FEASIBILITY STUDY: USING TREATED WASTEWATER FROM MANGERE AND ROSEDALE PLANTS FOR SPORTS-FIELDS IRRIGATION IN AUCKLAND

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ABSTRACT

Using treated wastewater to irrigate sports fields and urban parks is a practical solution to water resource scarcity worldwide. In New Zealand, recycled water reuse is not presently supported by regulatory authorities. However, water scarcity due to climate change, population growth, economic growth, and the fundamental need to protect precious natural resources for future generations will likely alter New Zealand's perception of treated wastewater from garbage to gold. This report assesses the feasibility of using treated wastewater from two of Auckland's largest wastewater treatment plants in Mangere and Rosedale to irrigate community sports fields, focusing on classifying the treated wastewater according to its physical, chemical, and biological properties in line with local knowledge and international guidelines. All effluent characteristics discussed (BOD, TN, TP, pH, TDS, salinity, sodium adsorption ration, and heavy metals - As, Cd, Cu, Fe, Pb, Mn, Ni, and Zn) are below or within range of the Australian wastewater reuse guidelines recommended values. Faecal coliforms were assessed according to USEPA guidelines and were generally higher than the strictly recommended value of nil detection. Pesticides and herbicides were also discussed, and diuron, terbuthylazine, mecoprop, and triclopyr were detected in both Mangere and Rosedale WWTPs. The future of treated wastewater reuse in NZ rests upon the endorsement by regulatory bodies, consultation with Māori, and a comprehensive recycled water reuse guideline document.

KEYWORDS

wastewater reuse, wastewater treatment, recycled water, sports-fields irrigation, emerging contaminants

PRESENTER PROFILE

Being in love with water her whole life, Sarisha joined Auckland Council to develop a water efficiency plan for the Community Facilities department and implement non-potable water reuse projects. Her joy stems from integrating her experience gained as a civil engineer over the last ten years with sustainability.

1. INTRODUCTION

The use of treated wastewater to irrigate urban open spaces is considered a practical solution to address water resource scarcity and is commonly used in arid and semi-arid parts of the world. In Auckland, all three metropolitan wastewater treatment plants (Mangere, Rosedale, and Army Bay) currently release treated effluent to the ocean rather than recycle it for re-use on land.

Auckland Council (AC), the second largest commercial water consumer in the city, has committed to reducing water consumption by 30% over the next ten years. Irrigation of sports fields comprises approximately half of AC's community facility asset's water usage. Using treated wastewater for sports fields irrigation can play a vital role in reducing the city's potable water demand and accepting treated wastewater as a valuable resource as an alternative to simply discarding the effluent.

Water is a vital element of Māori culture. The following is one whakataukī (proverb) reflecting the universal relationship Māori have with water: "Ko te wai te ora ngā mea katoa," meaning water is the life giver of all things. This proverb highlights the significance of water to New Zealand as a community. It also emphasizes the need to understand the social and cultural implications of using treated wastewater to irrigate municipal sports fields.

This research paper investigates the feasibility of using treated wastewater from two of Auckland's largest wastewater treatment plants (WWTP) in Mangere and Rosedale to irrigate community sports fields, with a focus on classifying the treated wastewater according to its physical, chemical, and biological properties in line with local knowledge and international standards. Potential public health and environmental risks will also be discussed, along with cultural connections to Māori in terms of "te mauri o te wai" (the life-supporting capacity of water) and "te mana o te wai" (the vital importance of water).

2. TREATED WASTEWATER REUSE IN NEW ZEALAND

In New Zealand (NZ), using treated wastewater for irrigation is one of the potential land-based applications of clean effluent from a WWTP. It is commonly referred to as land-based wastewater discharge (GHD et al., 2020). A dedicated non-potable, public piped network to irrigate community parks or flush municipal toilets has not been implemented before in NZ (CH2M Beca, 2020).

The responsible bodies for NZ's drinking water control are changing governance, and a new organisation named Taumata Arowai has taken over from the Ministry of Health. The Resource Management Act 1991 (RMA) is the current approach to environmental management in NZ and aims to protect natural and physical resources by promoting sustainable practices. In early 2021, the government announced plans to revoke the RMA and replace it with three new acts to focus on the country's many urgent issues. A shift in policy and administration indicates a much-needed change in philosophy for managing natural resources and the water sector. However, it is not yet clear how the three new laws and Taumata Arowai will influence NZ's current position of using recycled water for public parks and sports fields irrigation.

2.1 EXISTING LAND-BASED DISCHARGE SCHEMES IN NZ

Rotorua, Omaha, and Thames-Coromandel districts are three areas in NZ with experience using land-based wastewater systems that are most relevant and applicable to the topic of wastewater reuse for public sports fields irrigation.

The Whakarewarewa Forrest scheme in Rotorua demonstrated that when the discharge project is aimed at providing additional treatment before reaching a water body, soil health deteriorates over a relatively long time, and the ground will eventually reach saturation point. Impaired soil health leads to damaged plant life and an unhealthy ecosystem. It is, therefore, crucial to treat the wastewater to the highest standard possible before considering using the clean effluent to irrigate sport fields.

The Omaha land-based discharge project provides a local example for golf courses and forestry irrigation. It shows that a WWTP with tertiary treatment can deliver the water quality needed for beneficial treated wastewater reuse on land within the Auckland region. The scheme uses surface and subsurface drip-fed irrigation (instead of a traditional pop-up sprinkler network), thereby protecting the public from direct exposure to treated wastewater by eliminating sprays drifting through the air. Continuous monitoring and community engagement are also essential to successfully recycling wastewater for non-potable end uses.

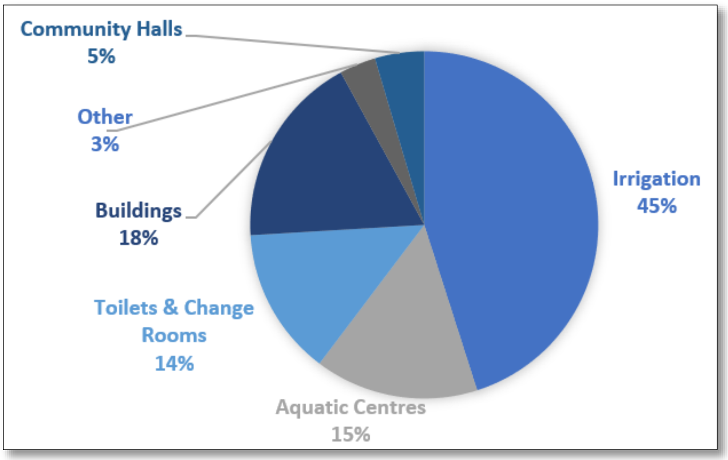
Thames Coromandel District Council has proven that it is possible to obtain consent under the current RMA to irrigate a community sports park (Mercury Bay Multi-Sport Complex) using treated effluent. However, without dedicated funding to comply with consent conditions such as monitoring bores, soil moisture probes, weather stations, and automated irrigation systems, the treated wastewater reuse system is at risk of not being implemented.

Water scarcity due to climate change, population growth, economic growth, and the fundamental need to protect precious natural resources for future generations will likely alter New Zealand’s perception of treated wastewater from garbage to gold. With an extreme drought experienced in May 2020, this resonates considerably more for Auckland.

2.2 AUCKLAND’S WATER SUPPLY AND DEMAND

Auckland Council (AC) is the second largest commercial water consumer in Auckland and has committed to achieving a 30% reduction in water use by 2030.

Figure 1: AC Community Facilities’ average water use



The Community Facilities department contributes to nearly all of AC's water use. Figure 1 shows the breakdown of the community facilities' average water use taken from the city's potable water network in percentage per category. Irrigation of parks and sports fields has the highest water requirement, averaging 45%. Reducing reliance on potable water for non-potable uses such as irrigation can play a considerable role in meeting the council's water reduction targets.

To obtain approval for irrigating community sports fields using treated wastewater in Auckland, the applicant would be required to apply for a resource consent primarily under Chapter E6 (Wastewater Network Management), rule E6.4.1(A6) of the Auckland Unitary Plan: "Discharge of treated or untreated wastewater onto or into land and/or into water from a wastewater treatment plant". There are currently no specific wastewater reuse rules/guidelines endorsed by regulatory authorities in NZ. This places a significant limitation on the country to transition to recycling wastewater for non-potable uses. A review of existing examples from the USA and Australia can provide a valuable foundation for developing a suitable framework and a basis for comparing effluent characteristics when evaluating feasibility.

2.3 INTERNATIONAL GUIDELINES

2.3.1 UNITED STATES OF AMERICA (USA)

The United States Environmental Protection Agency (USEPA) national guidelines for reusing reclaimed water – Guidelines for Water Reuse, provides suggested guidelines for using treated wastewater for sports fields irrigation. The minimum level of treatment required includes secondary, filtration and disinfection processes. Furthermore, biochemical oxygen demand (BOD) and suspended solid (SS) measured in effluent from secondary treatment should not exceed 30mg/l. Water quality parameters with recommended concentrations or value ranges provided in the USEPA guidelines are pH (6.0-9.0), BOD (≤ 10mg/l), turbidity (≤ 2 NTU based on a 24-hour average. No individual measurement may exceed 5 NTU), faecal coliforms (FC) (no detectable FC/100 ml based on a 7-day median. No single result may exceed 14/100mL) and residual chlorine (1 mg/l Cl2 residual).

2.3.2 AUSTRALIA

Australia is no stranger to frequent cycles of persistent drought, with many states having a harsh, dry climate. Applying treated wastewater for agricultural irrigation is considered an effective way to secure water supply and is presently widely used throughout Australia.

Historically, National and State guidelines adopted a water class system to match microbiological (Escherichia coli) and chemical/physical (turbidity and BOD) water quality with predetermined beneficial end uses. Class A+ is of the highest quality and can be used for non-potable, residential, dual reticulation systems. Class C and D have the lowest water quality and can only be used for non-food crops with restricted public access. Public sports fields would require Class A treated wastewater with <10 E-coli/100ml, turbidity <2 NTU and BOD <20mg/L, and removal of viruses, protozoa, and Helminths if required (Seshadri et al., 2015).

In 2006, the National Water Quality Management Strategy Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (AGWR) was published. The AGWR aims to provide a more comprehensive publication and consistent approach for local authorities. The most significant update in the 2006 AGWR release is the shift from the class system to a risk management framework. The intention behind this change was to move away from relying on effluent quality testing as a basis for controlling treated wastewater reuse to a proactive decision-making process that views the entire system holistically (NRMMCEP & HCAHMC, 2006).

The New South Wales (NSW) treated wastewater reuse guidelines classify the effluent on a strength-based system as a first step to understanding environmental hazards. Recycled water's strength can either be low, medium, or high based on the measure of nitrogen, phosphorus, total dissolved salts (TDS), BOD, metals, pesticides, and greasy substances present in the wastewater post-treatment. The strength of the effluent is subsequently linked to the national guidelines published in the year 2000 for recycled water. Even though the NSW regulations are based on an earlier version of the current AGWR, which does not explicitly refer to the class-based system, the recommended effluent quality parameters are the same as Class A treated wastewater with two additional parameters – pH and residual chlorine. Recommend pH values are 6.5-8.5 with 90% compliance in samples and 1 mg/L total residual chlorine after a minimum of 30 minutes of contact time. The NSW regulations also state that water from municipal WWTPs with secondary treatment is expected to be low strength (Department of Environment and Conservation NSW, 2004).

2.3.3 DISCUSSION

Table 1 summaries effluent quality parameters in treated wastewater reuse guidelines for sports fields irrigation by USEPA, the Australian government historical class A grading, and the state of NSW.

Table 1: Summary of effluent quality parameters for sports fields irrigation – USEPA, AGWR Class A, NSW

	USEPA	**AGWR Class A**	**NSW**
PH	6 - 9	-	6.5 – 8.5
BOD	< 10 mg/l	< 20 mg/l	< 20 mg/l
Turbidity	≤ 2 NTU	≤ 2 NTU	≤ 2 NTU
Residual Chlorine	1mg/l Cl2 residual	1mg/l Cl2 residual	1mg/l Cl2 residual
Faecal Coliforms	No detectable FC/100ml	-	-
Escherichia coli	-	< 10 E-coli/100ml	< 10 E-coli/100ml

The suggested PH range shown in the USEPA guidelines is marginally larger than NSW guidelines, whereas the USEPA's BOD value recommendations are half of those shown in both Australian regulations. All three standards have the same recommended values for residual chlorine and turbidity. When treated wastewater requires residual defection using chlorine, levels should be kept below 1 mg/l to minimise any adverse effects on grass species (Department of Environment and Conservation NSW, 2004). Faecal coliforms (FC) are a subgroup of bacteria commonly found in natural surroundings. E-coli is a major FC bacterium specifically found in human faecal matter. While FC and E-coli are not the same parameters, it can be concluded that USEPA's guideline for bacteria, in general, is more stringent than AGWR Class A and NSW.

Before assessing the characteristics of Auckland's WWTPs effluent quality with reference to USEPA and Australian guidelines, in this paper, it is necessary to understand the parameters discussed with a lens on environmental and public risks associated with using treated wastewater for watering sports fields.

3. ENVIRONMENTAL EFFECTS

Using clean effluent discharged from WWTPs for all types of irrigation has both environmental advantages and disadvantages. There are four main benefits associated with crop irrigation using treated wastewater – better soil quality due to increased organic carbon and nutrient supply, potable water savings, pollution prevention in marine environments, and reduced costs for compost (Ofori et al., 2020). Even though these benefits were discussed with a lens on the agricultural sector, similar advantages are expected for sports fields with a slight difference in soil health as it closely links to the type of plant species grown. For this reason, the impacts on soil quality are often highlighted in literature when discussing treated wastewater reuse for sports fields irrigation, followed by groundwater contamination.

3.1 SOIL HEALTH

In urban parks, healthy soil produces healthy turf. Quality turf is characterised by good tilth, sufficient depth, favourable nutrients, optimal pH, minimum pathogens, varied beneficial bacteria, and free of toxic chemicals. Using treated wastewater for sports field irrigation can theoretically harm soil and grass health and rely mainly on effluent quality. The extent of the effect is also influenced by the volume and duration of watering, existing soil properties, and weather (Ofori et al., 2020). The critical environmental concerns are levels of salinity, heavy metal accumulation, pesticides, herbicides and biocides, and nitrogen and phosphorus toxicity in soil.

3.2 GROUNDWATER CONTAMINATION

The greatest worry with groundwater contamination is the impact of using the resource for drinking. The two primary contaminants of concern are harmful microorganisms (pathogens) and nitrate. The movement of pathogens from surface irrigation to groundwater is complex and impacted by soil composition and the volume of treated wastewater. Nitrate found in groundwater used for human consumption is concerning due to its ability to cause methemoglobinemia (blue baby syndrome) in babies and the elderly (Whitehouse et al., 2000). If the location of the drinking water borehole is near sports fields where treated wastewater is used for irrigation, groundwater modelling and an evaluation of potential pathogen and nitrate contamination should be included in preliminary investigations.

Globally, an emerging contaminant of concern is per- and polyfluoroalkyl substances (PFAS). PFAS are a diverse group of artificial chemicals commonly found in many household and manufacturing products because of their high resistance to oil, water, and heat. As the research around the possible health implications of PFAS accumulation in humans and the environment is still developing, current data indicates it may cause severe health disorders. A recent study by Ojo et al. (2021) describes several adverse human health consequences of long-chain perfluoroalkyl acids (PFAAs) exposure, including reproductive toxicity, neurotoxicity, hepatotoxicity, immunotoxicity, endocrine disruption, and cancer. Szabo et al. (2018) investigated the presence of PFAS in groundwater below a site using recycled water for crop irrigation in Melbourne, Australia. The research paper concluded that using treated wastewater for irrigation can be a source of PFAS contamination in groundwater. Even though PFAS is not discussed further in this report due to data limitations, given the potential adverse health repercussions, consideration should include in environmental impact assessments for all reclaimed water reuse projects.

4. PUBLIC HEALTH RISKS

According to Milne and Gray (2011), health risks associated with non-potable water use for irrigation of unrestricted, public open spaces are mainly divided into two key categories: pathogens and toxic chemicals. In Australia, adopting the AGWR at the start of the project and during operation fundamentally eliminates the risk of widespread community exposure to pathogens. This emphasises the essential role national guidelines play in keeping the public safe when implementing a wastewater reuse project.

4.1 PUBLIC HEALTH RISK MITIGATION

Direct human exposure to pathogens, toxic chemicals, and emerging contaminants when irrigating sports fields with treated wastewater can occur mainly via aerosols, accidental ingestion, and contact with the soil immediately after irrigation (Yi et al., 2011). There is a higher risk of public contact with treated wastewater in the air when sprinkler systems are used for irrigation, especially on windy days. Hashem and Qi (2021) report that installing a drip irrigation system is the most effective way to limit exposure to pathogens drifting in the urban environment. Drip irrigation pipes can be laid either above or below ground allowing water to gravitate directly to plant roots without being dispersed in the atmosphere. With appropriate design, installation, and maintenance, drip irrigation systems are also considered more water efficient as they significantly reduce evaporation compared to pressurised sprinkler systems.

Accidental ingestion and contact with the soil can occur when children are playing at the same time fields are irrigated with treated wastewater or when sports field employees, and contractors in direct contact with the effluent are unaware of the potential hazards (Milne & Gray, 2011). Protocols to mitigate these risks are mostly related to operational controls. The main operational guidelines to safeguard kids and their parents are irrigating in the early morning hours to allow the effluent enough time to seep into the ground before public entry is permitted and community awareness via signs and posters on site. Employees and contractors should be inducted, and clear communication should be distributed around controls required for working with non-potable water. Some of these controls can include washing hands immediately after working with recycled water and prohibiting food and drink where treated wastewater is used.

Olivieri et al. (2020) explain that to care for public health adequately, emphasis should be placed on first removing pathogens and COCs as much as practically possible and adhering to standard log reduction requirements before distributing the effluent for irrigation. Installing drip irrigation systems and implementing operational controls are secondary steps in risk mitigation. This shows the importance of the treatment process in using recycled water for sports field irrigation, particularly in the tertiary/disinfection stage.

5. AUCKLAND'S WASTEWATER TREATMENT PLANTS

Watercare Services Limited (WSL) treats approximately 404 million litres of wastewater daily. The incoming sewage comprises residential waste, industrial waste, groundwater infiltration, and some stormwater flowing from historical, combined wastewater and stormwater networks in Auckland. More than 90% of the effluent is handled at either the Mangere or Rosedale WWTPs, and both use the universal four-step treatment process – preliminary, primary (mechanical), secondary (biological), and tertiary. The characteristics of treated wastewater fluctuate depending on where it originally comes from and how it is treated (Hashem & Qi, 2021). Figures 2 and 3 illustrate a simplified treatment train diagram at the Mangere and Rosedale WWTPs in Auckland. The diagrams were produced from a combination of the information shown on WSL's website and an email discussion with WSL during October 2021. The movement of liquids and solids through the treatment process is indicated by blue and red arrows, respectively, and any recycled waters or sludge within the plant are shown in black dashed lines.

Figure 2: Mangere Tertiary WWTP using Complete Mix Activated Sludge (CMAS) as a basis for secondary treatment (Watercare, 2022)

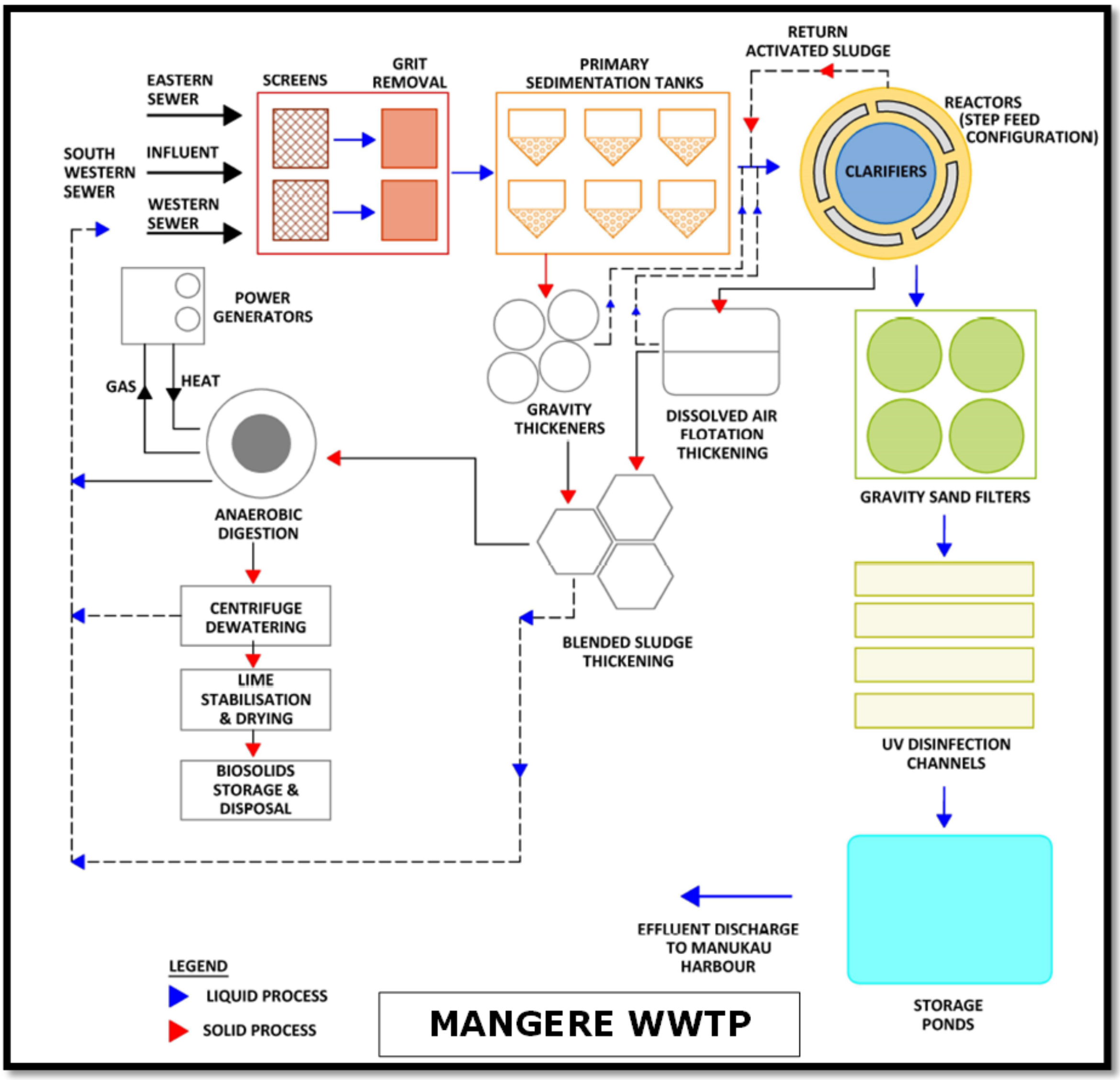
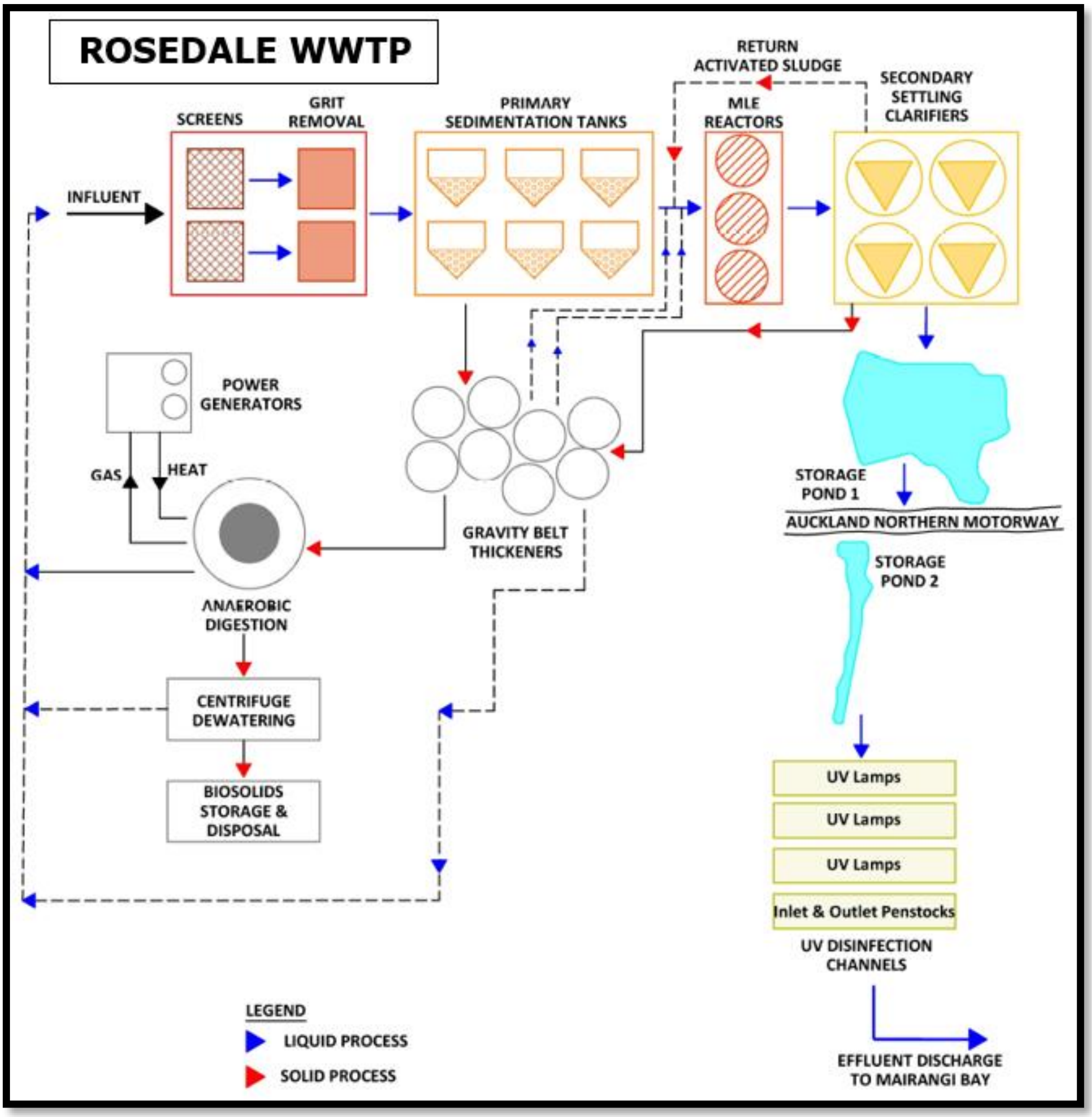


Figure 3: Rosedale Tertiary WWTP using Modified Ludzack-Ettinger (MLE) Process as a basis for secondary treatment (Watercare, 2022)



The Mangere WWTP is nearly six times larger than the Rosedale WWTP in discharge volume. Except for the variation in size, the two key differences between each plant are that at the Mangere plant, biological nutrient removal is carried out in complete mixed activated sludge system (CMAS) reactor/clarifiers, and the Rosedale WWTP uses Modified Ludzack-Ettinger (MLE) reactors. In saying that, the Mangere WWTP has recently installed two new MLE reactors to support nitrogen removal and are likely to provide a higher level of treatment; however, it has been omitted from this discussion due to insufficient data available at the time of writing this paper. As discussed in section 2.3.2, clean effluent from municipal WWTPs with secondary treatment is expected to be low strength according to NSW regulations. This is a promising indication that the treated wastewater from both WWTPs is one step closer to being generally suitable for sports fields irrigation.

6. DATA

Watercare provided effluent quality data for the Rosedale and Mangere WWTPs from two sources – historical records extracted from WSL databases and test data carried out by WSL laboratory services. The test data provided additional evidence for parameters not included in historical records.

Table 2: Watercare data – source and number of points

<table>
<tr><th></th><th></th><th colspan="2">WWTP SOURCE DATA</th></tr>
<tr><th></th><th>UNIT</th><th>MANGERE</th><th>ROSEDALE</th></tr>
<tr><td colspan="4">GENERAL EFFLUENT QUALITY CHARACTERISTICS</td></tr>
<tr><td>(BOD_5)</td><td>mg/L O</td><td>Historical Record
862,424 Points [1, 4]</td><td>Historical Record
115 Points [4]</td></tr>
<tr><td>Total Nitrogen (TN)</td><td>mg/L N</td><td>Historical Record
1,032,464 Points [1, 4]</td><td>Historical Record
25 Points [4]</td></tr>
<tr><td>Total Phosphorus (TP)</td><td>mg/L P</td><td>Historical Record
1,434 Points [1, 4]</td><td>Historical Record
26 Points [4]</td></tr>
<tr><td>pH</td><td>pH Unit</td><td>Historical Record
894,888 Points [1, 4]</td><td>Historical Record
623 Points [4]</td></tr>
<tr><td>Total Dissolved Solids (TDS)</td><td>mg/L</td><td>Test Data [2]</td><td>Test Data [2]</td></tr>
<tr><td colspan="4">PATHOGENS</td></tr>
<tr><td>Faecal coliforms (FC)</td><td>cfu/100 mL</td><td rowspan="2">Test Data [2]</td><td>Historical Record
631 Points [4]</td></tr>
<tr><td>Enterococci</td><td>cfu/100 mL</td><td>Historical Record
630 Points [4]</td></tr>
<tr><td colspan="4">SALINITY</td></tr>
<tr><td>Total Salinity (Electrical Conductivity - EC)</td><td>dS/m</td><td colspan="2" rowspan="2">Test Data [2]</td></tr>
<tr><td>Sodium Adsorption Ratio (SAR)</td><td>Ratio</td></tr>
<tr><td colspan="4">Heavy Metals</td></tr>
<tr><td>Arsenic (As)</td><td>mg/L</td><td rowspan="8">Test Data [2]</td><td rowspan="3">Historical Record - 8 Points [3]</td></tr>
<tr><td>Cadmium (Cd)</td><td>mg/L</td></tr>
<tr><td>Copper (Cu)</td><td>mg/L</td></tr>
<tr><td>Iron (Fe)</td><td>mg/L</td><td>Test Data [2]</td></tr>
<tr><td>Lead (Pb)</td><td>mg/L</td><td>Historical Record - 8 Points [3]</td></tr>
<tr><td>Manganese (Mn)</td><td>mg/L</td><td>Test Data [2]</td></tr>
<tr><td>Nickel (Ni)</td><td>mg/L</td><td rowspan="2">Historical Record - 8 Points [3]</td></tr>
<tr><td>Zinc (Zn)</td><td>mg/L</td></tr>
<tr><td colspan="4">Trace Organic Compounds</td></tr>
<tr><td></td><td>Unit</td><td>Mangere</td><td>Rosedale</td></tr>
<tr><td>Pesticides</td><td>µg/L OR mg/L</td><td colspan="2" rowspan="2">Test Data [2]</td></tr>
<tr><td>Herbicides</td><td>µg/L OR mg/L</td></tr>
</table>

Notes:

1 Historical records with more than a hundred thousand points have been reduced to a manageable data set of approximately 1500 points, ensuring at least one value is represented per day in the analysis. The historical source data were extracted over five years, from 22 July 2016 to 21 July 2021.

2 The laboratory certificate of analysis is based on final effluent samples collected from each WWTP on 12 August 2021, and the results were issued on 2 September 2021.

3 Heavy metals from historical records with eight points show data on the following eight dates – 18/07/2016, 25/07/2017, 26/07/2017, 28/07/2017, 16/04/2018, 30/04/2018, 6/08/2018, 16/07/2020.

4 Historical information with more than twenty points was converted to box and whisker plots corresponding to annual season data available.

7. DATA ANALYSIS RESULTS AND DISCUSSION

The data is grouped for discussion according to the following five parameters – general characteristics, pathogens, salinity, heavy metals, and trace organic compounds. Each parameter shows historical data in box and whisker plots and tables from the test data, followed by subsequent discussions.

7.1 GENERAL EFFLUENT QUALITY CHARACTERISTICS

7.1.1 BOD

Figure 5: Mangere WWTP BOD

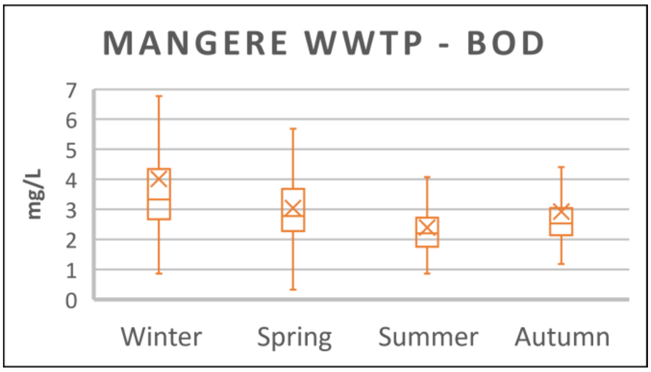
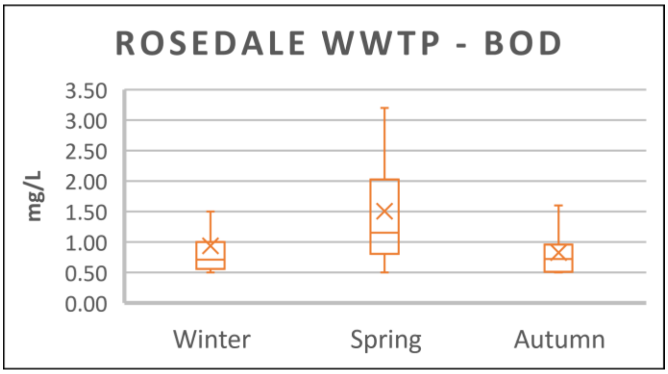


Figure 4: Rosedale WWTP BOD



The NSW recycled water standard reports a BOD range of 40-1500 mg/L is appropriate for sports fields and park irrigation, with the maximum value more suitable for moderately tolerant plants like lucerne (Rahman et al., 2016). The average values for BOD at Mangere and Rosedale range from 2.4 to 4 and 0.8 to 1.5, respectively and are significantly below the NSW regulations. At the Mangere WWTP, the maximum BOD value of 6.7 was recorded during winter, and at the Rosedale WWTP, the maximum BOD value of 3.2 was recorded during spring. The data set at Rosedale did not include summer records. BOD is not typically perceived as a critical parameter for land-based wastewater reuse, given that appropriate amounts can be advantageous to soil fertility (Department of Environment and Conservation NSW, 2004). High BOD values in the effluent could indicate that the WWTP has not successfully reduced organic pollution throughout the treatment process. However, this is not the case for both Mangere and Rosedale WWTPs.

7.1.2 TOTAL NITROGEN (TN)

Figure 6: Mangere WWTP TN

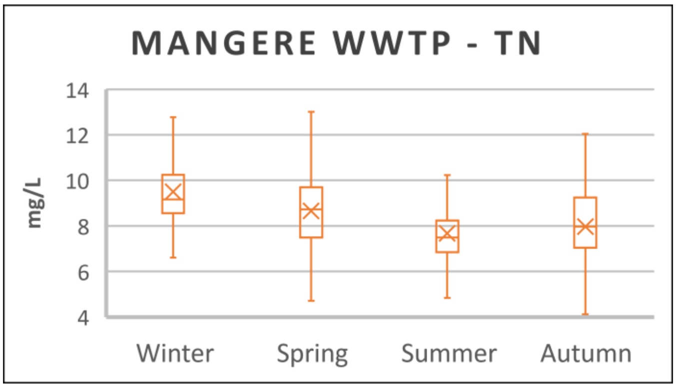
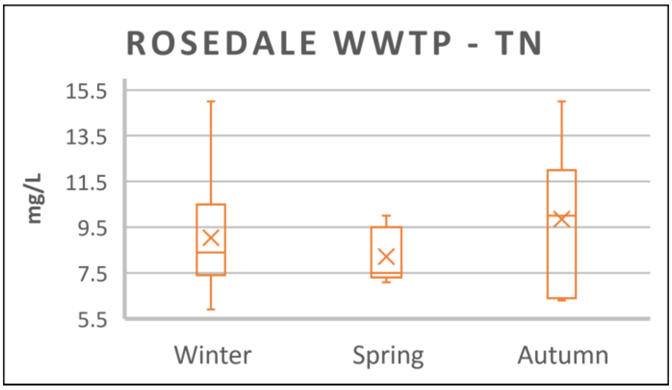


Figure 7: Rosedale WWTP TN



The mean values for TN at Mangere and Rosedale WWTPs range from 7.7 to 9.5 and 8.2 to 9.9, respectively and are within the NSW standard range of 5-50mg/L. All maximum values are also within the recommended TN range, with the highest value (15mg/L) recorded at the Rosedale WWTP during winter. The relatively low TN readings indicate groundwater sources will be safe from contamination. However, the relationship between grass species, nitrogen uptake, nitrate mobility, and groundwater sources should be further investigated to eliminate any potentially harmful effects.

7.1.3 TOTAL PHOSPHORUS (TP)

Figure 8: Mangere WWTP TP

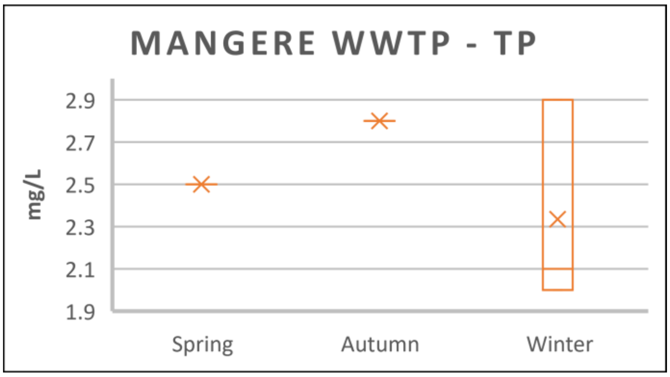
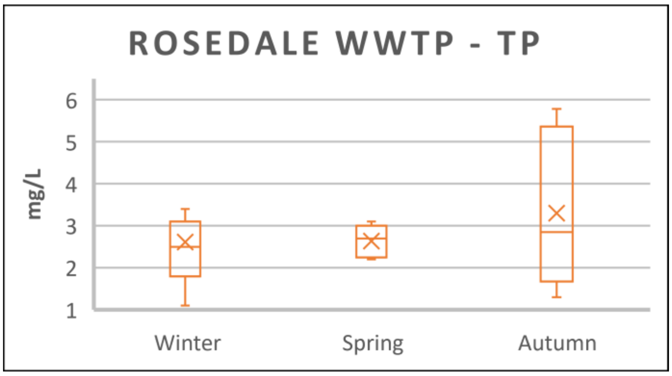


Figure 9: Rosedale WWTP TP



The NSW recycled water standard recommends TP to range from 0.5 to 10 mg/L. All maximum TP readings are less than 10 mg/L, with the highest TP value of 5.8 mg/L recorded at the Rosedale WWTP during autumn. Both data sets did not include TP numbers for summer. Whitehouse et al. (2000) report that phosphorus does not usually move around in NZ soils. However, long-term monitoring is required to ensure the soil does not become saturated with phosphorus and leaching to aquifers is minimised.

7.1.4 PH

Figure 11: Mangere WWTP pH

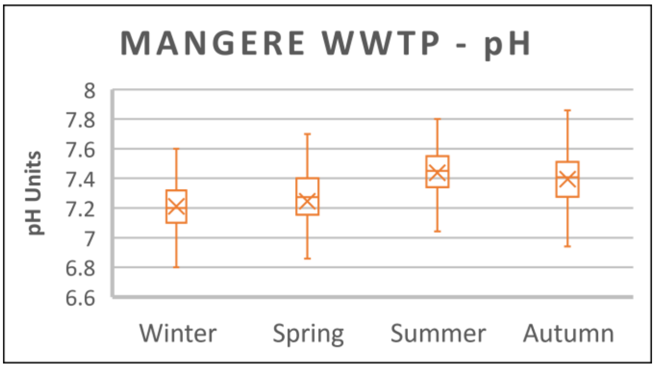
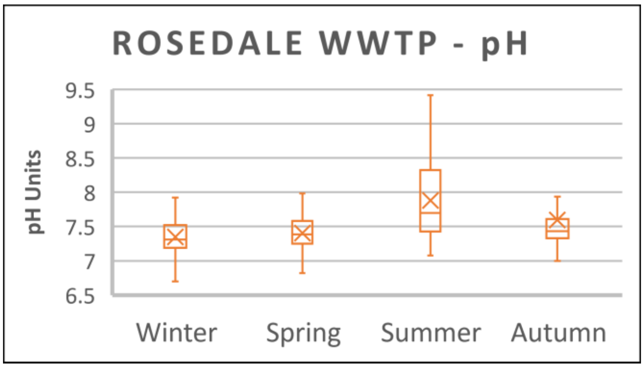


Figure 10: Rosedale WWTP pH



Treated wastewater with a pH between 5 and 8.5 is typically suitable for sports field irrigation (Department of Environment and Conservation NSW, 2004). The mean and maximum values recorded for Mangere and Rosedale WWTPs are within the recommended pH range, except for Rosedale's highest summer reading of 9.4. During summer, effluent from the Rosedale WWTP may need to be neutralised before irrigating as the soil pH affects the number of nutrients available to plants.

7.1.5 TOTAL DISSOLVED SOLIDS (TDS)

Table 3: Total Dissolved Solids

Parameter	Unit	NSW Standard	Mangere WWTP	Rosedale WWTP
			TEST DATA	
Total dissolved solids (TDS)	mg/l	600 – 1000	**480**	**450**

Both Mangere and Rosedale WWTPs returned TDS test results lower that the recommended NSW standards. Total dissolved solids can be used as a measure of salts in the effluent. Soluble salts can negatively affect grass growth and is therefore a key parameter when assessing the suitability of wastewater used to irrigate sports fields.

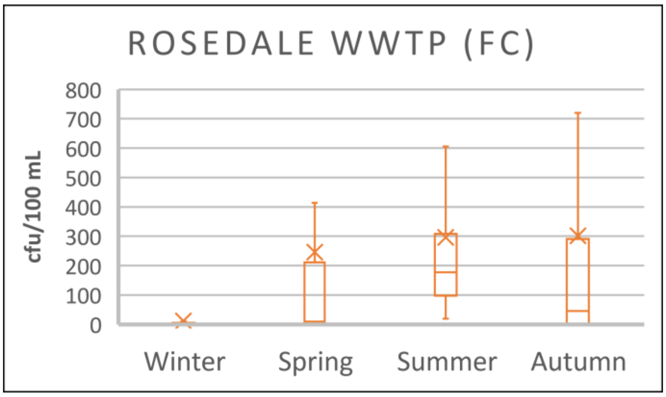
7.2 PATHOGENS

7.2.1 FAECAL COLIFORMS (FC)

Table 4: Mangere WWTP FC

Mangere WWTP TEST DATA	
Faecal Coliforms (FC)	31 cfu/100ml

Figure 12: Rosedale WWTP FC

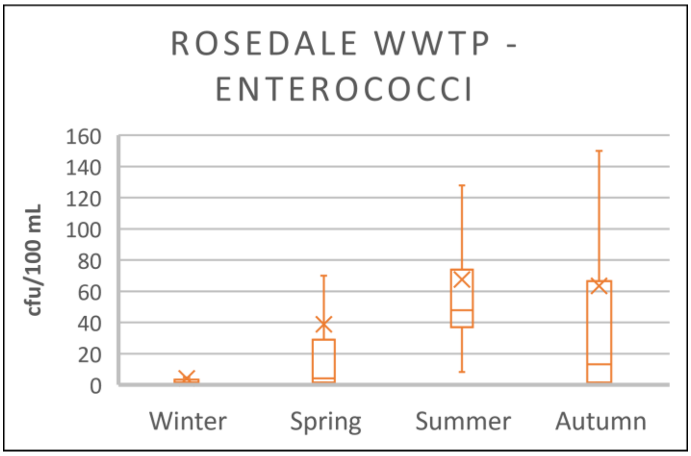


7.2.2 ENTEROCOCCI

Table 5: Mangere WWTP Enterococci

Mangere WWTP TEST DATA	
Enterococci	<1.6 cfu/100ml

Figure 13: Rosedale WWTP Enterococci



The USEPA reclaimed water reuse guidelines recommend no detectable FC/100mL. The Mangere WWTP reported 31 cfu/100mL in the test sample collected in winter. The Rosedale WWTP FC data has been plotted from Watercare's historical records with a significant difference in mean values ranging from 11.2 to 301 cfu/100mL and a maximum of 720 cfu/100mL during autumn. Watercare has confirmed that UV treatment does not operate full time at the Rosedale WWTP, which likely contributes to the difference in microbiological results observed.

Enterococci are bacteria more commonly known to survive in salt water. THE USEPA classifies enterococci as a good indicator of public health risk in recycled water used for irrigation and should be regularly monitored. The enterococci test result at Mangere is <1.6 cfu/100mL and is considerably lower than the maximum reading at Rosedale WWTP during autumn (150 cfu/100mL). The test data and historical records at both treatment plants for FC are not in line with USEPA's guidelines and need further investigation. This can be done by collecting more data, reviewing existing process performance and optimisation, and identifying additional treatment controls needed to manage public health risks.

7.3 SALINITY

Saline toxicity in the soil is the most critical environmental concern in using recycled water for sports field irrigation (Rahman et al., 2016). Salinity is the measure of soluble salts in the treated wastewater and is commonly evaluated as electrical conductivity (EC). Turf growth is altered by salt accumulation, and these effects are intensified by water-soluble cations or anions such as sodium, magnesium, iron, calcium, and chloride (Ofori et al., 2020). In particular, the ratio of sodium to calcium and magnesium characterises the harmful impacts of treated wastewater and is commonly assessed based on the sodium adsorption ratio (SAR).

Table 6: Salinity

Parameter	Unit	NSW Standard	Mangere WWTP	Rosedale WWTP
			TEST DATA	
Electrical Conductivity (EC)	dS/m^{-1}	0.65 – 1.3	0.545	0.545
Sodium Adsorption Ratio (SAR)	-	10 – 18	4.9	4.5

From the EC and SAR test results shown in table 6, it can be concluded that the probability of saline toxicity in the soil irrigated with treated wastewater from either Mangere or Rosedale WWTP is low. The test data values are significantly lower than the NSW recycled water guidelines and will be suitable for both warm and cool season turfgrass species typically used in NZ (Milne & Gray, 2011).

7.4 HEAVY METALS (AS, CD, CU, FE, PB, MN, NI, ZN)

Table 7: Heavy Metals

Heavy Metal	Unit	NSW Standard**	Mangere WWTP (Test Data)	Rosedale WWTP (Historical and Test Data)
Arsenic (As)	mg/l	0.1	0.0017	0.0018*
Cadmium (Cd)	mg/l	0.01	<0.00005	0.000221*
Copper (Cu)	mg/l	0.2	0.0015	0.0035*
Iron (Fe)	mg/l	0.2	0.058	0.099
Lead (Pb)	mg/l	2.0	0.00028	0.000439*
Manganese (Mn)	mg/l	0.2	0.065	0.038
Nickel (Ni)	mg/l	0.2	0.0078	0.00365*
Zinc (Zn)	mg/l	2.0	0.051	0.02975*

*Average of 8 points from historical data.

** Adapted from (Department of Environment and Conservation NSW, 2004) shows trigger values for heavy metals in treated wastewater applied on all soil types up for long term use (up to 100 years).

As, Cd, Cu, Fe, Pb, Mn, Ni, and Zn levels present in the Mangere and Rosedale WWTP are below the NSW standard trigger values for heavy metals. Heavy metals can be both beneficial and detrimental to plant growth. Metals such as Cu, Fe, Mn, Ni, and Zn (at low levels) improve nutritional levels and yield in grass species. On the other hand, these metals are toxic at high concentrations, especially if the soil is very acidic (has a pH value of less than 5). Heavy metal concentrations may take a long time to reach toxic levels. Therefore, regularly monitoring heavy metals is crucial to avoid permanently polluting the sports fields that have been irrigated using treated wastewater.

7.5 TRACE ORGANIC COMPOUNDS

Eighty-nine different types of pesticides and fourteen herbicides were tested in the wastewater samples from Mangere and Rosedale WWTPs collected on 12 August 2021. 7 of 89 pesticides and 5 of 14 herbicides showed positive values, higher than the detection limit. The trace organic compounds with positive values found in both Mangere and Rosedale WWTP have been highlighted in orange and discussed below.

Table 8: Trace Organic Compounds

Organonitrogen & Organophosphorus Pesticides by Liquid Chromatography-Mass Spectrometry				
		Mangere WWTP	**Rosedale WWTP**	**Method Detection Limit**
Diuron	µg/L	**0.3**	**0.7**	0.1 µg/L
Hexazinone	µg/L	0.1	<0.1	0.1 µg/L
Propazine	µg/L	<0.1	0.6	0.1 µg/L
Propiconazole	µg/L	0.1	<0.1	0.1 µg/L
Tebuconazol	µg/L	<0.1	0.6	0.1 µg/L
Terbuthylazine	µg/L	**0.3**	**4.2**	0.1 µg/L
Terbutryn	µg/L	4.5	<0.1	0.1 µg/L
Organics				
Acid Herbicides by Liquid Chromatography-Mass Spectrometry				
		Mangere WWTP	**Rosedale WWTP**	**Method Detection Limit**
Dicamba	mg/L	<0.0001	0.00041	0.00010 mg/L
MCPA	mg/L	0.00013	<0.0001	0.00010 mg/L
Mecoprop (MCPP)	mg/L	**0.00015**	**0.00051**	0.00010 mg/L
Picloram	mg/L	<0.0001	0.00023	0.00010 mg/L
Triclopyr	mg/L	**0.00012**	**0.00043**	0.00010 mg/L

Pesticides and herbicides are harmful to turfgrass growth, even in small amounts. The AGWR lists organic compounds that could risk the environment; however, most pesticides identified have insufficient data to establish a reliable trigger value. Diuron, terbuthylazine, mecoprop, and triclopyr were detected in both Mangere and Rosedale WWTPs. The USEPA registers all pesticides sold and distributed in the country to ensure there are no harmful effects on the public and the environment. According to the USEPA, diuron is considered slightly toxic and can irritate the eyes and throat. It is also poisonous to marine life and could potentially contaminate groundwater. Terbuthylazine is reported to have a relatively low acute toxicity level with insufficient evidence to establish human carcinogenicity. Mecoprop and triclopyr are known to be slightly toxic and can cause redness, swelling, and cloudy vision in humans. There is inadequate proof that mecoprop and triclopyr cause cancer in humans. A holistic risk management approach would be most valuable for herbicides and pesticides in treated wastewater used for irrigation to establish possible exposure events and implement appropriate controls.

8. TE MANA O TE WAI

The concept of te mana o te wai has become synonymous with New Zealand's freshwater management sector. The Māori phrase describes the intrinsic significance of water and recognises waterbodies as an entity/being with mauri (life force), whose existence needs to be protected first to ensure the health and wellbeing of the community are looked after for future generations (Afoa & Brockbank, 2019). This acknowledgement is linked to the phrase "te mauri o te wai o Tāmaki Makaurau" which describes the importance of water in the context of Auckland: "The life-supporting capacity of Auckland's water is protected and enhanced." Brockbank (2021) explains that te mana o te wai also means we consume water efficiently by reducing water loss and miss-use.

According to GHD et al. (2020), community engagement with local Iwi groups around wastewater management has revealed that the first choice from a Māori perspective is for treated wastewater to journey through the land before it flows to surrounding marine environments and water bodies. This shows consultation with tangata whenua (Māori people of a particular locality) at the start of a project and embedding Te Tiriti o Waitangi in environmental policies is a step in the right direction toward changing the narrative around recovering treated wastewater for non-potable uses in NZ.

Using clean effluent from Mangere and Rosedale WWTPs to irrigate public sports fields in Auckland is fundamentally linked to te mana o te wai and te mauri o te wai. Allowing treated wastewater to be reused and filtered through the land protects the rivers and oceans from pollution and safeguards the city's water future by reducing the burden on potable water sources. To give effect to te mana o te wai in proposed recycled water projects and ensure a successful outcome, it is essential for local government to actively engage with tangata whenua and communities from the very start.

According to Morgan (2006), recycling treated wastewater is a possibility; however, the integrity of the mauri will affect how it can be utilised. The Mauri Model is a practical approach to ensure recycling wastewater is culturally acceptable and consists of rating health, hygiene, technical and economic criteria according to mauri enhancement or deterioration. Morgan (2006) further states that returning the wai (water) to the ground or land is the only way to enrich the mauri of treated wastewater truly.

Māori ethics are based on the system of Kaitiakitanga (guardianship/stewardship). Kaitiakitanga creates a deep sense of duty in Māori to defend and improve the mauri of water for future generations. Using treated wastewater to irrigate sports fields can be viewed as enhancing the mauri of the effluent; however, tangata whenua consultation and the Mauri Model are essential to confirm this connection.

9. CONCLUSION

Climate change is affecting Auckland's weather patterns, and water sources are diminishing. Worldwide, using treated wastewater to irrigate sports fields is a practical way to overcome water shortages. However, recycled water reuse is currently unrecognised in NZ literature. This is highlighted by the absence of recycled water reuse guidelines for unrestricted irrigation and best practice documents in the country. Guidelines from USEPA and Australia can provide a starting point for NZ to develop a suitable regulatory framework for beneficial wastewater reuse on land. The Australian regulations offer a unique risk management approach and provide a holistic way to evaluate the feasibility of irrigating urban open spaces with clean effluent.

The two most significant public health risks associated with using treated wastewater for sports field irrigation are exposure to pathogens and groundwater contamination. The best way to protect public health is first to remove pathogens, emerging contaminants, COCs, and heavy metals as much as practically possible before distributing the effluent for irrigation. It is also imperative for groundwater modelling and plant uptake studies to be carried out when assessing the feasibility of applying recycled water on land.

The Mangere and Rosedale WWTPs in Auckland provide a robust and effective treatment process to classify the final effluent from both plants as overall suitable for sports field irrigation. In general, all effluent characteristics discussed are below or within range of the Australian recommended values. The only exceptions are faecal coliforms and enterococci, which were compared to stringent USEPA guidelines of nil detection of FC. Given the inconsistency of the data source, further investigation is required. Depending on the outcome, additional tertiary treatment may be a possible solution to effectively reducing pathogens so that the effluent can be used to irrigate sports fields without ill effects on public health. Together with further pathogen testing, consultation with tangata whenua is necessary to break community barriers and ensure a successful project.

The Rosedale WWTP is located nearby Rosedale Park, which consists of public sports fields and open spaces. The location of the WWTP is ideal for using treated wastewater for irrigation at the park as it eliminates the need for extensive bulk infrastructure to transport the clean effluent and reduces the need to incorporate additional amounts of residual chlorine in the piped network. Even though Mangere does not have any community sports fields in proximity, Ambury Regional Park is not too far away and could be investigated further for recycled water reuse opportunities.

The future of treated wastewater reuse in NZ rests upon the endorsement by regulatory bodies, consultation with Māori, and a comprehensive recycled water reuse guideline document.

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