

Biological Nutrient Removal

nitrogen and phosphorous removal in small wastewater treatment plants for rural communities

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Most major wastewater facilities for towns and cities now include biological nutrient removal as a matter of course. With large plants, where operational resource is easier to justify, and where the plant has qualified operators with laboratory and all the operational resource, it is easier to ensure that the plant is operated within design parameters for biological nutrient removal. When the nutrient removal becomes a requirement for small plants in rural communities, the operational resources normally available at large wastewater treatment facilities become difficult to justify. The need to contain energy costs and the associated carbon footprint is top of the agenda with most clients and utility companies; therefore the rural wastewater treatment works needs to be designed to perform with minimal labour input, power consumption and other operational costs.



UK Water plc Wastewater Treatment Plant with Physical Biological Tertiary Filter

Courtesy of KEE Process

In most parts of the world where water resource is scarce and needs to be preserved, operational resources and expertise is often not available. At rural locations it is sometimes necessary to treat the wastewater to a high standard without the available resources as at larger Works. In such circumstances, packaged wastewater treatment plants would offer the most ideal solution. The Valencia Region in Spain is mountainous, scenic and an environmentally sensitive area and the Authorities have identified the requirement for nitrogen removal and treating the wastewater to a high standard. There are many rural communities in the region where the contributing population in the catchment area would be relatively small, the site locations would be remote from areas of large urban habitation and experienced operational resource would be scarce.

The Authorities recognise the need for treatment plants which can provide consistent performance to produce high quality effluent, without the need for operator attendance on a regular weekly or bi-weekly basis. The plant also has to merge aesthetically into the surroundings, with low noise and power requirement, and is robust and reliable without the need for extensive maintenance. The Valencia Water Authorities tested various packaged plants from many manufacturers for their performance and ability to consistently produce high quality effluent with nitrogen removal. The objective was that the plant would be fed with Municipal wastewater, and would be tested over a period to ascertain the performance of the plant with respect to the stated final effluent discharge criteria. They also monitored the day to day operational requirements and the energy costs.

KEE Process Ltd submitted its KEE800-R NuDisc® for testing by the Authorities in Valencia. The KEE800-R NuDisc® is a self-contained Packaged Wastewater Treatment Plant which includes primary settlement chamber with built-in sludge storage facility, RBC with built-in forward feed bucket flow system for biological treatment, internal recycle using buckets, final clarifier with pump assisted hydrostatic sludge return system, physical biological tertiary filter and UV disinfection. This plant can be configured for reducing:

- BOD and built-in tertiary filtration for further suspended solids reduction.
- BOD removal and nitrification with built-in tertiary filtration.
- BOD removal with nitrification, de-nitrification and biological phosphorous removal with built-in tertiary filtration.

With each of the above options it is possible to disinfect the treated effluent prior to discharge, using a built-in UV disinfection system, which would enable the effluent to be recycled for non-potable use.

For the test in Valencia the plant was required to achieve the following discharge parameters:

BOD ₅	< 20mg/l
SS	< 20mg/l
COD	< 70mg/l
Total Nitrogen	< 15mg/l
Ammoniacal Nitrogen	< 5mg/l
Nitrate Nitrogen	< 10mg/l

KEE plant submitted for biological nutrient removal

To meet the Client criteria of packaged configuration, low noise and smell nuisance, low maintenance requirement and reduced power demand, KEE proposed its packaged RBC system for type testing.

The plant was configured for upstream biological phosphorous removal and de-nitrification using internal carbon source. The aerobic part of the RBC plant provided full nitrification, and the nitrified effluent was de-nitrified in the upstream first stage anoxic RBC. The packaged plant included a hopper bottom final clarifier with built-in pump assisted hydrostatic sludge return system to return the humus sludge to the PST stage for disposal at a later date. The settled effluent from the FST is directed through the built-in KEE physical-biological tertiary filter which would further reduce suspended solids, turbidity, BOD, COD, nitrate nitrogen and total nitrogen.

Analytical data of plant influent and effluent

The initial tests were carried out with the tertiary filter bypassed, and the analytical data as presented (below) represents the effluent discharged from the final clarifier of the plant.

KEE NuDisc-R® Packaged RBC Plant Performance

	Turbidity NTU			S.S. mg/l		
	INLET	OUTLET	%REML	INLET	OUTLET	%REML
Test Data A	257	4	98.4	260	11	95.8
Test Data B	219	3	98.6	244	7	97.1
Test Data C	154	3	98.1	164	9	94.5
95%ile	253.2	3.9	98.6	258.4	10.8	97
Average	210	3.33	98.4	222.67	9	95.8
Maximum	257	4	98.6	260	11	97.1
Minimum	154	3	98.1	164	7	94.5
	BOD ₅ mg/l			COD mg/l		
	INLET	OUTLET	%REML	INLET	OUTLET	%REML
Test Data A	280	17	93.9	570	44	92.3
Test Data B	290	15	94.8	610	32	94.8
Test Data C	160	10	93.8	315	36	88.6
95%ile	289	16.8	94.7	606	43.2	94.5
Average	243.33	14	94.2	498.33	37.33	91.9
Maximum	290	17	94.8	610	44	94.8
Minimum	160	10	93.8	315	32	88.6
	N _{total} mg/l			NH ₄ mg/l		
	INLET	OUTLET	%REML	INLET	OUTLET	%REML
Test Data A	73.9	10.1	86.3	53.4	0.4	99.3
Test Data B	52.4	10.5	80	30.8	0.9	97.1
Test Data C	34.2	12.6	63.2	13.2	0.5	96.2
95%ile	71.75	12.39	85.7	51.14	0.86	99
Average	53.5	11.07	76.5	32.47	0.6	97.5
Maximum	73.9	12.6	86.3	53.4	0.9	99.3
Minimum	34.2	10.1	63.2	13.2	0.4	96.2
	NO ₃ mg/l			P _{total} mg P/l		
	INLET	OUTLET	%REML	INLET	OUTLET	%REML
Test Data A	–	7.4	–	8	3	62.5
Test Data B	–	6.7	–	6.2	3.2	48.4
Test Data C	–	9.3	–	5.5	3.2	41.8
95%ile	–	9.11	–	7.82	3.2	61.1
Average	–	7.8	–	6.57	3.13	50.9
Maximum	–	9.3	–	8	3.2	62.5
Minimum	–	6.7	–	5.5	3	41.8

Power consumption

During the test period, the Authorities monitored the total power consumed by the plant and this is presented below in a tabular form for different flow rates as kWh/m³ and kWh/kgBOD.

FLOW RATE m ³ /d	kWh/m ³	kWh/kgBOD
6	0.48	1.63
8	0.34	1.17
12	0.29	1.01

The tests are still continuing, and the plant performance with the tertiary filter now operational would be finalised during the next 8 weeks at different flow rates.

KEE has installed similar packaged plants in the UK for water utility companies, and whilst the plants in the UK have not been configured for nutrient removal, the plant performance with respect to BOD, SS, ammoniacal nitrogen and total nitrogen prior to tertiary filter is better than what would be expected out of a ultra-fine membrane tertiary filter system or an MBR Plant. With most of the substrate removed, the quality of the effluent through the physical biological filter only improved with respect to ammoniacal nitrogen.

In the UK plants, the NH₄-N from the FST at 0.5mg/l (95%ile basis) was reduced to 0.06mg/l after the physical biological filter. The substrate in the influent to the tertiary filter is totally depleted and therefore the filter acts as a safety net for any accidental solids carry over, which otherwise is less than 2mg/l.

The concept of nutrient removal and high quality effluent from large treatment plants can now be achieved in small rural wastewater treatment plants without the need to make the plant complicated, or to build expensive instrumentation into the process control, or to require expensive day to day operational input. The simplicity of the packaged plants available up until now for normal BOD, SS and NH₄-N removal, can now be extended to removing nutrients, polishing effluent for SS, and turbidity reduction and disinfecting the discharge for re-use.

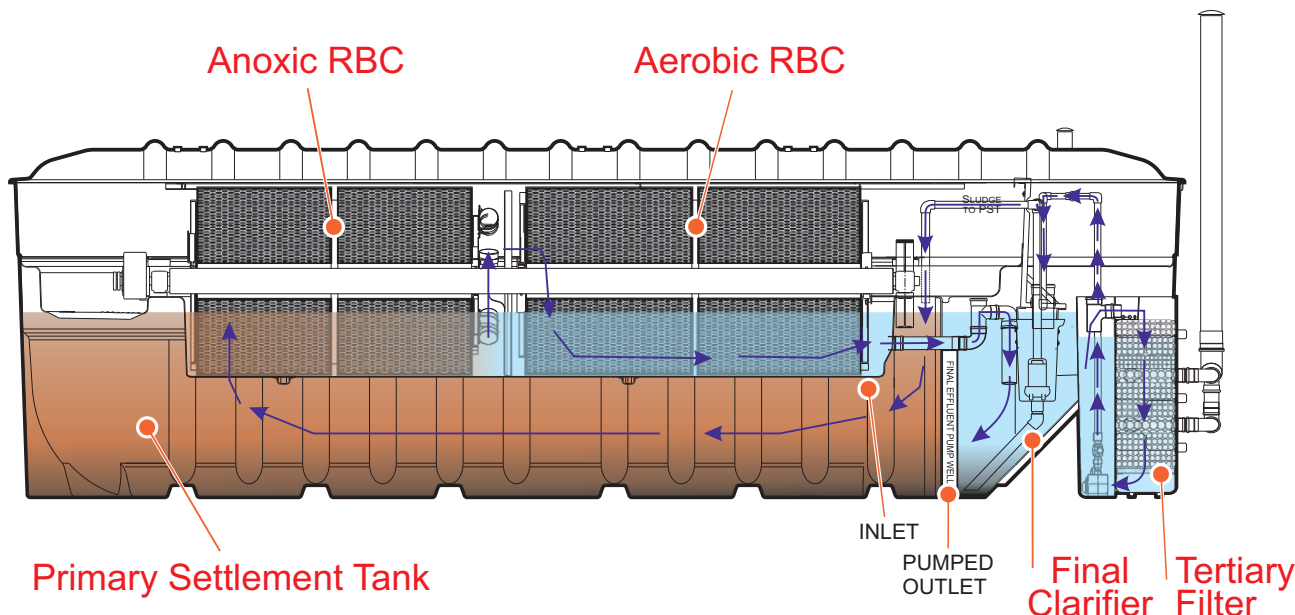
The plant tested by Authorities in Valencia is designed to treat 12m³/d, where the discharge was fully compliant with the specified effluent quality and the daily total power consumption of the plant was 3.5kWh/d.

The operational requirement would be the need to de-sludge the plant every three to four months, and provide electro-mechanical service once every year. The packaged plant would therefore provide lowest lifetime cost for the highest quality effluent, and the concept can be applied to contributory population equivalent of up to 5,000 PE.

Analytical results from packaged plant with Physical-Biological Tertiary Filter from UK water utility company site.

BOD mg/l	SS mg/l	NH ₄ -N mg/l	NO ₃ -N mg/l	TN mg/l	pH
Packaged Plant FST Outlet					
< 2	5	0.5	13.1	13.1	7.2
Physical Biological Tertiary Filter Outlet					
< 2	2	0.06	14.2	14	7.6

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