TECHNICAL BULLETIN – TB143

POOL WATER CHEMISTRY

AUGUST 2024

INTRODUCTION & SCOPE

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

However, recently, we have observed some unusual problems with cement-based grout in pools containing Magnesium Chloride (instead of ordinary salt—Sodium Chloride). We also note that water treated with 'mineral salts' contains 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 a measure of the Calcium and Magnesium dissolved in the water.

Pool water is 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 the tiles to debond.

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

It 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.

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. 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 depend 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 mechanical anchors, and the bonding formed is very strong. Chemical alteration by the sulphates 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 at high values above 7. The value 7 is set at the reading of pure water, considered 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 pool water pH is important because 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 add Sodium Carbonate or Bi-Carbonate, and to lower the pH, add Sodium Bisulphate or Hydrochloric Acid. Repeated additions of the Bisulphate will lead to a chemical attack on the cement-based adhesives and grouts previously noted above. However, as previously noted, the pH readings do not indicate low calcium levels in the pool water.

MAGNESIUM AND OTHER ELEMENTS

ARDEX has noted that recently, some pools have been treated with minerals other than common salt (e.g., sea salt) as the source of Chloride for the effective action of the electrolytic converters to generate free Chlorine. To our knowledge, these treatments won't affect polymer shell pools, but the "jury is out" on their effect 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. Magnesium substitutes for Calcium in minerals, which form the hardened cement paste matrix, and this change results in the weakening of the material. It is a recognised situation that Magnesium salts can damage cementitious 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 also note that pool water can be treated with 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 its use 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) suggests 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 element is the water purification medium that keeps the pool free of algae and other harmful organisms like bacteria. High levels of free Chlorine, apart from being an irritant to swimmers, can also change 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 be different shades or appear 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

The total alkalinity range recommended is 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 (saltwater pools) ~4000-6000ppm

While these values may differ slightly from what many operators would regard as normal, we emphasise that they 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 information regarding the effects of the chemical compounds noted in this technical bulletin. However, those standards also apply to other 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 Chlorine levels can negatively impact cement-based materials. Brominated materials, such as those used in spas, are aggressive and attack grouts and adhesives.

ADHESIVES AND GROUTS

This bulletin references only the types of adhesives and grouts 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 cement, 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 water flow through the cement-based adhesives and grouts, 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

R-Class

ARDEX WA EPOXY
ARDEX WA100 EPOXY

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 use the chemical resistance of epoxy R Class grouts.

Therefore, in pools using Magnesium compounds with a more chemically aggressive environment, we recommend replacing cementitious C-class materials 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 fallout.

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 provide excellent detail of all the chemicals used in pools, these details do not adequately emphasise the importance of Calcium or Sulphate concentrations in tiled pools. This is understandable, given that these guidelines are meant for all pool lining materials, such as vinyl, fibreglass, and 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 to withstand the effects of the pool water and the chemicals used that come into contact with the tile finish. Balim (2012) and Felixberger (2008) provide a more detailed discussion on calcium hardness.

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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 shorthand 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, chlorine is present as free Chlorine but is added as a Hypochlorite compound or cyano-chlorine compound or generated by the 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, such as carbonates, are relatively insoluble, 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 of 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 a more complex measurement. At pH 7, the water is neutral, and the acid and alkali counterbalance each other—H+ + OH- = H2O. 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 damages the cement base in these items over time.

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 as acidifiers, and aluminium sulphate ('Alum' used to clarify 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 corroding metal fixtures.

IMPORTANT

This Technical Bulletin provides guideline information only and is not intended to be interpreted as a general specification for the application/installation of the products described. Since each project potentially differs in exposure/condition, specific recommendations may vary from the information contained herein. For recommendations for specific applications/installations, contact your nearest Ardex Australia Office.

DISCLAIMER

The information presented in this Technical Bulletin is to the best of our knowledge true and accurate. No warranty is implied or given as to its completeness or accuracy in describing the performance or suitability of a product for a particular application. Users are asked to check that the literature in their possession is the latest issue.

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