THE PERFORMANCE OF BIOFILTRO AT KAKA POINT

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ABSTRACT

In a world-first application of Chilean technology, Clutha District Council constructed a trial *Biofiltro* plant to further treat the Kaka Point oxidation pond effluent before its discharge to the sea. The context of the consenting environment for the Kaka Point and other treated sewage discharges in the Clutha District produced some pressure on the Council to find an affordable solution for its urban communities so that their viability would not be threatened, while meeting enhanced environmental standards.

This context is described and the potential cost and other advantages of *Biofiltro* identified as the drivers for the decision to build the plant. Its performance is described and the effluent quality produced compared to the consent limits now in place for the discharge. While some aspects of performance still require attention, overall it has been good enough to enable the Council to commit to building four more plants.

The conclusion is reached that *Biofiltro* is an affordable and appropriate solution for the further treatment of oxidation pond effluent in the Clutha District context.

KEYWORDS

Biofiltro, sewage treatment, cost, performance, resource consent.

1 INTRODUCTION

Biofiltro is the proprietal name for a Chilean technology licensed to Biofiltro Ltd which is used to treat wastewater, whether human sewage, processing plant wastewater or animal effluent. It is a type of packed bed reactor which utilises timber shavings as a medium and worms to assist bed operation. Clutha District Council ("Council") has constructed a *Biofiltro* plant downstream of its existing oxidation pond at the coastal township of Kaka Point to further treat its effluent before discharge to the sea. Following satisfactory performance, four further plants are being constructed at oxidation ponds serving other townships in the District.

Council operates eleven sewage treatment plants, ten of which are oxidation pond systems. There are eight single ponds, one of which has a surface flow wetland for further treatment, and two twin pond (primary and secondary) systems, one also with a wetland. Nine of the ponds dispose of the effluent through a point discharge to a river or creek and one (Kaka Point) to the sea. Each of the discharges is consented by the Otago Regional Council, with a variety of expiry dates.

Five of these consents expired between 2005 and 2009. Council deals with its sewage treatment decisions and consent renewals through a Wastewater Working Party which is a Committee of Council and includes representatives from Fish and Game Otago, local Iwi and the Department of Conservation among its members. Each proposal for consent is approved by the Working Party, and this has proved to be an excellent mechanism for ensuring good consultation with these interested parties on each discharge. For each of these expiring consents, a proposal for renewal was approved by the Working Party and an application made six months before the expiry date. The existing discharges were therefore able to continue until new consents were issued.

By September 2010, no new consents had been issued. The major issue which delayed finalising the process was the objectives of the Regional Plan: Water. The first of relevance envisaged land based disposal for treated sewage in lieu of point discharges. The second called for the effluent to meet contact recreation standards for bacteriological contamination if land based disposal was not practical and a point discharge was to be authorised. Helpfully, the Otago Regional Council (ORC) wished to come to some agreement on these issues prior to granting an agreed consent, rather than deal with them adversarily through the hearing process. However, this meant effort was required to convince the ORC that meeting the bacteriological standard was not affordable for the local communities and that land based disposal was not practical. The argument for the latter is based on climatic and soil conditions in South Otago, where there is an annual surplus of precipitation over evapo-transpiration and generally low permeability soils. Soils are usually saturated for some months of the year, so land based disposal requires very large areas and storage to be effective. This means very large capital costs.

The *Biofiltro* process offered a solution to the affordability of meeting the bacteriological standard, but there was only one plant treating municipal sewage in New Zealand at the time Council was made aware of it, and that was newly completed and not treating significant volumes of effluent. Furthermore, there was no plant in the world treating oxidation pond effluent. Council felt that the process did not offer the degree of certainty required for it to commit to building five plants, but that the potential cost advantages could not be ignored. Accordingly, it decided to construct a trial plant at Kaka Point and evaluate its performance with a view to extending its application if it was warranted, an approach agreed with the ORC.

2 KAKA POINT

2.1 THE TOWNSHIP

Kaka point is a small township on the South Otago coast a short distance south of the mouth of the Clutha River. All but some outlying properties are on the community sewage disposal system which was installed in the early 1980s. The township is hilly and the reticulation drains by gravity to the coast, from where it is pumped to an oxidation pond in a secluded location about 500m from the sea to the north of the township. From the pond, effluent is discharged through a gravity pipe and outfall to the Pacific Ocean, where the final discharge point is at the approximate Mean Low Water Spring level.

There are 241 properties connected to the system, but the permanent population does not reflect this number of properties – the usually resident population in the 2006 census was 201. However, at peak periods when holiday homes are occupied, the population is estimated to reach 900. This means that effluent flows and associated loadings on the treatment system can vary widely during the year.

Historically, Council has not sought or maintained accurate records of the sewage flows (the consents held have generally not required it), so Kaka Point effluent flows are estimated from pump records. This is not entirely satisfactory, but as all effluent is pumped to the pond from the final pump station, the flow information is better than it might have been. On the basis of pump records, the average daily flow is $86m^3$ and the peak daily flow $418m^3$. This suggests a dry weather flow of perhaps $60m^3/d$ depending on the actual population at any one time.

Under Council's funding policies, until very recently each locality paid the full costs of its services. Hence, Kaka Point ratepayers paid the full cost of their sewage disposal system and were rated for it through a targeted rate. This has changed recently so that water and sewage disposal rates are capped at no more than 25% above the average rate before capping, a change which has been of material benefit to Kaka Point.

2.2 CONSENT RENEWAL BACKGROUND

The old consent (a Coastal Permit issued by the Minister of Conservation) expired on 7 July 2009 and Council, following its usual practice, engaged a consultant to identify different disposal options and a range of further treatment alternatives, to be followed by a consent application based on the preferred option.

Two land based disposal options were evaluated with estimated capital costs of \$3.0m and in the range of \$4.5m - \$6.0m respectively. These were eliminated because of the expense, the impact on 241 properties bearing this order of capital cost being obvious. Four other disposal options to a local wetland, or one of two local waterways, with or without additional treatment were also evaluated with capital costs in the range \$1.15m - \$1.5m. Each of these was eliminated on the bases of capital cost and potential consenting difficulties (including the necessity of obtaining a land use agreement from the Department of Conservation for the wetland).

This left two options on the table, both of which utilised the existing outfall. The cheaper, at $300,000, was to extend the existing outfall without any treatment improvements; the other, to upgrade the existing treatment through a rock filter and UV disinfection but do nothing to the outfall, was estimated to cost $875,000. The choice of which to proffer as part of the consent application was made on the basis of cost and likelihood of obtaining a consent.

Cost was assessed by calculating the increase in the sewer rate in the first full year of operation, a calculation which takes into account the interest cost on the necessary loan, depreciation and annual additional operating costs. The likelihood of obtaining consent was assessed by how well the disposal system and effluent quality would meet ORC objectives. In this latter respect, the approach of the ORC in wanting to reach some agreement on consent conditions, while being conscious of the costs which would be imposed on the township, was helpful as they were prepared to indicate their general approach. They accepted that land based disposal was too expensive and so focussed on the bacteriological quality of the effluent, advising that their objective would be met if the 90th percentile for enterococci was less than 140 cfu/100ml, to be set as a consent limit. This is the Alert/Amber Mode trigger level in the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (Ministry for the Environment, 2003). While Council was seeking a 35 year consent, ORC advised that a shorter term, perhaps as short as 5 years, was likely if this microbiological standard was not met, and that they viewed any claims of an environmental benefit from extending the outfall with scepticism.

The 90th percentile for enterococci concentration from the oxidation pond was 22,500 cfu/100ml, so Council felt that extending the outfall would only stave off the need to improve treatment for a five year period, hence the capital expenditure was not justified. The other option did not promise to meet the bacteriological standard, with a consent limit of 1,000 cfu/100ml being recommended by Council's consultants, but Council felt that a case could be made for a 35 year consent for this quality effluent and so resolved to seek a consent on this basis.

The increase in sewer rate in the first year for a treatment upgrade and no change to the existing outfall was estimated to be $430, which would almost triple the existing sewer rate of $222 (both excluding GST). Meanwhile, Council had settled on an increase of $250 including GST as a guideline to the cost increase it was willing to impose on its smaller communities for upgrades to sewage treatment necessitated by new consent limits. While this larger increase was well in excess of that, it was felt worthwhile if a 35 year consent could be obtained.

Accordingly, a consent application was made proffering a treatment upgrade at a cost of $875,000 and a consent limit for enterococci of a 90th percentile of 1,000 cfu/100ml. The response of the ORC was to query the costs given and suggest that, in their view, there may well be cheaper alternatives which would achieve the bacteriological standard they desired. In view of the fact that four other consents were in a similar state, rather than commit to spending significant sums on hearing (and perhaps appeal) costs, Council resolved to provide broader information to the ORC on the costs of achieving their bacteriological standard. It did this by engaging three consultants to do a desktop study and advise of methods and budget level costs to treat the effluent to meet the standard at all five sites. They were to provide not more than five options per site. It was this exercise which eventually gave the ORC comfort on what costs were actually involved in meeting their bacteriological requirements.

The result for Kaka Point was that seven options were identified which would meet a bacteriological standard of a 90th percentile of faecal coliforms less than 260 cfu/100ml, the measure specified in the study brief. Council's historical data for Kaka Point showed that this would be an equivalent standard to 140 cfu/100ml for enterococci. The seven options are summarised in Table 1.

Table 1: Increase in Sewer Rate for Various Additional Treatment Proposals

Additional Treatment Proposal	Increase in Annual Sewer Rate
Ozone Disinfection	$280
Pressure Sand Filter plus UV Disinfection	$310
Pond Redesign plus UV Disinfection	$330
Drum Filter plus UV Disinfection	$380
Disc Filter Plus UV Disinfection	$430
Membrane Ultrafiltration	$450 - $620
DAF plus UV Disinfection	$590

Council's strong preference has always been to adopt technologies which are simple to operate and so minimise annual running costs. Aside from the obvious advantages, this is also driven by the small size and widely dispersed nature of its sewage treatment facilities which tend to greatly magnify the costs where plants require frequent attendance. Following this practice, Council identified pond redesign and UV disinfection as its preferred option from this list, and sought from the consultant involved a proposal as to what further work would be required to investigate and prove the concept to a point where it could be relied upon to meet the required bacteriological standard. A proposal was received which incorporated eight month's monitoring and analysis of pond flows and effluent quality with associated design work.

It was now four months after the consent application had been lodged, during which what was proposed had been discussed with the ORC. That Council, still pursuing its objectives, agreed to halt processing of the consent to await the outcome of this further work in the expectation that it would show that a contact recreation bacteriological standard could be achieved for the indicated level of cost. It was at this point that Biofiltro Ltd approached Council with its proposal for Kaka Point.

3 BIOFILTRO AT KAKA POINT

3.1 INITIAL PROPOSAL

The initial proposal was received in mid-2009 and was of intense interest because it offered a good quality effluent which would meet the ORC bacteriological standard at a cost considerably less than any other proposal seen to date. The further work proposal Council was considering dealt with Kaka Point and two other sites at a total cost which exceeded $150,000. The *Biofiltro* proposal, with earthworks, power supply and metering of the discharge added, had a budgeted cost of $265,000 and, if it proved successful, would likely result in a 35 year consent being granted by the ORC. It was attractive on this basis alone because it offered the prospect of an immediate environmental gain for the expenditure.

It was also attractive because it offered significant improvements to the overall effluent quality as well as meeting the bacteriological standard. The expected effluent quality at the time of the proposal is given in Table 2, compared to the performance of the oxidation pond as recorded to that time.

Table 2: Biofiltro Expected Effluent Quality Compared to Oxidation Pond at August 2009

Effluent Parameter	Oxidation Pond (Mean Unless Stated Otherwise)	Plant (Mean Unless Stated Otherwise)
BOD_5 (g/m^3)	47	17
Suspended Solids (g/m^3)	84	19
Ammoniacal Nitrogen (g/m^3)	24	20
Total Phosphorus (g/m^3)	9.1	5
Enterococci (cfu/100ml)	22,500 (90th percentile)	60 (90th percentile)

The main selling point, however, was undoubtedly its cost relative to other options and the potential for it to be used elsewhere with similar cost advantages. This was helped significantly by its small footprint which would allow it to be sited within the existing site boundaries. The final expected cost of the Kaka Point plant, once an effective windbreak is installed (not thought necessary at the start of the project, but now known to be a necessity in locations close to site boundaries) is $300,000 which results in a first year sewer rate increase of $124, less than half its nearest rival.

Against these advantages, the plant at Kaka Point would be the first use of the technology anywhere to treat oxidation pond effluent. This introduced significant uncertainty for Council, an uncertainty not assuaged by the paucity of monitoring data available from the plants operating in Chile. Nevertheless, Council judged that the potential gains were well worth the risk of non-performance. This judgment was eased by risk being shared to some extent with Biofiltro Ltd, who offered essentially a "best endeavours" warranty of the plant's performance which included agreeing to enlarge the bed or the UV disinfection system if that proved necessary.

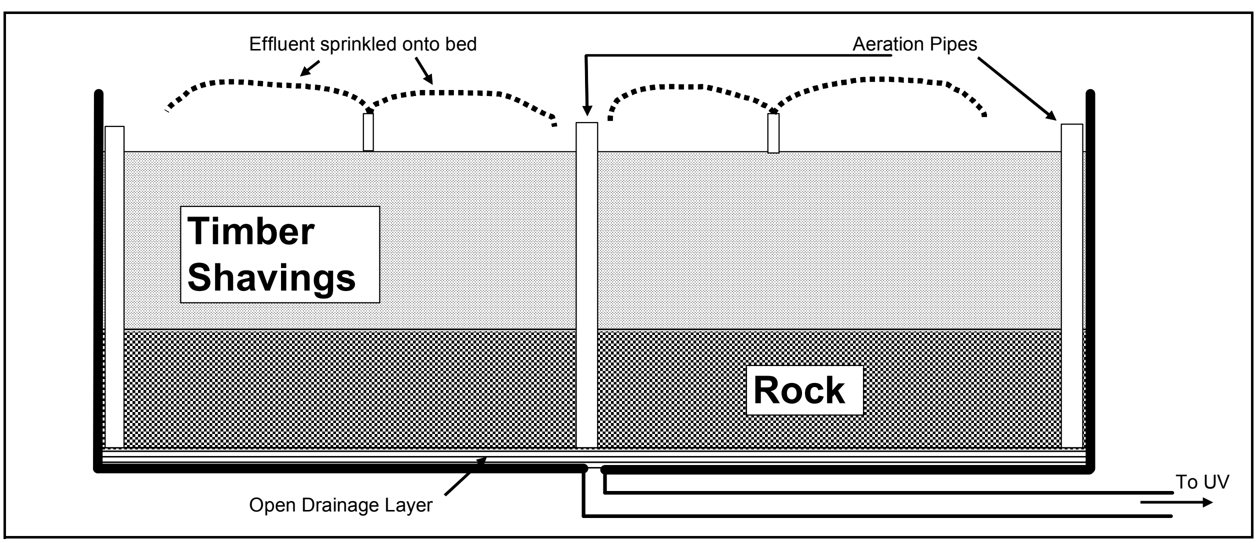
Accordingly, Council committed to building the plant and obtained the agreement of the ORC to delay further processing of the Kaka Point and other consent applications for twelve months to allow for construction, commissioning and evaluation of the plant.

3.2 THE PROCESS

The process is a type of packed bed reactor, using timber shavings as a medium. The bed is constructed above-ground, usually of precast reinforced concrete, with a concrete floor draining to one or more outlets. An open drainage layer is placed on the concrete floor, with successive layers of large equal-sized rock and wood shavings above. The rock allows good aeration of the bed, and this is assisted by aeration standpipes placed at regular intervals across the bed.

The shavings layer is populated with worms and a micro flora biomass. The effluent is sprinkled on the surface of the bed, to trickle through it and be gathered in the drainage layer, and discharged. The soluble nutrients contained in the applied effluent are consumed by the micro flora existing within the bed. These are taken up into the body mass of the individuals within the flora, which in turn form a food source for the worms. As the worms consume the micro flora, the nutrients, nitrogen and phosphorus, are assimilated into the mass of each worm as well as being defecated by the worms on the top layer of the bed. Over a period of time this forms a layer of worm humus at the top of the bed. As the worms die naturally, they too become part of the food chain as they are decomposed by bacteria and once again the nutrients become part of the bed cycle. The worms keep the bed in good condition by moving waste to the top layer and also contribute to the aeration of the bed as they create tunnels through it due to their activity.

Figure 1: Kaka Point Bed Schematic Cross Section



From the bed, the effluent is disinfected using a system of the Company's design. It passes the effluent over a series of flat-top weirs, resulting in a very shallow depth of flow. UV lamps are placed over the weirs in such a way that the lamps are in the dry and disinfection occurs at that point. Finally, the effluent passes over a v-notch weir by which the flow is measured before being discharged, either to the sea or recycled to the oxidation pond.

Initial commissioning involves seeding the bed with a small number of worms and associated biomass and running the plant at 5-10% of design flows. The flow is gradually stepped up over time as the biomass and worm population is established, until full flows are reached after 2 – 3 months. At Kaka Point, the first flow went through the plant on 8 February 2010 and full flow was reached on 24 May 2010, somewhat longer than the three months, but this was occasioned by a cautious approach being taken to ensure the bed biota were properly established and healthy.

The treatment process has proved to be reasonably stable, with consistent effluent quality being achieved, provided regular maintenance is kept up. The top of the bed needs cultivating and levelling at regular intervals as the surface tends to blind off over time which results in ponding. This was deliberately left unattended at Kaka Point until mid-October 2010, four months after the plant first accepted its design flow. Ponding occurred, but effluent quality did not deteriorate until mid-September at which time the ponding extended to the bed walls and short circuiting occurred down the shavings / wall interface. There is also potential for the bed to become anaerobic at some locations due to the ponding, but little tendency for this was observed at Kaka Point, as evidenced by the worm population still being widespread under the ponding.

The conclusion from this exercise was that the bed surface should be cultivated and levelled at monthly intervals to ensure a large margin between when maintenance is done and when it is likely that effluent quality will deteriorate due to the lack of maintenance.

The other regular maintenance item is the periodic replacement of the top 100-150mm of the bed shavings. This gradually becomes clogged with worm excretions over time. Kaka Point had not had this done by the beginning of September 2011, after sixteen months' operation at design flows. Indications at that time were that some parts of the bed top layer required replacing, but not all. Once again, to maintain a large margin of safety, annual replacement of the top layer is indicated for plants treating oxidation pond effluent.

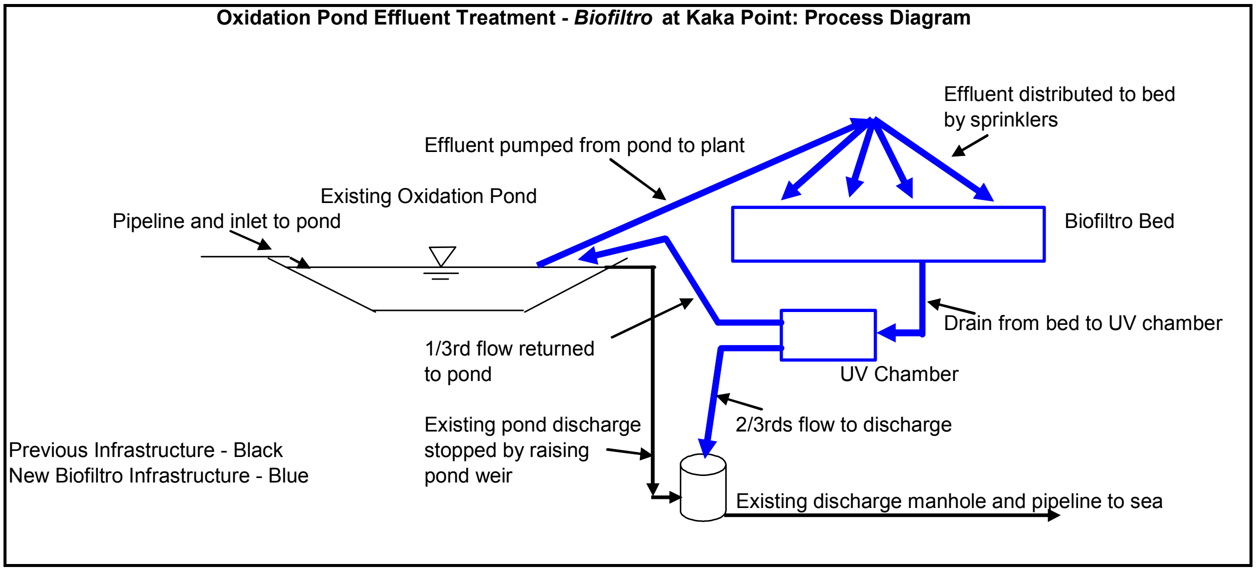
3.3 KAKA POINT DESIGN

The choice of bed size is determined by hydraulic and contaminant loads and, once established, results in a plant designed to operate at a steady flow. The bed can be split so as to provide different capacities, but in practice plants the size of Kaka Point run at total design flow or zero. This raises the issue of how to deal with the substantial variation in daily sewage flows, probably a range of 40m^3 to 418m^3/d at Kaka Point. Of course, the oxidation pond is a great buffer, but as flows were not actually metered to the pond and no correlation is available with rainfall records, there was a degree of uncertainty about whether the pond was large enough to completely buffer the flows itself. In other words, simply sizing the plant to process the average daily flow might result in the pond overflowing or even emptying.

The approach developed at Kaka Point was to size the plant for 150% of the average daily flow, rounded to 120m^3/d, discharging two thirds of the flow to the outfall, and recycling one third back to the pond. In practice this is achieved by discharging to the outfall two thirds of the time and recycling for the balance. The behaviour of the pond is measured by continuously monitoring its level and adjusting the operating regime to ensure the discharge volume is increased if the pond level increases too much, and it can be reduced if the pond threatens to empty. Thus a typical discharge volume is 80m^3/d but it can range from 40 to 120m^3/d if necessary. The flow from the existing pond outlet has been stopped by raising the outlet weir to 50mm above the maximum plant operating level so that the pond can discharge instead of overtopping in the event that the plant cannot cope with the flows. To date, this has not occurred.

The process is outlined in Figure 2.

Figure 2: Kaka Point Process Diagram



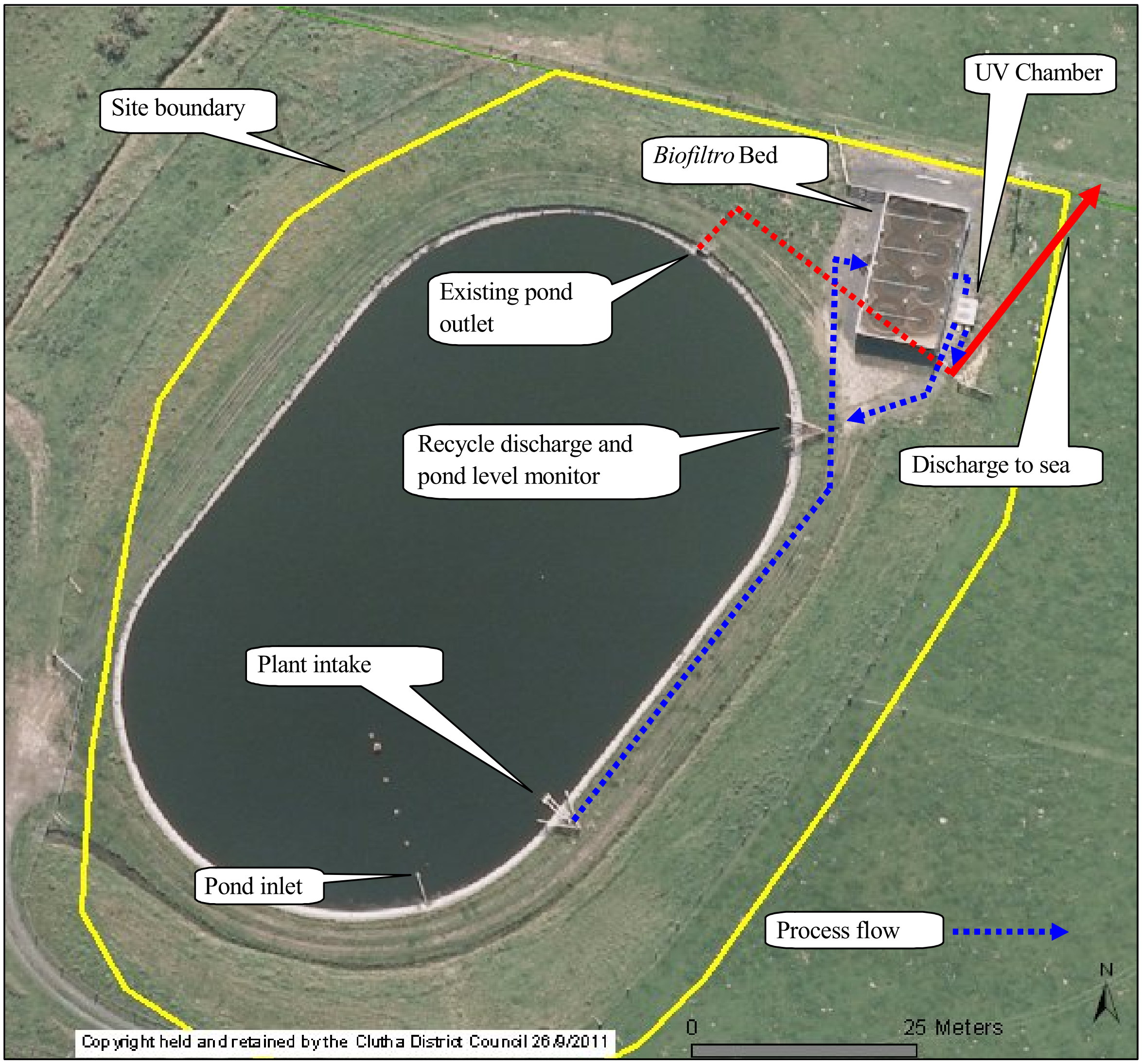
The other significant concern in the design stage was whether oxidation pond effluent would contain sufficient nutrients to maintain healthy and abundant biota. On the basis of the Chilean experience, there was confidence that raw sewage did, but of course no data existed for oxidation pond effluent. Some regard was had to this by the intent of the design to place the plant intake at the pond inlet, to ensure, as much as possible, that the effluent processed by the plant had qualities more akin to raw sewage than oxidation pond effluent. As fortune sometimes has it, the sub-contractor interpreted this requirement liberally and placed the intake 16m from the pond inlet, thus ensuring fully mixed pond effluent would be presented to the plant.

The obvious response was adopted, and the decision taken to make no adjustment until the plant performance was known. In the event, it became clear that oxidation pond effluent can support healthy and abundant biota in the bed, something obvious from worm populations observed during bed maintenance and the effluent quality produced by the plant.

The Kaka Point plant is shown in Photographs 1 and 2.

Photograph 1: Kaka Point Plant

Photograph 2: Kaka Point Site Layout - 30 March 2011



3.4 KAKA POINT PERFORMANCE

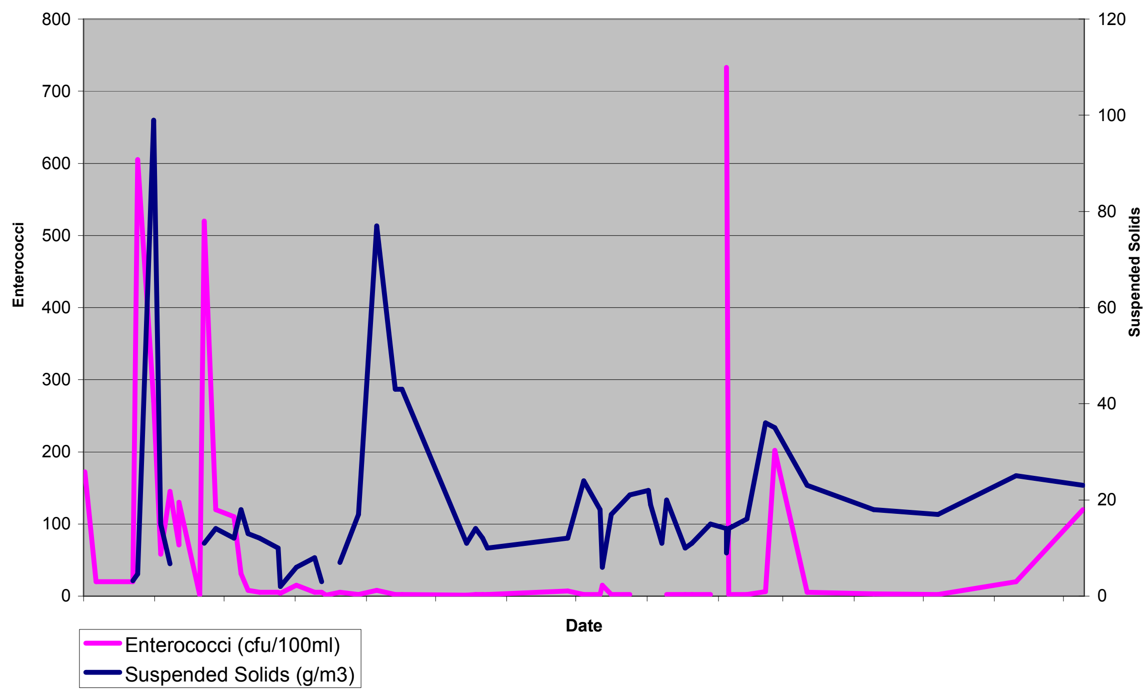
The plant performance was monitored by measuring for ten parameters at various times and frequencies. There is now a maximum of 54 grab sample results for the plant for one parameter, with more than 45 for each of the parameters in Table 2 and a minimum of 21 samples at worst.

Many of the bacterial results were not reported as absolute counts, but as a “less than” figure. Where this is the case, for the purposes of calculating means and 90th percentiles, they have been converted to absolute figures in accord with the following:

<100 + 50 (one E. coli count only)
< 10 = 5
< 5 = 3
< 3 = 2
< 1 = 1

Sampling has been done both by Council and Biofiltro Ltd and all results are included in the record as appropriate. However, when looking at the full sampling record, some adjustments need to be made to take account of changes in the plant or its operation. Two instances are of particular note, the capacity of the UV system in the early days and the impact of not doing routine maintenance on the bed. These, and other occurrences are highlighted in Figure 4, which plots suspended solids and enterococci concentrations over the full sampling record.

Figure 3: Sampling Anomalies



The record starts at 26 May 2010 and finishes on 3 August 2011. The enterococci concentrations were not stable early on, with some high peaks well above the targeted level. Accordingly, on 6 August the number of lamps in the UV system was doubled, significantly increasing the UV dose, producing a marked improvement. The two peaks towards the end of the record are single samples taken with other parameters in view. The plant had been stopped before sampling and it is likely they had not been subjected to UV. The apparent trend developing at the last record is two samples taken at monthly intervals which may be affected by a deposition of lime on the UV weirs and the lamps nearing the end of their service life. The larger sample had a concentration of 120 cfu/100ml, still below the consent limit.

There is no underlying reason apparent for the first suspended solids peak, which is one sample only. The next peak records the rapid fall-off in plant performance in September 2010 at the end of the period without routine maintenance being done. There is no apparent reason for the third peak, although it was a sample taken after the plant had been shut down.

For the remainder of this analysis, the unrepresentative samples noted above have been deleted.

3.4.1 PLANT PERFORMANCE

Table 4 gives the plant performance for all parameters for which there are consent limits from the full population of representative samples, with a comparison to the long-term consent limits (which do not come into effect until February 2012 to allow plant "tuning").

Table 4: Plant Total Performance

Parameter	Mean	90th Percentile	Consent Limit*
BOD_5 (g/m^3)	4.2	10.6	12
pH	6.2	6.4	6.5
Total Phosphorus (g/m^3)	5.8	7.8	10
Ammoniacal Nitrogen (g/m^3)	4.9	9.9	20
Total Nitrogen (g/m^3)	27.1	32.2	30
Suspended Solids (g/m^3)	12.7	23.0	30
Enterococci (cfu/100ml)	4	15	140

* 90th percentiles, except for pH which is the lower bound of an absolute range, 6.5 - 9.

Here, and later, performance is expressed as a mean contaminant concentration or a 90th percentile. The latter is because that is how the consent limits are expressed. The former is more usually expressed as a geomean to cater for extreme variations, but a mean is used here to allow direct comparison with early prediction of plant performance in addition to which the removal of outlying results lessens the impact of a mean compared to a geomean. The length of the record gives some confidence that the above is a good measure of long term plant performance and, if compared with Table 2, some observations can be made:

- Plant performance is considerably better than expected for BOD_5 and ammoniacal nitrogen.
- Performance is significantly better than expected for suspended solids.
- There is little practical difference for phosphorus or enterococci, although the actual latter is an impressively low number.

The other very positive outcome is that the plant 90th percentiles are comfortably within the long term consent limits for all but total nitrogen. Negatively, this parameter requires some attention, as does pH where the record shows a pH persistently lower than the bottom of the allowable range. These points are commented on further below after some consideration of seasonal variations.

The population of sample results includes two series of weekly samples done where the pond effluent was sampled as well as the plant effluent so as to give some assessment of the degree to which the pond effluent is improved. These were done over the periods 10 August to 17 November 2010 (“winter/spring”) and 10 January 2011 to 18 March 2011 (“summer”). These samples allow the differences in performance (if any) between winter/spring and summer and the effect of recycling to the pond to be assessed. The results from these two sample sets are given in Table 5.

Table 5: Seasonal Performance Compared to Pond Effluent

	Effluent Concentration Means						Reductions		
	Overall		Winter/Spring		Summer		Overall	Winter/ Spring	Summer
Parameter	Pond	Plant	Pond	Plant	Pond	Plant			
BOD_5 (g/m^3)	63	4.3	65	3.1	61	5.5	93%	95%	91%
pH*	7.69	6.11	NA	NA	7.69	6.11	1.58	NA	1.58
Total Phosphorus (g/m^3)	6.93	6.27	6.42	5.02	7.45	7.53	10%	22%	-1%
Ammoniacal Nitrogen (g/m^3)	23.9	4.1	21.5	3.6	26.3	4.6	83%	83%	83%
Total Nitrogen (g/m^3)	33.5	26.8	31.2	23.3	35.9	30.4	20%	25%	15%
Suspended Solids (g/m^3)	74	14	74	9	73	18	82%	87%	76%
Enterococci (cfu/100ml)	5149	4	2150	5	8148	2	100%	100%	100%

*Because pH was not measured for the winter/spring samples, the overall results are the same as for summer

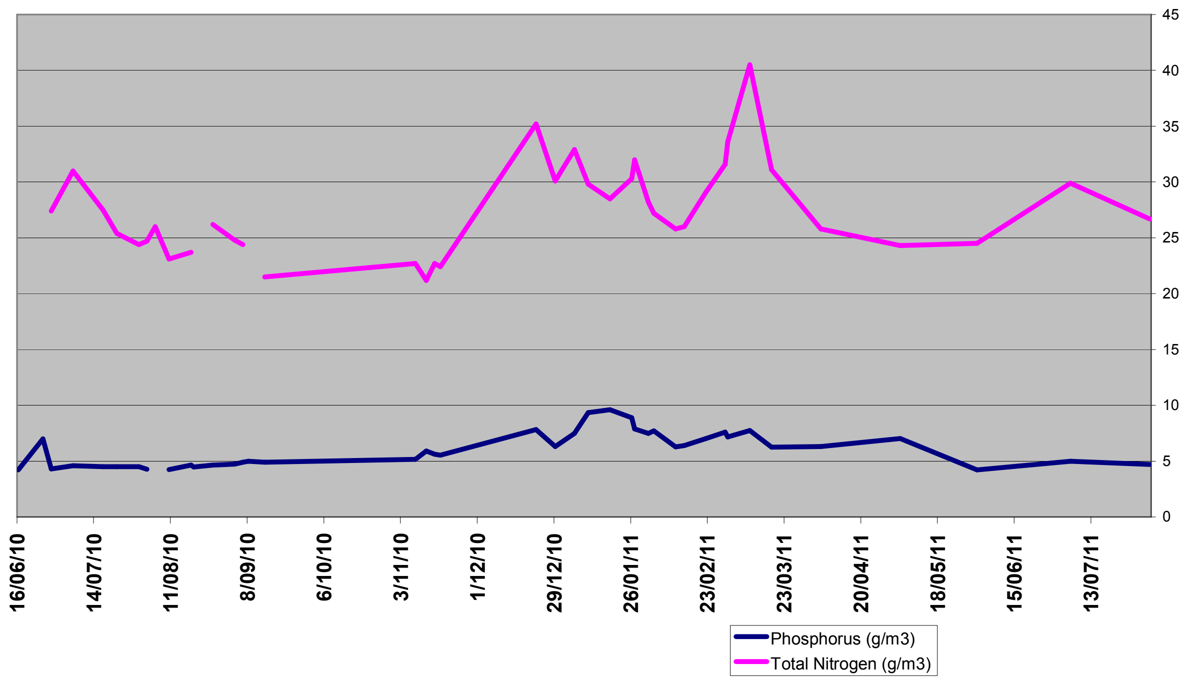
These results do not display any significant difference between winter and summer, contrary to what might be anticipated from the expected higher summer loads and what is actually shown by the historical records (which show generally lower levels in winter). However, the small sample sizes (there are only 28 samples in the

Council's historic record) mean that little can be invested in the differences: only the BOD_5 value is more than one standard deviation from the historical mean. Further, there is no indication here that the plant effluent recycling is reducing the contaminant concentrations in the oxidation pond.

However, the plant performance has remained consistent between winter and summer as measured by the contaminant reductions for all but phosphorus and total nitrogen. It had been anticipated that the higher loads would occur in summer but that the higher summer temperatures would increase biota activity and compensate. There is no indication that this has occurred. Nevertheless, the plant has proven very effective at producing a good quality effluent suitable for discharge to a salt- or freshwater environment for four of the seven parameters for which consent limits are set.

The exceptions are phosphorus, where removal seemed to cease in the summer; total nitrogen where the removal performance declined leading to a concentration in the final effluent which breaches the long-term consent limit; and pH. The variation of phosphorus and total nitrogen over time is set out in Figure 4

Figure 4: Phosphorus and Total Nitrogen Concentrations ex Plant, Whole Record



In both cases, concentrations have increased over the summer period but then reduced again as winter arrived, although not to previous levels in the case of total nitrogen. The summer period was slightly cooler and distinctly wetter than average (NIWA, 2011; Otago Regional Council, 2001), and the plant discharge rate was maintained at the average daily flow. This resulted in the pond rising beyond the maximum operating level, something encouraged by an unknown person blocking the pond outlet and so allowing the level to get above the waveband. This may have contributed to plant results, but the pond concentrations did not increase in any untoward fashion: the reduction in plant performance contributed as much to the increase in each parameter as the change in pond conditions.

The result for phosphorus is not particularly alarming as the long-term pond effluent meets the consent limit in any event, but there was concern at the total nitrogen concentration. This parameter arose late in the consenting process, well after the plant had been commissioned with the primary aims of achieving acceptable microbiological and ammoniacal nitrogen reductions. However, the consent limit was accepted on the basis of the winter/spring plant performance.

In normal operation, the effluent is not applied continuously to the bed: altering the application rates in relation to the total daily volume to be treated and the duration of each application gives rise to differing compositions of the treated discharge. By increasing the application rate to the bed and then applying the total volume over a shorter period, the total nitrogen reduced to below the required limits. This was of particular importance over the peak summer period. Because of this, as summer approaches again, the plant operation will be adjusted to meet the discharge limit.

It had been noted early in the plant commissioning that the effluent pH was lowered to just under 6.5, at that time the bottom of the expected range to be included in the consent limits. The actual results bear this out, with a range between 5.84 and 6.33, a steady range which buffers the variations in pond pH very well. The authors speculate that this occurs because of the substantial removal of ammoniacal nitrogen. This will have little environmental impact in the sea at Kaka Point, but it will be different in the smaller freshwater receiving environments, so it required attention. The consistency of the pH means that no complex dosing system to increase the pH is required, so running the effluent through limestone chips in a 10-litre bucket was trialled. This succeeded in adding 0.9 to the pH, taking it into the consent range. It may be that this will raise the suspended solids in the effluent, but while this may be occurring there is no present indication that the consent limit will be threatened. A more sophisticated arrangement than the bucket is in hand.

A final brief comment on UV transmissivity and disinfection should also be made. The unfiltered UV transmissivity out of the bed prior to the UV chamber averaged 39.8% over the winter/spring and summer sets of samples, with the mean filtered transmissivity being 47.2%. These are certainly values at least approaching what is viable to disinfect with UV, but the position is considerably aided by the bacteriological load in the effluent at that point. Unfortunately, only six samples have been analysed for enterococci, which showed a mean of 901 cfu/100ml, a substantial reduction from the pond mean of 5,149 in the winter/spring and summer series. If this is representative, then the UV performance will be materially aided by the bed's ability to significantly reduce bacteriological concentrations in the effluent.

In September 2010, Council considered the performance of the Kaka Point plant up to that point. There was only a small number of samples available, but they indicated that the technology very likely would meet ORC requirements for a 35 year consent. The 90th percentile results for the relevant parameters for the sample population and the total representative population now are compared below.

Table 6: Effluent Quality September 2010 v September 2011, 90th Percentiles

Parameter	Sept 2010	Sept 2011	Consent Limit
BOD_5 (g/m^3)	8	10.6	12
Total Phosphorus (g/m^3)	5	7.8	10
Ammoniacal Nitrogen (g/m^3)	12	9.9	20
Suspended Solids (g/m^3)	26	23.0	30
Enterococci (cfu/100ml)	445	15	140

In 2010, the main focus was on bacteriological quality and, while the 90th percentile was outside the targetted consent limit, the UV dose had just been doubled in the system and there were sufficient earlier results to give confidence that the target would be met. To some extent, the other parameters were of less significance, but they also gave positive indications that the effluent would be of a very much improved quality overall than previously. There have been obvious changes since, but the authors are of the view that the plant has repaid the confidence showed in it and delivered an effluent quality commensurate with that first indicated in practice. While some work is still required to obtain a better and totally compliant performance, the Kaka Point trial has been a resounding success. Council accordingly, in September and October 2010, committed to seeking a consent for the plant at Kaka Point and a further four plants at other townships in the District based on the results achieved from *Biofiltro*.

4 CONSENTS AND COSTS

The twelve month period to construct and trial Kaka Point agreed to by the ORC came to an end in September 2010 at which time additional information was provided to the ORC in support of amending the proposed effluent quality to reflect *Biofiltro* treatment. This was extended to the other four consents also on hold and the ORC set about processing them. Three of the consents had already been notified, but in the event only one hearing was held where no submitter opposed the application. One consent was processed on a non-notified basis. In each case, the ORC recommending report and proposed consent conditions were agreed between the ORC and Council officers and in December 2010 and January 2011 consents with 35 year terms were granted for each town.

The long-term consent limits are the same for all towns with the substitution of a 90^{th} percentile of 260 cfu/100ml for E. coli for the towns which discharge into freshwater. However, each consent has staged limits to allow the existing oxidation pond to operate until a plant is built, and then interim limits while the plant is commissioned and fine tuned if needed.

Biofiltro has proved an economic solution for Clutha District, as can be seen below.

Table 7: Biofiltro v Other Options: First Year Rate Increase Five Small Towns (excl GST)

Town	**Capital**	**No. Rates**	**Increase in Sewer Rate**	**Cheapest Other**
Kaka Point	$ 300,000	246	$ 124.00	$ 310.00
Lawrence	$ 580,000	319	$ 173.00	$ 240.00
Owaka	$ 730,000	203	$ 307.00	$ 410.00
Stirling	$ 420,000	140	$ 267.00	$ 520.00
Tapanui	$ 685,000	449	$ 151.00	$ 170.00

These costs include depreciation, amortisation and operating expenses. The annual operating and maintenance costs included above will be in the range of $15,000 to $25,000 per annum, including regular attendance, routine maintenance and electricity. The actual cost per plant depends upon its size and location.

Biofiltro has a considerable cost advantage over the other technologies: at only the largest plant, Tapanui, and to a lesser extent, Lawrence, is the margin not so great as to crowd out the competitor entirely. However, the above costs for other technologies were assessed on the basis of a desktop study and have a high margin for error compared to the hard cost for *Biofiltro*. Three of the other options were the addition of a rapid sand filter and UV, with the fourth (Stirling), a pond redesign and UV. Because the bacteriological standard was the focus at the time, their driving objective was to increase the UV transmissivity of the effluent so as to allow effective disinfection. Any improvement in other effluent quality parameters would be a side effect and no assessment was done to estimate its extent. However, the authors consider it highly likely that *Biofiltro* produces a considerably better quality effluent overall than the cheapest other option in each case.

Subsequent to the granting of consent, Council has contracted to construct *Biofiltro* plants at the other towns and those plants are nearing completion at the time of writing this paper.

5 CONCLUSIONS

Any treatment of sewage to allow its consented discharge to water must be tailored to the initial effluent quality and the final receiving water quality required. The latter is often specified in consents by defining the effluent quality which is required. Each situation is unique and the variation in requirements means that the appropriate treatment technology must be matched to the circumstances. In South Otago, the achievement of the ORC objective of land based disposal for treated sewage was not possible due to large capital costs, driven by the climate and low permeability soils. Point discharges to water remain the only option.

What this paper has demonstrated is that *Biofiltro* is a viable technology to further treat oxidation pond effluent to a sufficient quality for discharge into a variety of South Otago receiving waters. The operation of the trial plant at Kaka Point has demonstrated that the plant effectively treats the effluent from the pond to produce a very good quality effluent in the context of the receiving waters and associated consent conditions. The initial fears that there may be insufficient nutrients in the effluent to maintain healthy and abundant biota in the bed have proven groundless and it is clear that oxidation pond effluent is sufficient to maintain good bed health. Not only does the plant produce a consistent, good quality effluent in general, but its capital and operating costs are such that the arrival of the technology has greatly improved the affordability of sewage treatment for small, relatively isolated communities

Council's initial aim was to obtain long-term consents within a sewer rate increase of $222 excluding GST per annum. Table 7 makes it clear that this may only have been possible at one location prior to the advent of *Biofiltro*. There is no doubt that the performance of the plant at Kaka Point has demonstrated the capabilities of the technology and given the opportunity for Council to meet its objective in three of the five towns and come reasonably close in the other two, an opportunity which would not have existed otherwise. It has proven to be an affordable and appropriate solution to sewage disposal and treatment needs in the Clutha District context of urban settlement.

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