Water treatment plant solid waste management and local government challenges

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ABSTRACT

The Tweed Shire Council, located in Northern Rivers NSW, owns and operates the Bray Park Water Treatment Plant, which produces drinking water through a coagulation–flocculation ultrafiltration membrane process. The membranes act as a physical barrier to solids and microorganisms, which, via thickening and mechanical dewatering, produces a solid waste material. The material consists of river contaminants—such as clay, silt, vegetation and pathogens—and process chemicals including aluminium chloralhydrate, hydrated lime, carbon dioxide and sometimes potassium permanganate and powdered activated carbon.

The waste has high aluminium (Al) and manganese (Mn) concentrations, contains pathogens and is unlikely to perform in engineering applications. Management of the material presents regulatory challenges and circular economy opportunities, and options explored to date by Council staff have proven costly, difficult and ultimately unsustainable.

Council staff recently prepared to apply for a NSW Resource Recovery Order and Exemption to reuse the material locally as uncontrolled, non-engineered fill. This offered environmental and economic benefits while improving regulatory certainty. Ultimately this avenue was discouraged. Limited regulatory guidance for similar materials continues to place councils in difficult positions. This paper outlines some of the local water utility's journey, identified challenges and opportunities, and insights that can be shared with industry that may invite other alternative solutions.

INTRODUCTION

Bray Park Water Treatment Plant (WTP) extracts raw water from the Tweed River. The drinking water catchment has volcanic origins and is highly disturbed comprising a mix of agricultural and urban land uses. To combat raw water quality challenges and produce safe drinking water, the treatment chain includes among other processes pre-filtration chemical dosing systems. Table 1 describes the pre-filtration chemicals and Figure 1 is a flow diagram describing the WTP processes.

The WTP uses over 99% of the raw water extracted[1]; most of the wastewater is recycled and returned to the head of the plant as clarified supernatant. This part of the process, complemented by chemical and mechanical dewatering systems, produces the solid waste material commonly known as sludge or cake. Approximately 10 tonnes of sludge is produced per week.

Economic, regulatory and environmental drivers have influenced a body of work by Council including testing and industry consultation aimed at improving management of the sludge.

[1] Only neutralized acid chemical cleaning wastewater from the membranes is diverted to the sewer system.

Table 1: Pre-filtration drinking water treatment chemicals used at Bray Park WTP

Sequence of dose	Chemical name	Use	Dose (mg/L)^	Dose frequency (%)^^
1	Potassium permanganate	Precipitate dissolved manganese in raw water	0-0-0.62	35
2	Powdered activated carbon (slurry)	Combat algal blooms and associated toxins, and organic matter	0-0-12	23
3	Calcium hydroxide (Hydrated lime; slurry)	Raise alkalinity following rainfall; also raises pH	0-14-40	98
4	Carbon dioxide	Used with lime to increase resistance to pH changes in distribution system	0-16-36	94
5	Aluminium chloralhydrate	Primary coagulant	8-16-57	100
6	Polymer 1 (anionic)	Sludge thickening	0.05-0.15-2	100
7	Polymer 2 (cationic)	Centrifuge dewatering	4.6*	100

^ Min.-Median-Max.

^^ Five-year period between 26/05/2021 and 26/05/2026

* Feed rate as kg/dry tonne of thickened sludge (median value provided)

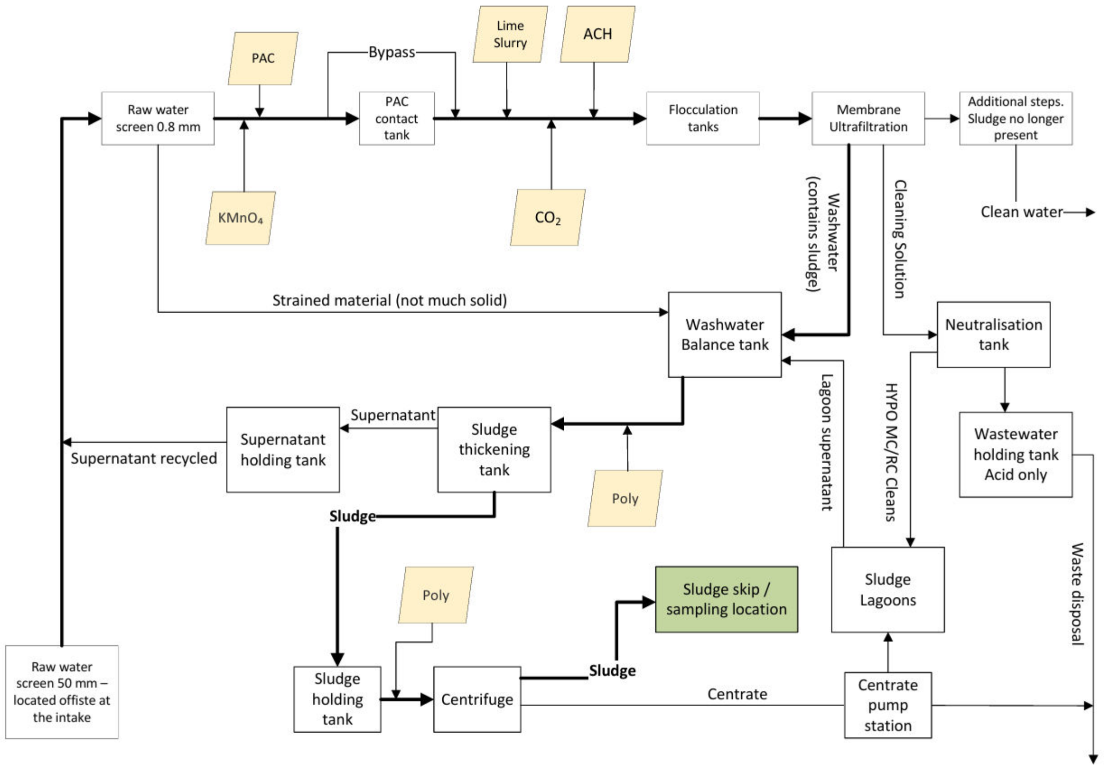

Figure 1: Bray Park Water Treatment Plant process flow diagram

<u>DISCUSSION</u>

Sludge investigations

The laboratory testing performed and summarised in Table 2 indicates the sludge material is pH neutral, has low electrical conductivity, holds around 75% moisture content (MC), has a significant organic carbon fraction with implications for physical characterisation, and high

Al and Mn concentrations that fluctuate. The heterogenous nature of the sludge reflects changing catchment water quality and associated pre-filtration chemical dosing (Table 1).

Table 2: Physical and chemical composition of sludge material

Parameter	Unit	(n)	Min.	Med.	Max.
pH	pH units	11	7.2	7.4	7.6
Electrical conductivity @ 25ºC	µS/cm	10	180	264.4	359
Moisture content	%	10	73.4	75.5	78.1
Sulfur – Total as S (LECO)	%	11	0.1	0.2	0.2
Aluminium	mg/kg	11	94,900	119,000	141,500
Antimony	mg/kg	11	<0.1	0.1	0.2
Arsenic	mg/kg	11	12.6	13.8	21.5
Beryllium	mg/kg	11	0.6	0.9	1.3
Cadmium	mg/kg	11	0.4	0.6	1.0
Chromium	mg/kg	11	16.3	27.9	34.7
Cobalt	mg/kg	11	15.9	18.0	28.7
Copper	mg/kg	11	25.4	30.2	39.2
Lead	mg/kg	11	5	7.8	10
Manganese	mg/kg	11	4,910	10,600	16,075
Molybdenum	mg/kg	11	0.3	0.6	0.8
Nickel	mg/kg	11	20.7	22.8	32.3
Selenium	mg/kg	11	1	1.5	6
Tin	mg/kg	11	<0.1	0.7	1.1
Vanadium	mg/kg	11	66	78	105.8
Zinc	mg/kg	11	44.1	62.5	81.5
Boron	mg/kg	11	<LOR of 5		
Mercury	mg/kg	11	<0.1	0.2	0.2
Total Organic Carbon	%	11	6.1	7.4	8.4

Limited further physical characterisation (n=2) was performed. Particle size distribution testing indicates the material is sandy to fine. The particle density is approximately 2.3t/m^3. The material has an Emerson Class Number of 8, exhibiting no slaking, dispersion, nor swelling; and describing the material as inorganic silts or organic clays. Atterberg limits varied significantly between the oven-dried and natural states. Dried results were favourable, likely due to hydrophobic characteristics at low MC. Drying to this extent at scale is likely not feasible. Atterberg limits for the wet material (n=1) were extraordinary with a natural MC of 283.5%, liquid limit of 425%, plastic limit of 89%, plastic index of 336% and linear shrinkage of 42%. If representative, these results are not favourable for use of the sludge material in an engineering context[2].

Microbial testing (n=1) was also performed with the results summarised in Table 3. The testing results whilst limited are unsurprising given the disturbed nature of the drinking water catchment; the sludge contained indicator pathogen species.

A small trial conducted on behalf of Council involved growing radish in varying sludge and soil compositions. The resulting seed germination, root elongation, plant growth and

[2] These testing results are further limited due to the presence of organic matter, flocculants and chemical dosing variability which would likely affect the accuracy of these test methods. Also, the information was summarised from a small sample size. These factors should be considered when interpreting these results.

development was measured. This investigation concluded that a 20% w/w mixture of sludge to compost or soil could be used to promote plant growth and development (Ipe, 2024). These findings were supported by soluble cation and other minerals testing of the sludge (n=1) performed by Council, which again limited, could suggest the sludge may complement soil health and structure, nutrient availability and plant growth, see Table 4.

Table 3: Sludge microbial testing results

Indicator species	Units^	Value
E.coli	MPN/g	160
Thermotolerant Coliform	MPN/g	160
Salmonella (VIDAS; 50g sample)	Presence/absence	Detected
Clostridium perfringens	Spores/g	250

^ Dry weight

MPN most probable number

Table 4: Soluble cations and other minerals testing of sludge

Mineral	Unit	Value
Calcium	mg/kg	12,172
Magnesium	mg/kg	2,758
Potassium	mg/kg	628
Sodium	mg/kg	193
Sulfur	mg/kg	2,028
Phosphorous	mg/kg	1,671

Waste reduction

Water Directorate guidelines (2012) suggest the material is a pasty solid to firm solid or perhaps soft to crumbly solid. In either case, further mechanical dewatering is deemed rarely practical to not possible, and evaporation seen as the most effective, probably only option to further reduce the MC (Water Directorate, 2012, p. 9). Council staff have trialled the transfer of the sludge stockpiles from the centrifuge building to a dewatered sludge lagoon over a 12-month period. This exercise has managed to reduce the MC of the sludge to around 26% from the middle of various aged stockpiles. Despite receiving 1280mm of rainfall during this period, this management option is proving effective for sludge mass reduction; the material probably proving its hydrophobic properties (Water Directorate, 2012). The Happy Valley WTP in Adelaide, owned and operated by SA Water, employs a sludge management facility that couples both centrifuge dewatering and sun drying to reduce moisture; development that in hindsight would have benefited Bray Park WTP.

Waste reuse, recycling and the circular economy

Historically the sludge was disposed of at the local waste management facility. The increasing cost associated with this method of disposal was the initial driver to investigate alternative management options.

Initial testing of the sludge and legislative interpretation culminated in Council becoming registered with the Queensland (QLD) Department of Environment and Science (DEC) as a resource producer for an end of waste code for water treatment residuals. This supported disposal at a facility licensed to accept the waste in QLD, with a more sustainable outcome realised by blending the sludge once dried with compost. Despite a lesser gate fee in QLD compared to NSW, this increased over time due in part to the handling required by the facility to dry the sludge prior to co-blending. Despite in-roads to reduce its volume, the economic and environmental cost of transporting the sludge to QLD from Bray Park, NSW remains.

Industry and supportive researchers are working to integrate WTP sludge into the circular economy through various re-use and recycling methods. Whilst Al toxicity is raised as a concern for use as sludge as a soil ameliorant, the aluminium oxides present have limited bioavailability and become more stable over time (Water Directorate, 2012). Furthermore, co-blending with biosolids has the potential to bind excess phosphorous allowing for greater reuse (Nguyen et al., 2022). Other potential reuses exist in the construction industry such as bricks, cement, concrete, ceramics and aggregates. Products of these investigations showed similar or improved performance when compared with the control products (GHD, 2015). Coagulant recovery through acidification is an option which reduces the mass/volume of the sludge while extracting a product that would offset coagulant costs (Nguyen et al., 2022). This process shows the potential to be economically viable; however, feasibility may be circumstantial (GHD, 2015). Another disadvantage of this method is the concentration of contaminants in the recovered coagulant (Nguyen et al., 2022). Dosing the product at an external plant (i.e. local Wastewater Treatment Plant) may circumvent the accumulation of contaminants in a closed loop.

Council staff initially pursued a NSW resource recovery order and exemption (RRO&E) for reuse of the sludge as a soil amendment. The NSW Environment Protection Authority (EPA) advised that the sludge would only be considered for use as fill, not an amendment due to the high Al content. Despite the change of tack, high concentrations of Al and Mn ultimately culminated in the NSW EPA discouraging reuse of the sludge as fill.

Tweed Shire Council's road maintenance engineers considered the possible use of the sludge as an admixture product in adjusting the properties of waste gravels for use in unsealed or sealed road construction. The staff raised concern that the material would cause an increase in the plastic properties of the waste gravel and combined with the particle size, would be very difficult to blend to a uniform product with the mechanical equipment available, and would require more specialised equipment to process.

Council staff have considered disposal to sewer which has the potential to benefit the WWTP process through residual coagulant properties (GHD, 2015). This avenue has not been explored in depth; however, flowrates may overwhelm the local shared sewer network.

Regulatory challenges

There appears to be a lack of clarity around acceptable chemical contaminant levels for such material except Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium & Zinc. Pertinently, no clear thresholds have been set for Al or Mn which are a primary concern for the material generated at Bray Park.

The NSW EPA has suggested the waste should be tracked across the border. To date, legislation interpretation by Council staff coupled with support from the QLD DEC has avoided this imposition.

The Water Directorate guideline (2012) provides important information for LWUs considering capital works to improve sludge handling and QLD does not appear to have a reciprocal publication. Considering contemporary research related to improved sludge management in a circular economy, the water industry more widely could benefit from updated guidance.

CONCLUSION

Despite its infancy sludge drying is proving effective, the design of new WTPs with sludge generation should strongly consider moisture reduction opportunities in addition to mechanical dewatering. Double handling of the sludge is not ideal, in the case of Bray Park being between the centrifuge facility and the drying facility established at the lagoons. Future WTP designers considering sludge management should factor evaporation processes to reduce moisture content and the associated volume of waste produced by these plants.

Circular economy opportunities are exciting however investigation from an implementation perspective is lacking, an industry partnership approach could explore opportunities for cost sharing arrangements for water authorities producing sludge. Cross border proximity may offer special opportunities for local water utilities in Northern NSW and their counterparts in QLD.

Regulators are willing to engage however legislation remains prescriptive especially for land applications in NSW. The statutory context is tricky and may benefit from legal interpretation for cross border transport of waste. Soft skills among water industry employees remain important for navigating regulatory systems and consulting with authorities.

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