

Nutrient Recovery From Liquid Waste Streams - Why, How and Where ?

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Wastewater Resources include:

- Carbon Energy as Methane
- Nitrogen Fertilizer and Fuel Cells
- Phosphorus .. Fertilizer
- Heat Extraction
- Water Reuse and Recharge GW

What About Phosphorus ?

- Phosphorus is **essential** for **all living organisms**
 - Phosphorus is a **building block of DNA**, cellular membranes and energy metabolism
 - The human **adult body contains approx. 1.5 kg** of phosphorus, mostly in the bones
 - There is **no known substitute** for phosphorus
- 

What About Phosphorus ?

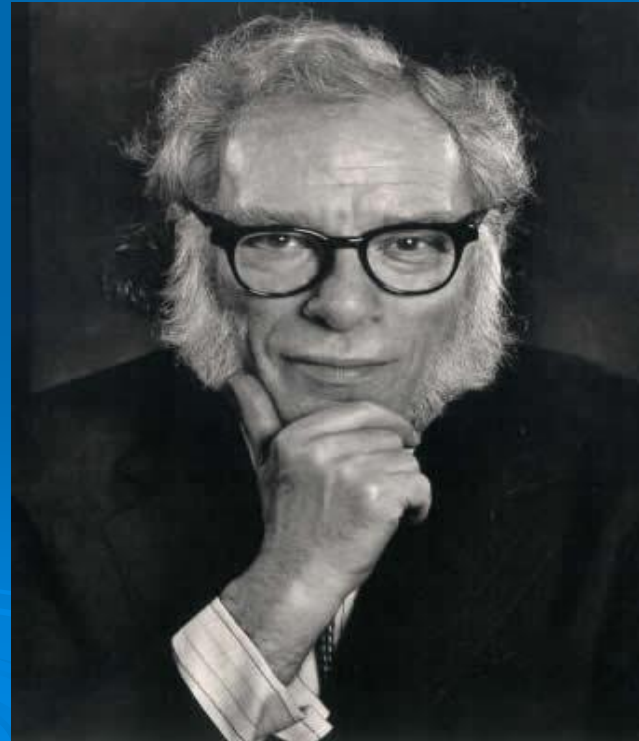
- Phosphorus **cannot be manufactured** or extracted from the atmosphere (like nitrogen)
- Phosphorus **cannot be destroyed**, since it has no gaseous phase
- **Humans excrete** between 3 – 4 grams daily in urine
- **Cows and hogs excrete** 12 - 16 times that amount daily

“We may be able to substitute nuclear power for coal, and plastics for wood, and yeast for meat, and friendliness for isolation - but for phosphorus there is neither substitute nor replacement”

Isaac Asimov

June 1974

Doubleday Pub.



What About Phosphorus ?

- Phosphorus is one of the three **key components of fertilizers**
- It is **crucial** for the **world's food supply**
- **Approx. 80%** of the phosphorus contained in rock mined for food production **never reaches the food consumed globally**

- Canadian limnologists were at the forefront of the eutrophication debate
- Experimental Lakes Area in Northwestern Ontario, run by the Freshwater Institute in Winnipeg, show impact of Phosphorus

N and C on *the top*

N, P and C on *the bottom*



Dave Schindler, Jack Vallentyne, John Stockner, Staffan Holmgren, Everett Fee

Lake Winnipeg has become severely eutrophic in the 1990s due to Phosphorus pollution



ENVIRONMENT

THE FOAMING SLUDGE at Connaught Beach on Lake Winnipeg is another sign that the lake is getting close to the tipping point

CANADA'S SICKEST LAKE

Living, toxic goo is killing lakes the world over. It may be too late for Lake Winnipeg.

tucked far away from industry and major population centres, has become the sickest big lake in the country. What was once a small patch of algae, first noted in the 1990s, now grows to smother more than half of the massive 24,500-sq.-km lake most summers. In 2006, the pea-soup sludge covered almost

they do on land: cause plant life to run wild and multiply like crazy. The process is accelerated by the channelization of waterways to allow rapid runoff from farmer's fields, and the destruction of wetlands and riverbank areas. Wetlands, "nature's kidneys," which act as natural filters and nutrient traps, have been

Shuswap Lake System - Algae Bloom



China



Phosphorus Facts

Collectively, **Morocco, China, South Africa, Jordan and Russia** hold over **95%** of known, high quality, economically-recoverable **phosphate rock**.



Phosphorus Facts

- Morocco holds approximately 90-92% of Global reserves, followed by China at about 5%
- US production of phosphates has already peaked and known high quality reserves are expected to be depleted within 5-6 years
- Canada has no reserves and is dependent on foreign supplies.

Phosphorus Facts

“Two Canadian fertilizer firms have become the dominant buyers of phosphate rock from the disputed territory of Western Sahara, after other companies have stopped the practice.

The study released by the Western Sahara Resource Watch (WSRW) found that Potash Corp. of Saskatchewan, Inc. and Agrium, Inc. shipped a combined 916,000 Tonnes of phosphate from the territory in 2015. That accounts for almost 65% of all purchases from the Western Sahara in 2015”

National Post, April 8, 2016

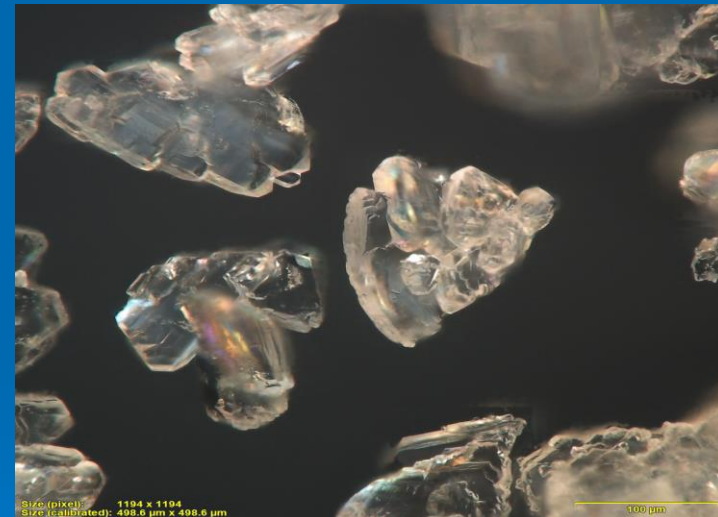
Struvite (trade name) – what is it?

- A form of inorganic fertilizer containing phosphorus
- Forms as a solid matrix in many biological Waste Water Treatment Plants (WWTPs)
- Leads to serious plugging of pipes and pumps



Struvite (Trade name) – what is it?

- Chemical composition: $\text{Mg NH}_4 \text{ PO}_4 \cdot 6 \text{ H}_2\text{O}$
Known as Magnesium-Ammonium-Phosphate = MAP

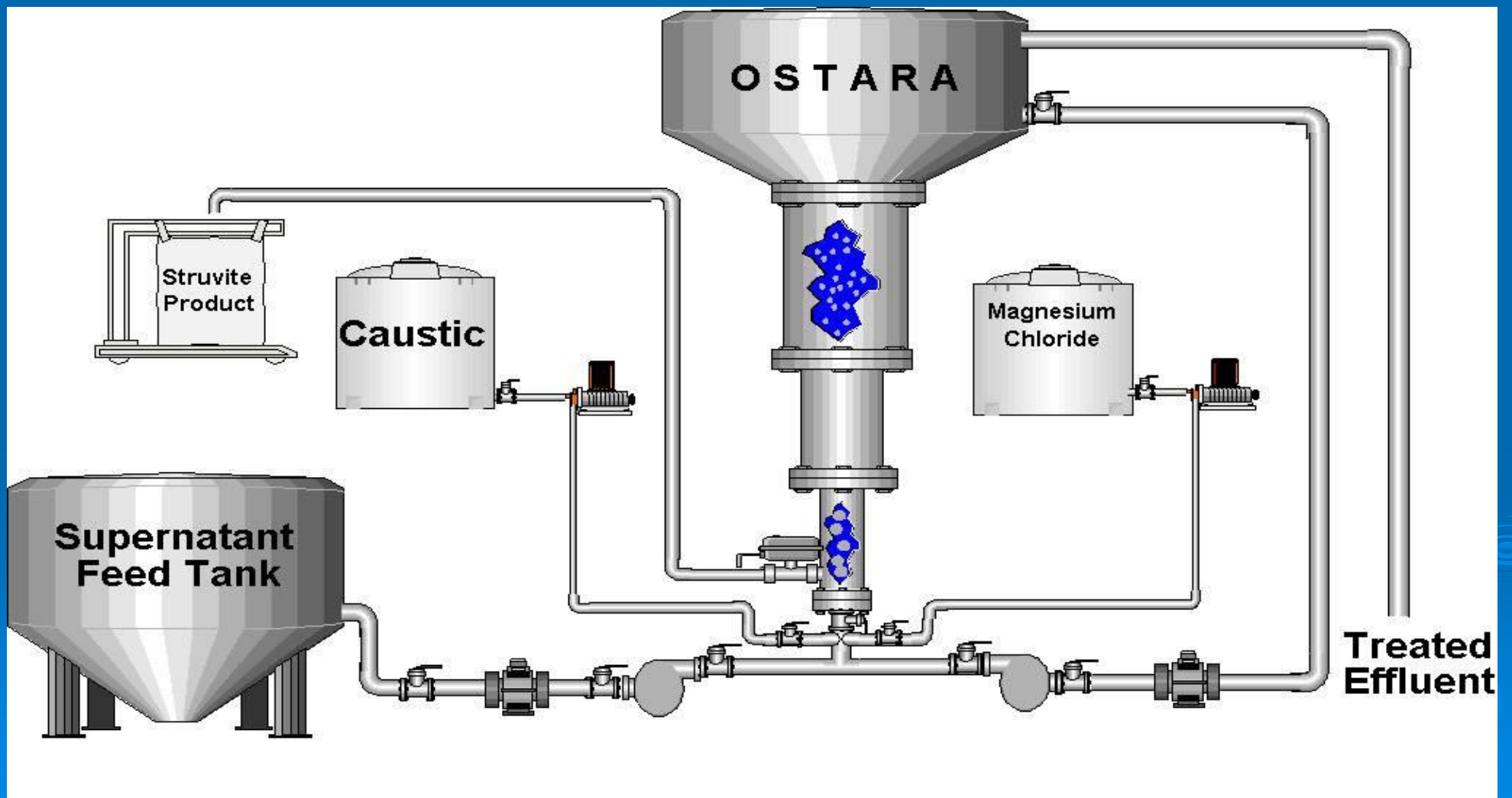


- Contains no organic material, hence is **not a biosolid**

UBC Pilot Scale Reactors



Full Scale Process



Many nations are now vigorously pursuing P recovery

North America's largest
P recovery reactor, in
Edmonton March/07

UBC Patented Design

November 2009




Struvite – Commercial Name

- Crystal Green[®] (Ostara Inc)
- 5-28-0 + 10 % Mg
- Easily Blended with other pellets
- Size: 0.5- 5 mm crystals



Crystal Green[®] - Struvite

- A sustainable, recoverable resource from human and agricultural waste streams
 - A slow-release fertilizer, that also generates Greenhouse Gas Credits during production
- 
- The background of the slide features a blue gradient with several concentric white circles of varying sizes, resembling ripples on water, located primarily in the lower half of the image.



- Three full scale P recovery reactors, Tigard (Portland)
- Serves 500,000 people,
- Recovers about 500 tonnes of Phosphorus per year



Struvite can command premium prices on world markets

Other uses for Phosphorus



Phosphorus - the Global Issue

First International Conference held in Vancouver May 2009

- Global review of current technology in Phosphorus Recovery
- Attended by officials and researchers from 32 countries

Conference Returned to Vancouver July 31-Aug 3, 2013

The image shows the front cover of a book titled "International Conference on Nutrient Recovery from Wastewater Streams". The cover is primarily white with a dark blue header and a vertical teal bar on the right side. The title is printed in white on the dark blue header. Below the title, the date "May 10-13, 2009" and the location "The Westin Bayshore Hotel and Resort Vancouver, British Columbia, Canada" are listed. A paragraph of text describes the conference's focus on closing the loop for nutrients in wastewater. Below this, a list of sponsors is provided. The right side of the cover features a collage of images related to water and environmental science, including a globe, a water tower, a person pouring water, and a landscape with mountains. At the bottom, there are logos for various organizations and a barcode.

International Conference on Nutrient Recovery from Wastewater Streams
May 10-13, 2009
The Westin Bayshore Hotel and Resort
Vancouver, British Columbia, Canada

Closing the loop for nutrients in wastewaters (municipal sewage, animal wastes, food industry, commercial and other liquid waste streams) is a necessary sustainable development objective, to reduce resource consumption and greenhouse gas emissions. Chemistry, engineering and process integration understanding are all developing quickly, as new processes are now coming online. A new "paradigm" is emerging, globally. Commercial marketing of recovered nutrients as "green fertilizers" or recycling of nutrients through biomass production to new outlets, such as biorenergy, is becoming more widespread.

The papers from this exciting conference bring together various waste stream industries, regulators, researchers, process engineers and commercial managers, to develop a broad-based, interdisciplinary understanding and joint projects for phosphorus and nitrogen recovery from wastewater streams, as well as reuse. Over 70 papers from over 30 different countries presented in this volume.

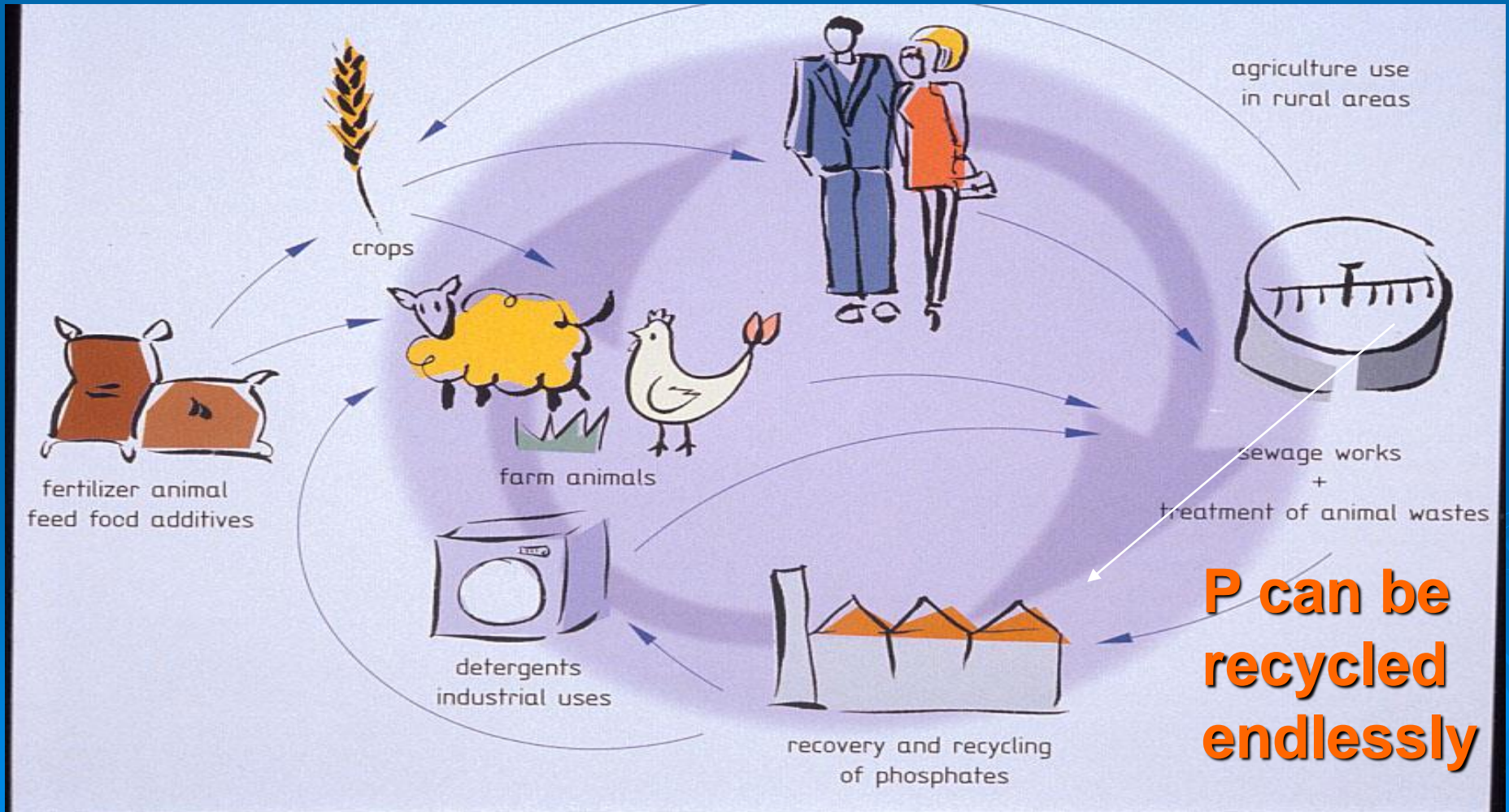
This conference is sponsored by:

- Metro Vancouver
- Global Phosphate Forum
- Sarnec Consulting Ltd.
- The Chartered Institution of Water and Environmental Management (CIWEM)
- Osara Nutrient Recovery Technologies, Inc. (ONRTI)
- The University of British Columbia (UBC)
- Bonneville Power Authority
- Dayish & Knight Ltd.
- NORAM Engineering and Constructors Ltd.
- Investment Agriculture Foundation of British Columbia

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Recent European Community directives recommend **P recovery/recycling** from farms and biological waste water treatment plants (WWTP)



The Next Challenge

- Recovery of P from animal manure
- Represents a huge opportunity to recover P and protect the environment
- The planet has 7.5 billion people, but 70 billion livestock!!



Applications of MW-AOP

Dairy manure/ Sewage Sludge

MW-AOP

Energy Recovery

Anaerobic
Digester

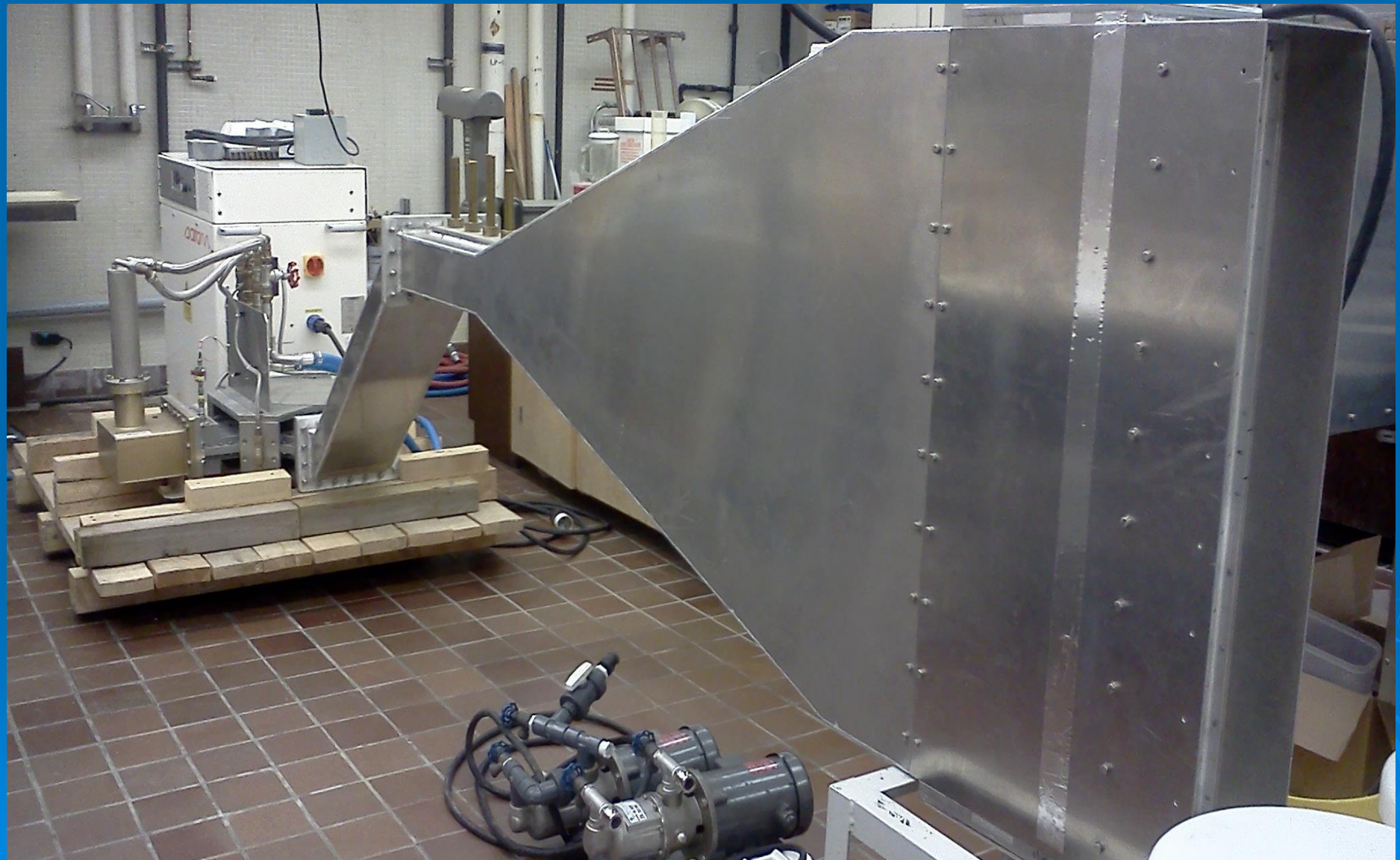
Solids Reduction

Nutrient Recovery

Struvite
Crystallizer

Outputs: Lower solids disposal cost
Higher N & P recovery
Higher Energy (biogas) recovery

UBC designed MW-AOP System



Solids Destruction from MW-AOP



Untreated Sludge

Treated Sludge

UBC Dairy Education Research Center (DERC)

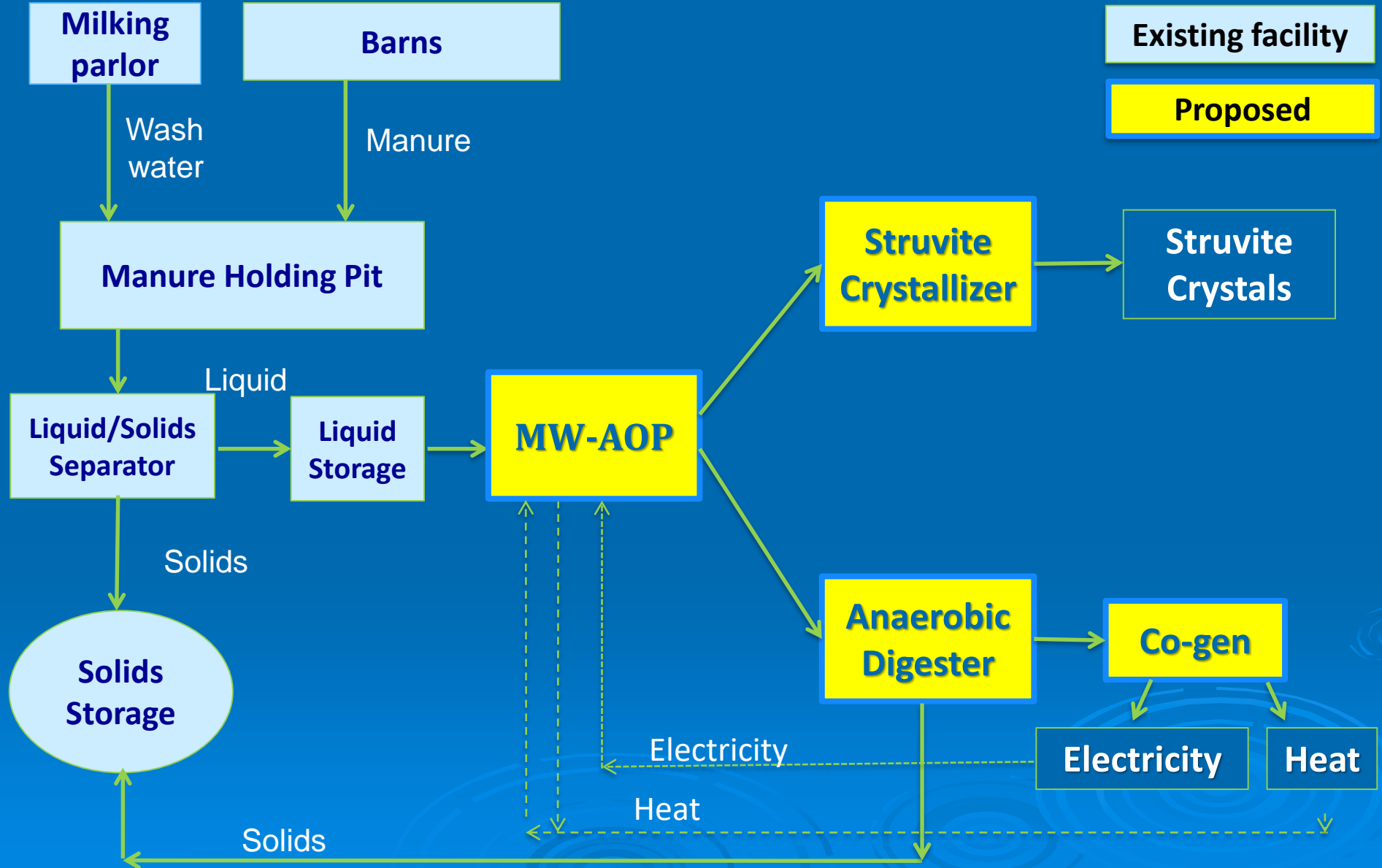


Struvite Crystallizer - on Site

- Forms **crystalline fertilizer** (\$)
- Uses **most of the nutrients** in the **treated solution**



Dairy Manure Treatment Facility



Integrated Wastewater Treatment System

Key components:

- MW-AOP System
- Struvite Crystallizer
- Advanced Anaerobic Digesters
(Two phase)

Design criteria

- Herd size = 120 lactating cows
- Liquid fraction of manure after liquid-solids separation to be treated
- Volume of liquid fraction of manure = 12.7 m³/day ± 20%
- Total solids content in the liquid fraction = 4%
- Microwave operation of 8 hours/day

James WWTP – Abbotsford, B.C.



Reduce, Recycle and Recover

- A “*Zero Sludge*” process
- Bio-Energy Recovery (Methane)
 - Energy neutrality
- Phosphorus recovery (struvite)
 - Phosphorus is a finite resource
 - Balanced nutrient cycle
- Reduced carbon footprint

Summary

- **Global phosphate reserves are rapidly being depleted, threatening the world's future ability to produce food**
- **Phosphate rock, the basis for large scale fertilizer production, is a non-renewable resource**
- **Cheap fertilizers are a thing of the past as global demands begin to outstrip the available supply of high-quality, economically recoverable P reserves**

Summary

- Many countries are now limiting phosphate rock exportation and are mandating P recovery and reuse
- Phosphorus removal and recovery from domestic treatment plants is now a reality
- Phosphate removal and recovery from agricultural wastes (e.g. cattle and hogs) shows great promise

Figure 4. Number of struvite recovery facilities

