Managing Increasing Brine Concentrate Discharges in Drought Conditions

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Abstract

As a result of the drought in South East Queensland (SEQ) there has been a significant increase in approvals relating to the installation of alternative water supply initiatives, such as desalination plants and advanced water recycling plants, which rely on reverse osmosis membrane technology. Such membrane-based treatment typically produces a waste stream that is many times more concentrated than the source water. These waste streams are typically referred to as the “Brine” or “Reverse Osmosis Concentrate” (ROC) and can have high concentrations of dissolved salts and toxicants. The salinity of the waste streams presents a challenge as it can impede complete mixing of the ROC with receiving waters and potentially result a hypersaline layer that may adversely affect benthic communities. For some ROC waste streams, a major issue is the potential toxic environmental effects from metals, ammonia, disinfectants, biocides, antiscalants and detergents. The majority of issues related to brine release appear to be in the near-field, although the combined effect of multiple brine releases on the salinity and water quality in rivers and enclosed estuaries could also be significant. In SEQ, the Queensland Environmental Protection Agency (EPA) has been required to approve a number of significant water supply initiatives including the Western Corridor Recycled Water Project (WCRWP) and the Gold Coast Desalination Project (GCDP), and many other regulated and non-regulated activities are commencing or planned. This paper will discuss some of the environmental issues related to activities that involve brine discharges and the approach that the EPA is using to assess and approve such activities. This will include recent examples from approvals in SEQ.

Introduction

The term “brine” hereafter will be used to broadly refer to three types of hypersaline waste streams produced in the treatment or use of waters, namely *Reverse Osmosis Concentrate* (ROC), referring to the reject component of water treatment utilising reverse osmosis membranes. Examples of recent water conservation and recycling initiates in South East Queensland (SEQ) that involve the production of brine waste streams discharged to urban waterways include the Gold Coast Desalination Project (GCDP), the Western Corridor Recycled Water Project (WCRWP).

Gold Coast Desalination Plant

The GCDP involves treating seawater resulting in reserve osmosis (RO) standard water. The RO water is then treated to reduce its oxidative properties within the reticulated water supply network through the addition of lime and carbon dioxide. The conditioned water is then supplied directly to the water supply network (GCDP, 2008).

Once commissioned, (November 2008) the GCDP plant will commence to discharge over 100 ML of concentrated seawater per day back to the sea approximately 1.8 km off the coast of

Tugun. The brine will be composed of 1.8-1.9 times the salinity of the intake seawater, potentially contain concentrated levels of some background minerals typically found in seawater, combined with process additives, and will possess a reduced concentration of dissolved oxygen (1.5-2.0 mg/L) and be elevated in temperature (1-2ºC). The treatment process additives will include shock or continual chlorine dosing of the intake pipeline to control biofouling, one of two potential antiscalants (either Hypersperse MDC220 or PermaTreat PC-1020T, dependant on the results of commissioning trials), ferric sulphate (as pre-filtration coagulant), and an inorganic nitrogen-based polymer (filtering aid) (GCDP, 2008).

Western Corridor Recycled Water Project

The WCRWP involves treating wastewater resulting in Purified Recycled Water (PRW). The PRW is supplied to power stations, industry and agricultural customers and to Brisbane's primary water storage, Wivenhoe Dam, through a network of pipes and supporting infrastructure. This involves more than 200 km of large diameter pipeline, three advanced water treatment plants (AWTPs), eight storage tanks and nine pumping stations (WCRWP, 2008).

The WCRWP AWTPs are situated at Luggage Point, Gibson Island and Bundamba discharging ROC into the Brisbane River at 1.5 km, 9.7 km and 67 km AMTD, respectively. The discharges are currently taking place. The brine will be composed of low salinity relative to the estuarine seawater containing concentrated metals and organics that manage to pass through the contributing sewerage treatment plant treatment processes together with process additives, reduced concentration of dissolved oxygen (1.5-2.0 mg/L) and be elevated in temperature (1-2ºC). The treatment process additives will include continual chloramine dosing prior to the RO membranes to control biofouling, one of two potential antiscalants (either Hypersperse MDC220 or PermaTreat PC-1020T) and ammonia (WCRWP, 2008).

Both the Swanbank Power Station (SPS) and the Tarong Power Stations (TPS) are currently receiving PRW delivered to Swanbank Lake and TPS dam, respectively, which act as water storages for process water, including cooling tower blowdown end-use water. Drought condition induced Government requirements on industry to reduce demand on potable water and PRW supplies has resulted in cooling tower blowdown water being recycled through the system more times than usual, creating a hypersaline wastewater (HSW) that is discharged to the environment. Considering that the receiving water courses are ephemeral freshwater ecosystems, the Queensland EPA has working with the licence holders to monitor and manage the potential impact of these HSW discharges in already stressed ecosystems and the environmental values downstream.

Assessment Process Summary

Gold Coast Desalination Plant

While concerns regarding the impact of treatment process additives might have on marine organisms were addressed through parallel assessments, the primary environmental concern related to the elevated concentration of salts (salinity) (i.e. the brine stream) impacting upon benthic organisms in the vicinity of the discharge point.

The ensuing discussions between the Queensland EPA and the GCDA led to the initial designs of a 4-port, single turret style marine diffuser being modified into a 185 m long, 14-port diffuser. A further extension to the modified diffuser design (397 m long, 20-port diffuser) was driven by a later State Government requirement to facilitate increased clear water production (should it be necessary) from a 125 ML/day to 170 ML/day with minimal disruption caused by the need for additional infrastructure.

In order to assess the potential salinity-related environmental impacts of the brine, the Queensland EPA reviewed the material presented in the Environmental Impact Statement (EIS) relating to the salinity tolerance thresholds of marine organisms, and the Roberts Model discharge dynamics calculations, and also requested that an expert third party reviewer be commissioned by the Gold Coast Desalination Alliance (GCDA).

The resulting investigations indicated that under worst case mixing conditions, defined by the situation where the brine is at the highest salinity concentration (100% plant duty) and lowest observed receiving water oceanic currents, predicted a 40-fold dilution at the edge of the near-field mixing zone (bounded at 60 m from any point of the diffuser – total area 120 m x 404 m) and a 25-fold dilution at the point where the brine plume impacts with the sediment (16 m from the diffuser). These dilution figures and supporting evidence from the Perth Desalination Plant indicate that minimal adverse environmental impact is expected due to elevated salinity concentration in the area of highest risk (i.e. within the near-field mixing zone).

These model-predicted dilution values will be validated in the field once the brine discharge commences through a Diffuser Performance Monitoring Plan (DPMP). An additional concern related to the possible development of a *persistent diluted brine field*, an area where higher salinity water extends down the natural grade of the benthos from the diffuser. As part of the DPMP, the existence of the persistent diluted brine field will also be investigated through a series of electrical conductivity readings taken close to the sediment at 100 m intervals up to 500 m distant from the diffuser.

Routine biological monitoring of the potential impacts upon the benthic macroinvertebrate community began approximately 2 years ago with “before impact” sampling taking place at 4 reference sites, situated north, south, east and west of the diffuser (impact site), and at the impact site itself. Each of the 4 reference sites and the impact site comprise of 4 sampling locations, and the data collected at each sampling location consists of 5 Van Veen Grab samples. The “before impact” monitoring is aimed at identifying both intra-site and seasonal variation in benthic macroinvertebrate community assemblages and hence the ensuing “after impact” monitoring regime will be capable of identifying potential macroinvertebrate community impacts.

Western Corridor Recycled Water Project

Due to the WCRWP AWTPs RO treatment process sourcing low salinity STP effluent and the receiving environment being estuarine in nature, the resultant ROC was not hypersaline and therefore salinity not identified as the predominant environmental concern. Rather, the environmental concerns were focussed around the presence of toxicants in the form of chloramines and ammonia being injected into the influent for the purpose of protecting the RO membranes. Furthermore, the RO treatment process concentrates metals and metalloids to potentially environmentally harmful concentrations. Therefore, the focus of the Queensland EPA assessment revolved around ensuring that the dilution dynamics in the near-field mixing zone was capable of controlling the extent of potential toxicity zone to an acceptable distance. The toxicant concentrations initially presented to the Queensland EPA in the EIS were later revised when data from pilot RO plant results became available. Comparison of the toxicant concentrations with ANZECC/ARMCANZ (2000) toxicant trigger values (TTVs) indicated that a standard STP outfall would be insufficient to maintain chronic toxicity zone within an acceptable distance.

Similar to the GCDP scenario a diffuser was identified as being necessary at each of the three AWTP discharge locations, however in the WCRWP cases, not to facilitate the dilution of hypersaline brine discharges, but to maintain brine-associated toxicant concentrations below the TTVs within 5 m of the discharge point under worst case mixing conditions. Additionally, similar monitoring programs for water quality and biological communities have been established.

To further quantify the potential risk to the aquatic ecosystems of the Brisbane River estuary, the Queensland EPA recommended that the WCRWP undertake voluntary direct toxicity assessments (DTAs) using pilot-plant ROC from each of the associated AWTPs and utilise locally-relevant estuarine/marine toxicity test species. The DTAs involved exposing the test species to the undiluted ROC and to a series of dilutions of the ROC (all corrected for salinity), thereby providing further environmentally relevant ecotoxicological data to feed into the minimum design requirements of the diffusers. Whilst the DTA results verified that chronic toxicological effects were being observed in the neat and some of the diluted pilot-plant ROC effluents, they also indicated at which dilutions these adverse effects were no longer observed. The diffuser designers were then charged with achieving the required number of dilutions to negate observable chronic toxicological effects beyond the authorised 5 m chronic toxicity zone. The next stage of the assessment will involve an intensive series of four quarterly confirmation DTAs of the actual ROC produced from the commissioned AWTPs to verify the earlier attained toxicological data. The confirmation DTAs will commence once the post-commissioning AWTP treatment processes have stabilised so that the results will be representative of the long-term ROC discharge.

Discussion

Increasing Application of Reverse Osmosis Technology and associated Brine Discharges

Whilst the Queensland EPA has endeavours to mitigate adverse toxicological impacts in aquatic ecosystems in the near-field, there are some concerns over the potential long-term effects of these low concentration (diluted) brine discharges in the far-field. Whilst some of these brine discharges may be remote or isolated, such as in the case with the GCDP, others, such as those associated with the WCRWP, are situated upon partially enclosed urban waterways that are not continually flushed with previously unexposed receiving waters. Furthermore, as the impacts of the drought continue to force wider water saving measures upon industry, more and more companies are resorting to RO technology to produce water of sufficient quality to be compatible with their processes, and as a consequence, more and more brine discharges are appearing in these comparatively confined aquatic ecosystems.

Within the last 2 years, four other large companies situated between Brisbane and the Port of Brisbane have informed the Queensland EPA of their intent to commence drawing river water for RO treatment and discharge the brine produced back into the river. Others may be doing so unknown to the Queensland EPA because under current legislation, only water treatment installations with a 20ML/day capability or greater are identified as an Environmentally Relevant Activity (ERA) and need to be assessed through a formal process and regulated.

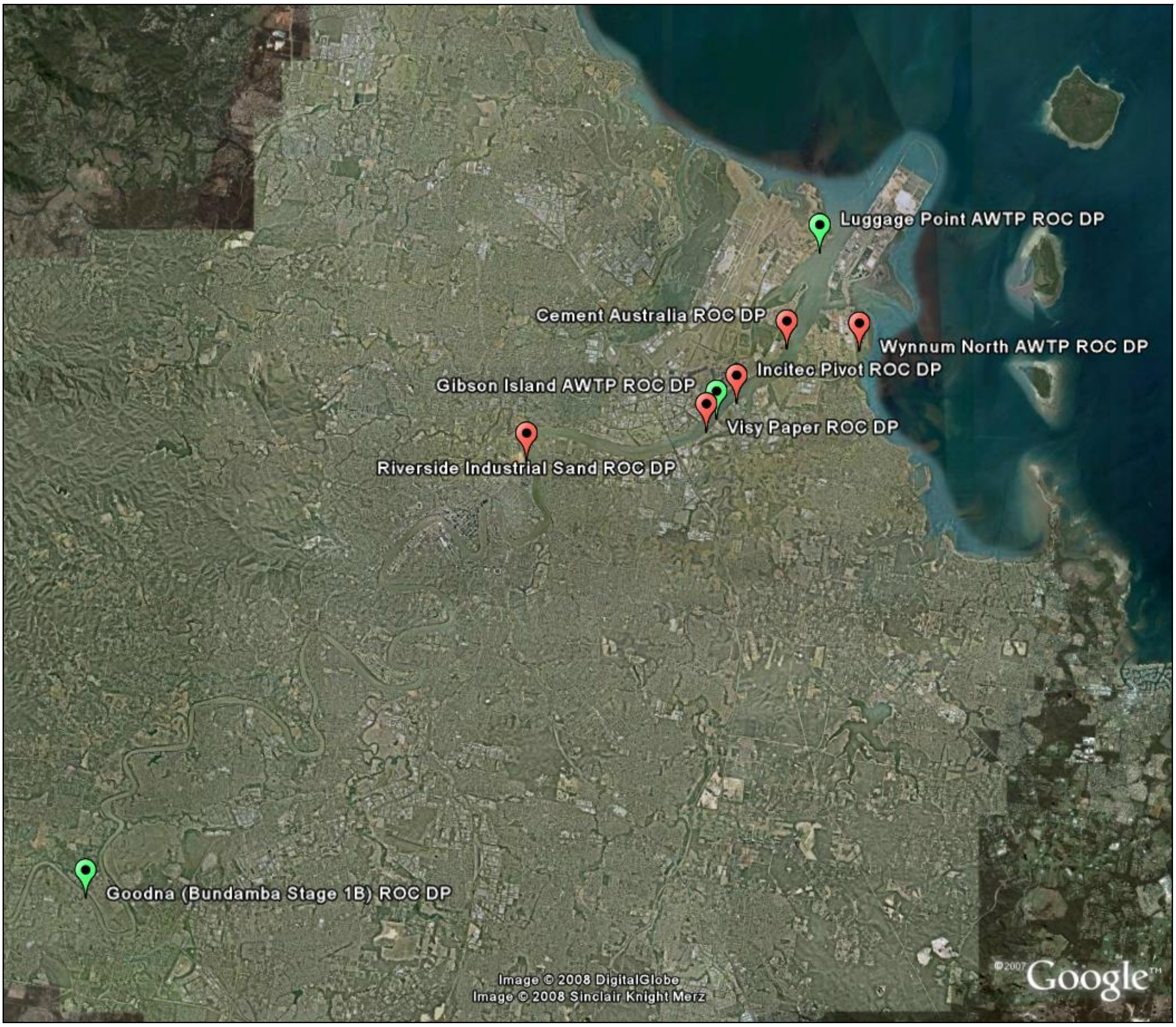

Figure 1: Lower Brisbane River brine discharge locations (AWTP ROC Discharge Points (DP) indicated with a green flag, medium-scale desalination plants indicated with a red flag)

Additionally, since the commencement of long-term water restrictions on domestic households has taken place, hundreds if not thousands of small-scale domestic desalination units have been sold in SEQ, particularly in the Gold Coast and Brisbane metropolitan areas. Whilst their respective individual discharge volumes are miniscule in comparison to industrial-sized installations, large numbers of these units nonetheless have the potential to cause localised increases in salinity and consequent environmental impacts, especially in poorly flushed zones within canal estates and upper estuaries.

For AWTP applications, there are potential benefits for the removal of nutrients that would otherwise be released to the environment from STP discharges. A significant amount of phosphorus can be removed through the process (over 50 percent) as a result of chemical phosphorus removal. However, without additional treatment, nitrogen removal is largely limited to the nitrogen that goes though to the product water (note that this may also ultimately be release into the upper catchment at some stage). Furthermore, significant amounts of ammonia are added to the process. Without additional treatment, there is a potential for the loads of dissolved inorganic nitrogen in the discharge to be increased compared to the original treated sewage wastewater. Additional biological treatment has been adopted for the Bundamba AWTP and additional treatment (including nitrification filters and wetlands) are being investigated for the Luggage Point Plant. The Queensland EPA will be working with the WCRWP to assess the impacts of any increase in dissolved inorganic nitrogen and to implement additional management or treatment options to reduce loads of nutrients in the future. This additional treatment is likely to set the benchmark for best practice for such systems over the next five years.

Potential Research Areas

Specific research questions for the management of ROC need to be developed as a priority. This paper has been prepared to assist with this process and generate discussion on priority areas for potential research. Potential research areas related to management of brine concentrate and protection of aquatic environments are proposed below.

1. Process design & ROC management

Modification to desalination plants or AWTP including additional treatment to reduce levels of contaminants in the ROC would be an effective way of minimising environmental risks to receiving waters. Some options could also involve beneficial recovery of saleable products. Specific priority areas of research could include:

- Additional treatment/process design options to manage toxicants in ROC release;
- Additional treatment/process design options for manage nutrients in ROC release;
- Beneficial recovery options for ROC components for commercial gain (e.g. fertilisers, rare minerals);
- Alternatives to surface water release including volume reduction towards zero discharge, and
- Development of best practice management guidelines/handbook for ROC management (for use by industry and regulatory authorities).

2. Characterisation of chemicals in ROC from Desalination Plants and Advanced Wastewater Treatment Plants (relevant to SEQ)

Given the recent emergence of large-scale RO membrane AWTPs in Australia there is limited data available describing the quantities and characteristics of chemicals in ROC discharges. Developing an understanding of these chemicals in the ROC is essential for their management. An understanding of chemicals in both the source and product water would also assist with understanding the influence of the RO process and the ways that these chemicals could be best managed. Priority research areas could include characterising:

- RO additives (biocides, antiscalants and detergents) used in the membrane process and quantities released in the ROC;
- Salinity and salt makeup in the source water and ROC;
- Nutrients (total and dissolved nitrogen and phosphorus components including ammonia) in source water, product water, and ROC, and

- Metals and pesticides in source water, product water and ROC.

3. Assessment of impacts of ROC release on aquatic environments in SEQ and implications for management

There are many knowledge gaps and challenges related to assessing potential impacts of ROC release to tidal waters. These include near and far-field effects and would require a combination of monitoring, modelling and laboratory investigations to address adequately. Priority research areas could include:

- Investigation of near field mixing and modelling of ROC in riverine/estuary and coastal environments, including optimisation of combined ROC/STP releases;
- Application of Direct Toxicity Assessment (DTA) of ROC using Australian biota;
- Understanding the fate and effects of RO additives in the receiving environment;
- Investigating the accumulation and effects of toxic metals and metalloids in sediments and bioaccumulation in fisheries species;
- Understanding the effects of stratification and brine release anoxia on aquatic environments, and
- Investigating the changes in surface water quality such as conductivity, metals, and ammonia (and net flow for riverine/estuaries?) from ROC release to tidal waters and the potential effects on environmental values.

Conclusions

The major environmental for brine discharge relate mainly to the near—field. For desalination this is near-field mixing issues related to hyper-saline plumes. For AWTP this involves toxicity from ammonia, chlorine and concentrate metals. Near field issues can typically be managed through adequate diffuser design (although site location is probably important). Far-field issues are not as well understood but are probably less of an issue than near-field ones.

There has been an increase in the number of brine discharges in SEQ and the EPA has been working with clients to assess and minimise the impact of these discharges. The operation of large scale examples in SEQ will be closely monitored over the next twelve months

There is a need for further research to better manage brine discharges. Key topics include alternatives to surface water release and additional treatment options for toxicants and nutrients in ROC.

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