ADVANCED ON-SITE WASTEWATER TREATMENT FOR GREENFIELD AND RETROFIT APPLICATIONS

MEMBRANE AERATED BIOLOGICAL REACTOR TECHNOLOGY OFFERS SUPERIOR PERFORMANCE, SIMPLER OPERATION, AND WATER REUSE OPPORTUNITIES

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CONTENTS

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EXECUTIVE SUMMARY

Many owners and operators of traditional decentralized municipal wastewater treatment plants, also referred to as on-site or off-grid treatment, are acutely aware their systems are at risk of becoming obsolete. These systems include:

- septic fields
- lagoons
- oxidation ditches and ponds
- rotating biological contactor (RBC) mechanisms, and
- sequencing batch reactor (SBR) processes.

Why the concerns?

Recreational vehicle and mobile home parks, residential and commercial developments, campgrounds, and private utilities are increasingly challenged to treat wastewater cost-effectively when facing:

- the probability of more stringent discharge quality requirements in the years ahead
- the capital costs to upgrade or replace existing facilities
- water scarcity issues and the demand to beneficially reuse treated wastewater
- the pressure to keep the plant easy to operate and maintain
- the need to scale operations as treatment demands grow
- limited space to build and upsize
- unpleasant odors arising from collection and treatment activities
- a social imperative to offer a sustainable process to minimize the environmental impact.

However, an advanced wastewater treatment technology known as the Membrane Aerated Biological Reactor, or MABR, is particularly well-suited to overcome each one of these challenges.

EVOLVING REALITIES CHALLENGE TRADITIONAL ON-SITE WASTEWATER TREATMENT

Wastewater treatment challenges are escalating for developers of residential communities and commercial properties, owners of RV and mobile home parks and campgrounds, and private utilities. Broadly defined, the issues are:

- **Stricter Discharge Quality Requirements** – Local, regional, and national standards regulating the quality of water discharged to the environment are becoming more restrictive. Treatment must deal with pathogen-removal and minimizing nutrient discharge as well as contending with a growing list of new contaminants.

- **Capital Cost Considerations** – Decision-makers have two options as to how they will treat the wastewater they generate.

  1. They can connect to a centralized wastewater treatment plant if that option exists.
  2. They can construct an on-site treatment plant.

  Often, an on-site system is the most cost-effective solution. The capital outlay required to secure the rights-of-way and install lengthy underground piping to the point of connection with a regional treatment facility can be prohibitive. Importantly, when discharging to a central treatment plant, the control over what can be treated and at what cost lay in the hands of others.

- **Water Scarcity** – Water is becoming a scarce resource in many jurisdictions, driving the urgency to reuse treated wastewater.

  The following table is an example illustrating the minimum level of wastewater treatment acceptable in California for reuse. Expect future regulatory requirements in all jurisdictions will mandate higher performance from decentralized treatment plants.

Ranges of Water Quality for Water Reuse Applications in California

Type of Reuse	BOD (mg/L)	TSS (mg/L)	Turbidity NTU	Tot. coliforms, (No./100 mL)
Agricultural Irrigation				
Nonfood crop	≤ 30	≤ 30		< 23
Food crop	≤ 10		≤ 2	< 2.2
Landscape Irrigation				
Restricted Access	≤ 30	≤ 30		< 23
Unrestricted Access	≤ 10		≤ 2	< 2.2
Industrial				23
Groundwater recharged			≤ 2	≤ 2
Recreational/Environmental	≤ 10		≤ 2	< 2.2
Non-potable urban uses	≤ 10		≤ 2	< 2.2
Indirect Potable Uses			≤ 2	< 2.2

*Blanks denote no values are given

Source: Adapted from the California Code of Regulations, Title 22 (California Plumbing Code, 2010) & Metcalf and Eddy, 2003).

- **Overtaxed Facilities** – Operators of septic fields, RBCs, lagoons, oxidation ditches, and other traditional on-site treatment processes, are feeling the pinch to deliver higher quality effluent while maintaining outdated equipment and processes designed for less demanding treatment standards.
- **Staffing Problems** – Finding and retaining qualified operations and maintenance personnel can be a hefty challenge. Increasing demand for talented operators is expected to intensify the situation.
- **Limited Space** – Maintaining a small physical footprint for treatment is critical where the cost of land is high, or space is limited.
- **Esthetic concerns** – Decentralized treatment facilities are located close to the source of the wastewater. They commonly generate nuisance odors that result in complaints and upset customers if the operation is not monitored closely.
- **Carbon Footprint** – Operating a wastewater treatment process can be expensive, particularly in regions where electrical energy costs and surcharges for time-of-day use are high.

OUTDATED TREATMENT PROCESSES CAUSE HEADACHES

Legacy off-grid wastewater treatment systems in operation today suffer their fair share of drawbacks. Owners and operators of such systems will recognize at least several of those noted below.

- **LARGE CAPACITY SEPTIC SYSTEM** (designed for sanitary waste only from multiple dwellings or non-residential sources with a capacity to serve 20 or more people per day)
    - Rigorous regulatory scrutiny to upgrade the system
    - Site-specific variables can radically affect design and costs to improve, operate, and maintain
    - Limited range of treatable influent contaminants
    - Risk of groundwater contamination
    - Drainfields require controlled pumping for proper dosing
    - Drainfield capacity and life can be difficult to assess
    - Drainfield is susceptible to plugging and damage – costly to refurbish
    - Limited ability to control process
    - Large footprint
    - Odor issues
    - Messy solids removal process
    - Adjacent land use and value can be negatively affected
    - Limited ability to upsize.
- **LAGOON/OXIDATION DITCH/OXIDATION POND**
    - Planning, design, and construction of upgrades can be expensive and subject to rigorous regulatory scrutiny
    - Energy-intensive and noisy aeration and mixing requirements
    - Limited ability to control process
    - Effluent may contain high concentrations of algae
    - Wastewater detention times can be long
    - Subject to short-circuiting, affecting effluent quality
    - Poor nitrification in cold temperatures
    - Large footprint
    - Odor issues
    - Susceptible to freezing
    - Can become a breeding area for insects
    - Open basins present safety hazards to operators and the public
    - Require ongoing maintenance and removal of weed growth on banks and in water
    - Burrowing animals can present challenges
    - Costly and messy solids removal and treatment
    - Basins subject to erosion and linings subject to damage and pathogen leakage.
- **ROTATING BIOLOGICAL CONTACTOR (RBC)**
    - Costly to operate and maintain—skilled operators required
    - Lower treatment efficiencies requiring multiple trains
    - Reduced pathogen removal
    - Limited ability to control process
    - Inefficient oxygen transfer; little ability to adjust for higher organic loading
    - Susceptible to freezing (must be housed in colder climates)
    - Odor issues

- Mechanical drive and media subject to failure and replacement.

- **SEQUENCING BATCH REACTOR (SBR)**
  - Requires skilled operators; more sophisticated operation of cycle times
  - Low pathogen removal
  - Relatively high operating and maintenance costs and requirements
  - Risk of discharging sludge during processing
  - Frequent sludge disposal
  - Effluent discharge may require equalization before disinfection.

HOW OFF-SITE TREATMENT MUST EVOLVE TO MEET THE FUTURE

Tweaking the make-up and operation of traditional treatment processes that were never designed to achieve current stringent effluent quality standards is an exercise in diminishing returns.

Accounting for such factors can strain or outright disqualify the use of traditional treatment processes. Further, the risks associated with taking no action become intolerable – operators who cannot meet permit requirements face stiff fines and penalties. In the extreme instance, their operation can be shut down.

Facing such circumstances, plant owners must implement more robust and capable treatment solutions for the customers they serve. The right choice of decentralized treatment will be cost-effective. It will produce reuse quality effluent meeting increasingly strict government standards even as wastewater flows and strengths vary. It will be compact and straightforward to operate and maintain. Selecting a modular design will enable the process to scale quickly to accommodate the demands of a growing community. Importantly, the best systems will also operate sustainably, imposing a small carbon footprint.

MABR ADVANCED WASTEWATER TREATMENT – A COMPELLING ALTERNATIVE

An emerging technology for effective on-site wastewater treatment that offers considerable promise is the membrane aerated biofilm reactor or MABR. This process is a uniquely attractive option for owners and operators who seek:

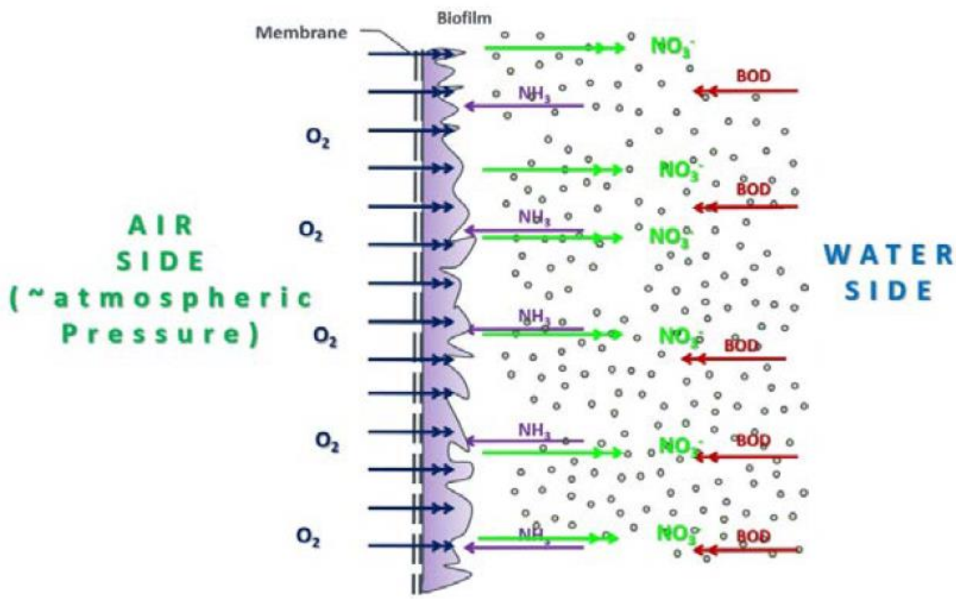
1. enhanced nutrient removal of nitrogen and bio-phosphorus
2. high-quality effluent suitable for irrigation and other beneficial reuse purposes
3. reduced capital costs
4. low operating costs due to efficient energy and chemical use
5. no odor concerns
6. treatment modules that require no maintenance
7. straightforward operation requiring minimal operator training
8. smart technology that enables remote monitoring and operation
9. quick installation and simple scaling as treatment demand increases
10. the flexibility to apply to either a greenfield installation or to retrofit an existing plant.

MABR is a biological wastewater treatment process employing permeable membranes immersed in wastewater. Low (roughly atmospheric) pressure air is gently pumped into the clean side of a sealed membrane element to concentrate oxygen relative to that found in the wastewater. By the natural process of diffusion, oxygen migrates across the membrane into the wastewater (a process also referred to as passive aeration) and supports the growth of a biofilm on the exterior membrane surface.

One distinct advantage of this low-energy passive aeration process is that it can be powered by sustainable energy sources such as solar arrays, enabling treatment to take place in areas not previously considered practical.

MABRs are most effective when deployed within suspended biomass (mixed liquor) as an integrated fixed film activated sludge (IFAS) system. The aerobic biofilm that develops on membrane surfaces is composed of nitrifying (autotrophic) bacteria in the presence of suspended solids circulating through the process as in a typical activated sludge process. The nitrifying bacteria consume most of the available oxygen, creating anoxic conditions elsewhere throughout the mixed liquor—ideal for denitrifying (heterotrophic) bacteria to convert nitrates and nitrites to nitrogen gas while oxidizing biological oxygen demand (BOD). This simultaneous nitrification and denitrification, or SND, slashes the need for supplemental carbon sources compared to conventional processes that alternate between anoxic and aerobic conditions. SND can also significantly reduce a treatment plant's footprint since both nitrification and denitrification occur in the same compact vessel instead of in separate tanks.

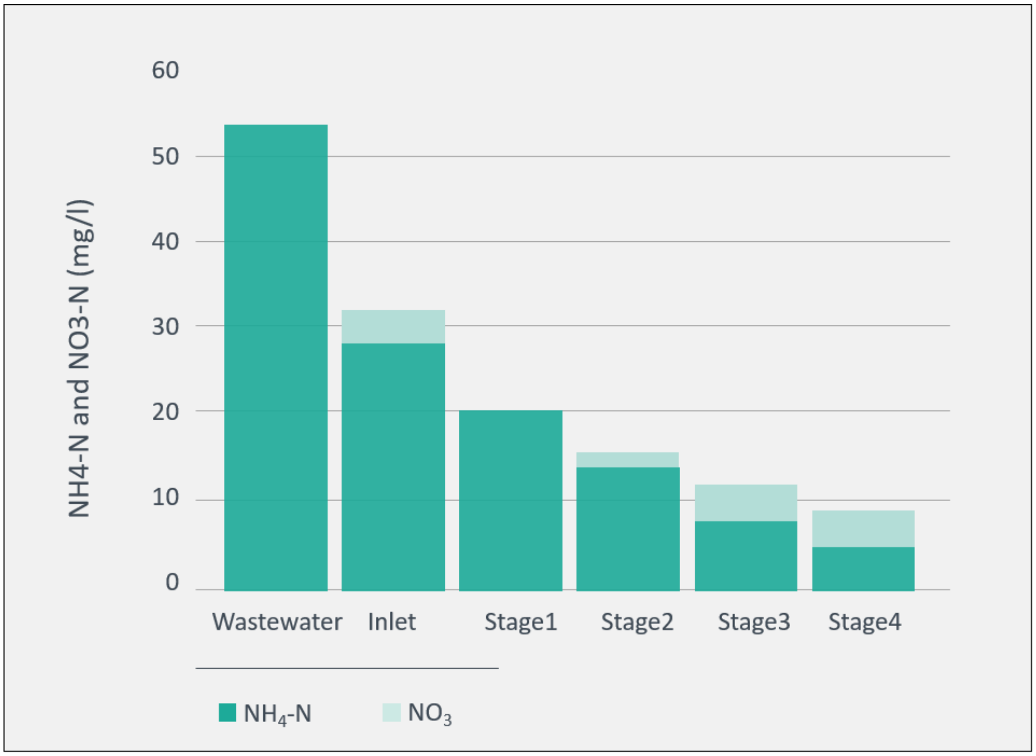
Biological Operating Principle of a Membrane Aerated Biofilm Reactor



Oxygen diffuses through the membrane (known as passive aeration) to feed a nitrifying biofilm on the membrane's exterior surface, consuming oxygen and creating anoxic conditions beyond that are ideal for denitrification to occur.

Characteristic of a multi-stage single-pass MABR process, nitrification is gradual and measurable along the reactor. The nitrification rate also decreases with decreasing concentration.

Nitrogen Removal Process Within a Multi-Stage, Single-Pass MABR



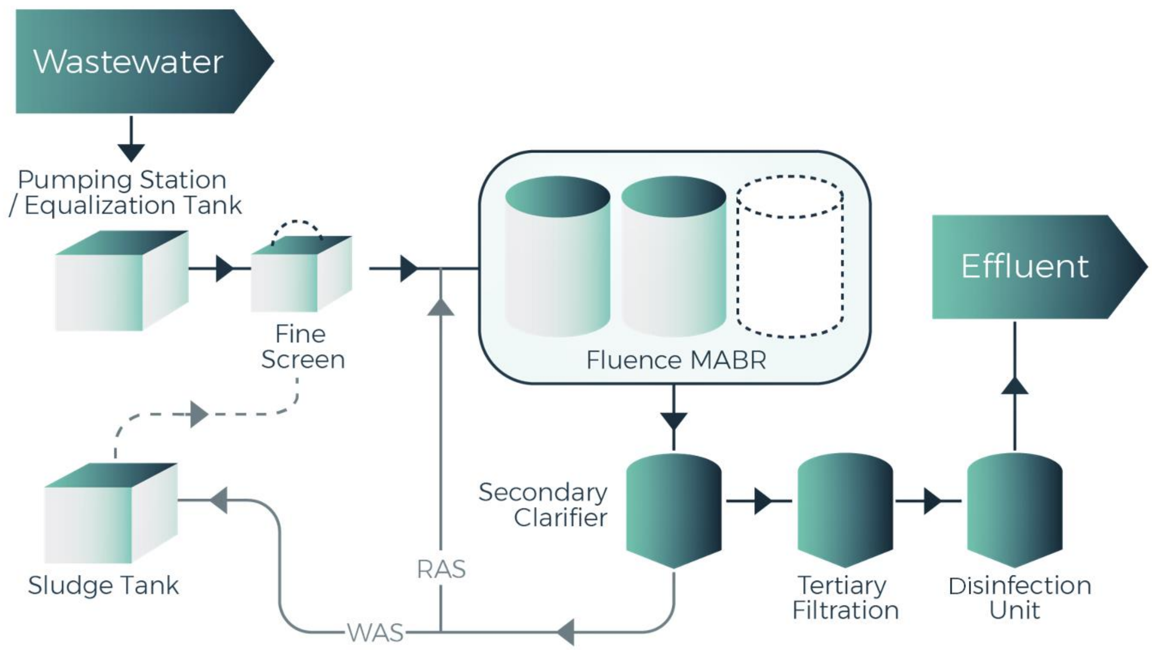
MABR module in Stage 1 is operating at the highest nitrification rate but produces zero nitrate – it is all denitrified by the suspended biomass. Modules in Stages 2 and 3 continue the treatment. Effluent ammonia concentration out of polishing Stage 4 (containing no module) is less than 5 mg/L, and TN is less than 10 mg/L.

MABR plants employ pre- and post-treatment processes found in conventional activated sludge plants, including oil and grit separation, fine screening, and equalization. Oil separation is generally recommended for cold climate plants when excess fats, oils, and grease occur in the influent. Equalization supports secondary clarification and moderates wide flow swings experienced by smaller decentralized plants. Fine screening ensures excellent membrane performance.

As with other IFAS processes, MABRs use a secondary clarifier to refine the effluent and collect waste activated sludge (WAS) while providing return activated sludge (RAS) to the wastewater entering the MABR.

Periodic mixing maintains the solids in suspension within the reactor basins. Conventional air diffusers are used to generate this mixing, and the frequency is typically several times per hour lasting 15-30 seconds. Mixing frequency and duration can be increased to enhance nitrogen removal.

Typical MABR Process Flow Diagram



Aeration processes used to degrade organic matter represents anywhere from 25 to 60 percent of a traditional wastewater treatment plant's energy expenditure. Using passive aeration, MABRs demonstrate a dramatic 87 percent reduction in aeration energy consumption compared to conventional activated sludge (CAS) processes that employ diffusers and high-powered blowers (see table below).

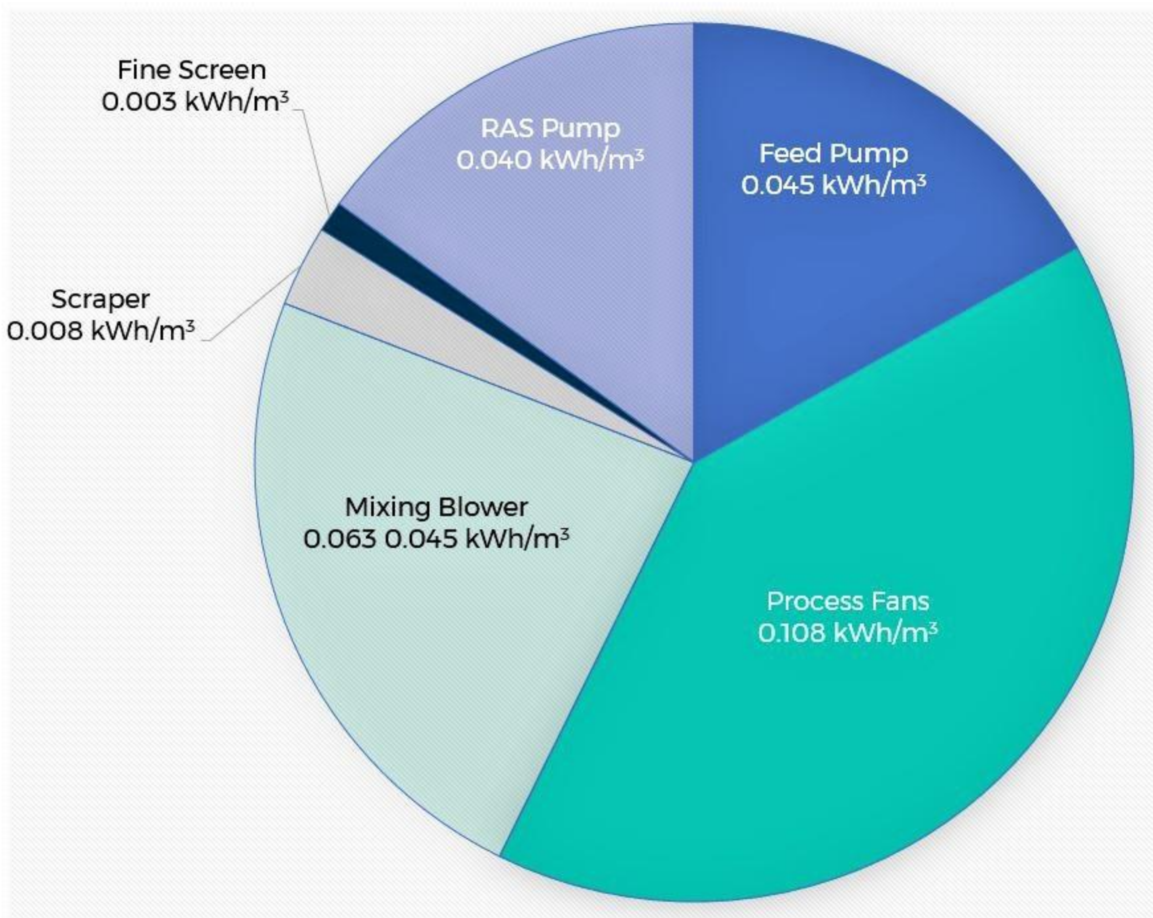
MABR Aeration Energy Consumption (as a Percentage of CAS)

	Pressure	Flow	Duty Cycle	Energy
Mixing	**80%**	**500%**	**1.7%**	**6.8%**
Process	**7.7%**	**80%**	**100%**	**6.2%**
Total				**13.0%**

MABR treatment processes employ passive aeration, dramatically reducing the aeration energy consumption compared to conventional activated sludge (CAS) processes.

An industry baseline for the typical energy consumption of a small nitrifying CAS secondary treatment plant is observed to be 0.685 kWh/m3 of wastewater treated. The energy consumption breakdown of a comparable MABR treatment plant, shown in the following graph, is 0.267 kWh/m3 – a reduction of 61 percent.

Energy Consumption Breakdown of a Typical MABR Treatment Process



MABR plants use 0.267 kWh/m^3 of wastewater treated, a 61 percent reduction in energy use compared to a small nitrifying conventional activated sludge secondary treatment plant.

All the benefits MABR technology offers for decentralized wastewater treatment applications is attracting global attention. MABR treatment plants now operate worldwide, including the US Virgin Islands, California, Israel, Spain, the Philippines, and China.

WHAT TO LOOK FOR IN THE IDEAL ON-SITE WASTEWATER TREATMENT SOLUTION

Clients seeking all the benefits MABR technology can offer to treat their municipal wastewater will specify a pre-engineered, containerized plant that can be delivered quickly and installed in a week or less without complications. Each plant will offer:

- treatment up to 80,000 gallons per day (300 m3/day) per plant, generating high-quality effluent suitable for beneficial reuse

- complete nitrogen removal without internal nitrate circulation
- a passive aeration process to reduce aeration energy consumption by at least 85 percent compared to conventional aeration techniques
- simplified operation requiring an on-site operator only twice a week for four hours per session for a total of eight hours per week
- the option to upgrade capacity by installing additional MABR modules.

CONCLUSIONS

Membrane aerated biological reactor technology is becoming the preferred, advanced wastewater treatment process for owners and operators of residential and commercial developments, mobile home and RV parks, campgrounds, and private utilities – people who presently struggle to operate outdated on-site treatment systems. The reasons become apparent when considering the benefits that a modular packaged MABR treatment system offers:

- A consistently high-quality effluent with enhanced nutrient removal suitable for irrigation and other reuse purposes
- Minimal odor issues
- Quick on-site installation saves money and fast-tracks the path to full-time plant operation
- Simple operation and maintenance and high aeration efficiency drastically reduce operating costs
- Straightforward upgrading of plant capacity by adding more treatment modules
- A compact system footprint for the treatment capabilities delivered
- Modules can be retrofitted to bolster treatment and effluent quality of existing facilities.

STANFORD U VALIDATES MABR TECHNOLOGY FOR TITLE 22 COMPLIANCE

Title 22 of California's Water Recycling Criteria is among the strictest water treatment standards for water recycling and reuse in the United States. In 2018, the Codiga Resource Recovery Center (CR2C) in Stanford CA undertook a year-long pilot study of a modular MABR plant supplied by Fluence to evaluate its treatment capabilities, focusing on turbidity removal, chemical oxygen demand (COD) reduction, and enhanced nutrient removal in the form of Total Nitrogen.

Sebastien Tilmans, Ph.D, P.E., and Director of Operations at CR2C, states that Stanford's wastewater was significantly higher strength, approximately 2-3 times higher in nitrogen and COD than typical municipal wastewater. Tilman's reported results delivered ample confirmation that MABR technology delivers advanced wastewater treatment and enhanced nutrient removal even at elevated contaminant levels.

Details of this pilot study, including test results, can be accessed in CR2C's "Interim Report of Testing of a Membrane-Aerated Bioreactor at the Codiga Resource Recovery Center at Stanford – 12/21/2018."

MABR SCORES HIGH MARKS WITH CLIENT SEEKING SUPERIOR TREATMENT

Hubei ITEST sought advanced on-site wastewater treatment for its commercial development located in Hubei Province, China, that encompasses restaurants, gas stations, a mechanical repair shop, accommodations, shopping, and parking, all situated in a compact service area.

The developer selected Fluence's MABR technology as the treatment modality best suited to achieve Class 1A effluent standards while addressing their unique challenges and desires:

- *a small physical footprint*
- *a visually appealing aesthetic*
- *odor management*
- *quiet operation*
- *effective nutrient removal*
- *low energy consumption*
- *low capital and operating expenses.*

The plant consisted of a modular design suitable for treating 200 m^3/day. From start of construction to completion, the project was commissioned within two months.

Treatment results are well within permit parameters.

3rd Party Wastewater Test Report

Released by Henan PONY Testing
Report No. HMBHPJ0A79050555ZB

Item (mg/L)	pH	NH_4-N	COD_{cr}	TN	TP	TSS	BOD_5
Influent	6.85	68.8	452	86.3	5.26	38	172
Effluent	**6.81**	**0.206**	**16**	**2.18**	**0.04**	**8**	**4.4**
Class 1A Standard	**6 ~ 9**	**< 5/8**	**< 50**	**< 15**	**< 0.5**	**< 10**	**< 10**

LEARN HOW FLUENCE'S GAME-CHANGING MABR WASTEWATER TREATMENT SOLUTIONS CAN RELIEVE YOUR PROCESS HEADACHES

Decentralized and Retrofit Wastewater Applications Powered by MABR

This webinar will discuss two design configurations in MABR technology, as well as data on global installations, provided by Fluence. ASPIRAL is a prefabricated packaged biological treatment system ideal for decentralized wastewater treatment, eliminating the need for septic systems or piping to municipal lines. SUBRE is designed to retrofit existing plants to increase treatment capacity and optimize nutrient removal within a plant's existing footprint. SUBRE is also available as a greenfield, ensuring exctpion process from the design phase.

WE INVITE YOU TO ATTEND OUR FREE WEBINAR AT 12:00 EST ON AUGUST 14, 2019

Register for Webinar

OR CALL LINDA ZUPON AT 763-746-9278 TO RESERVE YOUR SPOT.

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ABOUT FLUENCE CORPORATION LIMITED (ASX: FLC)

Fluence is a leader in the decentralized water, wastewater, and reuse treatment markets, setting the industry pace with its Smart Products Solutions, including Aspiral™, NIROBOX™, and SUBRE.

Fluence offers an integrated range of services across the complete water cycle, from early stage evaluation, through design and delivery, to ongoing support and optimization of water related assets, as well as Build Own Operate Transfer (BOOT) and other recurring revenue solutions.

With established operations in North America, South America, the Middle East, Europe, and China, Fluence has experience operating in over 70 countries worldwide and enables businesses and communities globally to maximize their water resources.

Further information can be found at https://www.fluencecorp.com/.