Self Optimizing Water Filtration

To Maximize Water Re-use

6th Water Arabia Conference

Aqua Pure Technologies Inc.

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Presenter

Presenter: Guy Bolton

Mr. Bolton has been active in the oil and gas industry in both Europe and North America for 15 years, initially working with Oilflow Solutions Ltd (Bradford, U.K., Aberdeen U.K., Calgary Canada) in chemical product development and delivery system design and optimization. Latterly he has been working with Pi-Cubed Process Systems Ltd (Calgary, Canada) and Aqua Pure Technologies (Grande Prairie, Canada) designing and optimizing water treatment systems for operation in Canada, USA and Mexico. Previously Mr. Bolton spent 15 years designing embedded measurement and control systems in various industrial sectors. Mr. Bolton holds a joint honors degree in Physics and Electrical Engineering, Brunel University, London UK.

Introduction

Water treatment both for industrial and demostic consumption often comprises many steps, some requiring chemical treatment to achive material removal, pH adjustment or other. Each step is designed to address to specific aspect of the purification process, removing impurities in groups and in an order such that succesive steps can be operated at optimum efficiency.

Certain steps are separated or preceded by filtration to various degrees. The current presentation will discuss some of the limitations of such filtration stages and present new methodologies that can be be implemented to minimise some of those limitations and make use of state-of-the-art techniques adopted from other industries to minimise waste streams, maximise capacity of equipment and maximise cleaned water content. When implmented for industrial processes these lead to reductions on pressure for use of domestically clean water. If implemented ate a domestic level, waste water can be recovered and prepared for industrial use again releaving pressure on drinking water sources.

Waste-Water Classifications Pertinent to Filtration

Contaminant	Requirement (Oman MD 159-2005)	Unit
pH	6-9	
Chemical Oxygen Demand (COD)	200	mgO_2/l
Biological Oxygen Demand (BOD)	20	mgO_2/l
Total Nitrogen	15	mg/l
Bacterial Count (faecal coliforms)	10,000	per liter
Total Suspended Solids (TSS)	30	mg/l
Oil & Grease	15	mg/l
Specific Metals	Various < 0.001 - < 5	mg/l
Total Dissolved Solids (TDS)	Undefined	mg/l
Specific ionic species	Various	mg/l

Waste-Water Classifications Pertinent to Filtration

Example one: Gulf region reverse osmosis reject water to be blended into a process stream

Contaminant	Process Water RO Reject Water	Unit
pH	7.5 – 8.1	
Chemical Oxygen Demand (COD)	16 – 39	mgO_2/l
Biological Oxygen Demand (BOD)	<2	mgO_2/l
Total Nitrogen	0.5 – 1.0	mg/l
Bacterial Count (faecal coliforms)	N/A	per liter
Total Suspended Solids (TSS)	<5	mg/l
Oil & Grease	10 – 35	mg/l
Specific Metals	0.1 - 15 TOTAL	mg/l
Total Dissolved Solids (TDS)	62,500	mg/l
Specific ionic species	N/A	mg/l

Waste-Water Classifications Pertinent to Filtration

Examples two: Gulf region, process water from boiler condensate/blow down stream

Contaminant	Process Water Boiler Blowdown Water	Unit
pH	7.4 - 9.8	
Chemical Oxygen Demand (COD)	<5 – 102	mgO_2/l
Biological Oxygen Demand (BOD)	<2 – 16	mgO_2/l
Total Nitrogen	2.6 - 21.9	mg/l
Bacterial Count (faecal coliforms)	N/A	per liter
Total Suspended Solids (TSS)	Not measured	mg/l
Oil & Grease	28.1	mg/l
Specific Metals	0.1 - 3.25	mg/l
Total Dissolved Solids (TDS)	Not measured	mg/l
Specific ionic species	N/A	mg/l

Waste-Water Classifications Pertinent to Filtration

Example three: Gulf region, oil and gas production water, treated to be blended into a combined stream

Contaminant	Process Water Treated Produced Water	Unit
pH	6.8 - 7.1	
Chemical Oxygen Demand (COD)	67 – 261	mgO_2/l
Biological Oxygen Demand (BOD)	2 – 16	mgO_2/l
Total Nitrogen	16 – 209	mg/l
Bacterial Count (faecal coliforms)	N/A	per liter
Total Suspended Solids (TSS)	<5	mg/l
Oil & Grease	0.1 – 10	mg/l
Specific Metals	1 - 470	mg/l
Total Dissolved Solids (TDS)	428,000	mg/l
Specific ionic species	N/A	mg/l

There is no such thing as just a filter…

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Chemical Oxygen Demand (COD)	200	mgO_2/l
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Total Suspended Solids (TSS)	30	mg/l
Oil & Grease	15	mg/l
Specific Metals	Various < 0.001 - < 5	mg/l
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Specific ionic species	Various	mg/l

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MF or UF

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Total Suspended Solids (TSS)	30	mg/l
Oil & Grease	15	mg/l
Specific Metals	Various < 0.001 - < 5	mg/l
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Specific Metals	Various < 0.001 - < 5	mg/l
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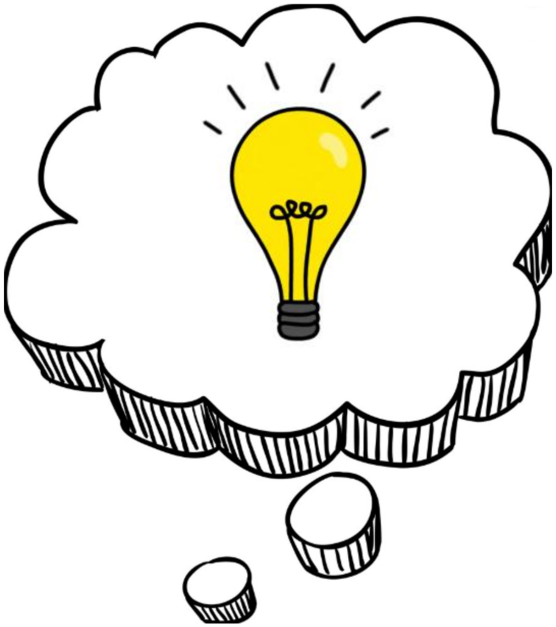
NF or RO

Limitations of Filtration Technology

- System design fixed to cater for worst conditions
- Multiple systems multiply effects
- Reject streams are larger than necessary
- Water for re-use can be significantly smaller than might otherwise be possible
- Filters do not run under optimum load conditions
- Reject stream less concentrated than could be ultimately achieved
    - Consider: Waste stream sent to evaporation – **more heat energy** required!
    - Consider: Waste stream sent to disposal well – **more disposal well capacity** required!

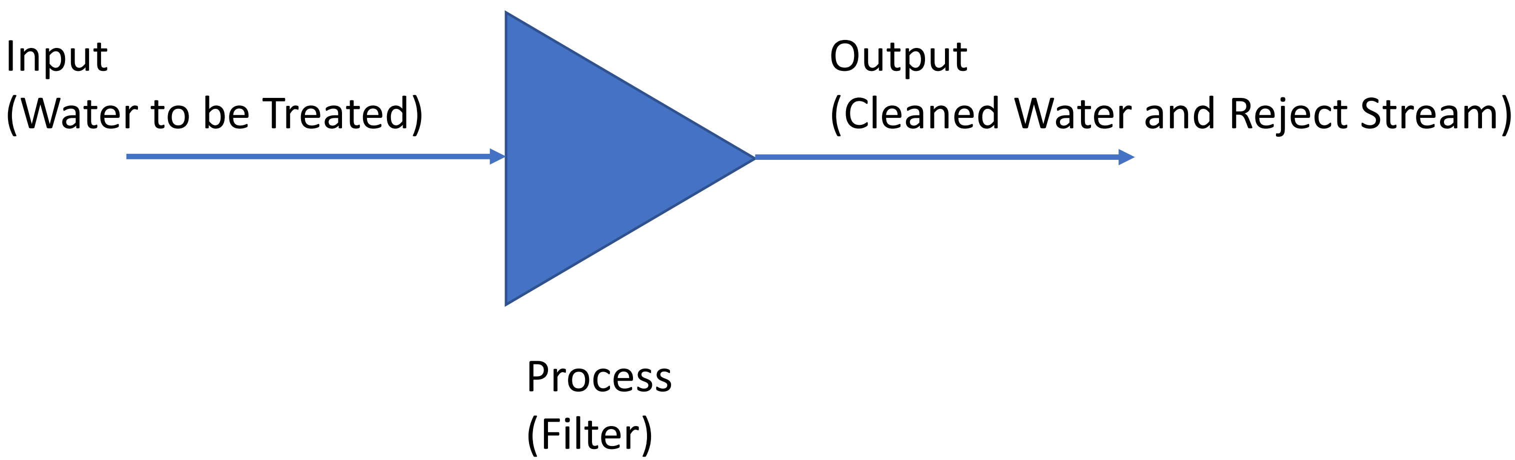
So how can we improve matters?

- Feedback Control
- Look-ahead Systems
- Adaptive Systems



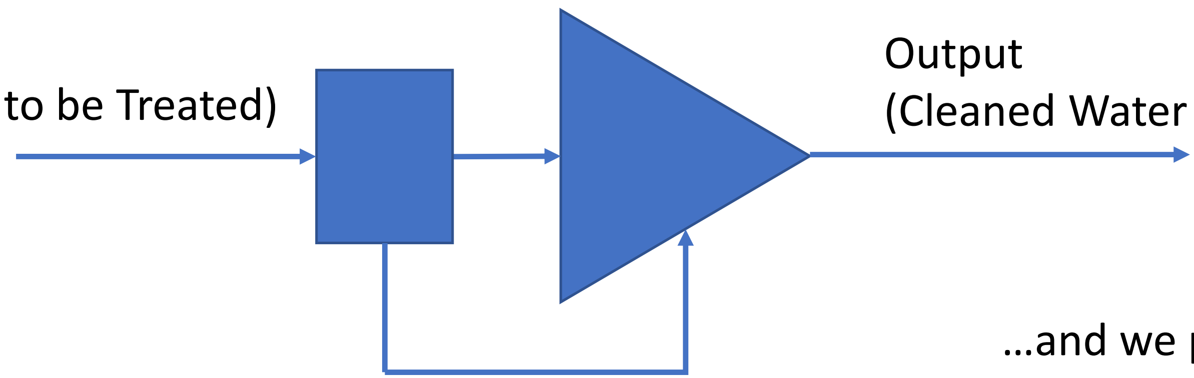
Introduction to Look-ahead and Feedback General Systems

A conventional *(water treatment)* system has
an **input**…
a **process**…
and an **output**



Introduction to Look-ahead and Feedback General Systems

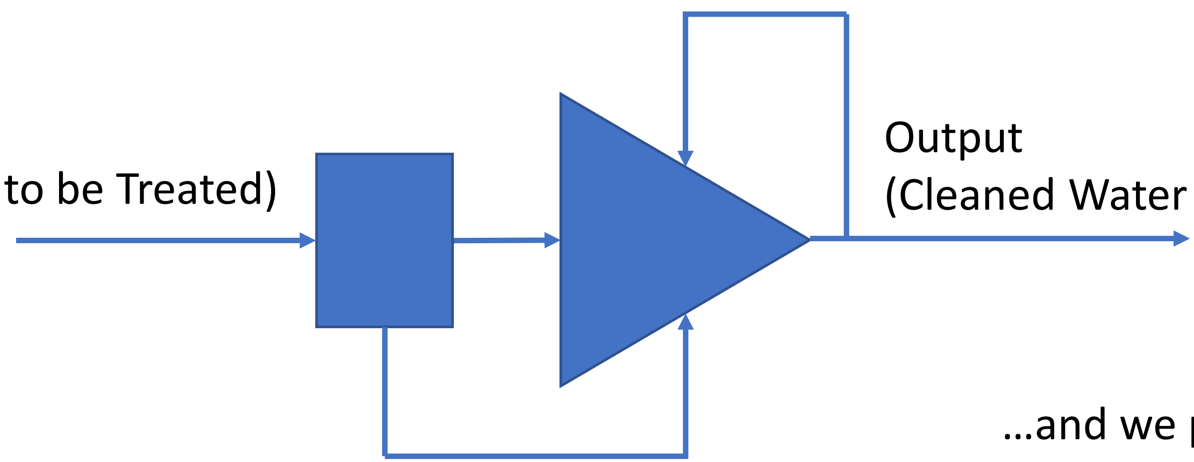
But if we want to be able to adapt our system to changing environments we add in look-ahead capability



…and we pass information forwards to the process

Introduction to Look-ahead and Feedback General Systems

Say we now want to maintain tight control of our process, we add in feedback such that the system always knows what it is being output



…and we pass information forwards to the process

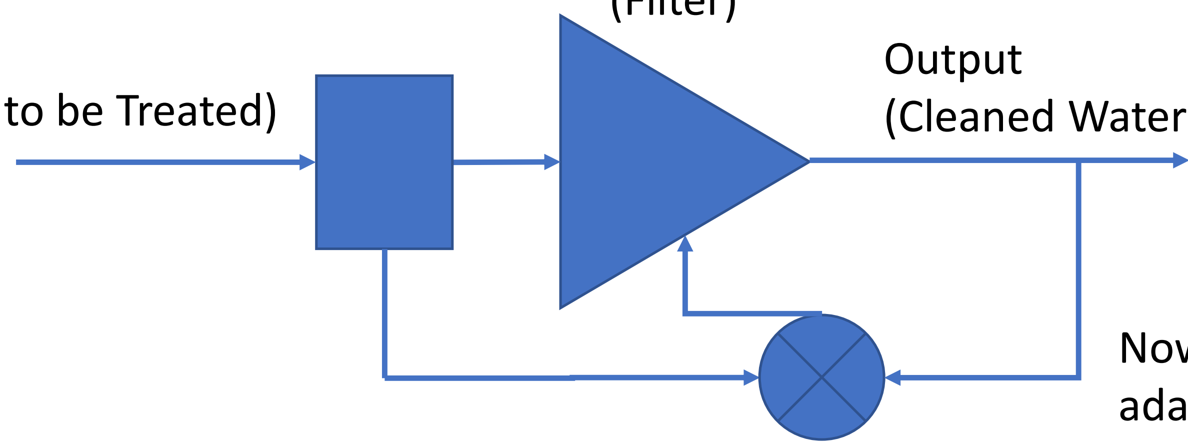
Introduction to Look-ahead and Feedback General Systems

Challenges:

- Sample period, Nyquist sampling requirement
- How to quantify fastest condition change
  - Force using “homogenization” stage
  - Implies non-ideal batch treatment
- Designing for abnormal conditions, plant upset conditions
- True continuous requires lots of representative upfront data
- Appropriate sensitivity of measuring systems
- Redundancy
- Feedback cycle time, filter functions, inadvertent filter effects
- System averaging and integration effects
- System response time
- Avoiding oscillation

Introduction to Adaptive Systems

But what if we give the system the ability to learn from the decisions it makes to make better or faster decisions in the future

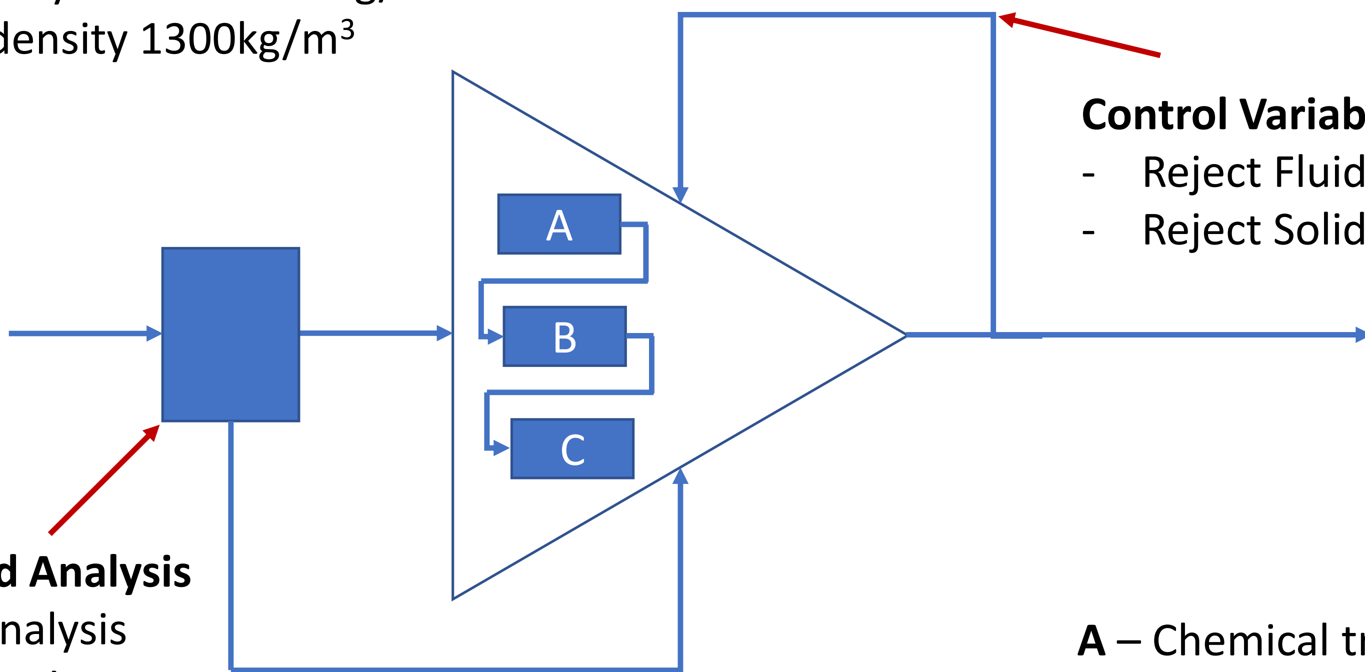


Now we have an adaptive system that learns to adapt to its environment!

Implementing Look-ahead and Feedback Control into Water Treatement Systems – Solids Removal Example

Input
Solids loading 10 – 85%
Solids density 1600 – 2700 kg/m^3
Aqueous density 1300kg/m^3

Output Specification
Solids loading < 0.1%



Control Variables
- Reject Fluid Density
- Reject Solids %

Look-ahead Analysis
- Solids Analysis
- Total Density
- Fluid Density

Control Variables
- Flocculation Rate
- Flocculation Concentration
- Volume Flowrate

A – Chemical treatment
B – Settling System
C – Crossflow Ultrafiltration

Benefits of Implementation

Input Sample 1, Drill Mud

A Sample 1

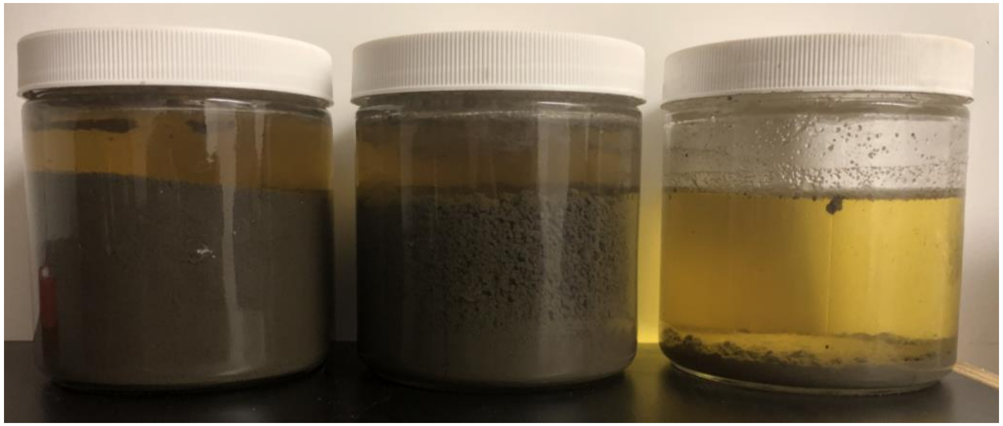
A Sample 2

Input Sample 2, Drill Mud

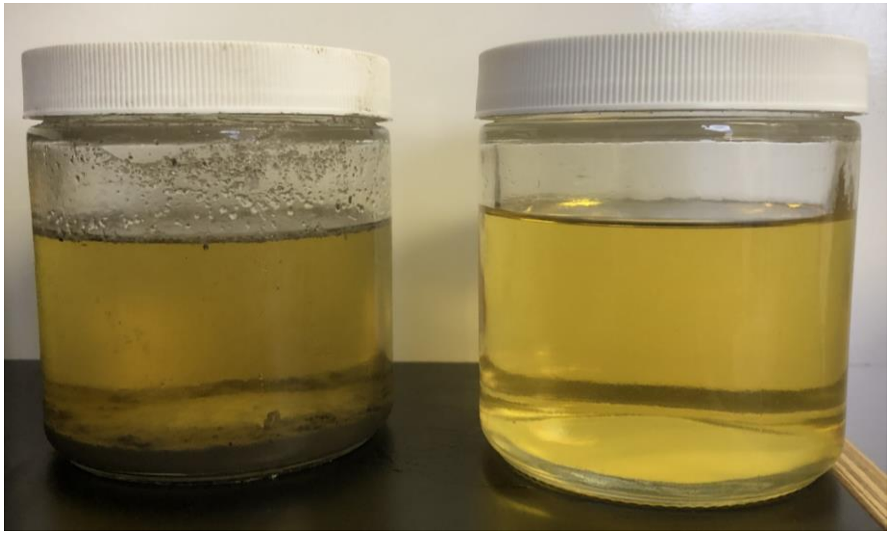
A Sample 3, note density difference!

A Sample 4

Benefits of Implementation



Left A Sample 1, Centre A Sample 2, Right B Sample



Left B Sample contains residual flocculant ~2% suspended solids, Right C Cleaned Sample

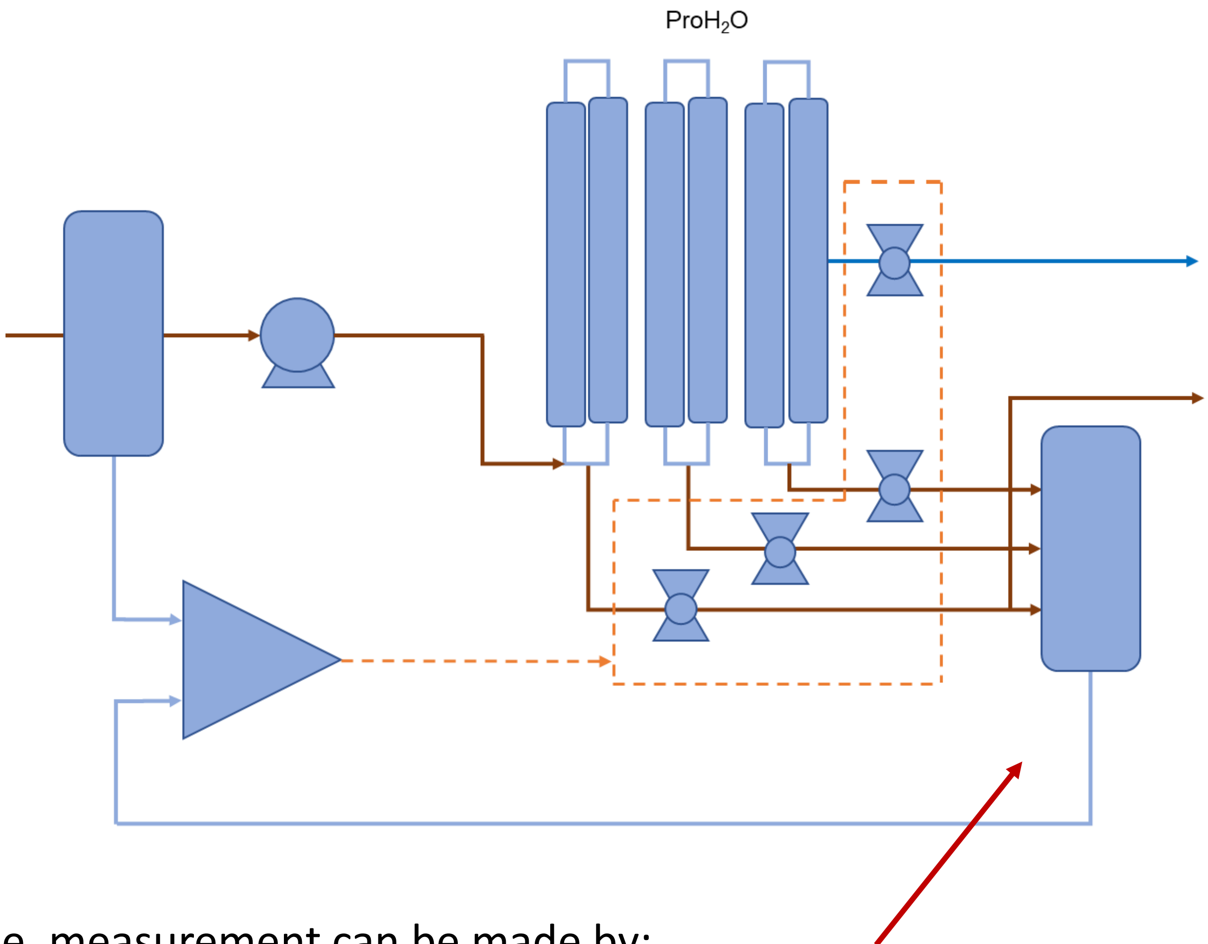
Reject Sample from Stabilized Control System,
~2% free water**. **Historically, observed >10% free water

Reduction of waste stream volume ~30% in this instance

Limitations Observed

- Unable so far to test real time automated Look-ahead system. Work is continuing on this process
- Control variables are very much defined by fluid types, generic model has yet to be developed
- Sensitivity of measurement is critical
- Closed loop control systems are extremely sensitive to feedback loop period (time) in order to track variables. Distributed system cycle times can be challenging. PID loops are ideal, embedded PLC PID may not have sufficient resolution
- Measurement systems can be expensive, spectrographic, high sensitivity density, optical, rheometry
- Complex measurement systems tend to be fragile

Low Cost Multivariate Approach



In this case, measurement can be made by:

- Inline rheometry, density, spectrography, laser light scattering ~ $20K

However a simple low cost approach was tested

- Differential pressure across reject balanced control valve ~$200
- Along side Reject Flow calculation Reject flow = Total Flow – Clean Flow

Summary and Conclusions

- Water streams for treatment can vary wildly over both short and long timescales
- Treatment often requires many steps commonly separated by stages of filtration
- Open loop filtration generally removes worst case volumes from fluid streams resulting in unnecessarily large waste streams
- Reducing waste streams is critical to reducing energy requirements for down stream waste management processes
- Closed loop feedback control complemented by look-ahead technology can significantly reduce volumes of waste streams
- Control input variables need to be sampled within the Nyquist criterion and with appropriate sensitivity
- Lookahead systems allow for broad scale reconfiguration of the system, while closed loop feedback allow tight monitoring to match output criterion to specification
- Knowledge gained can readily be transferred to municipal sewage treatment, closed loop proffers additional benefits to reduction of total chemical usage

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