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IS CHEMISTRY REALLY THE QUERKIEST PART OF STORMWATER QUALITY MANAGEMENT (OR IS IT THE HUMANS) ?

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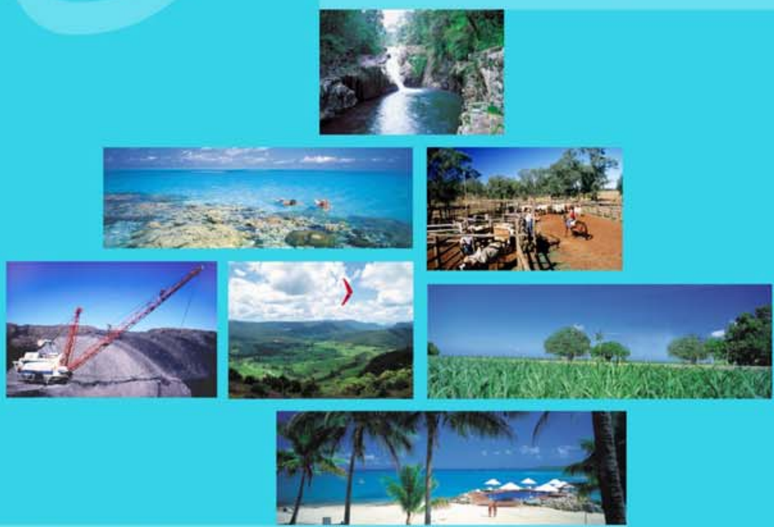

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IS CHEMISTRY REALLY THE QUERKIEST PART OF STORMWATER QUALITY MANAGEMENT (OR IS IT THE HUMANS) ?

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Abstract

All infrastructure operators have a responsibility to manage the quality of stormwater because of due diligence, corporate governance and/or direct statutory obligations. This paper quickly revisits the basic drivers for stormwater quality management but, primarily, it describes two recent projects that examine assessment or approval for the achievement of water quality objectives.

The first example pertains to management and assessment at an airport site in North Queensland, regulated under Commonwealth *Airports Act.* Although ANZECC (2000) water quality guidelines are referenced for water quality assessment, natural reasons may preclude their achievement. The natural effects of the environment must also be recognised when assessing compliance.

The second example describes the State and Commonwealth requirements at an industrial site now under development at Gladstone. At this site, default ANZECC style limits are applied to the likely stormwater emissions meaning that, all in all, releases will likely be much 'cleaner' than in the receiving creek.

The upshot is that, irrespective of whether a statutory process allows, requires or demands an outcome to be at a certain level, only those things physically practicable can actually be achieved.

Key Words: stormwater quality; water quality objectives; environmental compliance assessment

Introduction

Infrastructure planners and operators have a direct obligation and responsibility to manage the quality of stormwater by various mechanisms. These are affected by due diligence and corporate governance expressed as legal or political risk by Boards and Councils, or statutory obligations with the onus for conformance on managers and employees of corporations and organisations.

In Queensland, conditions of approval that relate to stormwater management have long appeared as requirements of town planning or development approvals and, for ERA's, in environmental authorities for local government and EPA. Although the intention of such conditions is to attain best practice, the outcome rarely achieves this without further refinement of the treatment train or amendment of the approval to reflect practical limitations.

For diffuse catchment runoff, all Queensland local governments have been compelled to prepare urban stormwater management plans in response to the EPA's *Environment Protection (Water) Policy.* This has Council's direct their interest on higher density activities that may contribute sediments, persistent chemicals and nutrients to receiving waters. The urban effect on the Great Barrier Reef is an effect and a strong perception in Queensland where many of our larger urban centres are on the coastal fringe. Integration with ICM has also to be realised to proportion contributions of loadings from contaminants of concern.

Stormwater quality management is as much an art as a science because it has to be set in the context of people's acceptance of the management / treatment standard. While we have education and environmental awareness campaigns and other tools for managing our catchments, we really lack knowledge of just how important sporadic 'pulse' runoff events are to the long term water quality of our receiving water systems. We know that banks can erode and contaminants are deposited into these waterways, but managing stormwater quality may be cost-ineffective. Also, long before any European catchment development, stormwater quality, particularly in monsoonal and sub-tropical coastal Queensland, would simply not have met with the ambient freshwater quality stated in ANZECC (2000). Some of the stated concentrations are shown in Table 1.

Table 1: Levels of water quality parameters for some constituents in Queensland's freshwater (source: ANZECC 2000).

Parameter	Level
Total Nitrogen	0.2-0.3 mg/L
Total Phosphorus	0.01 mg/L
Nitrates	0.01 mg/L
Turbidity	2-15 NTU

It is proposed that we should rely on our learning from formal statutory environmental approvals so that we apply these to more dynamic stormwater programs such as urban stormwater management (USQMPs) or catchment management initiatives. To do this, we have summarised the findings of 2 recent projects conducted by Maunsell Australia.

What influences acceptable stormwater quality ?

The interests and beliefs of people influence the limits that define acceptable stormwater quality. This paper contrasts two recent, parallel Commonwealth processes that aim to manage stormwater quality outcomes at two Queensland sites. The approaches of the various agencies are actually not disparate, although they appear to be. Both processes have been interpreted against a very flexible set of operating rules.

But importantly, background physical and chemical conditions of the natural environment also dictate just how clean stormwater (and groundwater) can be.

Case Study 1: Townsville Airport

For airports regulated under the Commonwealth's *Airports Act*, a Local Standard may be instituted as the statutory foundation for future judgement of compliance in terms of water quality. If adopted it also will be the first of its kind in Australia.

Townsville Airport – Sampling Regime

Stormwater samples are collected by rising stage samplers. Over the course of many years monitoring has been conducted for:

- Metals (inc Cu, Zn, Ni, Cr, Pb, Cd, As, Hg)
- Total petroleum hydrocarbons, BTEX
- Volatile halogenated compounds
- PAH, PCBs, total phenols, pesticides
- Nutrients and suspended solids
- Oil spill dispersants
- Some other compounds and elements listed in Schedule 2 *Airports (Environmental Protection) Regulation*.

'First flush' samples are captured in order to obtain data typically at its highest. After years of monitoring, agreement has been reached with the regulator, the Commonwealth Department of Transport and Regional Services, to monitor only a subset of parameters but in particular metals and hydrocarbons that may be indicative of pollution events in its leased part of the catchment.

Townsville Airport – Past Approach

In relation to water quality, Schedule 2 of the *Airports (Environmental Protection) Regulation* (AEPR) sets concentration levels for a broad range of analytes. Where the Regulation does not specify the levels, it directs us to the "AWQ guidelines".

The AWQ guidelines ascribe single-number guidelines and have been further developed into the Australian and New Zealand Guidelines for Fresh and Marine Water Quality ("WQG") by ANZECC / ARMCANZ. The essential difference between the AWQ guidelines and WQG is that the former ascribes single figure limits for toxicant levels, whereas the WQG provides for ambient measures by listing several levels according to disturbance level of an area and assigning limits as "trigger values", in that if exceeded they should trigger a management response, such as investigation of potential causes and sources, and into development of site-based values. On airports, this is acknowledged formally in the preparation and endorsement of 'local standards' for an airport. The airport environmental protection regulation recognises a local framework which *enables flexibility in the administration of (water quality) standards under these Regulations where, because of climate, topographic and similar considerations,… or to the region in which an airport is located, inflexibility would be unreasonable." Regulation 5.01.*

Townsville Airport – Results

Years of monitoring has revealed that some metals exceed the prescribed water quality levels. These are summarised in Table 2.

Table 2: Summary of constituents and rates of non-compliance.

	Schedule 2 AEPR (µg/L)	ANZECC (2000) 95-99% sp protection (µg/L)	% set of data exceeding Schedule 2 AEPR
Copper	2	1.4	100
Lead	1	3.4	93
Zinc	5	8	100
Cadmium	0.2	0.2	≈70

In the absence of pollution events, repeatable exceedance of Schedule 2 levels is vexing for both site managers and environmental regulators. An example of the time series of zinc concentrations is shown in Appendix A.

Townsville Airport – Important Natural Effects for Elevated Stormwater

Natural Effects

Surface and shallow groundwaters in tropical situations may experience enrichment in some metals and elements from a variety of sources not found in more temperate locations. These sources may include colloidal materials and adsorbed metals and enrichments due to hypersalinity in salt-flat environments (including contributions from possible acid sulphates).

Climate

Temperature in Queensland is relatively high all year round and in the monsoonal (seasonally arid) tropics, rainfall is usually restricted to 3 to 4 months of the year. During this time 80-90% of the annual rain may fall. In the wet season, it is often restricted to short intense bursts and falls in excess of 100 mm in a 24-hour period relatively common.

Annual evaporation may exceed precipitation by factors of 2 to 10 times (Townsville is approximately 3 times).

In the dry season, soil moisture may increase in the concentration of its dissolved constituents towards and at the surface. Thus, runoff that drains from this surface may be quite elevated in the dissolvable constituents (ie. first flush effect).

Surface (and seasonal groundwater) waters vary upon a seasonal and tidal basis ranging from fresh during seasonal inundation, marine saline during high ("king") tides and possible hypersaline at surface and subsurface with either marine or non-marine characteristics during periods of aridity and low tides.

Weathering
Year-round high temperatures, the intense seasonal rainfall flushes and the increasing upwards concentration of soil fluids during the dry season all lead to relatively rapid breakdown of mineral materials. Additionally, regular wetting and drying of surfaces and soil profiles via rainfall and humidity may lead to surface (soil) material having a disaggregated particle size much smaller than that found under more temperate regimes.

Increases in salinity are usually associated with increases in chloride content (+/- sulphate +/- carbonate) both of which may be kept to much lower levels due to mineral reactions and precipitation). A consequence of this high salinity and high chloride is to enhance the solubilities of many minerals. Thus, natural waters in some salt-flat situations may have naturally elevated concentrations of a range of heavy metals including Cu, Zn and Pb.

Colloids
The weathering process tends to form mixed layer clays (illite-smectite, smectite-kaolinite) and a range of poorly ordered oxyhydroxides of iron, aluminium, manganese and silicon. Most of these are of colloidal size (much less than 0.1μm), and have high surface charges and surface area to volume ratios. They thus have the ability to adsorb relatively high concentrations of metal and other ions on to their surfaces.

Since most of them will pass through at 0.45μm filter (standard) and then be analysed in the "dissolved" phase, this may lead to many tropical waters generating high levels for some analyte that are in excess of WQG guidelines. However, the majority (80%) of this metals loading is not truly in solution but probably adsorbed onto colloids. As such it is not usually as bioavailable as ions wholly in solution.

However, these overall levels are such that apparent non-compliance within WQG guidelines may occur.

Interactions with Groundwater
Local coastal plain sediments consist of inter-digitation riverine sand, beach sand, salt flat, mangrove and bay-mud sediments, a product of sea-level changes over the last 100,000 years. This has led to the development of a complex series of aquifers, usually interconnected in three dimensions. These sediments contain the weathering products of the parent rocks and anoxic muds both of which may have high levels of absorbed chemical species which will absorb, for example, during fresh water flushing. Introduction of oxygenated fresh water may lead to the oxidation of bacterial sulphides ("acid sulphates") with consequent increase in acidity and enhancement of metals levels.

Analytical and Chemical Effects

Filtration
Standard filtration is to 0.45 or 0.39μm through commercial filters may not remove the fraction of very small colloids present in tropical, Queensland coastal catchments. That is, under temperate conditions approximately 75% or more of suspended material is filtered out (with probably as little as 10% below 0.22μm). However, the reverse trend may be true under normal tropical conditions as little as 10% of the suspended material may be filtered out.

Thus, 0.45μm filtration of test samples may lead to an over-estimation of analytes that are truly in the dissolved phase.

Hardness Correction
The water 'hardness' (equivalent calcium carbonate content) is caused by the presence of mineral ions (such as calcium,

magnesium, iron). Hardness effects the availability of metal contaminants so must be considered when determining the ecotoxicity of contaminants in waters, even when concentration levels are very high. Generally, as hardness of water increases then potential toxicity effects from metal contaminants decrease.

Urban and Up-Catchment Effects

The leased area of Townsville Airport operates in the downstream part of an urbanised and developed catchment. In some areas, commercial activities exist and throughout the catchment area, there are roads and drainage that service municipal and military needs.

In terms of whole of catchment management, these off-site sources can confound identification of significant risks from the airport.

Townsville Airport – Future Stormwater Quality Management

The approach both permitted and encouraged by the regulators and taken by the operator is to seek to have a Local Standard adopted for the Townsville Airport. This requires submission to and approval by the Minister for Transport.

Such a Local Standard would, for those parameters both not being met and justifiably amendable for scientific reasons, be comprised of more appropriate levels. In some cases, this may mean pushing existing limits up by a minimum of 2- to 20-times on the current Schedule 2 levels ("low effect level") and . Such "new" levels can be interpreted based on the above factors. What appropriate, unambiguous levels can do is:

- Low to middle range data will be excluded. These data are currently viewed as putative, and uncertain, apparently non-complaint data, but in reality, probably resultant from natural or catchment processes;
- Such low to middle range data will no longer be identified as potentially contaminated, but put into a regional context;
- Medium range data beyond the accepted low effect level will be subject to further consideration, but not judged to be non-compliant;
- High range data greater than the 'high effect' level will, upon commencement of the Local Standard, be clearly identified as non-compliant and subject to further investigation and management action.

Case Study 2: Aldoga Aluminium Smelter

Aldoga Aluminium is a multi-billion dollar venture which has a number of comprehensive and inter-related planning and environmental approvals. Limits on the quality of stormwater quality emissions arise from State of Queensland and Commonwealth conditions which require the quality in Table 3 to be provided.

Table 3: Summary of some constituents conditioned into operating approvals.

Quality Characteristic	Permitted Limits
Turbidity	10 NTU
Total suspended solids	5 mg/L
Total nitrogen	0.5 mg/L
Aluminium	0.055 mg/L

The above limits essentially equate to the ANZECC (2000) WQG. A comparison of these levels to the reported water quality of freshwater sections of nearby Larcom Creek (Connell Wagner, 2002) indicates that nitrogen, phosphorus and suspended sediments have exceeded these levels especially during river runs.

Another notable feature of the approval for the project was the original requirement to manage all and treat all stormwater, up to and including the Q100 event. It has only been subsequently by mutual agreement that the practicalities of not doing this have been considered by the environmental regulators, and an agreement made to focus attention on first-flush parts of frequent runoff events.

Given the impost of the water quality limits, the primary proposed design response is to manage first flush stormwater to be retained within the wetland. Travel time will typically be very long (>50 days) and purpose designed cells will target the sedimentation and water column filtering to target particulate and dissolved contaminants. Operating strategies for the wetland are essential in order to retain water for its own environmental health (ie. wetland plant sustainability) and release water at times when the water quality objectives are met or when they exceed the quality in the adjacent intermittent receiving water. The stringency of the water quality objectives - which has dictated the design response and which do not actually reflect the ambient nature of regional freshwaters – means that significant commitment of planning and capital resources has been required.

So….Humans or Chemistry ?

Chemistry presents a series of factors that heavily influence the content of constituents in stormwater (and groundwater). Such effects dictate, along with past influences and present diffuse catchment activities, just how clean a site's stormwater might actually be. Humans, however, have an extra ability to influence themselves and others to ignore or over-simplify these technical issues in order to deliver other results (including political or financial benefits). This can lead to misconceptions that can stymie the uptake of environmental best practice, as:

- it is not rewarding for the proponent because of the risk,
- the technical limitations of the day may mean that outcomes cannot be delivered;
- the quantum improvement can often be too great.

The Townsville Airport example shows a process that appears to "lower the technical bar" but, in a way that, for sound reasons, enhances delivery of catchment and site based management. The Aldoga Aluminium example shows the more traditional regulatory approach of "raising the technical bar" with very strict operating conditions. For the latter, the risk of non-compliance is a disincentive for poor performance. In an emerging technological arena of sub-tropical stormwater management, it is suggested that incentives for progressive environmental performance might be better placed, but this would require very high level and far sighted commitments from all parties.

Man-made pollutants such as litter, oils and grease and possibly sediments are characteristics that should be primary targets for stormwater quality management and, to date, there has been success in this area for purpose-built or proprietary SQIDs. However, for naturally occurring parameters, such as metals (elements), nutrients, organic material and sediments, purposeful consideration should be given to determining the non-anthropogenic influence on baseline storm and receiving water quality. We can apportion society's fixed "bucket of money" to manage the environmental risk arising from our stormwater only once the portion due to nature's activity is understood.

Conclusions

In efforts to better manage stormwater there are contemporary Queensland examples of the bar being both lowered and raised to promote environmental outcomes.

Natural catchment effects and baseline conditions must be considered because:

- Other than apparent best practice, it may not be ecologically meaningful to achieve very low prescribed levels;
- It may be acceptable to achieve lesser standards, if it actually helps to

clarify and commit to improved management actions.

Decision-makers and industry must be challenged, not only with getting the best socio-political outcomes, but also to be confident that the adopted stormwater management contains appropriate scientific and technical bases.

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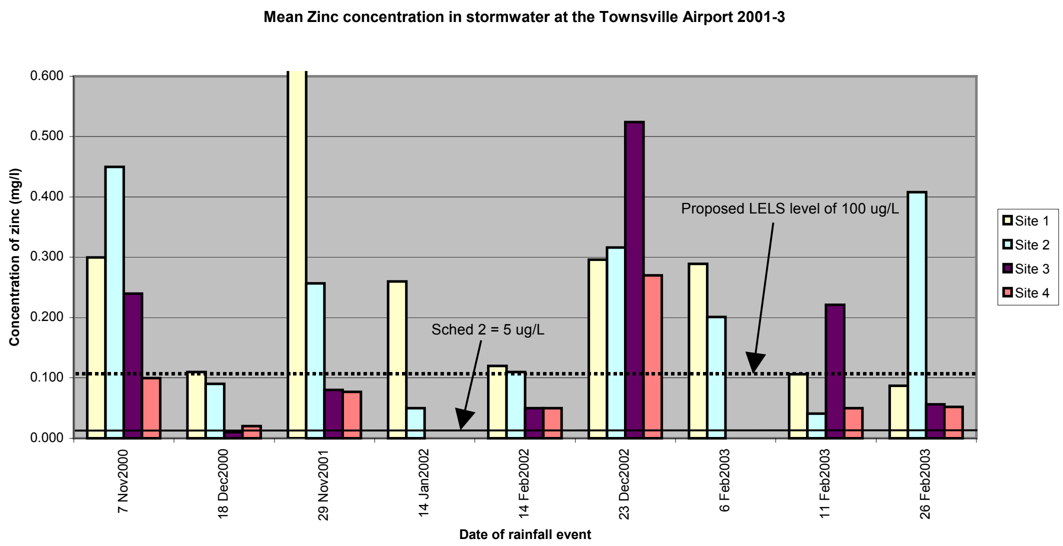
Appendix A



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