TORWASH of Water Plants

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TORWASH of Water Plants

3DO.5.2 CONVERSION OF WATER PLANTS TO BIOMASS FUEL USING TORWASH

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Overview

- Introduction
  - Waternet and ECN
  - Background information on aquatic plants
  - TORWASH technology
- TORWASH of water plants into fuels
  - performance of process
  - focus on alkali and chlorine removal
  - focus on fuel quality
- Alternative technologies
- Conclusions

Introduction

ECN : A rich and evolving history

~600 employees

~110 patents

1955 Opens as Reactor Centre for the Netherlands

1975 Wind Energy and Coal Programmes

1985 Fuel Cell programme starts

1990 Solar Energy & Environmental research programmes start

1994 Biomass research programme starts

1998 Energy Efficiency in the Industry programme starts

2000 Intelligent Energy Grids Programme starts

2011 New Strategy & Focused activities

~500 reports in 2011

~270 conferences in 2011

~5 licenses a year

We are in our 59th year of pushing technology boundaries

Waternet as a mutual organization

City of Amsterdam

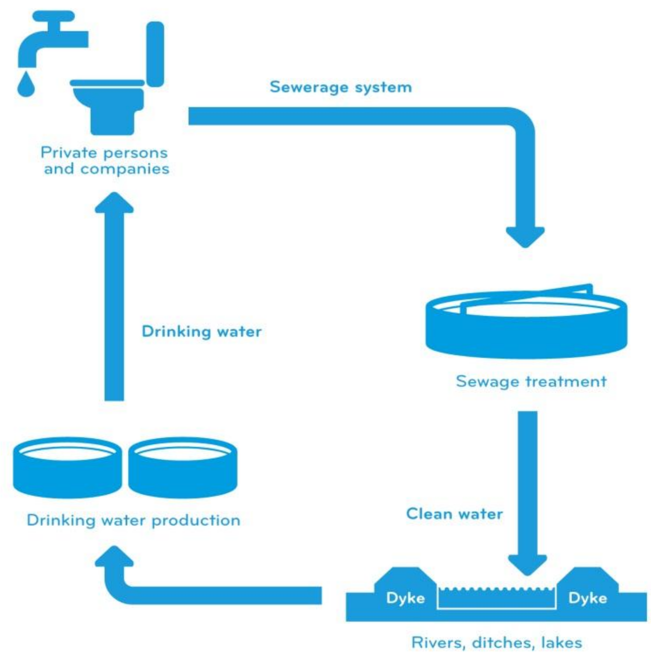
- Sewerage system
- Groundwater
- Drinking water
- Shipping and inland waterways

Amstel, Gooi and Vecht Water Board

- Dykes
- Water level
- Water surface area
- Cleaning waste water

waternet

Waternet foundation



Introduction Aquatic Plants

- Invasive water plants in Amsterdam region
  - *Elodea nuttallii* (water weed) is an invasive species, introduced in the Dutch aquatic system 1860's
  - *Cabomba caroliniana* (fanwort) is also an invasive species, rampant since 1990's
- Very fast growing and thriving in the P and N-rich (eutrophicated) Dutch fresh water system
- Reason for enhanced growth: clean water = transparent water = more light reaches bottom = faster growth
- Nuisance for commercial and recreational shipping

Cabomba Caroliniana

Introduction Aquatic Plants

- In Amsterdam region:
  - up to 30.000 ton water plants
  - harvested in July-August, depending on weather
- In other regions: other plants, same problems

- Waternet is searching for utilisation options
  - As a feedstock for a renewable fuel (i.e. for coal replacement) or other useful application in bio-based and circular economy
  - As a way to remove surplus nutrients from the aquatic system
- One of the possible solutions is ECN's TORWASH process (wet torrefaction)
  - ECN performed screening tests

Problem definition TORWASH

- Easy and clean fuels → $$$

- Low-cost biomass
- Negative price biomass

Problems when used as fuel

Economic margin for upgrading?

Upgrading to standard fuel

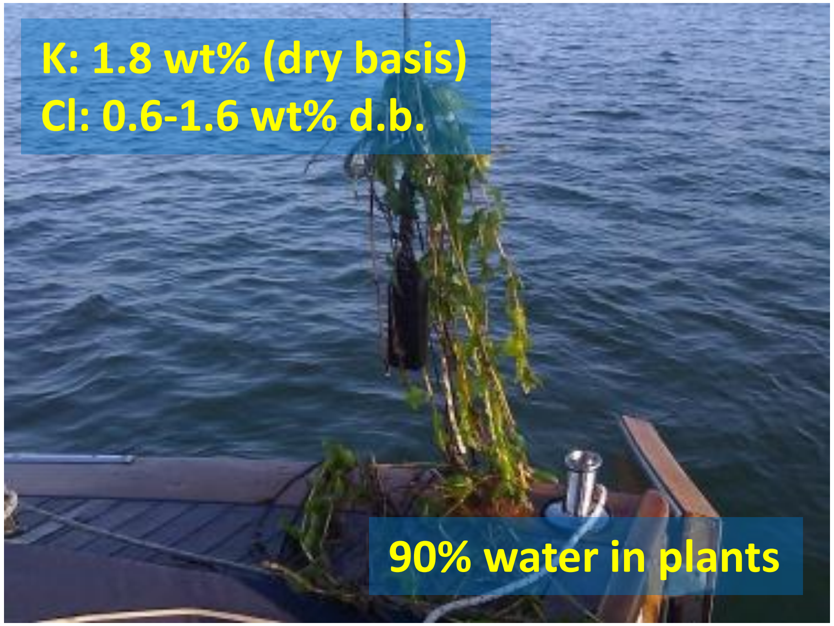
- Water
- Air
- Problem elements
- Fluctuations in harvest

time
volume
quality

Solution : TORWASH

First goal: >95% salt removal

- Relevant salts: alkali chlorides
  - sometimes 99% removal is needed…
  - … and it is possible!
- Why?
  - chlorides cause corrosion
  - alkalis cause agglomeration in fluid beds
  - alkalis increase PM emissions
  - both have negative impact on ash quality



- Second goal: dewatering
  - mechanical dewatering takes away water + dissolved salts
  - 65%, even 75% dry matter content has been reached!
- Third goal: improve fuel quality like torrefaction
  - grindability, energy density, water resistance, no biological degradation, etc.

TORWASH = Combination of Washing with Torrefaction

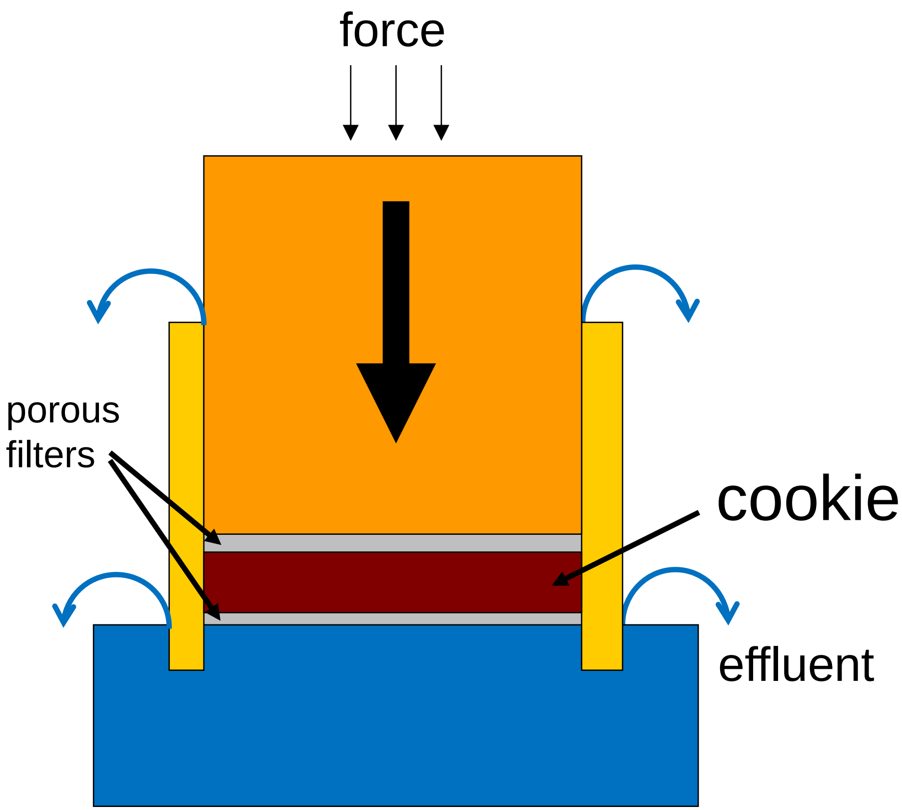
- Hydrothermal treatment
  - in water – under increased pressure
  - 150-250°C & 10-30 minutes
  - milder than HTC (hydrothermal carbonization)
- Optimized for maximum energy recovery in the form of solid material
- Product: torrefied fuel pellets (or briquettes or powder) with high added value
- Biogas as a by-product from liquid effluent results in high overall energy yield

TORWASH of water plants

Experimental approach

- Freshly harvested Elodea and Cabomba
  - Directly shipped to ECN and cold-stored
- Kilogram batches for exploratory tests
  - chopped in household kitchen appliances
  - no additives, no pre-washing
  - heat treatment of samples in 0.5 L autoclave
- Optimal conditions determined by
  - yield in mass and energy
  - water content after pressing
  - ‘Fingerspitzengefühl’ = experience
- Conditions used for tests in 20 L autoclave
  - 190°C & 30 minutes
  - mass, element and energy balances
  - analyses of input and output streams
  - evaluation of solid produce as a **fuel**

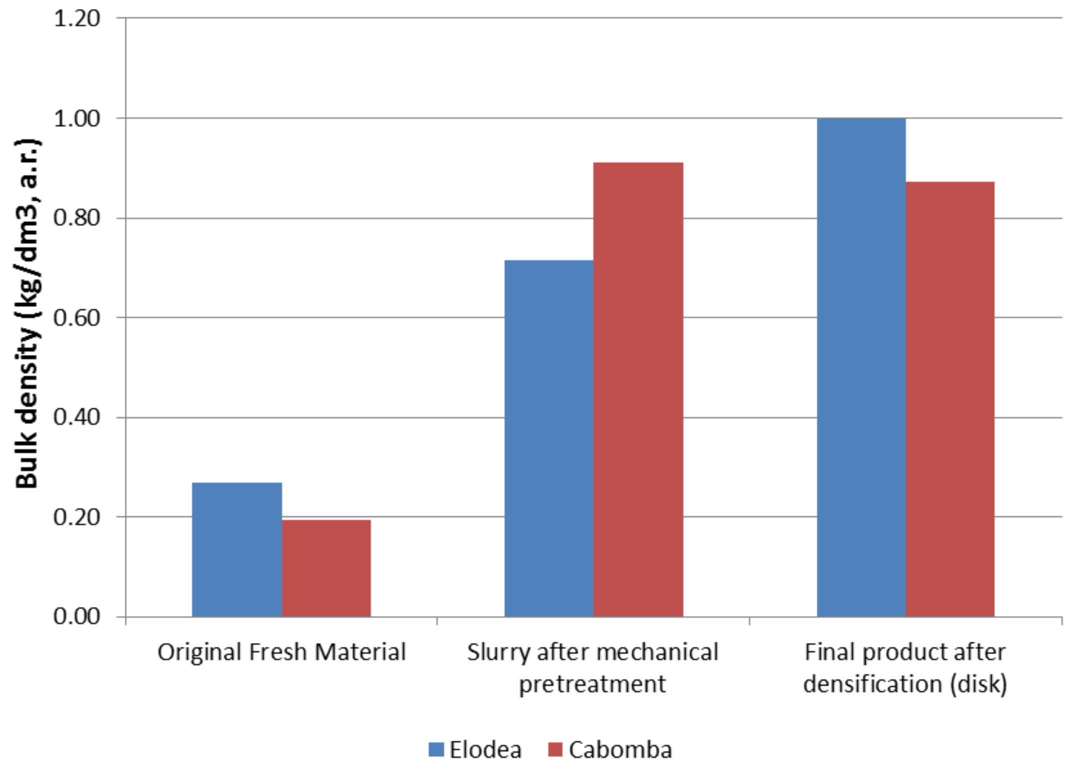
Densification: “cookies”



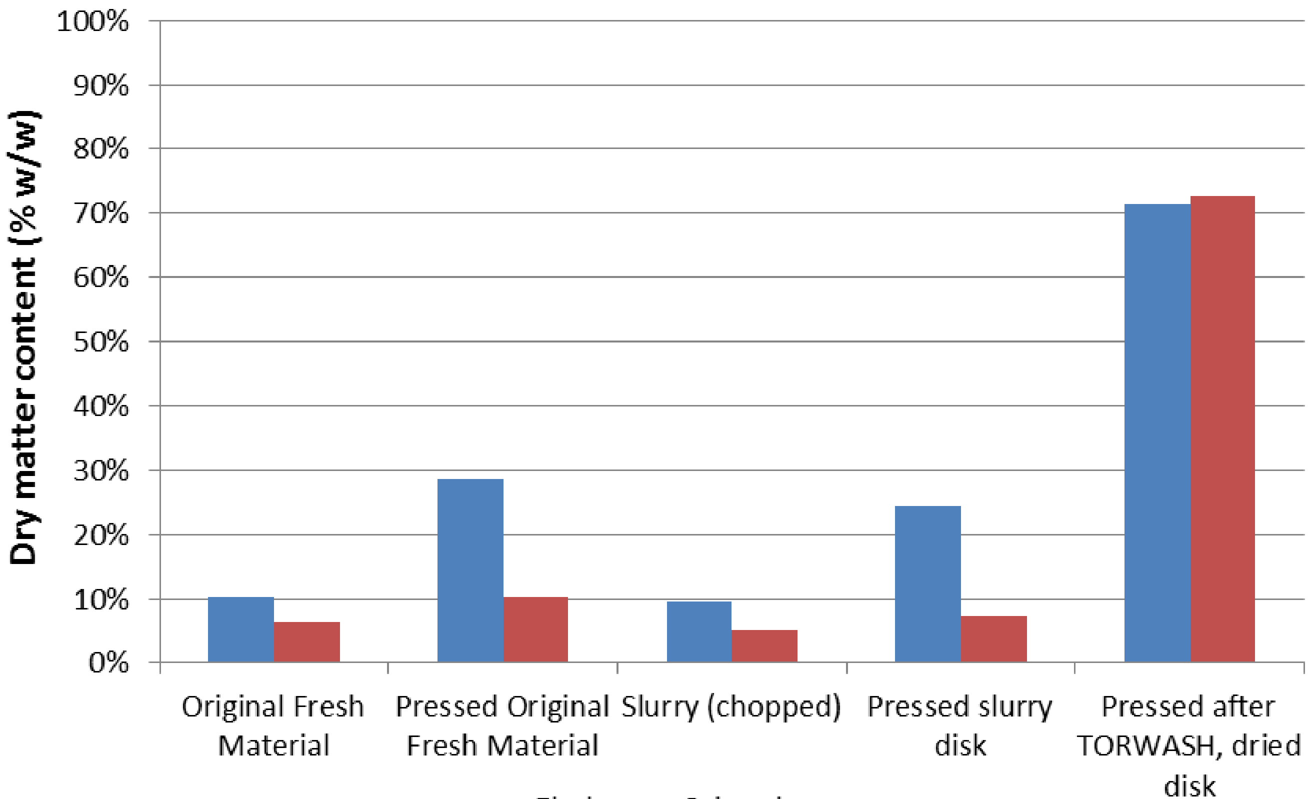
- Uni-directional press
- Carver die (2¼ inch)
- Slurry after TORWASH pressed into disks
  - good TORWASH → 65% dry matter or better

TORWASHed Water Plants
Density changes

- Volume reduction (densification)
  - calculated on as received bases (wet mass in vs wet mass out)
  - including water and ash
- Densification factor
  - Cabomba 4.5x
  - Elodea 3.7x
- Primarily achieved in pre-treatment



TORWASHed Water Plants Mechanical Dewatering



- Yes, after TORWASH it works!
- 70% dry matter content

Further drying is not really necessary, but it makes a better fuel

TORWASHed Water Plants
Mass yield – Energy yield

ECN

- Mass yield results:
  - 20 L autoclave tests at 190 °C, 30 minutes
  - calculated on dry bases (dry mass out vs dry mass in)
  - excluding water, but including ash

- Values:
  - Elodea: 61 wt% (dry basis)
  - Cabomba: 64 wt% (dry basis)

✓ Conclusion: both values above the 60 wt% threshold

- Calorific value (HHV)
  - Elodea: from 10.9 to 11.3 MJ/kg (dry basis) → 63% energy yield
  - Cabomba: from 15.6 to 17.7 MJ/kg (dry basis) → 73% energy yield

✓ Conclusion: only Cabomba compliant with fuel pellet standards

TORWASHed Water Plants Fuel Characteristics

	moisture (105°C)	ash (550°C)	ash (815°C)	volatile matter	HHV	C	H	N	O	S
	% a.r.	% d.b.	% d.b.	% d.b.	MJ/kg	% d.b.				
Cabomba, fresh	94	17	16	64.7	15.6	39.2	5.25	2.9	37.8	0.30
Cabomba, disc	29	22	21	59.6	17.7	42.6	4.85	2.2	29.3	0.30
Elodea, fresh	89	40	27	54.1	10.9	31.2	3.85	2.3	36.2	0.26
Elodea, disc	27	47	33	42.5	11.3	32.5	3.35	1.8	31.3	0.19
Thinning wood (chips)	8.2	2.6	2.1	79.0	19.2	48.2	6.5	0.5	43.7	0.04
Subbituminous coal	10	6.6	6.2	42.0	26.4	67.9	5.0	1.0	23.9	0.33

- Heating value
  - Cabomba similar to thinning wood, Elodea low
- Nitrogen
  - both TORWASHed water plants ~2% range
  - some depletion upon TORWASH… not much
  - high/regular fuels values
- Sulphur levels comparable to sulphur-lean coal

- Ash (550°C, dry base)
  - Cabomba ~20%, Elodea ~40%
  - benchmark coal (< 10%), pellets criterion (0.7 – 3.0% %)
  - high but may still be technically acceptable for fluidized bed
  - possible but unnatractive for co-firing in pulverized fuel burners

TORWASHed Water Plants Fuel Characteristics

	Si	Al	Ca	Mg	K	Na	P	Cl
Cabomba, fresh	19766	2318	9536	2605	17877	31234	3013	16051
Cabomba, disc	60961	4974	22227	2016	2575	1738	261	545
Elodea, fresh	11417	1217	141776	2120	18438	7842	4199	6201
Elodea, disc	17329	2551	183875	1916	2255	921	6025	418
Thinning wood (chips)	840	267	4780	627	2479	179	520	295
Subbituminous coal	5744	4884	8737	1715	228	716	320	29

- Silicon
  - profound in cabomba (possibly as sand)
  - silicon in cabomba may be problematic in combination with the Ca
- Calcium
  - dominates Elodea ash
  - does not decrease upon processing
  - Elodea ash high melting, hence likely not troublesome in combustion
- Alkalis (K and Na)
  - ~90% removed upon TORWASH as expected
  - final levels comparable with thinning wood
- Cl
  - ~90% removed upon TORWASH as expected
  - final product comparable with thinning wood, but too high compared with pellet criteria (300 ppm)
  - S/Cl relatively high in product (safe for chlorine corrosion)

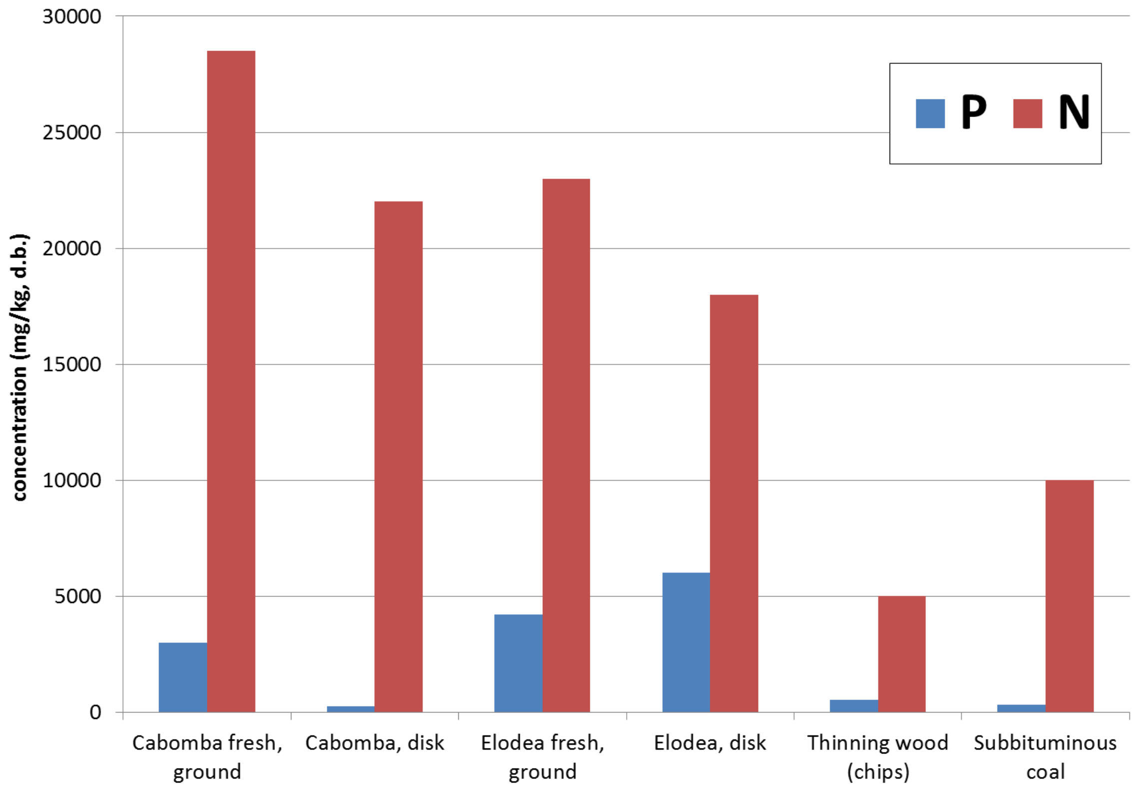
Summary of fuel characteristics

- TORWASH works as expected, but is it good enough?
- Mass and energy yield
  - Over 60% solid mass is recovered in the solid product (👍)
  - About 70% energy yield in solid product (Cabomba 👍 - Elodea 👎)
- Proximate/ultimate
  - High in ash (20-40%) means limited applications (👎)
- Elements
  - Elodea ash very calciferous (high melting, likely non-problematic (👍))
  - Cabomba ash still contains much silicon (risk of melt in the boiler (👎))
  - Chlorine overall efficiently removed, yet still at increased levels vs wood
    - further washing or accepting counterbalance by the presence of sulphur (👍)
  - Alkalis efficiently removed by TORWASH (👍)

Ashes good for making cement

TORWASH Water Plants
Fate of nutrients

- Phoshorus (P)
  - Similar starting levels but…
  - Cabomba ~90% depletion (removal in effluent)
  - Elodea ~20% enrichment (retainment in solid)
  - Cabomba: poor sink for phosphorus if liquid effluent returned to the environment
  - Elodea: good option to deplete P from environment, but potentially problematic for combustion
- Nitrogen (N)
  - some depletion
  - fuel is sink for N



- Potassium (K)
  - 90% in effluent
  - further washing removes more (also for P in Cabomba)

Alternative techniques

- Drying on land → direct improvements of logistics
  - requires sunny and dry conditions (in the NL July is the most rainy month of the year…)
  - increase in dry matter content from 10% to 70%
- Silage before further use
- Cattle feed – not suitable: low protein, high calcium
- Biogas through digestion – preferably combined with drying on land
  - high efficiency of digestion (unpublished results)
  - digestate as unwanted and troublesome residue
- Biocomposites – higher added value than fuel
- Pyrolysis (same 'tech level' as TORWASH)
  - preferably combined with drying on land
  - four products: oil, syngas, wood vinegar, biochar
  - nutrients (N, P, K) removed from ecosystem – end up in biochar (only at low T)
- Economic feasibility needs to be studied in all cases

Conclusions

Conclusions (1)

- First improvement of logistics
  - chopping already identified as major upgrading: 4x density increase (outside TORWASH)
- TORWASH for making fuel works on water plants
  - chlorine and potassium 90% removal – but that may not be enough → post-washing
  - dewatering effective
  - fuel is made, but…
- Main disadvantage
  - … fuels do not comply with standards…
  - high ash content of solid product – fuel buyer must know what he gets!

- Uncertainty for TORWASH and all alternative applications:
  - seasonal aspect of water plant harvest
  - contribution to bio-based or circular economy <u>or</u> low tech residue disposal

Conclusions (2)

- Nutrients
  - Potassium dissolved and goes to effluent
  - Nitrogen distributed between effluent and solid phase
  - Phosphorus behaviour very different for both species
  - Where do you want them? (solids or liquids?)

- Other techniques considered
  - Waternet has not yet made a selection
  - Studying economic feasibility

Thank you for your attention

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