand Chini and Mbwambo).

5.4.1 Clarified wash water (partial recycled water)

There is sufficient evidence to support the use of clarified wash water collected from CPO with or without dilution with water from other sources into the collection well or sedimentation tank. It has been found that the quality of the water in terms of pH, total solid, chloride and sulfate content was well within the ASTM C94 limits, with the exception of the total solid content in the water collected from the bottom of the well. This supports the assertion that clarified wash water is suitable for making concrete provided that it is systematically collected and monitored.

All studies indicated that using clarified wash water with a solids-content at or less than the ASTM C94 limit would produce concrete with strength and setting time complying with the Standard. In some cases, the compressive strength at 7 or 28 days was 90–103% of that mixed with tap water. The higher strength might be due to the activation of the pozzolanic reaction of fly ash and slag by the high alkalinity of wash water. Drying shrinkage and rapid chloride permeability of concrete batches with clarified wash water were similar to the control batches. However, aged wash water (up to seven days) seemed to have marginally detrimental effects.

5.4.2 Slurry water (complete recycled water)

The use of slurry water to replace the same amount of tap water will influence the effective w/c of the concrete due to the high solid content in the slurry water. The use of water with solid content exceeding the 50,000 ppm limit by up to 13,400 ppm (pH 12, SG 1.03) has been found to reduce slump but no significant effect on unit weight or semi-adiabatic temperature rise. Increase in the percentage of slurry water resulted in reduction of compressive and flexural strength, and the elastic modulus. Compressive strength was not less than 90% of concrete with tap water. Increase in the proportion of slurry water as a replacement of tap water also had a negative effect on the drying shrinkage and the resistance to acid attack.

The NRMCA study[6] found slurry water, with significantly higher solids content, increased water demand and accelerated setting time. The effects were more pronounced with an increase in the age of the slurry past one day and an increase in the solids content. Mixtures that had higher water contents due to the use of higher solids recycled slurry had an associated reduction in strength and increase in drying shrinkage and rapid chloride permeability. Hydration Stabilising Admixture (HSA) was effective in overcoming the negative effects of age and higher solids content in the wash water.

The University of Toronto study[6], commissioned by the ready mixed concrete producers in Ontario Canada, found the primary issue with the use of recycled water at higher solids content to be the acceleration of the setting time. At the same w/c, strength, permeability, shrinkage and other characteristics were similar to the control batches.

Extreme caution is needed when considering the use of recycled water slurries with higher solids than the specified limit. The effect of such waters varies with increased solid contents as well as the age of the slurry.

6 SOURCES OF WATER

There are existing and new sources of water which may be suitable for direct replacement of potable water for concrete making or for dilution and processing of the CPO water. They include reclaimed water, groundwater and treated water from sewer mining or water mining.

Water authorities are moving towards identifying new sources (including recycled water) for potable and non-potable water. There are also a number of residential dual-pipe schemes operating or under development in Australia such as the Rouse Hill Estate in New South Wales, Mawson Lakes in South Australia, Pimpama Coomera in Queensland, Aurora Development in Epping North, Sandhurst and Eynesbury Estate in Victoria. With an increased emphasis in supplying reclaimed water for non-potable uses, as well as the promotion to councils and businesses to gain direct access to untreated wastewater in sewer mines, these new sources of water represent opportunities for the concrete industry to tap into as part of its water management strategies. However, it required the source (eg wastewater treatment plant) and the target user to be in close proximity. For sewer mining, it is necessary for individual on-site treatment facilities to be established.

6.1 Metropolitan Potable Water

The World Health Organisation criteria for drinking water are summarised in **Table 5**. The quality of metropolitan water in major Australia cities and five US water-supply are tabulated and compared in **Table 6**. There was a wide range of variation of chemicals in water from different sources. The level of solids, chloride, sulfate and other chemical contents were very low compared to limits specified for concrete mixing water. This information indicates the range of chemicals and their variation that can be expected from one metropolitan supply to the other.

TABLE 5 Drinking water standards of the World Health Organisation Concentration in milligrams per litre (mg/L) *(after Ryan and Samarin[8])*

	WHO International (1958)			WHO European (1961)	
Chemical constituent	Permissible limit	Excessive limit	Maximum limit	Recommended limit	Tolerance limit
ammonia (NH_3)	–	–	–	0.5	–
arsenic	–	–	0.2	–	0.2
cadmium	–	–	–	–	0.05
calcium	75	200	–	–	–
chloride	200	600	–	350	–
chromium (hexavalent)	–	–	0.05	–	0.05
copper	1.0	1.5	–	3.0*	–
cyanide	–	–	0.01	–	0.01
fluoride	–	–	–	1.5	–
iron	0.3	1.0	–	0.1	–
lead	–	–	0.1	–	0.1
magnesium	50	150	–	125†	–
magnesium + sodium sulfates	500	1000	–	–	–
manganese	0.1	0.5	–	0.1	–
nitrate (as NO_3)	–	–	–	50	–
oxygen, dissolved (minimum)	–	–	–	5.0	–
phenolic compounds (as phenols)	0.001	0.002	–	0.001	–
selenium	–	–	0.05	–	0.05
sulfate	200	400	–	250	–
total solids	500	1500	–	–	–
zinc	5.0	15	–	5.0	–

* *After 16 h contact with new pipes: but water entering a distribution system should have less than 0.05 mg/L of copper*

† *If 250 mg/L of sulfate is present, magnesium should not exceed 30 mg/L*

TABLE 6 Chemical analysis of metropolitan water in Australia and the US *(Ryan and Samarin[8] and Steinour[3])*

Chemical	Location (year analysed) Adelaide Happy Valley 1983–1987	Brisbane North Pine 1978	Perth Mirraboka region* 1986–1987	Melbourne Cardinia 1987	Sydney Ryde 1986–1987	Five US supply authorities – highest for each item† 1960
Total dissolved solids	413	370	404	49	93	983
pH	7.6	7.1	6.7	7.0	7.19	–
SiO_2	7	17	15.0	6.3	3.72	22.0
Na	101	43	89	6.3	12.6	215
K	5.5	2.5	5.4	0.8	1.63	18
Ca	23	31	29.8	3.0	8.2	96
Mg	20	20	9.3	1.6	5.0	34
Fe	0.68	0.1–0.3**	<0.1	0.2	0.10	0.2
SO_4	36	29	54	2.0	7.1	121.0
Cl	180	115	153	8.4	24.8	280
HCO_3	85	115	51.5	–	–	549
NO_3	–	–	–	–	–	13.0

Notes: All values in ppm except pH All values are presented as an average for period shown except for Hobart and Perth

* *Treated groundwater*

** *Data given as a range by water authorities concerned*

† *Data was give as typical values by water authorities concerned.*

TABLE 7 Some of the potential quality concerns for industrial reuse

Quality	Problem
Microbiological quality	Risk to health of workers and the public
Chemical quality (eg ammonia, calcium, magnesium, silica, iron)	Corrosion of pipes and machinery, scale formation, foaming.
Physical quality (eg suspended solids)	Solids deposition, fouling, blockages.
Nutrients (eg phosphorous and nitrogen)	Slime formation, microbial growth.

6.2 Reclaimed Water

There are many potential options for the reuse of reclaimed water within industry sectors. Some examples are:

- Cooling system make-up water
- Boiler feed water
- Process water (for example, concrete batching plant)
- Wash-down water
- Fire protection (such as sprinkler systems)
- Dust control/suppression at construction sites, quarries and mines.

Some of the potential quality concerns for industrial reuse are tabulated in **Table 7**. The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2001) provides guidance on appropriate water quality for a range of industrial uses.

6.2.1 Sources of reclaimed water

Current and future sources of reclaimed water in various Australian states are listed in **Appendix A** and summarised in **Table 8**. It shows both current and future sources of reclaimed water. However, it is best that individual users contact the relevant water authorities for their advice of the best source of nonpotable water.

6.2.2 Quality of reclaimed water

Abrams[2] examined the effect on concrete strength of waters carrying sanitary sewage and waters carrying industrial wastes. He found waters carrying sanitary sewage to give strengths between 83 and 102% of control. The analyses of these waters involved simply the usual determinations of suspended solids, total solids, ignited solids, silica and inorganic ions. The amounts did not differ significantly from those for the city waters. For industrial wastes, the contents are so diverse that only the total solids content was analysed. Of all these waters, only lime soak from tannery, refuse from paint factory and acids waters were considered unsatisfactory. The other waters gave no strengths below 85%. All of the waters with reported total solids below 4000 ppm fall into this category.

Specific quality of reclaimed water can be obtained from the respective supplier. The typical quality of some reclaimed water from Liverpool, Penrith, and Rouse Hill in NSW is given in **Table 9**. The data demonstrates the suitability of reclaimed water from these three sources for use as concrete mixing water.

TABLE 8 Sources of reclaimed water

Scheme	Areas/suburbs served	Quantity (billion litres/ year)	Available from
NEW SOUTH WALES – **Western Sydney Recycled Water Initiative** (via dual reticulation).		27	2015
Camillia (drinking water)	Camillia and Smithfield	6	2010
Hoxton Park	Edmondson Park, Glenfield Road, Ingleburn Gardens, Inghams, Yarrunga, Cecil Hills (South) and South Hoxton Park Aerodrome.	3	2009 2019
Dunheved Industrial Estate	East St Marys	NA	NA
Liverpool to Ashfield pipeline (sewer mining)	Many suburbs via a 24-km-long pipe from Liverpool STP to an existing sewer at Ashfield. http://www.sydneywater.com.au/MajorProjects/LiverpoolAshfieldPipeline/	NA	Late 2008
VICTORIA – Melbourne Eastern Treatment Plant			
Onsite	Eastern Treatment Plant.	13.4 13.8	2004/05 2009
Eastern Irrigation Scheme – TopAq (Class A recycled water)	Cranbourne-Five Ways, Sandhurst development.	0.2 5.0	2005 2010
South East Water	Frankston and Mornington Peninsula via Eastern Treatment Plant's 56-km outfall pipeline.	1.4 1.7	2005 2010
Western Treatment Plant – Werribee			
Onsite (Class C recycled water)	Werribee Agriculture.	20.7 37	2004/05 2009
Western Treatment Plant	Werribee Tourist Precinct	0.1 0.5	2004/05 2009
Southern Rural Water (Class A recycled water)	Werribee Irrigation District, Werribee South.	3 8.5	2006/07 2009
City West Water	City of Wyndham, Werribee Fields, Manor Lakes and Bluestone Green, Werribee Technology Precinct, Hoppers Crossing.	1.0	In planning.
QUEENSLAND Brisbane – **Western Corridor**			
Recycled Water Scheme: linking Luggage Point on Brisbane's east to Caboonbah in the north-west. It Involve the construction of three advanced water treatment plants at Bundamba, Luggage Point and Gibson Island by an approximately 200 km long which has a capacity to supply up to 230 ML per day. www.westerncorridor.com.au/map.aspx?docId=30 See the proposed pipeline route and summary of SQC Councils Recycled Water Information in **Appendix A**.		80	2008

continues

TABLE 8 *continued*

Scheme	Areas/suburbs served	**Quantity** (billion litres/ year)	**Available from**
WESTERN AUSTRALIA			
Kwinana Water Recycling Plant	Major industries in Kwinana.	6 +3.5	2006 future
Albany Waste Water Treatment	Used to water gum trees and tree farms in Albany.	NA	2006
Pinjarra	Used for dust control	NA	
CANBERRA			
Lower Molonglo Water Quality Control Centre	Supplies reuse schemes, adjacent vineyard and golf course.	1.9	2006
North Canberra Effluent Reuse Scheme	Provides effluent to irrigators, the Australian Defence Force Academy.	0.3	2006

TABLE 9 Typical impurities in reclaimed water *(courtesy of Sydney Water)*

	Typical impurities (mg/L) **in reclaimed water from**		
Parameter	**Liverpool** (Secondary)	**Penrith** (Tertiary)	**Rouse Hill** (Residential recycled)
Alkalinity (bicarbonate)	259	41	
Alkalinity (carbonate)	84	0	
CBOD	10.3	2.8	2.4
Chloride	145	124	156
COD	57	33	30
TDS (total dissolved solid)	488	442	535
TSS (total suspended solid)	11	2.6	2.6
Total nitrogen	40	3	5.6
Total phosphorus	6	0.08	0.02
Sulphate	48	64	~60
Turbidity, NTU	10	0.7	0.5
Reactive silica		5.7	

CBOD is the carbonaceous biochemical oxygen demand, COD is the chemical oxygen demand

6.2.3 *Classes of reclaimed water*

In many states, reclaimed water is classified for a range of usage. Examples of classification from Victorian EPA and Queensland EPA are given in **Tables 10 and 11** respectively. Industrial use of reclaimed water within enclosed systems (such as sealed conveyance systems, tanks or vessels) will minimise the risk to workers and allow the use of a lower class of reclaimed water. For an 'open system' industrial use, where there is potential for worker exposure due to ingestion or inhalation of aerosols, Class A reclaimed water is generally needed to protect worker health. Lower levels of disinfection (reclaimed water Class B or lower) may be possible but will depend on assessment of the measures employed to control worker exposure to such water. Measures could include ventilation or extraction of enclosed spaces (adequate air exchange to outside the work area), or personal protective clothing and equipment.

As shown in **Tables 10 and 11**, all classes of reclaimed water have very low suspended solid content and hence are highly likely to be suitable for concrete production. Class A reclaimed water appears particularly suitable for consideration for use in concrete batching plants including mix water as it should post no health risks to the worker.

According to EPA Victoria's *Guidelines for Environmental Management: Use of Reclaimed Water*[17], treatment will be required to achieve a median concentration of biochemical oxygen demand (BOD) of 20 mg/L and suspended solid (SS) of 30 mg/L (30 ppm) for recycled water. Secondary treatment is the minimum standard of treatment needed for most agricultural and municipal reclaimed water use scheme. For class A, B or C reclaimed water, the treatment process also needs to include a pathogen-reducing disinfection step such as chlorination.

Note that the use of any class of recycled water should involve development and implementation of a Recycled Water Management Plan incorporating risk management.

TABLE 10 Classes of reclaimed water and corresponding standards for biological treatment and pathogen reduction *(Table 1 of EPA Vic guideline)*

Water quality objectives – **median unless specified**	**Classes of reclaimed water**			
	A	**B**	**C**	**D**
E.coli org/100 mL	<10	<100	<1000	<10000
Turbidity, NTU*	2	–	–	–
BOD	<10	<20	<20†	<20†
Suspended Solid, SS	<5	<30	<30†	<30†
pH**	6–9	6–9	6–9	6–9
Residual (or equivalent disinfection)	1 mg/L	–	–	–
Range of uses (industrial specific)	Open system with worker exposure potential	Closed industrial system	Closed industrial system with no potential worker exposure	Agriculture – non-food crops.

Notes: * *Turbidity limit is a 24-hour median value measured pre-disinfection. The maximum value is five NTU.* ** *pH range is 90th percentile. A higher upper pH limit for lagoon-based systems with algae growth may be appropriate, provided it will not be detrimental to recipient soils and disinfection efficacy is maintained.* † *Where Class C or D is via treatment lagoons, although design limits of 20 mg/L BOD and 30 mg/L SS apply, only BOD is used for ongoing confirmation of plant performance.*

TABLE 11 Recommended water quality specifications for recycled water, its uses and recommended monitoring (Tables 6.2 and 6.3 in *Queensland EPA Water Recycling Guidelines*[18])

Water quality specifications	Classes			
	A	B	C	D
E.coli, median (cfu/100 mL)*	<10	<100	<1000	<10,000
Turbidity, NTU 95% ile (max.)	2 (5)*	-	-	-
BOD^5, median (mg/L)	20	20	20	-
Suspended solid, SS, median (mg/L)	5	30	30	-
pH	6–8.5	6–8.5	6–8.5	6–8.5
TDS, median (mg/L) EC, median µS/cm)**	1000 1600	1000 1600	1000 1600	1000 1600
Recycled water use (Industrial specific)	Open system (potential for occasional human contact, but with safeguards in place.	Washdown of hard surfaces in agricultural industries.	Closed system (low human contact)	Turf, cotton, wholesale nurseries with controlled access.
Recommended monitoring	*E. coli* weekly, turbidity and disinfection continuous, pH weekly	*E. coli* weekly, disinfection weekly, pH weekly, SS weekly	*E. coli* weekly, disinfection weekly, pH weekly	*E. coli* monthly, pH monthly

Note: Turbidity would generally be measured before the disinfection point at the treatment plant as this is the point at which low turbidity is essential.

* *As these values are medians, for each of these guideline values a response value should be set (eg 50% above the guideline value).*

** *For sustainable irrigation, salinity should be kept as low as possible. For example, if TDS >1000 mg/L or EC>1600 µS/cm, a salinity reduction programme should be implemented.*

6.3 Sewer Mining

Sewer mining (NSW) or water mining (ACT and Queensland) is the process of tapping directly into a sewer either before or after a sewage treatment plant and extracting wastewater for treatment and reuse as recycled water. Some sewer mining by-products may be returned into the sewerage system, subject to trade waste disposal and licensing requirements.

The user will be responsible for treating the water from sewer mining to the required quality. It is likely that the treated water will cost more than water obtained from water authorities but with the certainty of supply.

Examples of such schemes include Kogarah Council and Pennant Hills Golf Club in Sydney, Rocks Riverside Park in Brisbane and Southwell Park in Canberra.

6.4 Groundwater or Bore Water

Botany Sands Aquifer bore water supplies are used for industrial purposes such as cooling and manufacture of paper and chemical products. The water is also used for irrigation of parks and gardens, golf courses and bowling greens. Natural groundwater discharge from the sand bed aquifer supports important dependent ecosystems such as the Botany Wetlands.

In NSW, the Department of Natural Resources is responsible for managing access to water and ensuring water is shared between the environment, towns and cities, and farmers and industry as well as for Aboriginal cultural activities. To access groundwater for any purpose requires approval from the Department.

In Melbourne, the Department of Sustainability and Environment (DSE) is responsible for co-ordinating groundwater management activities across the State. To support this role, it undertakes groundwater investigations using in-house and contracted resources. These include the provision of technical advice on groundwater resource, salinity and contamination matters, as well as information management and mapping.

In Queensland, there is a moratorium banning the drilling of new water bores in Brisbane and Toowoomba.

Groundwater may be a suitable source of concrete mixing water. It has a tendency to be saline or may contain appreciable amounts of dissolved carbon dioxide. In securing a source of groundwater, quality requirements (**Table 2**) and guide on impurities (**Table 3**) could be used to gauge the suitability of a particular source.

6.5 Occupational Health and Safety

The following best-practice measures, recommended by EPA Victoria, should be implemented to minimise the exposure of on-site workers to risks associated with the use of reclaimed water:

- Education of on-site workers as to the risks associated with exposure to reclaimed water (ingestion and inhalation of reclaimed water droplets and mist).
- Appropriate immunisation (immunisations are not considered necessary for any Class A schemes, due to the high microbiological water quality).
- Installation of wash basins.
- No consumption of food or drink while working directly with reclaimed water, and the washing of hands with soap before eating, drinking or smoking, and at the end of the working day.
- Using protective equipment appropriate to the tasks being undertaken and the quality of reclaimed water being used.
- Avoiding high exposure to, and inhalation of, reclaimed water spray by limiting access to irrigation areas to a minimum during irrigation periods.

An Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1) was released in 2006. It is an authoritative reference for the supply, use and regulation of recycled water schemes. It provides guidance on how recycling can be safely and sustainably achieved.

It can be downloaded from http://www.ephc.gov.au/taxonomy/term/39

7 DISCUSSION AND RECOMMENDATIONS

Water naturally contains a wide range of dissolved chemicals and suspended solids. Potable water, for example, can contain up to 1000 ppm of total dissolved solids and dissolved chemicals ranging from silica, alkalies, iron, chlorides, sulfates, bicarbonates and nitrates. Water containing a range of impurities can therefore be quite suitable for concrete production. Some waters which could adversely affect hardened concrete may be harmless or even beneficial when used in mixing (eg seawater in plain concrete).

The bulk of research on the effect of impurities in mixing water on concrete performance was conducted in the first half of the twentieth century. The essences of these studies have been reviewed by Steinour[3] and summarised in **Table 3**. Most recent literature focused on the use of wash water and slurry water from concrete production operation (CPO). The suitability of CPO water has been assessed based on its effect on setting times and strength. This approach follows the performance requirements of National Standards on concrete mixing water including recycled water. **Table 4** compares the Australian, American and European specifications.

Table 2 gives mandatory limits for chemical and total solid content. **Table 3** serves as a checklist to identify potential harmful impurities in any new source of water for concrete production. **Table 4** can be used to assess CPO waters for concrete production, and Appendix X1 in ASTM C1602 provides guidance for testing frequency of CPO waters.

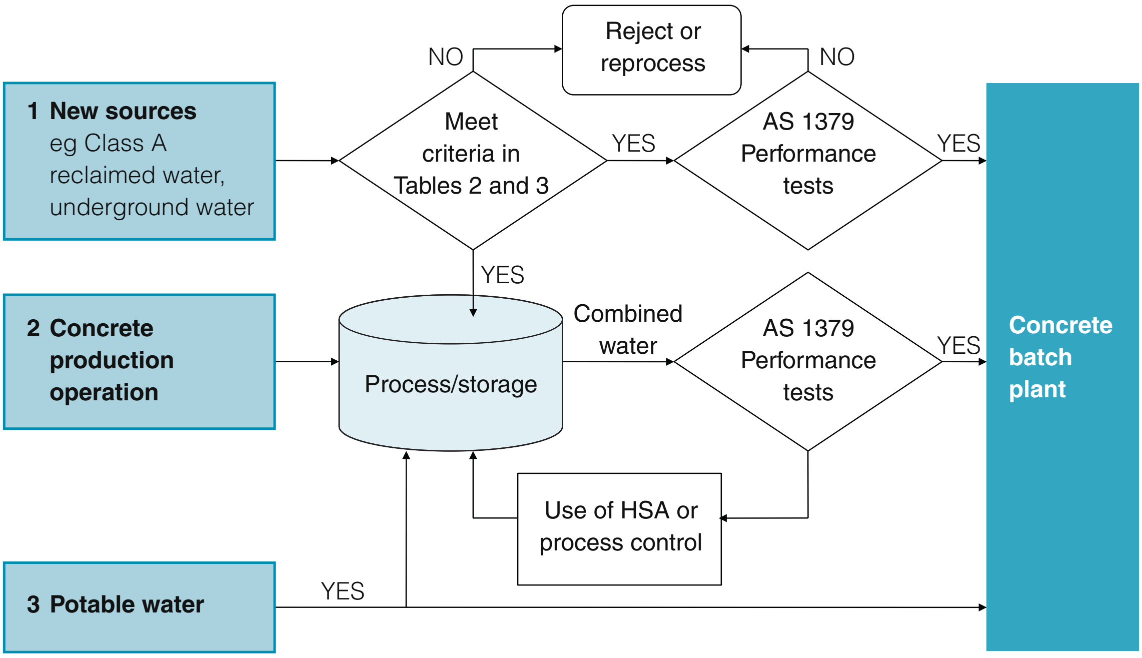
Most Water Authorities are strongly promoting the use of reclaimed water for domestic, agricultural and industrial usage. Sources and availability are provided for all capital cities in Australia. Information on the quality of reclaimed water is available from water suppliers (see examples in **Table 9**). From the OH&S viewpoint, there are 'water quality objectives' for various classes of reclaimed water. They vary slightly from state to state, and examples from EPA Victoria and Queensland EPA are given in **Tables 10 and 11**. From such limited information, Class A reclaimed water appears to be suitable for concrete production but concrete performance testing will be required for any new source of reclaimed water.

Under three broad water-use scenarios given below, there are two different sets of criteria to be used to check if the quality of water is suitable for making concrete:

- If a new source of non-potable water, such as reclaimed or groundwater, is considered for use as mixing water or as part of CPO water, a stringent set of criteria should be adopted from **Tables 2 and 3** to check if there are excessive impurities which are detrimental to the production and durability of concrete. In most cases, the water is supplied by a Water Authority or its water retailers. Reclaimed water is usually supplied to specific classes with corresponding standards for biological treatment and pathogen reduction such as shown in **Table 10**. The availability of reclaimed water in all major cities is listed in **Table 8**. It is best to contact the local water authority for details about supply and quality.
- Where recycled CPO water is chosen, the quality of the water must comply with criteria specified in AS 1379 or similar standard for recycling water summarised in **Table 4**. Different levels of process control are implemented depending on whether partial or complete recycled water is used. Appendix X1 in ASTM C1602 provides a guide for testing frequency.
- Potable water is considered suitable for concrete production. However, if potable water is used as part of the CPO water, the AS 1379 criteria used to assess recycled water would apply to the combined water.

Where full recycling of CPO water is targeted, there is evidence that slurry water containing suspended solid matters greater than 50,000 ppm (limit given in ASTM C94) can be used, but testing of the specific water and possible use of hydration stabilising admixture (HSA) or other admixtures is recommended. If water, other than potable water, is introduced, it seems that Class A reclaimed water (or higher class) can be used where there is potential for worker exposure. Where groundwater or sewer mined water is used, the *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks*[19] should be followed.

WATER USE SCENARIOS



8 SUMMARY

All waters are likely to contain a wide range of dissolved chemicals and suspended solids which may affect concrete production in various ways. Extensive review of literature and standards in Australia and overseas has provided information on the following two aspects of concrete-mixing-water quality:

- **Table 2** – Existing mandatory limits on chemicals and total solid content in the mixing water to ensure long-term durability of the concrete produced, and
- **Table 3** – A guideline on the type and amount of impurities which may adversely affect the properties of fresh and/or hardened concrete.

There is not sufficient research for a specific limit to be placed on each impurity in **Table 3**. In practice, the possible effects of this whole range of impurities in the mixing water are tested simply for their effects on the setting times and strength development of a standard mix compared to the same mix prepared with potable or distilled water. Any adverse results are accommodated in terms of tolerances in the setting times and strength. This is the approach used in all standards including AS 1379 (**Table 4**).

Water authorities in many states are promoting the use of non potable water to industry and are in a position to provide information on the availability and quality of water from a specific supplier. In sourcing alternative water supply, quality requirements can be compiled from **Tables 2 and 3** for concrete mixing water which will help the supplier to identify the most appropriate source of water. In the case of reclaimed water, classification of the water according to the quality objectives for a range of water usage including level of human exposure, can be made available to assist the water user with OH&S management. In sewer or water mining, the choice of water processing technology and quality objectives become the responsibility of the licensee.

APPENDIX A: Current and future sources of reclaimed water

New South Wales Water authorities such as Sydney Water have implemented or plan to increase water supply sources for households, industrial and commercial use. They include:

- Deep water in dams
- Options for transferring more water from Shoalhaven
- Groundwater in the event of severe drought.

The NSW Government has identified a number of ways to increase the use of recycled water by industry. The first of these is the innovative water scheme in the Camellia area near Parramatta. This has the potential to save up to six billion litres of drinking water a year. Smaller industrial schemes around Sydney such as that at the Dunheved Industrial Estate in East St Marys are being developed.

Apart from using wastewater treated at sewage treatment plants and harvesting stormwater, businesses and councils can also gain direct access to untreated wastewater in sewer mines and treat it themselves for their own use or for supply to others.

The NSW Government has planned for more-diverse recycled water markets including residential, industrial and agricultural markets in Western Sydney. The total recycling in these markets is projected to be more than 70 billion litres per year by 2015, or about 15% of all the wastewater collected.

Victoria In Melbourne, stormwater, greywater and reclaimed water are all alternative water supplies. Reclaimed water is treated water from major sewage treatment plants, and is supplied by local water retailers: Southern Rural Water or TopAq and the metropolitan retail water companies. Greywater usually refers to domestic water recycling from baths, showers, basins or washing machines for gardens. In Melbourne, reclaimed water is also a source for greywater. See **Table 8**.

Onsite water recycling (referred to as sewer mining in NSW) involves the removal and treatment of effluent from sewer mains to produce high quality recycled water while returning remaining water or sludge to the sewerage system. Melbourne has successfully trialled onsite water recycling plants in parks around Melbourne.

South Australia SA Water supplies water state-wide through its distribution network This includes potable water for all purposes and recycled water principally used for irrigation. There are three main sources of potable water. The 2005–06 reported volume from these three sources was: River Murray (114 billion litres, 48.7%), surface water (105 billion litres, 44.8%) and ground water (15 billion litres, 6.5%).

Overall, SA Water reclaimed approximately 18.9 BL or 18% of treated wastewater during 2005–06 for reuse. SA Water supplies recycled water from some of its wastewater treatment plants for use in the irrigation of crops, primarily in Virginia and Maclaren Vale, golf courses, parks and gardens. SA Water is a partner in the Mawson Lakes residential third-pipe scheme.

The scheme combines recycled wastewater from the Bolivar Wastewater Treatment Plant and captured stormwater from the Salisbury area to provide an alternative supply for irrigation of gardens and open space areas as well as toilet flushing.

SA Water describes recycled water as reclaimed water. Reclaimed water[20] is treated to reduce the risks associated with use of such water. Reclaimed water is divided into classes A, B, C & D. Class A is the highest quality of reclaimed water or non potable water classified for primary contact recreation, residential non potable use (e. garden watering), local council use with public access, dust suppression and unrestricted crop irrigation. Class B is classified for secondary contact recreation, restricted crop irrigation and fire fighting.

Western Australia While water recycling has been undertaken in regional areas of Western Australia for many years, large-scale use of recycled water in the metropolitan area has been limited. To address this situation, the State Water Strategy sets a target of reusing 20% of WA treated waste water sources by 2012. It identifies large-scale, scheme-based reuse options as a priority above reuse at a household scale. The Strategy highlights the potential for recycling to provide water 'fit for purpose' for irrigated horticulture, green space irrigation and industry, as well as the potential for managed aquifer recharge to increase water availability in groundwater systems and to maintain environmental values. The WA Department of Water is also working to increase recycling of stormwater.

Kwinana Water Recycling Plant is currently supplying six billion litres of recycled water annually with expansion of supply underway.

Queensland The Queensland Environmental Protection Agency provides water recycling guidelines[21] which aim to encourage and support water recycling that is safe, environmentally sustainable and cost effective, and hence reduce pressure on existing potable water sources. These guidelines provide advice on recycling water for non-potable reuse that has been sourced from sewage treatment plant effluent, but not from other sources.

The Western Corridor Recycled Water Scheme is the largest recycled water scheme in Australia and will involve building a pipeline from six wastewater treatment plants in Brisbane and Ipswich to take recycled water to industry and agriculture. The Western Corridor Recycled Water pipeline (see Project overview map below):

- will be capable of delivering up to 95 million litres of recycled water per day from Brisbane to the power stations;
- could provide up to 115 million litres per day for other uses, such as replenishing the dams with purified recycled water.

Tasmania The Tasmanian Government supports the use of recycled water and provides guidelines[22] for such use. Recycled water may be available from treatment plants; local councils should be contacted for possibility of supply. Current recycling is primarily for broad-acre agribusinesses and golf courses such as the Clarence Recycled Water Scheme which provides up to 2700 megalitres of recycled water to potentially more than 100 Tasmanian growers. Public health requirements are given in the guidelines.

Darwin The Northern Territory Power and Water Corporation have been recycling water for 20 years in Darwin and Alice Springs. Recycled water is used on a limited basis in Darwin, Pine Creek, Katherine, and Alice Springs. However, the demand for recycled water from large irrigation customers is increasing. Recycled water can be reused for watering public sports playing fields, golf courses, tree lots, pastures and public areas. In Darwin, the Marrara sporting complex ovals and golf course are irrigated by recycled water, while in Alice Springs, Blatherskite Park uses recycled water to water its ovals. In Alice Springs, the project directs effluent from waste stabilisation ponds down to underground storage before being used in irrigation horticulture projects.

Canberra The ACT Government issued a strategy for sustainable water resource management in 2004 [23]. It targets an increasing use of reclaimed water to 20% by 2013. It reported that the average volume of sewage collected in the ACT (from Canberra and Queanbeyan) potentially available for reuse is 35 GL per year. The 2006 reuse was around 2.2 GL per year.

ACT Electricity and Water (ACTEW) confirmed the availability of recycled water from the Lower Molonglo Water Quality Control Centre.

REFERENCES

1a EN 1008 *Mixing water for concrete – specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete.*

1b ASTM C1602-06, *Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete*, USA.

1c AS 1379 *Specification and supply of concrete* Standards Australia

2 Abrams DA, 'Tests of impure waters for mixing concrete' *American Concrete Institute* Journal 20 (1942) pp 442–486.

3 Steinour HH, 'Concrete Mix Water – How Impure Can It Be?' *Portland Cement Association Journal* Research and Development Laboratories, 3, No. 3 pp. 32–50 Sept. 1960.

4 Kuhl H 'The Chemistry of High Early Strength Cement', *Concrete* (Cement Mill Edition), 33, No. 1, pp 109–111, July, 1928; 33, No. 2, pp 103–105 August 1928.

5 Neville AM *Properties of Concrete* Fourth Edition, Longman, England 1997, p734.

6 Lobo C and Mullings GM 'Recycled Water in Ready Mixed Concrete Operations' *Concrete InFOCUS* Vol. 2, No. 1, pp 17–26 Spring 2003, (Reprinted by permission of National Ready Mixed Concrete Association).

7 Cebeci OZ and Saatci AM 'Domestic sewage as mixing water in concrete' *ACI Materials Journal*, 86, No. 5, pp 503–6 1989.

8 Ryan WG and Samarin A *Australian Concrete Technology*, Longman Cheshire, Melbourne, 1992.

9 Netterberg F 'Occurrence and Testing for Deleterious Salts in Road Construction Materials with Particular Reference to Calcretes', Proceedings of Salts Symposium, IEAust, 1970.

10 '*Analysis of water encountered in construction*' BRS Digest No. 90, HMSO, London, July 1956.

11 ASTM C94 – 05 *Specification for Ready Mixed Concrete* USA.

12 *Design and Control of Concrete Mixtures* PCA Skokie, IL, 1990.

13 Su N, Miao B and Liu FS 'Effect of wash water and underground water on properties of concrete', *Cement and Concrete Research* 32, pp 777–782, 2002.

14 Chatveera B, Lertwattanaruk P and Makul N ‘Effect of sludge water from ready-mixed concrete plant on properties and durability of concrete’ *Cement & Concrete Composites* 28, pp 441–450, 2006.

15 Sandrolini F and Franzoni E ‘Waste wash water recycling in ready-mixed concrete plants’, *Cement and Concrete Research* 31, pp 485–9, 2001.

16 Chini SA and Mbwambo WJ ‘Enviromentally friendly solutions for the disposal of concrete wash water from ready mixed concrete operations’, Proceedings CIB W89 Beijing International Conference, 1996.

17 *Guidelines for Environmental Management: Use of Reclaimed Water (*Publication 464.2), EPA Victoria 2003.

18 Queensland EPA – Queensland Environment Protection Agency *Queensland Water Recycling Guidelines* December 2005 (p17).

19 *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks’*, NWQMS, Nov 2006.

20 *Water, for growth, development and quality of life for all South Australians*, Sustainable report, SA Water 2003.

21 *Manual for Recycled Water Agreements Part 4*, Queensland Government, available from http://www.nrw.qld.gov.au/compliance/wic/guidelines_recycle.html.

22 *Environmental Guidelines for the Use of Recycled Water in Tasmania*, Department of Primary Industries and Water, December 2002.

23 Think water, act water: Strategy for sustainable water resource management in the ACT, 2004–2005 Progress Report, ACT Government January 2006.

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