Electrocoagulation Wastewater Treatment

Evaluation for Taipa Wastewater Treatment Plant

Prepared for Far North District Council
Prepared by Beca Limited

20 August 2020

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Contents

Revision History

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on behalf of	Beca Limited		

1 Introduction

The Far North District Council (FNDC) East Coast Wastewater Scheme collects wastewater from the residential, commercial and school properties in the Taipa, Cable Bay, Coopers Beach and Mangonui communities and pumps to the wastewater treatment plant located to the south behind the built-up area at Taipa (Taipa WWTP). Treatment consists of three treatment basins in series followed by a maturation oxidation pond.

The three series basins operate as an aerated primary basin, a quiescent settlement basin and a mixed stabilisation basin. The stabilisation basin discharge enters a large maturation basin for effluent quality improvement through a long residence time (approximately 20 days), the growth of algae and the effect of sunlight. The treated effluent is pumped to wetlands that discharge to the Parapara Stream.

FNDC has been approached by a local equipment vendor (Maurilogical Ltd - Mr Kurmann) for consideration of upgrading the quality of the effluent by treatment with an electrocoagulation technology.

In 2018 NIWA prepared a report for FNDC titled *Electrocoagulation of Wastewater Treatment Pond Effluent.*[1] The report provided a comprehensive review of the electrocoagulation technology and performance, and documented bench-scale tests of electrocoagulation of algal wastewater pond water carried out at NIWA facilities using samples from the Cambridge WWTP. Operational requirements and treatment costs were presented.

This Beca report evaluates the technology, reviews the performance and costs, to objectively inform FNDC and to provide a basis for an implementation decision with reference to the Taipa Wastewater scheme. The comprehensive information on the EC technology and operating conditions provided in the NIWA report will be referenced where appropriate, rather than re-presenting data in this report.

2 Electrocoagulation

Electrocoagulation (EC) is not a new process and was first proposed in the late 19th Century as a sewage treatment process. Following a long period where EC was not a favoured technology for large scale application, it has re-emerged as a viable technology, particularly for treatment of industrial wastewaters containing heavy metals and complex organics. Municipal wastewater treatment by EC is still considered a niche application.

[1] *Electrocoagulation of Wastewater Treatment Pond Effluent – Electrocoagulation Review,* NIWA, March 2018.

Evidence tabled at the Northland Regional Council (NRC) resource consent hearing for the Taipa WWTP discharge in July 2019, noted that the treatment plant effluent after the wetlands was generally adequate for BOD, TSS and bacterial removal, however the ammonia concentration was considered excessive. Improvements for ammonia reduction were considered appropriate. The FNDC option to treat the maturation pond effluent with EC would target specifically the removal of algae, reduction of nutrients (N & P) and reduction of microorganisms. There are relatively few examples of this EC application, so the bench trials conducted by NIWA on algae pond waste water are particularly informative.

2.1 How does it work

The removal of suspended particles from wastewater to improve water quality is often achieved by adding a coagulating chemical such as alum or ferric chloride. When mixed in the wastewater the chemicals first dissolve to form aluminium or ferric ions, which carry a positive charge. Natural suspended particles, such as sediments or algae, carry a negative charge which is neutralised by the positive ions, causing the particles to clump together and form a sludge. Removing the sludge leaves cleaned water for discharge.

In its simplest form electrocoagulation is another means of putting aluminium or ferric ions into water. Rather than adding a chemical, the ions are "dissolved" directly from metal aluminium or iron electrodes using an electric current.

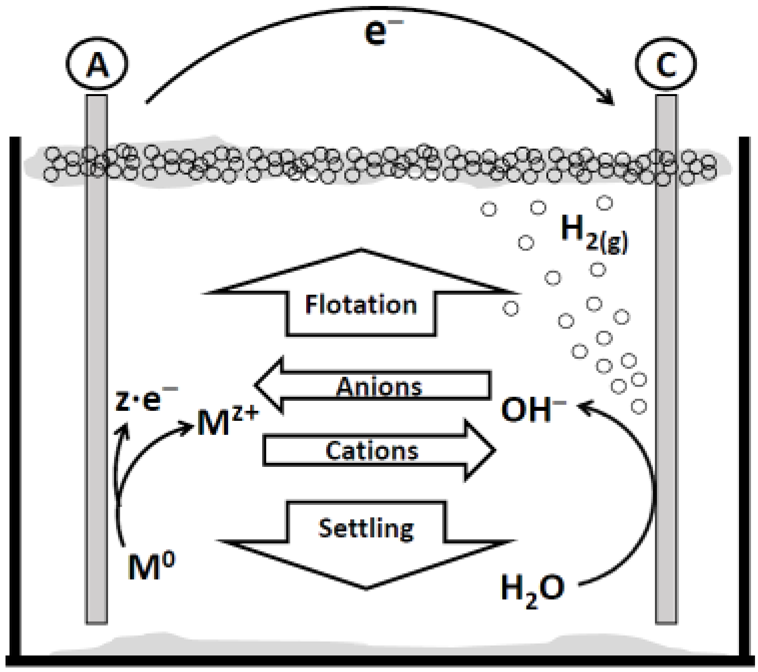

Figure 1: Configuration of EC cell

While the basic coagulation effect is similar for both chemical addition or EC, there are a number of other reactions that occur simultaneously with EC that can enhance the treatment performance (Figure 1). These include, formation of metal hydroxide flocs that capture small solids by enmeshment, cathodic liberation of oxidants (hydroxyl radicals OH^-) that react to reduce the COD, liberation of hydrogen bubbles that assist to "float" the flocs for enhanced removal and electrical disruption of bacterial cells to reduce viable microorganisms, such as *E.coli*. If the wastewater contains sufficient chloride ions the electrical current also produces hypochlorite that increases oxidation of organic material, ammonia and reduction of microorganisms.

2.2 Electrical configuration

Three different modes of electrical connection of the electrodes are applied in electrocoagulation as shown in Figure 2, (a) monopolar parallel, (b) monopolar series, (c) bipolar parallel.

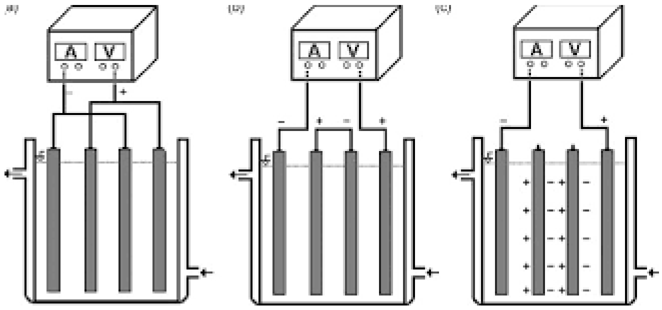

Figure 2: Electrode electrical connection (image[2])

The monopolar parallel connection (a) splits the current between all electrodes regardless of the resistance of the individual electrodes resulting in a lower voltage difference compared with serial connections (b). In the bipolar parallel connection (c), sacrificial electrodes are placed between parallel electrodes without electrical connection. The bipolar arrangement has simple setup and low maintenance. The EC bench test reported by NIWA and the trials by Andreas Kurmann submitted in the resource consent hearing used a bipolar parallel connection.

Passivation of the of the cathode due to the formation of an oxide layer results in a decrease in current flow between the electrodes leading to increased power consumption and decreased treatment efficiency. Various electrical power techniques have been developed to minimise cathodic passivation. Periodic polarity reversal and alternating pulse current (APC) are reported to significantly reduce passivation effects.

2.3 Electrode composition

The anode composition of the EC cell determines the nature of the reactions that will occur. For aluminium or iron electrodes the reactions add the related metal ions to the water to act as coagulant. Selection of the metal type for coagulation (aluminium or iron) is usually based on experience or bench-scale testing to determine the optimum metal.

The cathode is typically the same material as the anode although an inert material (SS or graphite) can be used. The NIWA and Mr Kurmann bench trials used an iron–iron electrode pair.

2.3.1 Electrodes for algae removal

For algal removal by EC both aluminium and iron electrodes have been used. Literature references appear to favour aluminium for algal removal. Aluminium electrodes produce cations with an oxidation number of +3 (Al^{3+}), whereas iron electrodes produce cations with a mixed charge (Fe^{2+} and Fe^{3+}) and can thus be a slightly weaker coagulant at some pH levels compared with Al^{3+}. It is reported that iron electrodes perform better at lower pH and that the sludge produced is denser and settles faster. However, removal efficiency is also determined by electrode voltage and current density and electrical conductivity of the liquid, so the optimal electrode metal selection is site specific. The maturation pond pH will typically tend to rise (above pH 8) during the day due to photosynthesis and decline during darkness, so the overall performance difference between the different electrodes may be marginal. It is noted that the NIWA algal EC studies were carried out successfully with iron electrodes.

[2] *Techno-economical evaluation of electrocoagulation for the textile wastewater using different electrode connections,* Kobya M. et a, J.jhazmat, 2007

The presence of chlorides in the water generates hypochlorite at the anode which can become an additional oxidising agent and bactericide to increase COD removal and bacterial reduction. The release of hypochlorite also increases the reduction of ammonia by chlorination. No information is available on the chloride concentration in the Taipa wastewater but, given that the sewerage area is in the coastal fringe, there may be an elevated chloride level due to saline groundwater infiltration. Gaining an understanding of the chloride concentrations in the raw wastewater and post maturation pond effluent would be a necessary part of any characterisation programme for procurement of an EC system for Taipa.

2.4 EC Performance

2.4.1 Optimal performance conditions

There are multiple parameters that influence the optimal operating conditions of the EC process:

- Wastewater characteristics – pH, TSS, TDS, electrical conductivity, ionic composition, temperature,
- Cell configuration – electrode material, electrode orientation, inter-electrode spacing, electrical connection,
- Residence time – wastewater flow rate, EC volume,
- Power input – voltage, current, current density, polarity reversal.

2.4.2 Cell configuration – vertical/horizontal – electrical configuration - spacing

It is more common for EC electrodes to be placed in a vertical configuration with the waste flow either horizontal or vertical depending on the supplier. There are advantages and disadvantages of either arrangement.

Vertical orientation with upflow of the waste allows for evolved gasses from the electrodes to be expelled upwards with the waste thereby minimising the potential for solids to clog between the electrodes.

2.4.3 Power -voltage – current density – polarity reversal, pulsed AC

For electrocoagulation the anode material is sacrificial and “dissolves” as the coagulant chemical. The rate of anodic metal dissolution is governed by Faraday’s law, which states that the mass of metal liberated is directly proportional to the quantity of electricity (charge) passed. The metal coagulant dose is therefore controlled by the current between the electrodes. The solution conductivity and electrode spacing determines required current and voltage necessary to achieve the required metal dose to achieve satisfactory coagulation. Some EC systems dose salt (NaCl) to maintain stable conductivity.

The power supply is typically drawn from the AC grid mains and conditioned to direct current (DC) to suit the operating settings of voltage and current of the EC unit. Automatic control of applied voltage and current to meet the required current density (metal coagulant dose) can be adjusted based on the conductivity. Automatic polarity reversal or pulsed AC is applied to minimise polarisation effects.

2.4.4 Electrode replacement

The loss of metal from the anode means that the anode system must be replaced on a regular basis when the plate cross sectional area reaches a minimum operating condition. To expedite the replacement operation the electrode assembly is generally constructed in a modular configuration whereby the complete assembly is replaced.

The plate life is determined by the rate of metal loss and the mass of the plate. For a 25 mg/L $FeCl_3$ equivalent dose (8.6mg/L Fe^{3+}) at the consented Taipa ADWF of 790m^3/d, the plate loss is approximately

6.8kg/d. Mr Kurmann's response to the Hearing Commissioner notes the requirement for electrode replacement every 6 to 8 weeks.

2.4.5 Removal of contaminants

The objective of the proposed EC treatment is to improve the quality of the wastewater discharge in respect of:

a) Suspended solids (TSS), dissolved solids (TDS),

b) Organics (COD, BOD),

c) Nitrogen (ammonia, nitrate, organic),

d) Phosphorus,

e) Microbiological,

f) Heavy metals.

a. Suspended and dissolved solids

The formation of positively charged metal ions within the EC reactor will coagulate (destabilise) negatively charged suspended solids (algae, biosolids) along with the formation of metal hydroxide flocs, resulting in the agglomeration of solids into a flocculant sludge within the EC reactor. Suspended solids removal can be by settlement or mechanical separation (e.g. centrifuge) from the clarified effluent. Settlement TSS removal rates >90% were reported in the NIWA EC trials on algae pond effluent.

b. Organics

A high level of COD-BOD removal could be expected by EC, especially if the maturation pond effluent is treated. The reduction of the COD-BOD fraction of the wastewater associated with suspended solids (algae, biomass) is effectively removed with the sludge. The soluble fractions will be reduced by the coagulation and oxidation at the electrodes. Greater than 90% of COD-BOD can be removed.

c. Nitrogen

The removal of nitrogen compounds by EC is variable. Organic nitrogen (as TKN) associated with particulate material, such as algae, is reduced when solids are removed. NIWA reports 50 – 80% TKN removal.

Nitrate removal is sensitive to the reaction time and the current density. Increasing the reaction time to an excess of 30 minutes and increasing the current density demonstrated a 96% nitrate removal using aluminium electrode pairs[3]. Results from Mr Kurmann's trials on Taipa settlement pond overflow indicate nitrate removal rates of up to 85% using iron electrodes. The current density was not stated.

EC reduction of ammonia is generally poor, typically around 50%. As effluent ammonia is one of the critical parameters identified in the Resource Consent as requiring reduction, the ability of the EC system to maximise removal is crucial. Enhanced removal of ammonia is demonstrated by some EC systems with increasing residence time and current density. The removal appears to be related to the electrolytic production of hypochlorite ions from the chloride content in the wastewater, leading to oxidation of ammonia by chlorination. Additional COD removal is also attributed to the generation of hypochlorite and oxidation of organic material. Whether the chloride content of the Taipa wastewater is sufficient to meet the ammonia and COD organic demand has not been determined. Current wastewater chloride data is not reported in the present results.

[3] *Improvement of aqueous nitrate removal by using electrocoagulation/electroflotation unit with vertical monopolar electrodes,* M. Majlesi et al, Sustainable Environmental Research, 2016.

The NRC recommended Resource Consent conditions (July 2019) propose that the annual median ammonia – N concentration in effluent after upgraded treatment shall not exceed 10mgN/L. Ammonia results for the overflow of the settlement pond (pond 3) reported by Mr Kurmann indicate values of up to 73mg/L (Sample 29 5/2/2019). The Taipa and NIWA bench trials show it is unlikely that EC treatment of the pond effluent will consistently achieve the required ammonia removal of >80% to meet consent conditions. If the maturation pond ammonia concentration can be reduced by upstream process modifications, e.g. increased aeration capacity to encourage nitrification or augmentation of the chloride content, the EC treatment may be able to assist in meeting the proposed ammonia limits.

d. Phosphorus

Phosphorus (phosphate) removal by EC using aluminium or iron electrodes is effective and generally removal rates approach 100%. The phosphorus is chemically bound into the sludge. The NIWA bench trials report >99% DRP removal. The trials undertaken by Mr Kurmann on Taipa effluent record phosphorus (phosphate) concentrations after treatment of ~1mg/L or less, starting from levels of 20 – 30mg/L.

e. Microbiological

Bacterial concentrations are reduced during EC treatment due to coagulation of solids, cellular disruption by electric field between the electrodes, exposure to hydroxyl radicals (OH-) and by disinfection by hypochlorite produced from chloride. The NIWA study reports a 3-$\log_{10}$ reduction in *E.coli* with algal pond water. Mr Kurmann also reports *E.coli* reductions in the similar 3-$\log_{10}$ range (99.9%). Note that this does not mean the effluent is fully sterilised by EC treatment, only that the treated effluent could be expected to meet *E.coli* standards for recreational freshwater quality.

f. Heavy metals

Heavy metals removal efficiencies are determined by the electrode metal selection, the applied current density, the residence time and pH. Under neutral pH or alkaline conditions, the removal is generally close to 100% from the formation of metal hydroxide solids or adsorption onto the sludge. The Taipa wastewater is anticipated to have heavy metal concentrations typical of domestic sewage, with the expectation that heavy metals would be effectively removed with EC treatment. The precipitated metals would be recovered into the sludge. Sludge disposal should consider the heavy metal content.

2.5 Post EC treatment

After the coagulation and electrochemical reactions in the EC system the treated wastewater will require post treatment to remove the produced flocculated solids and provide a clarified effluent. Options include:

Clarification:

- simple sedimentation (clarifier) if the flocculated sludge from the EC unit settles well,
- Floatation clarification (DAF) using the inherent hydrogen gas buoyancy from the EC unit,
- Media filtration (sand, multimedia) following the primary floc removal step,
- Direct mechanical sludge separation (centrifugation).

A review of literature available from EC supplier websites indicates that utilisation of the hydrogen gas evolution from the EC unit cathode to assist with the floatation of the sludge is commonly applied in an integrated EC – floatation treatment step. The need for post filtration following an EC – floatation step depends to the desired quality of the final effluent. For the Taipa discharge to wetlands or irrigation it is unlikely that total clarification of the effluent would be required.

Dewatering:

Following clarification, the sludge can be dewatered for disposal. Typically this would be by mechanical dewatering by;

- Centrifuge – this may also be used as the primary clarification step with appropriate equipment selection.
- Belt press
- Screw press
- Filter press

Disposal of the sludge will need to consider the Ministry of Health guidelines to identify the appropriate method and location to meet sanitary requirements.

2.6 Commercial EC

Internet search results suggest that there are relatively few electrocoagulation equipment manufacturers globally, however there are over 20 water treatment suppliers identified who offer integrated wastewater treatment solutions using original EC equipment from manufacturers. The following manufacturers of EC plant are noted, although it is not a definitive list:

- Powell Water Systems - USA
- Boydel – Canada
- WaterVision Inc – USA
- Watertectonics Inc – USA
- Kaselco (Baker Corp) – USA
- Samtech Pty – Australia
- Aqualogy – Spain (now part of Suez)

The majority of EC installations referenced by the suppliers are for industrial wastewater. While several bench scale tests on municipal domestic wastewater are reported in literature there are few larger scale applications reported. The applications appear to be used for small scale, decentralized municipal domestic sewage treatment. Powell Water Systems refer to trials undertaken on Publicly Owned Treatment Works (POTW) plants and provide results in a technical bulletin[4]. The results appear to be from a pilot study not a full-scale operation.

We are not aware of any municipal wastewater treatment systems using electrocoagulation in New Zealand.

3 EC at Taipa WWTP

3.1 PWS EC Equipment

The FNDC proposal offer by Mr Kurmann is based on the Powell Water Systems (PWS) technology. The pilot test unit used by NIWA for bench testing was supplied by PWS.

As a supplier of electrocoagulation systems, PWS has been in the marketplace since circa. 2000 and would be considered a mature and reputable company. PWS holds a patent (Issued 2002) for the specific configuration of the electrode plates and the power supply arrangement of their equipment which claims to

[4] Powell Water Systems Inc. Technical Bulletin Copyright 1994 – 2001.

provide an efficient and effective EC treatment process. Their primary configuration of vertical electrode plates is arranged to provide a water flow path that permits co-movement of the coagulated waste and the generated gas bubbles to minimise potential fouling of the inter-plate space. This configuration permits close spacing of the electrodes allowing the use of a simple power supply system, increasing efficiency and reducing cost.

As noted in the NIWA report (Section 7.3) PWS have commercial-scale EC equipment with a treatment capacity up to 2750L/min. For the full-scale plant Mr Kurmann proposes a PWS EC500 process unit with a nominal treatment capacity of 50m^3/h. This is sufficient to accommodate the consented average daily flow of 790m^3/d (33m^3/h) from the Taipa WWTP plus a peak wet weather flow to 1200m^3/d. Mr Kurmann has provided a budget capital cost for the PWS EC500 unit alone of $950,000. The cost does not include design, site development, power supply and additional costs for sludge storage thickening or dewatering.

The basic EC unit offered (as per website details) does not appear to have any integrated solids removal processes so additional downstream equipment is required. Bench-scale EC trials by Mr Kurmann (submission to Taipa WWTP consent hearing 2019) provided photographs of algal sludge settlement after 5 minutes and 4 hours. The sludge appeared to have settled well, indicating that a simple clarifier may be effective for solids removal. EC trials carried out at NIWA laboratory (NIWA report) show a similar effective settlement. Quantification of the sludge volume relative to the quantity of wastewater treated is not given in the results.

However, relatively little further detail on the actual PWS EC equipment and sludge management equipment has been provided. Additional information has been sought from Mr Kurmann.

This information was received in August 2020 subsequent to the writing of the main report and is provided in the Appendix with additional commentary where appropriate.

3.2 Other EC equipment suppliers

EC equipment by other manufacturers use a variety of electrode and reactor configurations. Each claim to have an advantage in terms of power efficiency, electrode replacement etc. It is beyond the scope of this report to evaluate alternative suppliers and equipment. It is noted a number of suppliers offer EC treatment units that are integrated with a flotation-clarification step using the evolved gasses from the electrolytic action of the EC cell. There appears to be some merit in this approach in terms of sludge separation efficiency and equipment configuration.

Complete containerised EC treatment units are offered by some suppliers, including sludge removal, effluent filtration and laboratory space. This concept may be of interest to FNDC as it possibly obviates the need for buildings and other infrastructure.

4 Location of EC at Taipa WWTP

Within the Taipa treatment plant process there are potentially three process locations where the EC treatment could be applied, as shown in Photo 1;

1. Between basins 2 and 3,
2. The overflow of basin 3 to the maturation pond,
3. The overflow of the maturation pond to the wetland.

Photo 1: Taipa WWTP configuration (from A. Kurmann evidence to Hearing Commission July 2019)

Mr Kurmann has provided information to the Hearing Commission on EC bench tests he has carried out on the discharge from locations at the WWTP. Reference is made to samples from the “settlement pond”, unfortunately is unclear whether this relates to location 2 or location 3.

Treatment of the discharge from basin 2 (location 1) would place the highest load on the EC system and would require the highest peak flow processing capacity due to the limited upstream hydraulic buffering. The EC performance would need to perform with a high inlet quality variability from the aerated treatment process (basin 1) and settlement (basin 2). EC in this location would have a limited contribution to the quality objectives of the final effluent as the following downstream treatment (basin 3 and maturation pond) will still contribute changes to the final effluent quality from continuing biological and wildlife activity.

Placing the EC system at the overflow from basin 3 to the maturation pond (location 2) would allow treatment of a reduced load with respect to the location 1 load but will still require a greater peak flow processing capacity as the hydraulic buffering of the small upstream basins is limited. Discharging EC treated effluent into the maturation pond will still allow subsequent changes to the final effluent quality due to additional biological growth in the pond and the impact of birds and animals on the microbiological quality.

The most effective location would be where the concentration of contaminants is lowest from the existing treatment processes and the least load is applied to the EC system. The overflow from the maturation pond (location 3) is considered the best location as the contaminant load is lowest and the buffer volume of the maturation pond smooths flow and quality variability and allows for a consistent water quality to be applied to the EC system. The peak flow requirement of the EC equipment is reduced at this location. The maturation pond primary contaminants will be algae solids, dissolved nitrogen (ammonia, nitrate) and phosphorus. Bacterial concentrations will be reduced due to sunlight disinfection in the pond and would be expected to be the lowest in existing treatment process sequence. The effluent quality from an EC system installed at this location would have the greatest flexibility for final disposal, either to the existing wetlands or to a land irrigation scheme.

Under maturation pond conditions the EC system can be optimised to address the contaminants of concern while producing the lowest quantities of sludge for disposal, consisting primarily of algal cells and hydroxide flocs from EC electrode reactions. Options for sludge removal could include settlement clarification or DAF. Mr Kurmann proposed a centrifuge for sludge thickening to ~20% solids for disposal, with a budget capital cost of $200,000. Without data to confirm the inlet solids concentration to the centrifuge it is not possible to assess the expected performance.

Beneficial use of the dewatered solids as a fertiliser or soil conditioner will depend on the composition of the organic matter (mainly algal cells) and the residual concentrations of metal flocs from the electrode. The use of iron electrodes is less likely to create residual limitations in the soil. Residual aluminium in the sludge from the use of aluminium electrodes may limit the land application rates. The economic viability of beneficial sludge reuse would require further investigation, including compliance with Ministry of Health requirements for wastewater sludge disposal.

Disposal of sludge from the EC process into the basin 2 settlement pond has been suggested as an alternative to landfill or land disposal. Accumulated sludge would be removed with the periodic desludging every 8 to 10 years. The idea is attractive as the expense of dewatering the EC sludge on a continuous basis is avoided. The rate of sludge accumulation and the impact of metal coagulant on the basin performance would need to be evaluated.

5 Operational requirements

The following preliminary assessment considers the installation of a PWS EC treatment process and ancillary sludge handling equipment at the Taipa WWTP site to treat wastewater from the existing maturation pond outlet for discharge to the existing wetland and Parapara Stream system or to a land irrigation disposal scheme. This is based on information provided by FNDC, submissions by Mr Kurmann to the Resource Consent Hearing and the bench scale testing by NIWA.

1. Iron or aluminium electrodes

   As noted in section 2.3.1, while both aluminium and iron electrodes are capable of flocculating algae, the use of aluminium electrodes is favoured for algal removal. The PWS EC bench scale unit used iron electrodes for cathode and anode. It is assumed that the full-size EC equipment would also use iron – iron electrodes.

2. Power demand

   The power consumption of the EC process will depend on the voltage and current settings used, the area of plates and the conductance of the liquid. The NIWA EC bench trials measured a power consumption range of 0.26 – 1.52 kWh/m^3 across 3 trials at various current densities. Literature values range from ~0.9 – 2.5kWh/m^3 for algal removal depending on the evaluation conditions.

   Using a moderate power demand of 1.0kWh/m^3, the EC treatment of 790m^3/d ADWF would require 790kWh/d. For an energy tariff of $0.30/kWh the annual EC power cost would be $86,000. Mr Kurmann estimated an annual power cost of $73,000. This does not include the additional power demand associated with pumping wastewater through the EC unit, sludge dewatering and handling or other ancillary power consumption. It is not possible to assess these additional demands with the current information available but a provisional site electrical allowance of up to 70kW would not appear unreasonable.

   By comparison, a modern, high rate, nitrifying activated sludge process uses about 0.9kWh/m^3 in total for pumping, treatment, UV disinfection and sludge dewatering

   It has been suggested that solar photovoltaic power could be used to offset the energy consumption from the grid. Assuming that solar PV power would be available for 8 hours per day (averaged over the year) a PV system to power the EC unit alone for this period would need an installed capacity of at least 35kW (~120 panels with total area ~200m^2). Additional PV capacity would be necessary to meet the total daily power demand of the treatment system. Battery storage of sufficient capacity to operate the plant at night or for any sustained cloudy period would appear to be in the order of

400kWh. This is a large battery installation and would require additional PV capacity to charge during the day. It is unlikely to be economically viable. A more detailed analysis of the power demand and solar PV capacity would be needed to examine the business case for economic viability and carbon footprint.

3. Electrode life and replacement

   The operational life of the electrode stack has been estimated by Mr Kurmann as 6 – 8 weeks based on a nominal Fe dose of 25mg/L. The simplicity of electrode replacement for the EC500 unit is not provided in detail but Mr Kurmann notes that replacement of the iron plates would take 1 to 2 hours. Depending on the specification and shape of the plates it is assumed that the plates could be sourced locally. In his answers to the consent hearing (July 2019) Mr Kurmann notes the annual cost estimate for electrode replacement would be $14,900. It is not stated if this includes site installation.

4. General operational requirements

   The EC unit should require relatively low operator attendance as the electrical control is automatic. A daily check is suggested by Mr Kurmann. Management of the sludge removal system (two-way dewatering centrifuge) and would require additional operator input. This additional time is not quantified. An annual operator cost of $8,500 has been suggested by Mr Kurmann. The number operator hours per week is not stated.

6 Summary

The current assessment of electrocoagulation technology and the applicability of an EC treatment plant for the Taipa East Coast Wastewater Scheme has been based on information provided by FNDC, Mr Kurmann and a report on electrocoagulation by NIWA. Additional information was drawn from the Resource Consent Hearing evidence and publicly available resources on the internet.

The key observations from the review are:

1. The electrocoagulation process is a mature treatment technology based on the electrolytic liberation of soluble metal ions from metallic plates to provide coagulation of the wastewater stream. In addition to the liberation of metal ions there are a number of electrooxidation reactions that produce oxidants (hydroxide radicals, hypochlorite) that enhance the reduction of contaminants. Several commercial suppliers of EC equipment are available, including completely containerised units. All are located internationally outside of New Zealand.
2. EC has been successfully applied to a variety of commercial full-scale industrial applications. It is less frequently applied to municipal wastewater treatment, particularly at larger scale where it is less economic than conventional treatment processes. We are not aware of any EC treatment plants in New Zealand treating municipal wastewater.
3. The specific application of EC to the Taipa Wastewater Scheme has been considered as a concept proposal based on treatment of the wastewater from different locations within the existing pond system. The preferred treatment location would be the effluent discharge from the final maturation pond. This location is considered to apply the lowest organic load to the EC process, consisting primarily of algae solids, and to make most use of the maturation pond volume for peak flow buffering.

4. Testing of EC treatment of algal pond effluent reported by NIWA and similar tests by Mr Kurmann has shown that a good-settling sludge can be obtained that would favour a simple clarifier for post treatment. Thickening of the sludge by centrifugation for disposal is considered by Mr Kurmann, although little detail of the equipment is available. The quantity of sludge produced has not been identified. The potential of sludge disposal to the existing settlement pond is an option to reduce dewatering costs.
5. The effluent quality from the EC process is required to meet the discharge criteria set out in the Resource Consent conditions. The performance of the EC process in terms of effluent suspended solids, BOD/COD, phosphorus, heavy metals and microbiology is considered likely to be adequate to meet the consent conditions. The ability of EC to meet the ammonia limit of <10mgN/L is less certain as removal rates of 50% - 80% may not be sufficient, given the relatively high inlet ammonia concentrations reported.
6. Capital and operating costs are difficult to determine from the available information specific to the Taipa WWTP proposal as no actual equipment specification has be provided. Mr Kurmann has given a budget cost of the EC unit as $950,000 and a cost of $200,000 for the sludge dewatering centrifuge. Costs for the balance of plant, e.g. pumping, power supply, civil works, buildings etc. are not provided and would have to be estimated.
7. Power consumption has been estimated from NIWA test results and typical literature values for EC operation. A typical reported value is of the order of 1kWh/m^3 treated. For the Taipa WWTP consented design average flow of 790m^3/d a power demand of approximately 790kWh/d could be typical. At design flow this is an annual cost of some $83,000. Power costs would be lower at the inception of the scheme with lower flows.
8. While solar PV could be an option to offset the daily power demand it is unlikely that the cost of a battery system to cover night time and cloudy periods would be viable. Further financial analysis would be required to define CAPEX and operating return.
9. Other operating expenses relate to the periodic replacement of the electrodes (6 – 8 weeks) with an estimated cost of $14,900 pa and an operator expense of $8,500 pa (data from Mr Kurmann).
10. The current information provided on the detail of the proposed EC treatment process for the Taipa WWTP is insufficient to assess whether the process will be economically viable for the improvement of the effluent for discharge to the stream or for irrigation.

A

Appendix – Information from Mr Kurmann

Information from Mr A. Kurmann

An email information request was made to Mr Karmann on 23rd September 2019 for clarification and additional information on his proposal for EC treatment at Taipa. Further telephone contact was made with Mr Kurmann on 25th June 2020 to request an update on the supply of information.

Information was received from Mr Kurmann by email on 3 August 2020. Five items were provided:

1. EC Trial TWWP AK.pdf
2. Final FNDC Electrocoagulation report.pdf
3. Electrocoagulation-is-it-cost-effective-for-Wastewater-Treatment-NIWA-2019.pdf
4. Sewage Hydro OK.pdf
5. Worksheet in EC trial TWWP.xlsx

Items 2, 3 and 4 appear to be information previously presented in evidence at the NRC Resource Consent Hearing in 2019. They contain no new information and have already been commented upon in the body of the Beca report.

The EC Trial TWWP report (item 1) dated July 2020 provides an update on the previously submitted information with additional testing of the Taipa wastewater using an alternative small EC unit (Maurilogical) and a small commercial EC unit (Maurilogical). The Worksheet (item 5) contains the laboratory test results for 3 sampling periods undertaken after the consent hearing evidence presentation, viz June 2019 (4 results), December 2019 (2 results) and May 2020 (4 results). Samples were taken from the settlement pond, which is Location 3 in the Beca report.

Removal Performance

The EC Trial TWWP report details additional performance information based on the testing of the Maurilogical EC unit. A table of % removal performance is provided. It is not possible to establish the correlation between table removal values and the sample analysis results given in the spreadsheet as the report table samples are unidentified.

Analysis of the results for the Murological EC unit indicate significantly different inlet quality for the 3 sampling periods. June 2019 results show high ammonia and low nitrate concentrations, whereas the December 2019 show a lower ammonia and higher nitrate. The May 2020 test results refer to a Vortex treatment (undefined in the EC report) which results in very low ammonia (0.1mg/L) and high nitrate (261mg/L). It is presumed that the Vortex treatment is some form of aeration/biologic treatment to reduce the ammonia to low levels.

The based on the data provided the calculated Maurilogical EC performance for these periods is:

Sample	EC influent ammonia concentration mg/l	EC effluent ammonia concentration mg/l	Ammonia removal %	Nitrate removal %	Phosphate removal %
June 2019	72	27 - 28	61% - 63%	44% - 49%	97%
Dec 2019	21	1.8	91%	77%	99%
May 2020	2.7	0.3	89%	56% - 59%	96%

Average values quoted in EC report			75%	>80%	>95%

The ammonia % removal performance is similar to the values noted in the Beca report and correlates with the influent concentration where lower removal occurs with the higher ammonia. Note that the discharge consent condition has a maximum of 4 samples per year allowed to exceed an ammonia concentration of 15mg/L. The measured EC performance for June 2019 could breach this limit if a sustained period of high influent ammonia occurs. The nitrate and phosphate % removal values are consistent with the Beca main report.

The report makes reference to a Vortex trial which purports to reduce the ammonia concentration by conversion to nitrate. No details of this process are provided. The wastewater sample (27/5/2020) was treated for 24 hours by this process with a resultant residual ammonia concentration 0.1mg/L. The pond overflow inlet sample contained 2.7mg/L ammonia, which is not a particularly challenging input to the Vortex trial to determine efficacy.

Sludge management

Additional information of options for clarification of the EC effluent to remove the flocculated sludge have not been advanced. It is suggested that the sludge could be beneficially reused as a fertiliser. As the sludge is associated with sanitary wastewater treatment the national biosolids guidelines will determine the acceptable reuse requirements.

Operating costs

The EC report has provided revised estimate figures for power consumption and electrode consumption. The power consumption is estimated at 0.75kWh/m^3 treated. The power rate is quoted at $0.18/kWh. The power cost will vary with the expected wastewater flow and the electricity rate. The EC report estimates an annual power cost of $27,000 based on a flow rate of 200,000m^3 (~550m^3/d). Note this is not the maximum permitted flow of 790m^3/d.

The cost estimate used in the Beca report is 1.0kWh/m^3 with a nominal power rate of $0.30/kWh.

An estimate of the electrode consumption has been provided in the EC report based on an equivalent Fe dose of 23.7g/m^3 and a flow of 200,000m^3/d. A total annual consumption of 4740 kg/annum at a cost of $2/kg for iron plate giving an estimate electrode replacement cost of $9,855 per annum. It is not stated if this cost includes fabrication of the electrode stack and site replacement.

The equivalent Fe consumption rate in the Beca report was 25g/m^3 with a rolled steel plate cost of $1.70/kg.

CAPEX

No additional information on the cost of the EC unit and ancillary equipment has been provided. The proposed EC equipment vendor has been changed from Powell Systems (due to excessive capital cost) but no specific alternative vendor has been identified. The previous capital estimate for the EC unit was $900,000. No new costs are given. Sludge dewatering by centrifuge or co-settlement in the existing pond is proposed. No additional centrifuge costs are provided. The previous centrifuge cost estimate was $200,000.

Commentary

The EC report has added some additional information based on further testing, however there is no substantial change from the data available at the time of the consent hearing. The key effluent quality performance of ammonia removal and power costs, electrode costs and solids dewatering equipment are still unresolved.

Beca considers there is still insufficient information provided by the additional reporting to allow a considered evaluation of the EC process as a viable treatment strategy for the Taipa Wastewater Treatment Plant able to meet the discharge resource consent conditions.

The EC report recognises that the treatment trials to date are based on a batch treatment process and that a pilot trial with continuous flow is required to fully define the performance and operating parameters. If FNDC wish to pursue electrocoagulation as a potential treatment solution it is recommended that continuous pilot trial is considered. It will be important to develop a comprehensive and detailed implementation pilot testing programme to ensure that all the critical parameters are quantified and a robust cost benefit analysis can be completed.