ABSTRACT

SBR (sequential batch reactor technology) is widely introduced in New Zealand and overseas as a modern wastewater treatment process. The SBR process enjoys growing popularity worldwide and is based on the principle that treatment of wastewater works significantly better under defined volume conditions. Classic sewage plant technologies (i.e. continuous flow plants) cannot provide the same process stability. The more reliable operational performance of SBR plants can cover a wider range of dynamic wastewater discharges arriving at the plant.

So far sewage lagoons and ponds were exempt from the benefits of the SBR technology as constant SBR process volumes were not achievable due to pond geometry and process (continuous flow/running plant). Twelve years ago, the German Company GAA mbH near Hamburg, created a Constant-Waterlevel-SBR process (CWSBR®) for waste water ponds, introducing a fully operational SBR system for any type of sewage pond. Due to the reduced structural costs and state of the art construction, savings are substantial and can be up to 50%. Distributed through GWS - Technologies, Taupo, New Zealand, CWSBR® pond systems are now also available in Australia and New Zealand.

INTRODUCTION

In the past the main discussion about wastewater treatment was focused on the amount of concrete, and machinery required for building a plant. Remembering the early 1990’s, waste water treatment was back then characterized by continuous flow plants.

Although the principle of SBR was known since the early twentieth century, the development of programmable logic control (PLC) systems enabled the SBR technology to finally take off and say good bye to continuous flow plants as the only way of treating sewage effluent. However in rural areas wastewater was still treated in simple ponds and lagoons with the quality of treatment not sufficient to comply with high environmental standards. Hence the construction of new pond systems even for rural communities was discarded as the applying standards could no longer be met. This has now changed with the introduction of the CWSBR® Technology.

CWSBR® (CONSTANT WATER LEVEL SBR)

CWSBR® follows the original SBR process including all operational advantages. Like the original SBR system, CWSBR® is based on modern PLC-technology and was also made possible through the development of modern synthetic materials and geotextiles, creating the tools for a dynamic pond technology.

CWSBR® combines the principles of a standard above ground SBR plant with the low cost installation of a traditional lagoon type treatment plant. Since batch processes are characterized by periodically changing water levels, common SBR-plants normally use structural tanks as reactors to handle large sewage quantities.

In order to transfer SBR technology to a pond type treatment plant, the initial task was to substitute the vertically moving batch volumes of the classic SBR process with defined volumes moving horizontally under a fixed (constant) water level in a pond. This problem was solved with the introduction of the so called “Hydrosails”.

The Hydrosails finally made it possible to replace concrete walls with an earth-worked lagoon naturally supported by surrounding soils.

CWSBR® Hydrosail system is attached to the pond floor. Fixed floats on the top edge are keeping the sails always upright enabling the Hydrosails to separate the pond volume into the different SBR reactor zones with the simple but ingenious difference, that the volume changes are now operated horizontally compared to the vertical changes in a standard SBR configuration (Figure 1).

Figure 1: Comparison of water volume changes of CWSBR® and a standard SBR plant
The CWSBR® process is the same as in standard SBR plants. From the primary wastewater-collecting zone, the CWSBR® system pumps the water into the activated sludge zone, the CWSB® Reactor. The Hydrosails follow the change in volume passively. With balanced water tables on both sides of the sails, tension and stress is not a problem as the Hydrosails just move with the alternating flows. As the water table throughout the pond maintains a constant level at all times buoyancy problems for the pond liner caused by fluctuating volumes are unknown and slope stability is not an issue. Figure 2 illustrates the attenuation effect of a CWSBR® plant over a period of 6 days. Like in continuous flow plants, hydraulic peak flows do not proceed into the receiving waters even under storm conditions.

Figure 2: Equalization of a dynamic wastewater inflow by CWSBR® during SBR treatment over six days including storm weather impact. Peak flows become hydraulically attenuated by the entire water volume. The outflow is harmonized and continuous.

The invention of the CWSBR® system presents a low cost sewage treatment system with the ability of outstanding Nitrogen and Phosphorus removal. The CWSBR® system complies with the latest German and European standards for wastewater treatment (ATV Standards) which are acknowledged as a high industry standard allowing for comparability and adaptability of SBR plants worldwide. A full animation of the CWSBR® cycle is presented at www.g-a-a.de and www.gwswater.co.nz.

DEVELOPMENT AND PLANTS CONSTRUCTED TO DATE

The first CWSBR® plant was built in Germany in 2000 in order to retrofit an existing sewage lagoon system. After twelve years the accumulated knowledge and experience with CWSBR® pond retrofitting can be summarized as follows: CWSBR® guarantees full SBR performance including nitrification, denitrification, phosphorus removal by Bio-P and fully stabilized sludge.

The typical attribute for SBR technology, that the treatment success is largely independent from the plant size also applies for the CWSBR® systems. To date new plants sizing from 800 PE to 210,000 PE (Population Equivalent) were designed and constructed. Upgrades of existing ponds and lagoons were carried out from 5,000 PE to 10,000 PE by retrofitting and extending existing wastewater ponds (Picture 1/2).

Figure 2: CWSBR® is a full performance SBR process in the shape of a pond technology, which grants highest wastewater treatment standards.

Picture 1: CWSBR® System under running conditions, showing aerated zone

SHORT TIME OF CONSTRUCTION - USAGE OF EXISTING STRUCTURES

For retrofitting projects, an average construction time of 3 months has been established. New CWSBR® plants are typically constructed within 3 to 6 months depending on size and local conditions. As the CWSBR® system is a high-end wastewater treatment process, increasing the treated volume-per-time ratio substantially, approximately 70% of the total pond footprint will be available after the upgrade for other tasks like stormwater retention or further sludge stabilization processes. Existing buildings and structures will be incorporated in the design and will be used for the installation of the plant equipment.

CWSBR® COSTS
The key argument for a CWSBR® installation is the low capital cost to establish a state of the art, full-scale SBR technology, where investments can be less than 50% compared to a standard above ground SBR plant.

Other cost advantages derive from OM reductions i.e. the elimination of expensive pond sludge removal every 5 to 7 years, which is replaced by continuous sludge stacking in a separate bed. Whereas the energy demand for wastewater aeration is comparable to standard SBR plants, the cost for circulation pumping is reduced by 35%. This reduction is a direct result of the constant water level which requires the pumps to only overcome friction losses. Pumping against a static head is not involved because the level of the waterbody is not changing.

Also an important advantage of CWSBR® compared to classic SBR is the decrease of the required time for sedimentation and decantation. In the classic batch process, the SBR zone is a homogenous mixture of water and activated sludge. After the treatment process the sludge settles and above the sludge zone the clear water zone is consequently established. This clear water zone is skimmed and separated from the sludge zone by a floating decanter, which follows the sludge level until it has reached the minimum level of fill in the SBR reactor. However in a CWSBR® plant with constant water level the decantation is performed without changes in the water level. As a result the decantation device operates at a greater distance from the sludge zone and a very good water-sludge separation can be achieved even during high flow decanting velocities.

**CWSBR® PERFORMANCE**

The stability of the microbiological mixture in a CWSBR® system allows complete nitrogen reduction even at low BOD intakes (Figure 3).

**NITROGEN REDUCTION**

SBR plants are able to eliminate nitrogen without additional filters due to an enhanced denitrification performance. In contrast to continuous flow plants, where nitrification and denitrification are separated in different plant compartments, SBR plants achieve both reactions as usual in consecutive sequences, however in the same reactor volume. This kind of bioprocess engineering has a significant impact on the achievable level of denitrification.

Figure 4 shows the activation of a CWSBR® plant in winter 2011 starting at 6°C water temperature. The plant was inoculated with activated sludge from a standard continuous flow plant. It becomes obvious, that the activated sludge of a continuous flow plant was feasible to start up the SBR bioprocess, which fulfilled the standard nitrogen reduction values of 10 mg/l after 7 days! Subsequently, further adjustments of aeration time and batch reactor feeding minimized the nitrogen output down to 2 mg/l just by operational decisions but not by additional filter technologies or other added expenses.

This performance of a small (3,700 PE) CWSBR® plant is remarkable because the overall efficiency of wastewater treatment plants is typically decreasing with the size of the plant.

**LARGE CWSBR® PLANTS**

Originally developed for small lagoon type treatment systems in the recent past the CWSBR® system has shown its unique advantages when constructing large plants as well. CWSBR® plants to date have now been built for up to 210,000 population equivalents (PE). The latest plant was commissioned end of 2011 with several more in the design stage or under construction.
With the size of those plants the CWSBR® system is now established as one of the world largest built SBR systems, and has found its way from use in rural environments into the wastewater management of big cities. The decision to construct large size plants was naturally made in China and India where pond technologies have a long tradition. As already established for the smaller plants, the large plants are constantly showing the same treated effluent quality.

**SUMMARY**

CWSBR® systems are the first choice when it comes to building new plants or retrofitting and upgrading existing sewage ponds and lagoons to the standards of large municipal SBR-plants at low cost. Twelve years experience in building and operating CWSBR® plants have shown that this low price SBR alternative meets all expectations of modern wastewater treatment. CWSBR® applications are now established throughout the world ranging from 800 PE up to 210,000 PE demonstrating that the CWSBR® system and its simple form of construction can be adapted to all rural and municipal waste water treatment applications. The efficiency of wastewater treatment to the highest standards was continuously demonstrated at a high level of reliability. The CWSBR® system can be used for centralized or decentralized solutions with a substantial advantage in cost.
Table 1: Comparison of large and small CWSBR® plants operating in China (centralized, >100,000 PE) and Germany (decentralized, <5,000 PE). Both plants are constructed with CWSBR® Technology and operate under the same SBR conditions (PE=Population Equivalent).

<table>
<thead>
<tr>
<th></th>
<th>COD [mg/l]</th>
<th>BOD$_5$ [mg/l]</th>
<th>Suspended Solids [mg/l]</th>
<th>NH$_4^+$-N [mg/l]</th>
<th>Total Nitrogen [mg/l]</th>
<th>Total Phosphorous [mg/l]</th>
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<tr>
<td>China &gt; 100,000 PE</td>
<td>150-485</td>
<td>70-240</td>
<td>80-310</td>
<td>8-25</td>
<td>15-43</td>
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<td>4</td>
<td>8</td>
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<td>300-1,000</td>
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<td>0</td>
<td>0,1</td>
<td>2,2</td>
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</tbody>
</table>

Figure 4: Commissioning of a CWSBR® Plant 3700 PE in winter 2011 at 6°C water temperature. After seven days the plant fulfilled the nitrogen effluent standard. After three month the plants nitrogen effluent came below to approximately 2 mg/l, which corresponds to a removal efficiency of over 96%.
Figure 5: Schematic Layout for retrofitting an existing pond system to a CWSBR® Plant

SHORT BIO OF THE AUTHORS:

Werner Gebauer, managing director of GWS Technology is a Civil Engineer (MEng Dip. C.E. Germany) with more than 20 years of experience in waste water technology and holds a New Zealand CPEng certificate. GWS Technology operates in Australia and New Zealand distributing the CWSBR® system in Australasia.

Axel Dederichs, managing director and founder of G.A.A. (1989) is a Mechanical Engineer with more than 20 years experience in wastewater treatment. He developed and designed the patented CWSBR® technology in 2000 now making this outstanding technology available for a wide range of small and large applications.

Dr. Tim Koeckritz, chief knowledge officer of G.A.A. is a Biotechnologist with special emphasis on environmental sustainability and chemical water engineering. With more than 15 years of professional experience, he is the mastermind for every aspect of the SBR process and any other environmental concern.

Contact
GWS Technology Ltd.
5 Bernard Street
Taupo 3330
New Zealand
Tel NZ.: +64 22 091 77 39
Tel OZ: +61 48 7477 482
info@gwswater.co.nz
www.gwswater.co.nz
info@g-a-a.de
www.g-a-a.de