INSTITUTE FOR ENVIRONMENTAL BIOTECHNOLOGY, RHODES UNIVERSITY (EBRU)

INTEGRATED ALGAE POND SYSTEMS: WASTE WATER TREATMENT, RECOVERY AND REUSE

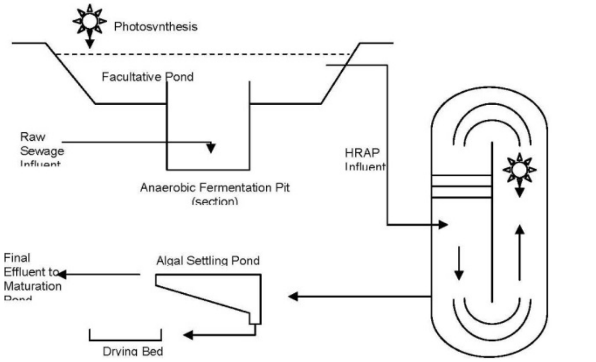
Integrated Algae Pond Systems (IAPS) utilise anaerobic and aerobic biological processes in waste water treatment and epitomise the principles of both water and nutrient recovery and reuse. These systems close the cycle of waste to biomass by converting organic waste into an algae biomass rich in protein, while stripping out nutrients. Furthermore, all this is accomplished without mechanical aeration by capitalising on solar energy and, following algae harvesting, to yield a high quality disinfected effluent comparable in quality to that obtained from using other biological or physicochemical treatment processes. Ponds not only provide low-cost reactors, at least an order of magnitude cheaper than concrete structures but algae photosynthesis yields large quantities of oxygen to support bacterial breakdown of organics.

Opening of the Integrated Algae Pond Systems research and reference plant by the Minister of Water Affairs and Forestry, Prof Kadar Asmal, in 1997.

The Water Research Commission (WRC) funded a 9-year study on application of IAPS to a range of waste waters in South Africa which was carried out by researchers from the Institute for Environmental Bio-technology, Rhodes University (EBRU). In addition to the treatment of domestic sewage, application of IAPS to treatment of abattoir, tannery, winery and distillery, and acid mine drainage waste waters, and application of water recycle and reuse in horticulture job creation were also studied.

INTEGRATED ALGAE POND SYSTEMS

The unit process operations of IAPS are similar to those of conventional waste water treatment plants and include; primary sedi-mentation, flotation, fermentation, aeration, secondary sedimentation, nutrient removal, storage, and final disposal. In the scheme below, the principal unit operations of an IAPS process are depicted which comprises a four-pond series and operate as follows:



Schematic of the principal unit operations of the IAPS constructed on site at the Institute for Environmental Biotechnology, Rhodes Univer-sity.

Primary Facultative Pond – The first of the four-pond series is the Primary Facultative Pond (PFP), in which the anaerobic bottom zone is overlaid with surface aerobic waters, creating two functionally separate zones in the pond. A fermentation pit is constructed in the base of the PFP in which solids sediment and anaerobic processes take place.

Raw waste is introduced near the bottom of the pit and solids tend toremain within. Overflow velocity is designed to be low enough (less than 1.5 m/day) so that helminth ova and other parasites remain in the pit. Carbon dioxide in the biogas is available to support algae growth in the upper layers of the PFP, and the generation of photosynthetic oxygen provides, in part, the aerobic function of this compartment. The upper aerobic layer is also responsible for particularly effective entrapment and oxidation of odour causing compounds. Retention and digestion of solids in the anaerobic pit means waste sludge handling is eliminated in the IAPS operation.

High Rate Algae Pond – The High Rate Algae Pond (HRAP) is a paddle wheel-driven raceway with short retention time of 3 days, and produces high amounts of dissolved oxygen due to algae photosynthesis. Algae in these systems form stable flocs, which settle readily, and >80% of the algal cells present in the system may be removed in a short residence time Algal Settling Pond (ASP). This biomass has a low respiration rate and may remain concentrated in the bottom of the ASP for a period of weeks or even months without loss of nutrients. The algae have been shown to provide an effective fertiliser for downstream use in horticulture applications. Algal photosynthesis in the HRAP tends to raise the pH of the treated waters, and a pH of 9.2 for 24 hours will provide a 100% kill of *E.coli* and pathogenic bacteria. It is not uncommon for the HRAP to reach pH of 9.5-10 daylight, so a high rate of disinfection is normally achieved. EBRU has confirmed that treated water meets the General Standard for ammonia, nitrate, phosphate and *E.coli*.

EBRU has also shown that the HRAP can be used as a free-standing unit to buffer poorly performing sewage works and the receiving environment.

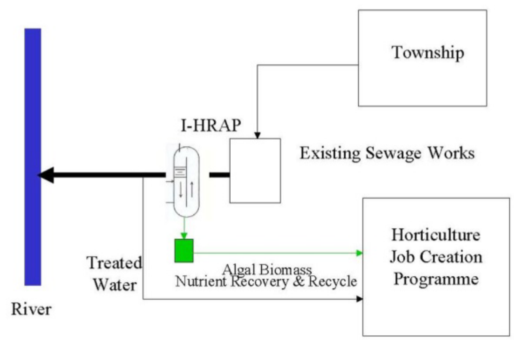
Maturation Pond – Where shorter retention times are used in the HRAP and the treated water is to be discharged under conditions leading to possible human contact, storage for 10 to 20 days in a deep maturation pond may be used instead of chlorination, and will provide adequate reduction of the bacterial count. Alternatively, a 5-6 day retention in the HRAP has been shown to produce <1 *E.coli* CFU/100ml. In this case the use of chlorination or a maturation pond may be optional.

Algae Biomass Utilisation in Horticulture

Algal biomass produced as a by-product of the IAPS and the HRAP may be used as a fertiliser in horticulture. Laboratory and field trials have confirmed that the algae biomass for nutrient enrichment in horticulture significantly enhances plant growth and is equal to that of using commercial chemical fertilisers such as 2:3:2 (N:P:K).

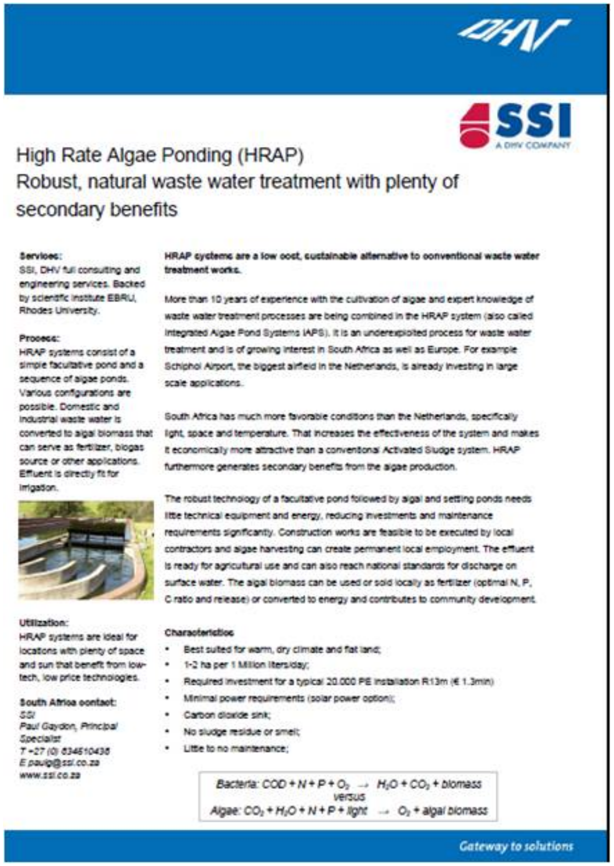
Integrated Waste Water Resource Recovery Concept

HRAP units for disinfection and nutrient removal act as buffers between poorly performing works and the environment and provide an ideal intervention to avoid a crisis situation. This idea led to the development of an Integrated Waste-water Resource Recovery concept where small, underperforming sewage treatment works can recover value in the form of high quality treated water and algae biomass for horticulture thereby protecting the receiving environment and the health of downstream users.



Schematic outline of the application of a HRAP as a retrofit to existing poorly performing sewage works. Tertiary treatment, including disinfection, would enable the recovery and reuse of the water resource, and algae biomass as fertiliser, in agriculture job creation projects.

The EBRU-DHV-SSI Initiative



High Rate Algae Ponding (HRAP)
Robust, natural waste water treatment with plenty of secondary benefits

Services:
SSI, DHV full consulting and engineering services. Backed by scientific institute EBRU, Rhodes University.

Process:
HRAP systems consist of a simple facultative pond and a sequence of algae ponds. Various configurations are possible. Domestic and industrial waste water is converted to algal biomass that can serve as fertilizer, biogas source or other applications. Effluent is directly fit for irrigation.

Utilization:
HRAP systems are ideal for locations with plenty of space and sun that benefit from low-tech, low price technologies.

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HRAP systems are a low cost, sustainable alternative to conventional waste water treatment works.

More than 10 years of experience with the cultivation of algae and expert knowledge of waste water treatment processes are being combined in the HRAP system (also called Integrated Algae Pond Systems IAPS). It is an underexploited process for waste water treatment and is of growing interest in South Africa as well as Europe. For example Schiphol Airport, the biggest airfield in the Netherlands, is already investing in large scale applications.

South Africa has much more favorable conditions than the Netherlands, specifically light, space and temperature. That increases the effectiveness of the system and makes it economically more attractive than a conventional Activated Sludge system. HRAP furthermore generates secondary benefits from the algae production.

The robust technology of a facultative pond followed by algal and settling ponds needs little technical equipment and energy, reducing investments and maintenance requirements significantly. Construction works are feasible to be executed by local contractors and algae harvesting can create permanent local employment. The effluent is ready for agricultural use and can also reach national standards for discharge on surface water. The algal biomass can be used or sold locally as fertilizer (optimal N, P, C ratio and release) or converted to energy and contributes to community development.

Characteristics
- Best suited for warm, dry climate and flat land;
- 1-2 ha per 1 Million liters/day;
- Required investment for a typical 20.000 PE installation R13m (€ 1.3mln)
- Minimal power requirements (solar power option);
- Carbon dioxide sink;
- No sludge residue or smell;
- Little to no maintenance;

Bacteria: $COD + N + P + O_2 \rightarrow H_2O + CO_2 + biomass$
versus
Algae: $CO_2 + H_2O + N + P + light \rightarrow O_2 + algal\ biomass$

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