



PIELKENROOD

SPECIALISTS IN
OIL/WATER SEPARATION AND WASTEWATER TREATMENT
SINCE 1962

SEQUENCING BATCH REACTORS



About Pielkenrood

Since 1962, Pielkenrood has been a leading international specialist in oil/water separation and wastewater treatment. We have always focussed on recovering valuable natural resources, reusing water and caring for the environment.

Our separators and wastewater treatment plants are the best you can get, and we have 60 years of experience to prove it.

Pielkenrood works for a selected group of industrial customers, who value sustainability, responsible use of resources and performance.

An innovative family business

As a family business, we pass on our knowledge and experience from generation to generation. Moreover, we have a long-term view on investments, relationships and innovation.

In 1895 Jacob Pielkenrood, a blacksmith, started his own company. A few years later, he invented a leak-proof iron barrel that soon evolved into the well-known steel oil drum. This was the starting point of a rich history of entrepreneurship and innovation. Another excellent example of innovation followed in 1962 when Royal Dutch Shell and Pielkenrood invented and developed the famous CPI or 'Corrugated Plate Interceptor'. This was the first type of oil/water separator equipped with corrugated plates, which greatly enhanced the separation efficiency.

The CPI and its successors became the world standard for oil/water separation

Water treatment is a specialist job

Designing and building a water treatment plant is a complex job that should not be underestimated.

Pielkenrood is your partner of choice for oil/water separation, valuable oil recovery from produced water and an array of effective wastewater treatment solutions.

We supply leading-edge and tailor-made packages that do what they are designed to do: deliver outstanding performance.

Sustainability

Water treatment has a significant impact on working towards a more sustainable and circular society. The core values of all Pielkenrood designs are:

1. Recovery of valuable natural resources. For example, hydrocarbons.
2. Safe reuse or discharge of treated water.
3. Minimize energy consumption, and where possible, recover energy.

We achieve our values because of our outstanding and proven process designs. Moreover, we select the right equipment and use the correct sizing in relation to the design capacity.

Performance

Often, the design of a treatment plant is cost-driven. Customers select the option with the lowest CAPEX.

Pielkenrood treatment plants are designed to deliver outstanding performance

That means that sometimes we might not be the cheapest in terms of CAPEX. Our priority is to achieve your sustainability goals, while reducing your operating cost.

For instance, during a pilot test, we showed an international oil company that we recover 1850 barrels of crude oil per day from 1600 m³/h of produced water. At the same time, we reduced the operating cost of downstream equipment.

We are good at smart designs and equipment that does what it has to do



Biological wastewater treatment

Biological treatment plants are also known as activated sludge or aerobic biological treatment plants.

This type of plant consists of tanks or basins, partly filled with activated sludge. The sludge is called 'activated' because it consists of microorganisms or bacteria. Wastewater is added to the tanks and mixed with the activated sludge.

The idea is that the microorganisms consume the pollution load. In order to enable them to 'eat', they need oxygen, which is supplied through an aeration grid.

Biological treatment plants are perfect for removing organic matter, nitrates and phosphorus from wastewater. However, they are not suitable to remove oil, VOCs and refractory chemicals. That's why for industrial applications, we always install a proper pre-treatment. For example consisting of CPLs, physical-chemical treatment in combination with a Dissolved Air Flotation or stripping towers.

In 1979 we designed and built our first biological wastewater treatment plant based on the superior Sequencing Batch Reactor principle, or SBR in short.

Today, we supply SBR plants for domestic as well as industrial wastewater treatment. Each application requires its own specific approach.

BOD and COD

BOD stands for Biological Oxygen demand, which is the pollution load that microorganisms remove from the wastewater.

COD stands for Chemical Oxygen demand and is the pollution load that the bacteria can't remove. COD is removed by oxidation instead. This is an automatic process facilitated by the aeration.

Both BOD and COD are used as a measure of the pollution load present in the raw water. Furthermore, BOD and COD are used to rate the quality of the treated water.

Continuous type plants

Most aerobic biological wastewater treatment plants in operation are traditional continuous

systems with separate aeration tanks and clarifiers. The clarifiers are usually the well known circular basins with slowly turning sludge scrapers.

The wastewater first enters the primary clarifiers, where heavier solids settle.

Subsequently, the clarified water is pumped to the aeration basins containing activated sludge, mixed with the wastewater by aeration.

Blowers, the biggest energy consumers in any biological treatment plant, provide fresh air to the aeration grid. In a continuous treatment plant, aeration must take place 24/7.

Continuous treatment plants consume a tremendous amount of energy

Biological treatment plants don't only remove organic matter from wastewater but also nitrates. This is important because nitrates cause algae growth in surface water.

Removing organic matter (BOD and COD) takes place under aerobic (aerated) conditions. However, getting rid of nitrates requires aerobic conditions followed by anoxic conditions.

The conversion of the ammonium compounds into nitrite and nitrate, takes place under aerobic conditions. For the subsequent conversion into nitrogen gas (N₂), anoxic conditions are required,

As such, a separate basin is required for denitrification.

After aeration and denitrification, the treated wastewater is pumped to secondary clarifiers in which the activated sludge settles. The clarified water is discharged, while part of the sludge needs to be returned to the aeration basins. Excess sludge goes to the sludge dewatering plant.

The disadvantages of continuous plants summarized:

- Very high energy consumption;
- Poor performance;



- Primary and secondary clarifiers with sludge scrapers that consume energy and require maintenance;
- Multiple aeration basins.

The design is outdated in this day and age of sustainability, energy savings and care for the environment.

Sequencing Batch Reactor

The SBR is also based on removing pollution using activated sludge, just like the continuous plants. The difference is the batch-wise operation, which offers significant advantages.

Batch-wise operation of biological treatment plants is not a new concept. The first SBRs were already in operation at the beginning of the 20th century.

Batch-wise operation is a logical choice, because it allows for efficient operation. Based on our revolutionary redox potential measurement, the blowers automatically stop aeration when the microorganisms have processed almost all of the BOD and COD.

Due to stricter regulations from the late 1970s onwards, the demand for more complex wastewater treatment plants was rapidly increasing.

As a result we started investigating the biological water treatment process and technologies. Initially using the famous Dégremont handbook for guidance. Our chemical engineers were of the opinion that a batch process was a logical choice.

We studied the publications of the American SBR specialist Robert L. Irvine and we learned that biological treatment takes place in subsequent stages: aerobic, anoxic and even anaerobic (for short periods of time).

The SBR is particularly suitable to create these different and subsequent stages. The only problem was that we couldn't find a way to control the aeration in such a way to create these different conditions. Traditional oxygen measurement didn't work.

Pielkenrood engineers found out that they could use the potential difference, that occurs as a consequence of the redox reaction of the dissolved oxygen with the pollutants in the wastewater, to control aeration. At that time

reliable ORP instruments were not readily available and so we created our own.

We could now measure the exact oxygen concentration, including negative ones, and oxygen demand based on the redox potential difference. We called our invention 'Debitox'.

So, the Pielkenrood SBR technology is based on two principles:

1. Sequential treatment process with aerobic, anoxic and anaerobic stages. This results in a very efficient treatment process, especially compared to the mixed aeration basins of continuous plants.
2. ORP controlled aeration allows us to prevent excess dissolved oxygen. That means that we don't supply more air than is strictly required for removing BOD and COD.

Consequently, there is a direct relation between the rated power of the blowers and the COD removed.

Our unique operating philosophy means that the blowers only operate when required.

*This results in huge savings
on energy consumption,
30% or more*

The downside is, or rather was, that you constantly need to measure and control the performance.

In the early days of "industrialized" biological treatment, automatic plant control was, of course, impossible. The operation of an SBR required constant attention. This drawback initiated the development of continuous biotreatment. Today, however, reliable plant control hardware and software are widely available, eliminating the old SBR disadvantage: the need for continued operator attendance.

Where continuous plants consist of multiple basins, we need only one basin or tank and a buffer tank for a Sequencing Batch Reactor.



Picture 1: traditional continuous biological wastewater treatment plant



Picture 2: Sequencing Batch Reactor biological wastewater treatment plant



This is because receiving wastewater, treating the water, decanting and discharging the treated water all occur in one basin or tank. That includes nitrification and denitrification. There is also no need to return the activated sludge from a secondary clarifier, as it simply remains in the same tank. Furthermore, it is easy to remove excess sludge from the SBR tank.

This treatment method is perfectly logical as the process conditions are easily controllable and adaptable. Therefore, the performance of SBRs is significantly better than that of continuous treatment plants. And the operating costs are much lower. The best of both worlds, so to say.

That is why Pielkenrood only supplies SBR type biological treatment plants.

For most biological treatment plants concrete basins are used. Smaller SBR plants, approximately with a capacity of up to 5000 m³/d, can also be built with above grade steel tanks. This is not possible with continuous type treatment plants.

Sustainability

SBRs offer a number of important advantages in terms of sustainability, as compared to conventional biological treatment plants:

- No primary and secondary clarifiers with rotating sludge scrapers, resulting in lower power consumption;
- 30% less power consumption because the air blowers operate only when needed and not 24/7;
- No need to return activated sludge from the secondary clarifiers to the aeration tanks, as all processes take place in one tank. This further reduces energy consumption;
- High COD, BOD, TSS, and Nitrate removal rate;
- The capability of handling severe load fluctuations;
- Automated activated sludge management;
- Far better process control, resulting in a cleaner effluent;

- Up to 40% less surplus sludge production reduces the size of sludge dewatering equipment;
- Suppression of bulking sludge;
- Resilience against toxic shocks.

With the current and vital focus on sustainability, we cannot ignore these advantages

So much so that we also modify existing continuous plants to SBR plants.

Basic design principles

In the SBR tank, the functions of equalization, aeration, and sedimentation occur in a time sequence rather than in the conventional space sequence of a continuous flow system, where these functions have to be performed in separate tanks.

If the wastewater flow is continuous, an SBR plant should comprise two or more tanks or basins.

A cycle of a typical SBR is divided into four or five discrete or stages:

1. Fill
2. React
3. Settle
4. Draw
5. Idle

The duration of these stages can be varied depending on the actual process conditions and requirements.

Fill

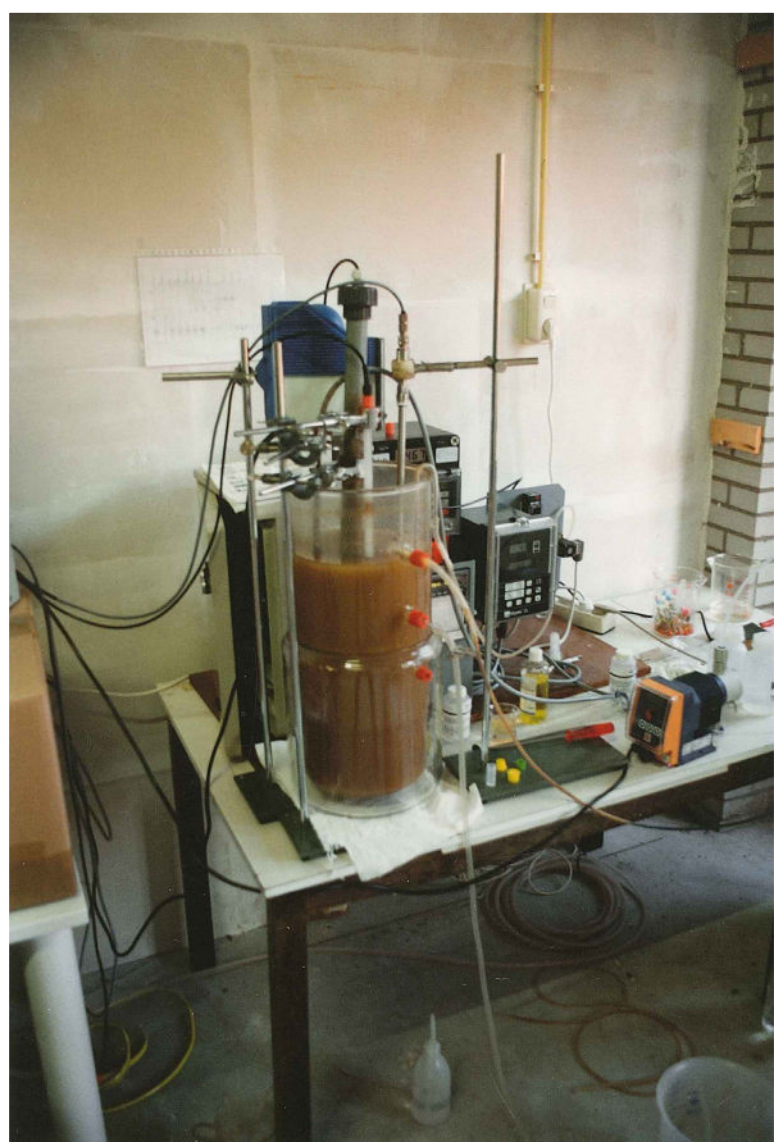
A key element with SBR systems is that the activated sludge is retained in the tank. This is the so-called rest volume. Determining the rest volume depends on several factors, one of which is the MLSS (Mixed Liquor Suspended Solids) concentration at low liquid level. Wastewater is added to the activated sludge remaining in the tank from the previous cycle. The fill stage ends either when the tank is full or when the maximum time is reached.



Picture 3: modular sewage treatment plant installed in the basement of a building



Picture 4: skimmer for a 625 m³/h plant



Picture 5: continuous R&D in our laboratory



The first part of this stage is static filling, characterized by no aeration and mixing. Static fill is followed by aerated filling.

React

Reactions already started during the filling stage are completed during this stage. Excess sludge wasting can take place during this stage.

Settle

During the settling stage, solids and liquids separate. Settling typically takes place under completely quiescent conditions.

Draw

During the drawing stage, the treated wastewater is removed from the tank. The discharge rate depends on the settling characteristics of the sludge (overflow rate). Sludge wasting may be performed during this stage.

Idle

During this stage, sludge wasting may take place.

Aeration control

In continuous treatment plants, aeration is controlled through Dissolved Oxygen (DO) measurement. Dutch Clean Tech introduced ORP, or redox potential, measurement to control the operation of SBRs. The advantage is that we can measure the oxygen concentration in both aerobic and anoxic conditions.

This allows us to operate the SBR at almost anoxic (zero dissolved oxygen) conditions with no more air being supplied that is strictly needed for the treatment process. The result is that the rate of oxygen supply is equal to the rate of oxygen consumption.

Consequently, the power consumption of the aeration blowers is a measure of the COD/BOD removed. This information enables fully automatic plant control and operation.

The advantages are:

- Alternate aerobic and anoxic conditions can be set as required;
- Nitrification/denitrification is achieved without the need for separate reactors;

- Sludge management is automated as sludge growth is proportional to COD/BOD removed.

Aeration system

The SBR aeration system is operated in an on/off mode, based on oxygen demand. Air bubble diffusers, such as membrane type diffusers are sensitive to this way of operation and will need frequent servicing or replacement, for instance, due to membrane rupture.

For the aeration of the SBRs, we use a coarse bubble aeration system, whereby the oxygen transfer efficiency closely approaches that of fine bubble aeration. Contrary to fine bubble aeration, no air diffusers are required with coarse bubble aeration.

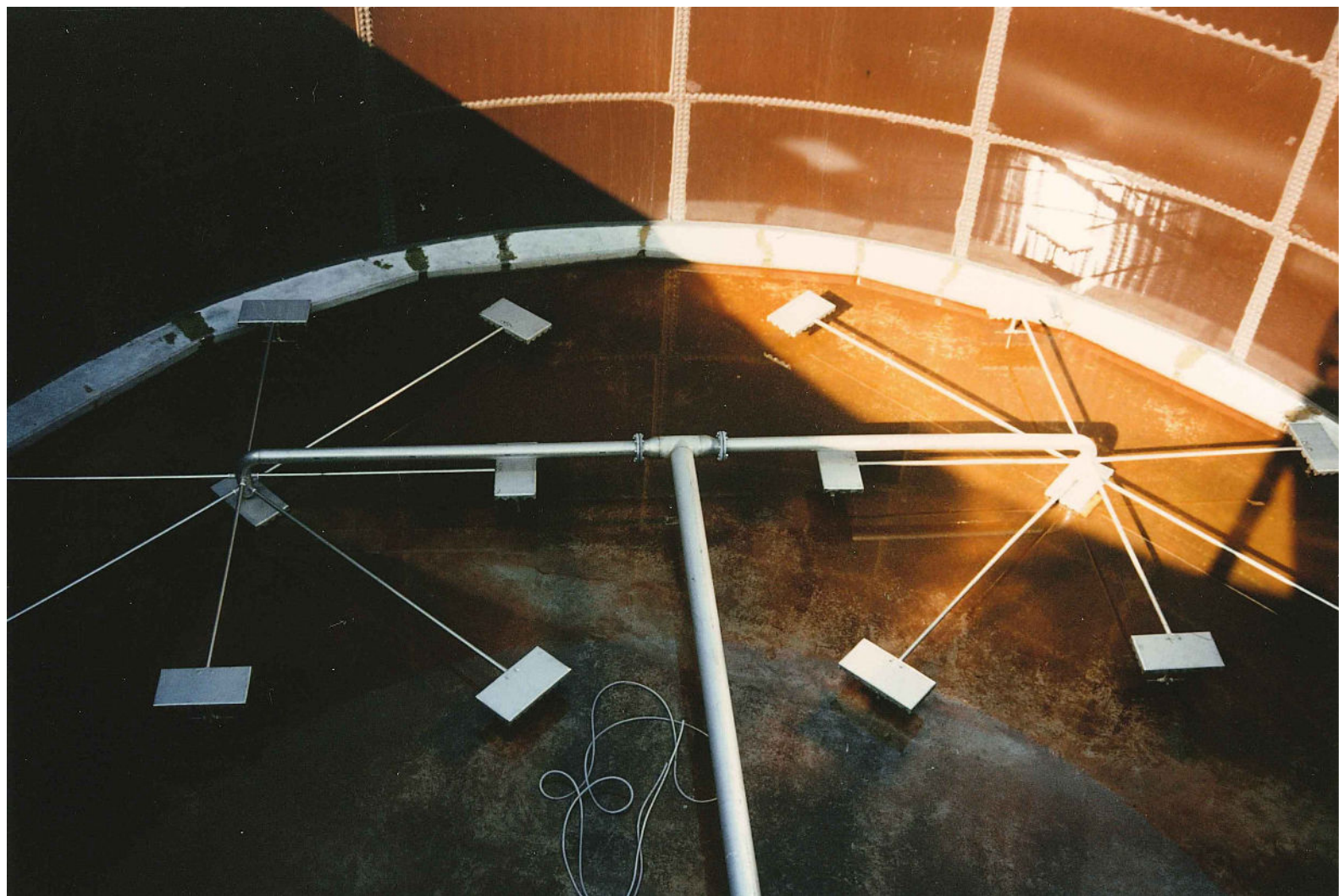
The air is distributed via a tank bottom-mounted air grid. The air is mixed with the entire activated sludge inventory of the SBR to provide oxygen for the breakdown of contaminants. A high mixing intensity ensures that all areas of the reactor are aerated, preventing local accumulation of sludge that may turn anaerobic.

The air distribution grid used is trouble and maintenance-free and ensures:

- a rapid transfer from anoxic to aerobic conditions;
- all areas of the reactor are aerated;
- the thorough mixing due to the injection of air stirs up the total activated sludge inventory of the reactor;
- air bubbles continue to transfer oxygen while rising to the liquid surface;
- the SBRs never need to be shut down for maintenance of the air distribution system.

Disinfection

If the treated water has to be reused for irrigation, for example, it is necessary to disinfect it before discharging. We use UV cells to remove Coliform bacteria and other pathogens.



Picture 6: aeration grid



Picture 7: optimal aeration and mixing



Food/mass (F/M) ratio

The F/M ratio is the inlet COD/BOD load (food) versus the mass of microorganisms that have to process the COD/BOD load (consume the food).

In a continuous flow-through sewage treatment plant, the F/M ratio is always near-constant as the amount of incoming food versus the biomass concentration hardly varies.

In an SBR, the F/M ratio is variable. During the fill stage, the F/M ratio is high, as a lot of food is delivered to the biomass in a short period. However, towards the end of the react (treatment) stage, the F/M ratio is very low.

The F/M ratio is a crucial operating tool:

- A low F/M ratio gives superior treatment results;
- A low F/M ratio results in a low surplus sludge yield;
- A low F/M ratio regime allows filamentous bacteria to thrive. Filamentous bacteria significantly impede the settling of the biomass so that bulking sludge carries over into the treated water takes place.

Because of this last consideration, continuous flow-through STPs are rarely operated with a low F/M ratio. The resulting higher sludge production and less than superior treated water quality are taken for granted.

Above, we have seen that the SBR has an alternating high/low F/M ratio. In this regime, filamentous bacteria cannot prosper. Therefore SBRs can be operated with a very low average F/M ratio, thus rendering a low surplus sludge yield and excellent treatment results.

Surplus activated sludge reduction

Activated sludge in a bio-treatment system will grow due to the aerobic biochemical breakdown of the contaminants by the MLSS biomass. Therefore surplus sludge needs to be wasted regularly.

The cost related to the disposal of the waste sludge can be a substantial part of the operating cost of the sewage treatment plant. It is therefore imperative to keep the volume of generated surplus sludge as low as possible.

In the SBRs, activated sludge mineralization already occurs because of the low average F/M ratio and because a long sludge retention time is maintained.

To further minimize the volume generated in the SBR plant, we recommend that the sludge be aerobically stabilized in a sludge stabilization reactor (SSR). Sludge stabilization will significantly decrease the sludge volume.

Consequently, sludge dewatering equipment can be sized accordingly, while considerable savings on sludge disposal costs can be achieved.

Aerobic sludge stabilization can be defined as the mineralisation of the activated sludge.

The SSR offers the following advantages:

- Similar to the operation of the SBRs the operation and process of the stabilisation reactor is flexible and can be totally controlled;
- SSR operation is fully automatic;
- Minimum aeration capacity is required to attain optimum results. Sludge reduction rates of 35 -50 % can be achieved;
- Not only cost of downstream dewatering can be saved but also very considerable cost savings can be realised for sludge disposal;
- If, due to extreme circumstances (abnormal pH of the waste water or a toxic load) a partial or total kill of the biomass in an SBR would occur, sludge from the SSR is at once available for re-seeding.

Conclusion

In this modern day and age, the SBR is the only logical choice for municipal and industrial wastewater treatment.

Superior treatment results are combined with huge energy saving and low waste sludge volumes.

Pielkenrood offers standard and modular treatment plants for smaller communities and tailor-made plants for larger cities. Furthermore we offer interesting financing options, such as pay for use instead of pay for ownership. The advantages for our clients are clear. Immediate results, no investment and no need



for a separate organisation to operate and maintain the treatment plants.

Contact details

Pielkenrood
Amperestraat 3
1704 SM Heerhugowaard
The Netherlands
Telephone: +31 224 216568
E-mail: info@pielkenrood.net
Internet: www.pielkenrood.net