Resource Recovery Potential of Wastewater Treatment: Biopolymers

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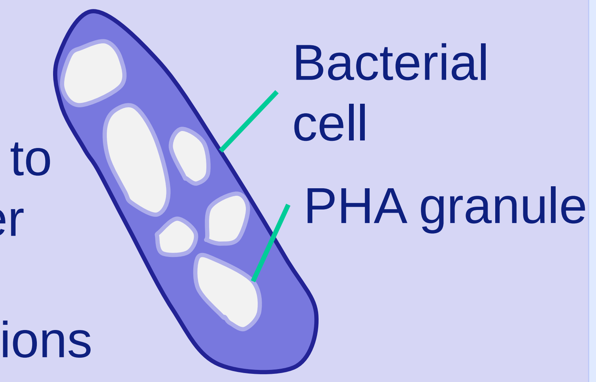
INTRODUCTION

Polyhydroxyalkanoate (PHA) is a type of biopolymer stored inside certain bacteria as granular carbon and energy reserves. These biopolymers can be extracted to produce biodegradable thermoplastics. The biopolymer plastics share similar mechanical properties to typical petroleum based plastics and can be used for applications in the packaging, agricultural, plastic and medical industries. However demand for PHA plastics is limited due to the high production costs. The production of biopolymers using wastewater sludge is suggested as a means of reducing PHA biopolymer production costs whilst simultaneously recovering carbon from wastewater treatment and converting it to a high value product.



Project aim: Determine the viability of PHA production as an resource recovery option in wastewater treatment.

Project objectives:
- Determine the applications and market for PHA biopolymers
- Investigate technical feasibility of PHA production
- Quantify potential yield from a wastewater treatment plant
- Compare PHA production with standard anaerobic digestion

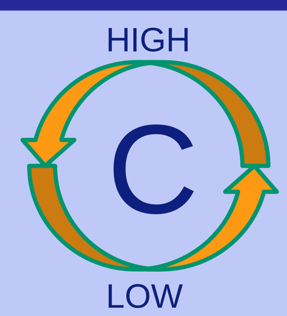
THE PROCESS OF BIOPOLYMER PRODUCTION

Four processes were identified for the production of PHA biopolymers in wastewater treatment:

1. ENRICHMENT

The microbes which store PHA are found in activated sludge biomass but at insufficient quantities for substantial biopolymer production. The enrichment process applies environmental conditions which favour the growth and survival of these microbes.

METHOD1: Anaerobic dynamic feeding



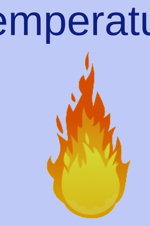
METHOD2: Enhanced biological phosphorus removal

Enrichment can be achieved be applying cycles of high availability and low availability of either carbon or oxygen

2. FERMENTATION

Microbes require a carbon source for PHA production. Although wastewater sludge is rich in carbon, the organic form is not suitable for microbial uptake. Therefore the wastewater sludge must be fermented under hydrolysis and acidogenesis processes to convert the organic matter into volatile fatty acids, which are a suitable precursor for PHA synthesis.

Temperature:



42°C[1]

Hydraulic Retention time:

4-5 days[2]

pH:

8-10[3]

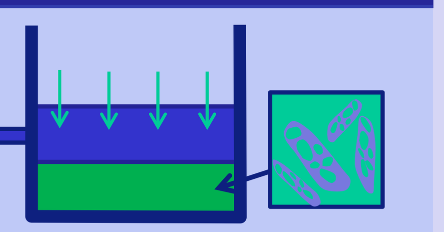
Optimal fermenter conditions for maximum volatile fatty acid production from wastewater sludge

3. ACCUMULATION

The biomass from enrichment is then transferred to a separate reactor where it can be fed volatile fatty acids from fermentation under controlled condition to optimise microbial PHA storage.

Multiple "pulsed" VFA feeding

Effluent decanting before each pulse

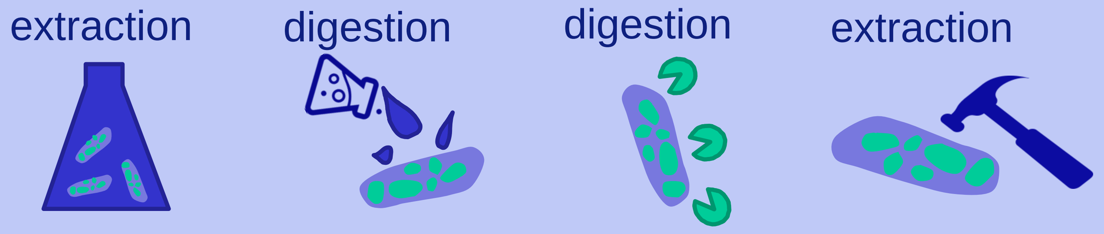


Optimal feeding regime for maximum PHA storage

4. RECOVERY

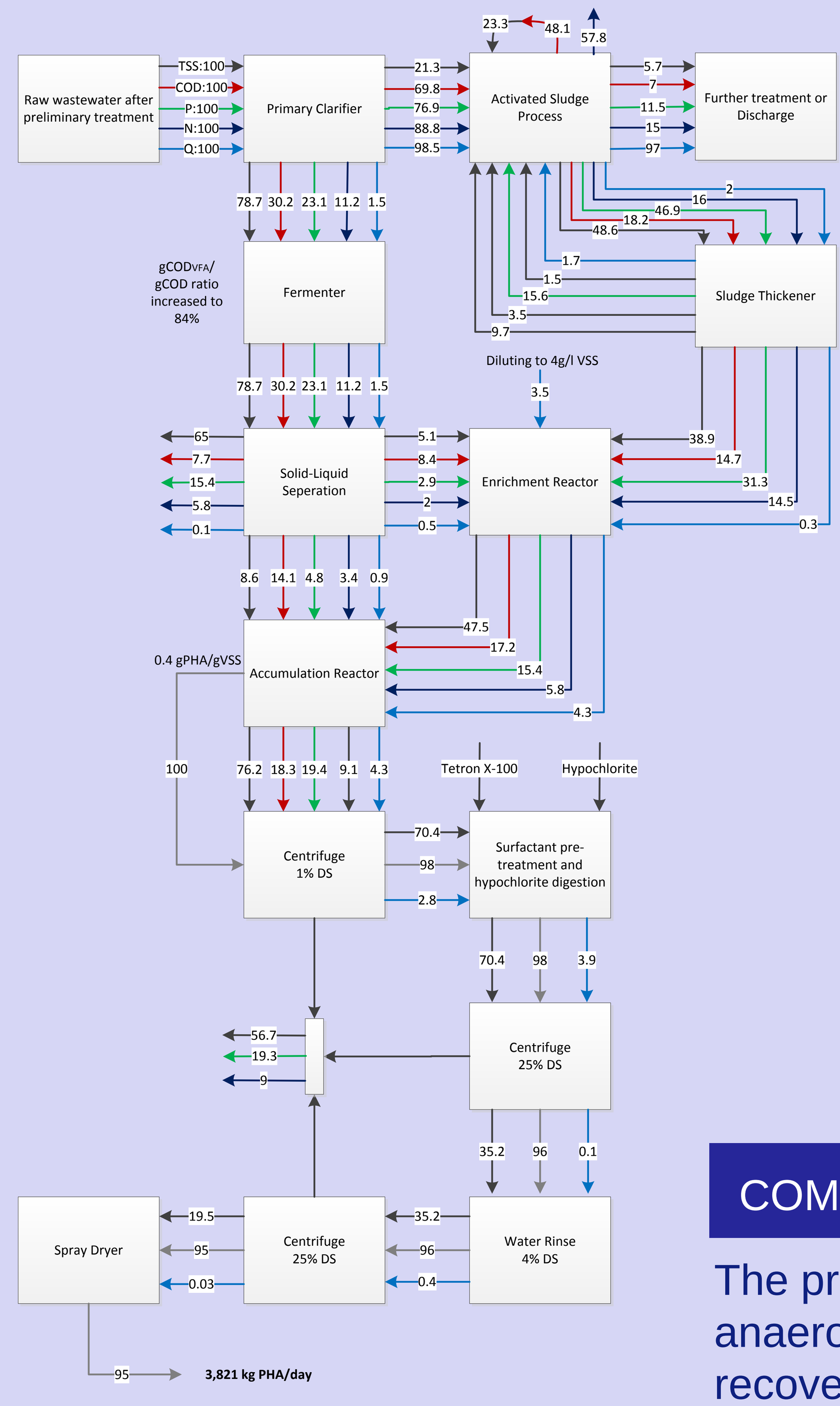
Once maximum PHA storage in the sludge biomass has been achieved, the biomass is subjected to a series of processes to separate the PHA granules from microbial cell material. The resulting form of the biopolymer is a powder or pellet, ready to be used for the manufacture of bioplastic products.

1.Solvent extraction
2.Chemical digestion
3.Enzyme digestion
4.Mechanical extraction



Recovery options for extracting PHA granules from biomass

THEORETICAL ANALYSIS



A theoretical model of a wastewater treatment plant was devised by incorporating the four processes for biopolymer production into a conventional wastewater treatment system; capable of serving a 250,000 population equivalent wastewater flow. A mass balance analysis of the model showed a production capacity of 3,821kg/day or 1,390t/year but with the potential for higher capacity by applying optimal conditions for PHA production.

CONTRIBUTION TO GLOBAL PHA PRODUCTION

Potential production capacities show that multiple wastewater treatment plants with PHA production can make significant contributions to global PHA production capacities

Manufacturer	Production capacity (t/year)*
This study	1,390 per treatment plant
Meredian (USA)	272,000[4]
Tianan Biological Material Company (China)	10,000[4]
Mitsubishi Gas Chemical Company (Japan)	10,000[4]
Newlight Technologies (USA)	22,500 target

*Data shows total capacity per manufacturer. Typical single facility capacity is 2,000-10,000t/year whilst the largest facility by Meredian is capable of 91,000t/year.

COMPARISON WITH CONVETIONAL ANAEROBIC DIGESTION

The production of PHA was benchmarked against anaerobic digestion; the standard resource recovery practice by the Water Industry. This was to compare the competitiveness of PHA production as a resource recovery option.

Revenue per year	
£4.95M	£0.60M
PHA	Anaerobic Digestion

CONCLUSIONS

Recovering biopolymers from wastewater treatment is a technically feasible option. With a few modifications to conventional wastewater treatment plant design, a high value and sustainable product can be produced which contributes to the UK's bioeconomy and is more economically favourable than standard water industry resource recovery practices. The process is cost competitive against industrial biopolymer production and has a lower environmental cost compared to petroleum-based plastics. Therefore there is a strong case for PHA biopolymer production to be incorporated into municipal wastewater treatment.

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