TECHNICAL BULLETIN – TB143.004

WATER CHEMISTRY FOR CEMENT BASED ADHESIVES AND GROUTS IN TILED SWIMMING POOLS

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INTRODUCTION & SCOPE

The purpose of this bulletin is to provide an initial understanding the effect of some of the chemicals used in swimming pool water have on cement based adhesives and grouts used with ceramic tile finishes. The traditional chemicals of concern are the Calcium based and the Sulphate based compounds that affect the mineralogy of the tile grouts and adhesives.

However in recent times we have observed some unusual problems with cement based grout in pools containing Magnesium Chloride (instead of normal salt – Sodium Chloride). We note also water treated with 'mineral salts' containing unusual trace elements.

While this bulletin is primarily related to tile finishes in immersed conditions, overflow and frequent wetting in the adjacent splash zones around pools may also show these effects.

CALCIUM HARDNESS

Hardness is said to be a measure of the Calcium and Magnesium dissolved in the water.

Pool water is said to be ***hard and non-aggressive*** when the Calcium level (expressed as Calcium Carbonate) exceeds, or can be maintained at over 200mg/L. In this situation Calcium is ***not leached*** from cement based materials and the tile adhesives and grouts will remain in good condition.

Where the pool water has low (<90 mg/L) Calcium levels, it is said to be ***soft and aggressive*** towards cement based materials. Calcium may be leached from the tile adhesives and grouts to such an extent that the grout is removed from joints between tiles and the tile adhesives may be weakened sufficiently to allow debonding of tiles.

High levels of Calcium may lead to lime scale (Calcium carbonate) deposits building up in the pool plumbing system. To prevent these deposits occurring, the pool water Calcium hardness levels have been recommended to be in the range 90 - 200 mg/L.

It is has been noted that when the water has low Calcium hardness and low bicarbonate alkalinity levels, the pH value may still be high (indicating overall alkaline conditions) and the water is still aggressive to cement based products. This may be corrected by using a water treatment that adds Calcium salts to the water.

The chapter on Calcium hardness in GB65 - 1998 (see references) indicates that the water supply in most Australian cities is soft, except in Perth, Adelaide and some country areas. Melbourne water is said to be particularly soft. The importance of correctly maintaining the pool water chemistry should always include the Calcium and Sulphate chemistry .

THE SULPHATE EFFECT

The effects of soluble Sulphates on cement based mortars and grouts are dependent on the Sulphate concentration. BS 5385.4 - 2015 states that the maximum permitted concentration of soluble Sulphates is 300 mg/L (expressed as SO_3 equivalent to 360 mg/L SO_4).

Sulphate weakens cement based products by changing the original cement crystalline form to an expanded, mechanically weaker crystalline form. This leads to deterioration within the cement based grouts as the expanded structure becomes more susceptible to chemical attack and physical stress.

Cement based products form strong bonds to the substrate and within adhesives and mortars by reacting (hydrating) with water and forming crystals that lock into the pores at the substrate (concrete) surface or interlock with each other in mortars and adhesives. These crystals may be considered as mechanical anchors and the bonding formed is very strong. Chemical alteration by the sulfates in the pool water changes these crystals to long thin needle-like shapes that are weaker than the original crystalline shapes.

Where both low concentrations of Calcium compounds and high concentrations of Sulphates occur, the corrosion effect is accelerated.

ACIDITY

The pH is a measure of the acidity or alkalinity of pool water and the ideal value is 7.5 with the normal range between 7.2 and 7.8. The scale ranges from 0 to 14 where acidic conditions are

indicated at low values below 7, and alkaline conditions are indicated by high values above 7. The value 7 is set at the reading of pure water which is said to be neutral, neither acidic nor alkaline. The pH may vary in a pool with the effects being sore eyes or itchiness, accelerated corrosion and possibly scale formation, reduced effectiveness of Chlorine sanitisers and increased cloudiness of the water, especially when the pH is below 6.8 or above 8.5.
The importance of the pool water pH is that it is an indicator of the pool quality and how some of the pool chemicals will be acting. To raise the pH, the procedure is to normally add Sodium Carbonate or Bi-Carbonate, and to lower the pH, add Sodium Bi-Sulphate or Hydrochloric Acid. Repeated additions of the Bi-Sulphate will lead to the chemical attack on the cement based adhesives and grouts previously noted above. However low levels of Calcium in the pool water are not indicated by the pH readings as previously noted.

MAGNESIUM AND OTHER ELEMENTS

ARDEX has noted that in recent times some pools are treated with minerals other than common salt (i.e. sea salt) as the source of Chloride for the effective action of the electrolytic converters to generate free Chlorine. Whilst these treatments won't affect polymer shell pools to our knowledge, the "jury is out" on the effect they can have on cementitious grouts and adhesives.

Magnesium

One type of mineral treatment uses Magnesium Chloride instead of, or with Sodium Chloride (common sea salt). The issue with Magnesium relates to its chemical similarity to Calcium in terms of compounds formed. The Magnesium substitutes for Calcium in minerals which form the hardened cement paste matrix, and this change results in weakening of the material. It is a recognised situation, that Magnesium salts can damage cementitious containing materials such as concrete (e.g. Sumsian & Guthrie 2013, Darwin et.al. 2007, Cody et.al. 1996, Mather 1964) and we have noted that pools containing high levels of Magnesium Chloride appear to be linked with several recent instances of powdery cement based grout. In lieu of this apparent situation we recommend that non-cementitious R Class grout materials are used in pools treated in this way.

Boron

We note also that pool water can be treated with water chemicals containing compounds of Boron, sometimes as a pH buffer at a concentration of less than 200ppm, but for other claimed reasons too. It also has properties for ion exchange and reducing water hardness. Otherwise, this is an uncommon element in normal household environments, and is probably best known for uses as a disinfectant, wood preservative, fire retardant and insecticide. However, it is common in the nuclear industry, and literature related to the compounds of this element in the nuclear waste industry (e.g. Coumes et.al. 2009, Kim et.al. 1992) suggest that Boron compounds inhibit the cure of Portland cement based systems for waste encapsulation. We know that improperly cured cement can have compromised properties, therefore in the absence of any hard data re pool issues, we would recommend cementitious materials used in pools treated in this way are *well cured before any Boron containing material is added (i.e. at least 21 days dry cure as per AS3958)*.

CHLORINE

This is element is the water purification medium to keep the pool free of algae and other harmful organisms like bacteria. High levels of free Chlorine apart from being an irritant to swimmers, also can create changes in materials such as grouts. Particularly if coloured or pigmented grouts are used, the Chlorine bleaches the colour rendering the grouts a neutral whitish colour. Notably the grout above and below the waterline can end up being different shades or even appearing to be different colours.

RECOMMENDATIONS

The recommended water chemistry balance in **pools with ceramic tile finishes using common water treatment** (dry or tablet Chlorine, common salt, and water treated with UV or Ozone) is as follows:

Required

Total alkalinity range recommended	80 - 200 mg/L
pH range	7.2 - 7.8
Calcium Hardness range	150 - 200 mg/L
Sulphate range	< 200 mg/L.

Other typical values

Chlorine (free)	~1-2ppm
Salt as Sodium Chloride (salt water pools)	~4000-6000ppm

While these values may be slightly different to what many operators would regard as normal, we emphasise that these values are related to ceramic tile finishes that have been fixed (adhered) and grouted with cement based products. The values given here are in the recommended ranges to prevent corrosion of the cement in the adhesives and grouts.
The Australian Standard references do include the information regarding the effects of the chemical compounds noted in this technical bulletin. However those standards also apply to other types of pool finishes and care must be taken to ensure that the appropriate range is used in tiled pools.
We would also advise that excessively high levels of Chlorine can have a negative impact on cement based materials, and Brominated materials as used in spas are very aggressive and attack grouts and adhesives.

ADHESIVES AND GROUTS

This bulletin makes passing reference only to the types of adhesives and grouts that are suitable for use in swimming pools.
Essentially polymer fortified, cement based adhesives and grouts are normally suitable and have been used successfully for many years. Increased durability has been achieved by replacing standard grey Portland cement with more Sulphate resistant, white cements; while the polymers used have increased bond strengths and resistance to turbulence in the water, as well as reducing the permeability of the adhesives and grouts. Reduced permeability reduces the flow of water through the cement based adhesives and grouts hence slowing the effects of out of balance pool water.

ARDEX recommends the following adhesives for fixing tiles in swimming pools using **standard** pool treatment chemicals:

C-Class

ARDEX OPTIMA
ARDEX X18 + ARDEX E90
ARDEX X77 + ARDEX E90
ARDEX STS8W + ARDEX E90

R-Class

ARDEX WA EPOXY
ARDEX WA100 EPOXY
ARDEX EG15 EPOXY with reduced filler

For grouting in swimming pools the ARDEX recommendations are:

C Class

ARDEX FG8 + ARDEX GROUT BOOSTER
ARDEX FSDD + ARDEX GROUT BOOSTER
ARDEX WJ50 + ARDEX GROUT BOOSTER

White cement based C-Class grout is recommended to avoid colour bleaching which occurs with the oxides in coloured grout.

R Class

ARDEX WA EPOXY
ARDEX EG15 EPOXY.

Non-standard pool treatments

The increasing use of epoxy based grouts is noted as pool operators see the effects of 'out of balance pool water' and make us of the chemical resistance of epoxy R Class grouts.
Therefore in pools using Magnesium compounds which have a more chemically aggressive environment, we recommend that cementitious C class materials be replaced with the R Class products, ARDEX WA100, ARDEX WA and EG15.
In the case of the latter two, they can be the adhesive and the grout in one. This also alleviates any

possible issues with so called 'dob' supported small glass mosaics and grout spot fall out.

STANDARDS DOCUMENTS

The guidelines for pool water published by Standards Australia currently used are:

GB65 - 1998 Residential Swimming Pools – selection, maintenance operation (originally published as HB65-1998);

HB241 - 2002 Water Management for Public Swimming Pools and Spas

Other interesting references include:

British Standard BS 5385.4 – 2015 Code of Practice for tiling and mosaics in specific conditions;

Design and Construction Process for Swimming Pools published by The Tile Association in the United Kingdom (circa 2002);

Factors Affecting Grout Performance in Swimming Pools by Mike Wheat, Technical Director, Norcros Adhesives U.K. published in Tile Today Issue 33, pp58 - 64.

While the above references all provide excellent detail of all the chemicals used in pools, these details do not appear to provide ***adequate emphasis on the importance of Calcium or Sulphate concentrations in tiled pools.*** This is understandable given that these guidelines are meant for all types of pool lining materials, such as vinyl and fibreglass, in addition to tiles. Many types of pool lining (other than tiles) do not have the same chemical requirement as cement based adhesives and grouts, hence the guidelines are not followed or are maintained at rates that allow the cement based adhesives and grouts to remain in good condition.

Therefore consideration must be given to ensuring the pool water is maintained in a non-aggressive condition to allow cement based adhesives and grouts withstand the effects of the pool water and the chemicals used that come into contact with the tile finish. More detailed discussion on Calcium hardness can be found in Balim (2012) and Felixberger (2008).

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GLOSSARY

Alkalinity—Refers to the presence of soluble alkaline materials that are included in the pool water to buffer it against acidity. Typical alkalinity modifiers are Sodium Carbonate ('washing soda") or Sodium Bicarbonate ('bicarb' or 'bicarb of soda'). Where the alkalinity rises too high, the pH also rises and Calcium compounds start to precipitate as scum lines.

Boron- This refers to compounds of Boron such as Borax (hydrated Boron Oxide) or Boric Acid.

C-Class- This refers to cementitious based adhesives and grouts as defined in ISO13007. The cement is normally ordinary Portland cement (OPC).

Calcium—This is a short hand for compounds of Calcium such as Calcium Carbonate ("lime scale").

Calcium Hardness-Is another form of shorthand to describe the concentration of Calcium and Magnesium compounds in the water (the two are treated as one combined entity). The hardness is controlled by soluble or partially soluble Calcium and Magnesium compounds (present as Carbonate and Bicarbonate) levels and pH.

Chlorine- In pools it is present as free Chlorine, but is added as a Hypochlorite compound, Cyano-chlorine compound or is generated by electrolytic background of Chloride salts such as Sodium Chloride (common or sea salt).

Hard water– Contains high concentrations of Calcium and Magnesium compounds, usually Calcium and/or Magnesium Carbonate. These metal cations are relatively insoluble so as Carbonates and so it is relatively easy to have hard water where they are available. Typically water obtained from limestone source areas is 'hard'. Note that water can have high alkalinity, but low or high hardness.

Magnesium- In this case, this is shorthand for Magnesium Chloride, but can also apply to the more aggressive Magnesium Sulphate (also called Epsom salts).

pH-This is unit of measurement to indicate whether the water is acid, alkaline or neutral. The range is 0-14 with tap water having a range 6.7 to 7.4 for most cases.

pH is defined as a measure of the concentration of acid (H+) or alkali (usually expressed as OH-) in the water. Alkaline water containing Carbonates is more complex measurement.

At pH 7 the water is neutral and the acid and alkali counter balance each other—$H^+ + OH^- = H_2O$. Distilled water is neutral.

R Class- This refers to adhesives and grouts composed of reaction polymers as defined in ISO13007. The typical R class materials are based on epoxy resin.

Soft water-Contains low levels of Calcium or Magnesium salts. Sodium Carbonate was traditionally used to soften hard water for washing purposes—hence the name 'washing soda'. Soft water is required for soaps to work correctly. In a concrete pool situation, where the water is too soft, it will scavenge Calcium from the cementitious components in the pool (i.e. concrete shell, grouts and tile adhesives) which over time damages the cement base in these items.

Sulphate– Spelled as Sulfate in American usages. This is an anion based around the parent compound Sulphuric Acid. Common Sulphates are Sodium Sulphate and Sodium Bisulphate which can be used acidifiers, or Aluminium Sulphate ('Alum' used for clarifying the water). Sulphate in pool water can attack the cement components in a pool, damaging them by forming Calcium and Magnesium Sulphate (gypsum and 'Epsom Salts') and also corroding metal fixtures.

REASON FOR REVISION - ISSUER
Revision of documents and to bring it into line with Dunlop DTB143.001

DOCUMENT REVIEW REQUIRED
Addition of extra commentary with regards to Magnesium and Boron compounds.

Technical Services 1800 224 070. email: technicalservices@ARDEXaustralia.com
Australia http://www.ARDEXaustralia.com

NSW-HO 61 2 9851 9100, **QLD** 07 3817 6000, **VIC** 03 8339 3100, **SA/NT** 08 8406 2500, **WA** 08 9256 8600
Customer Service and Sales 1300 788 780

New Zealand Christ Church 64 3373 6900, Auckland 9636 0005, Wellington 4568 5949
Technical Inquiries NZ 0800 2 ARDEX New Zealand http://www.ARDEX.co.nz

Web: Corporate: http://www.ARDEX.com