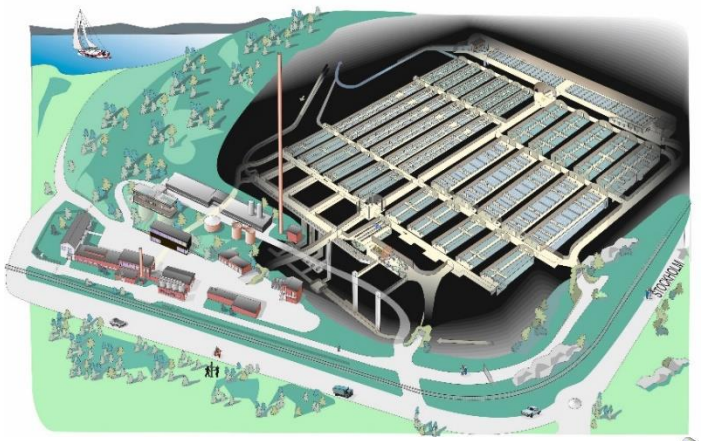
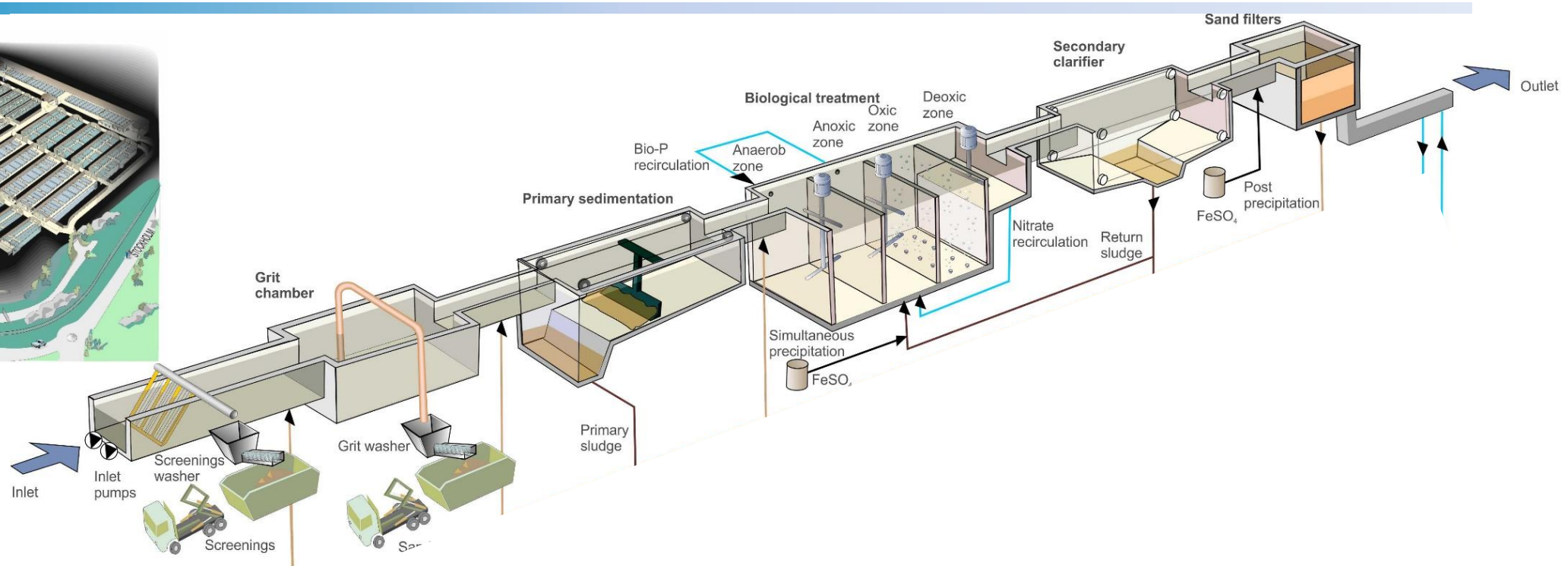
Full scale study – Sludge capacity test on sand filter for polishing of municipal wastewater

Sofia Bramstedt

Käppala Association

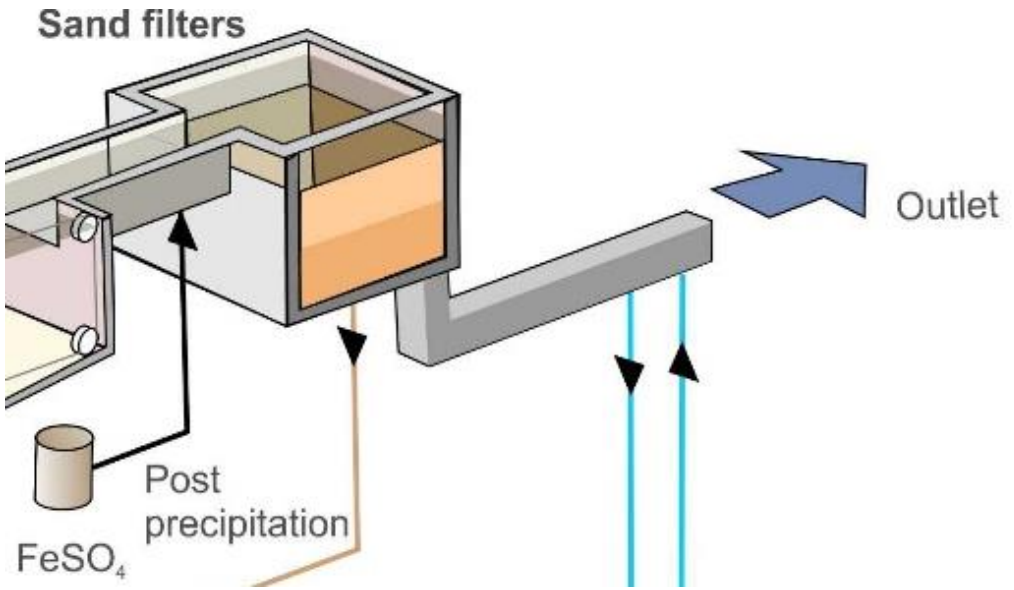




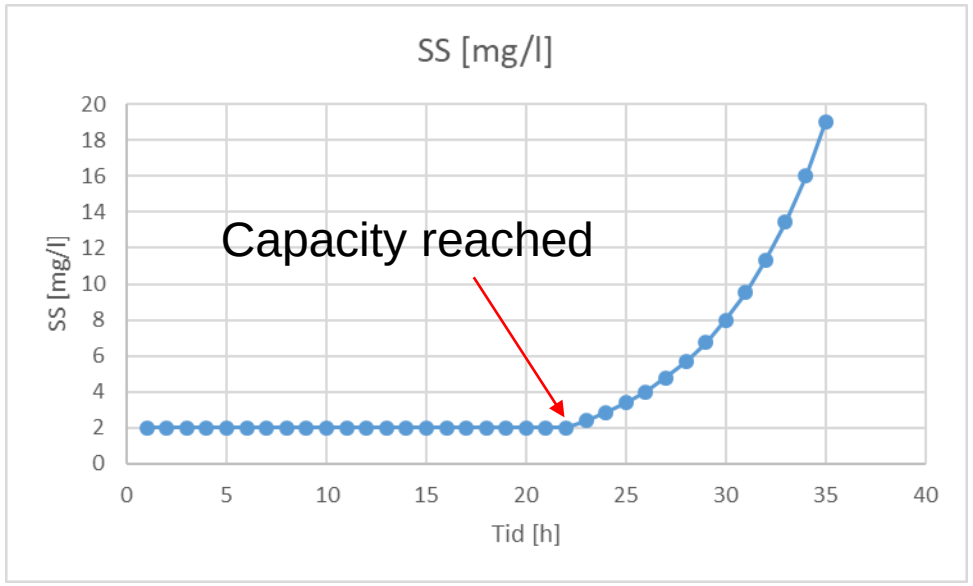
- The Käppala Association was founded in 1957. Owns and operates the Käppala wastewater treatment plant in Lidingö.
- Sweden’s third largest wastewater treatment plant and treats wastewater from 575 000 population equivalents.
- The plant was brought into operation in 1969 and was rebuilt and extended in the years 1994-2000.
- Future challenges drives a new period of large investments in new technology.

Background sand filters

- Filter design
  - 30 filters
  - 2 media
    - *0.5 m sand (grain size 1.2 – 2.0 mm)*
    - *1.0 m leca (grain size 2.5 – 4.0 mm)*
  - Hydraulic capacity of 12 m/h
  - Sludge capacity of 6 kg SS/m^2
- Capacity are limited at high flows and needed to be verified



Theory of sludge capacity



$$Sludge\ capacity\ [kg\ SS/m^2] = \frac{m_{SS\ loaded}\ [kg\ SS]}{Area_{filter}\ [m^2]}$$

(Tchobanoglous. et al.. 2013)

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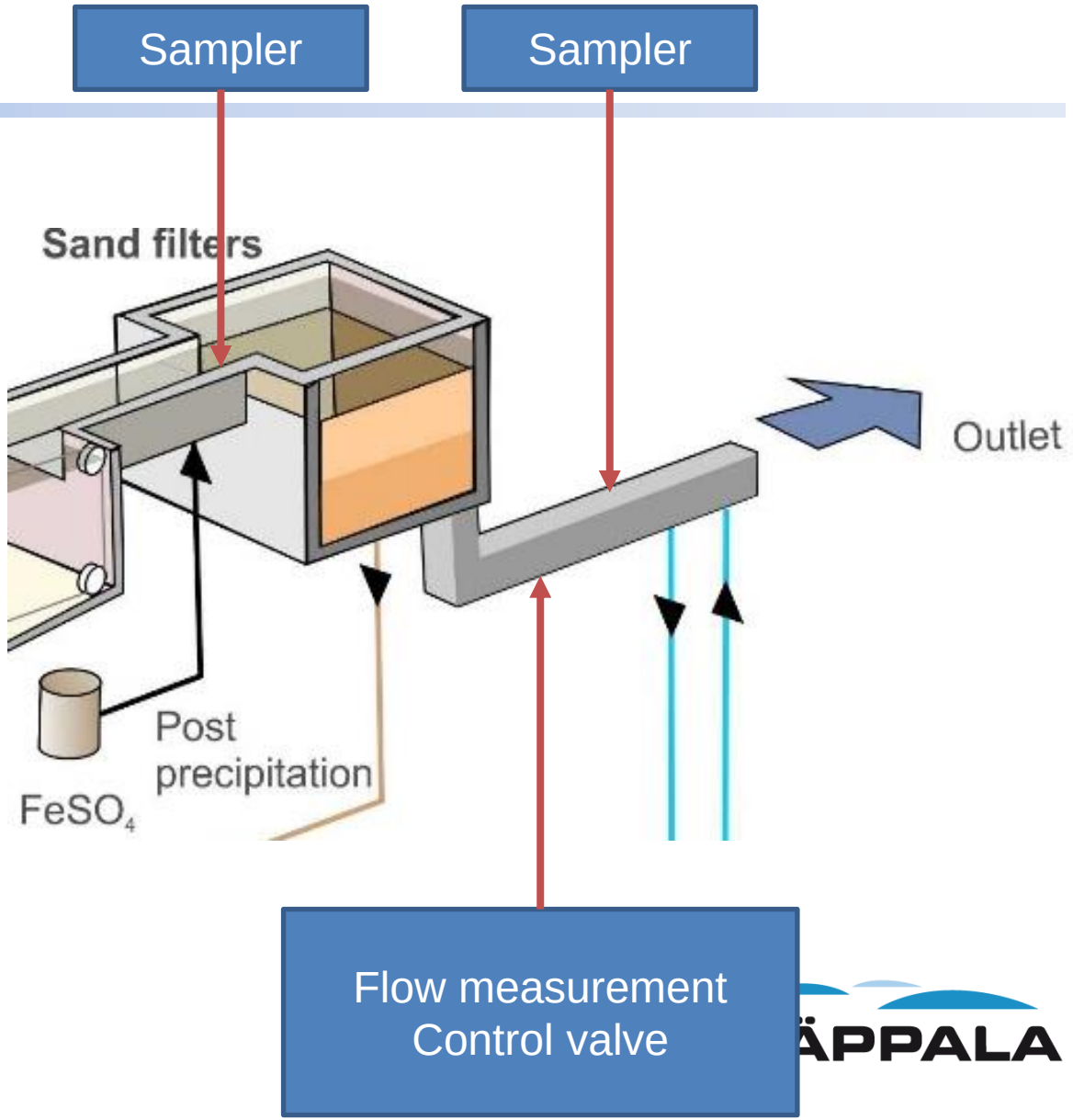
- Research questions
  - Determine the actual sludge capacity in full scale at Käppala WWTP
  - Determine if the sludge capacity is dependent of flow
  - Determine if the sludge concentration out increases when the capacity is reached
- Set up
  - Fixed flow set point
  - Collect sample 2nd – 8th hour
  - Analyse: Turbidity, SS and TP

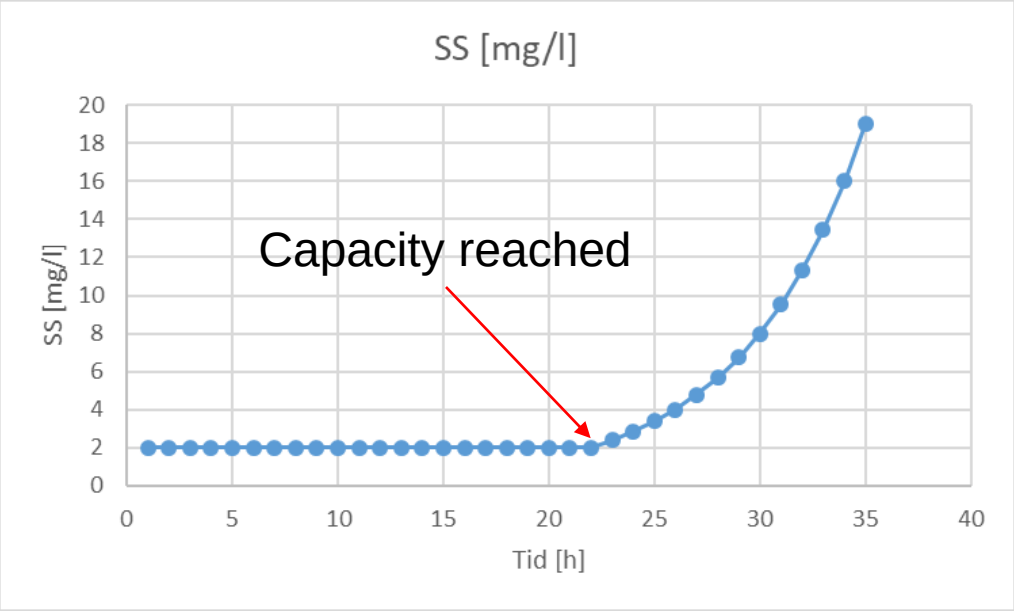


	Flow	SS in	SS out	Separation SS	P-tot in	P-tot out	Separation P-tot
Filter 30	300 m^3/h	10.7 mg/L	< 2 mg/L	90 %	-	-	-
		11.5 mg/L	< 2 mg/L	91 %	-	-	-
	500 m^3/h	12.0 mg/L	< 2 mg/L	89 %	1.01 mg/L	0.22 mg/L	78 %
	600 m^3/h	11.7 mg/L	< 2 mg/L	90 %	0.92 mg/L	0.22 mg/L	76 %
Filter 17	300 m^3/h	11.5 mg/L	< 2 mg/L	91 %	0.92 mg/L	0.16 mg/L	82 %
	400 m^3/h	11.5 mg/L	< 2 mg/L	91 %	1.07 mg/L	0.23 mg/L	79 %
	450 m^3/h	12.8 mg/L	< 2 mg/L	92 %	-	-	-
	500 m^3/h	10.8 mg/L	< 2 mg/L	87 %	0.77 mg/L	0.18 mg/L	76 %
	600 m^3/h	10.5 mg/L	< 2 mg/L	90 %	-	-	-

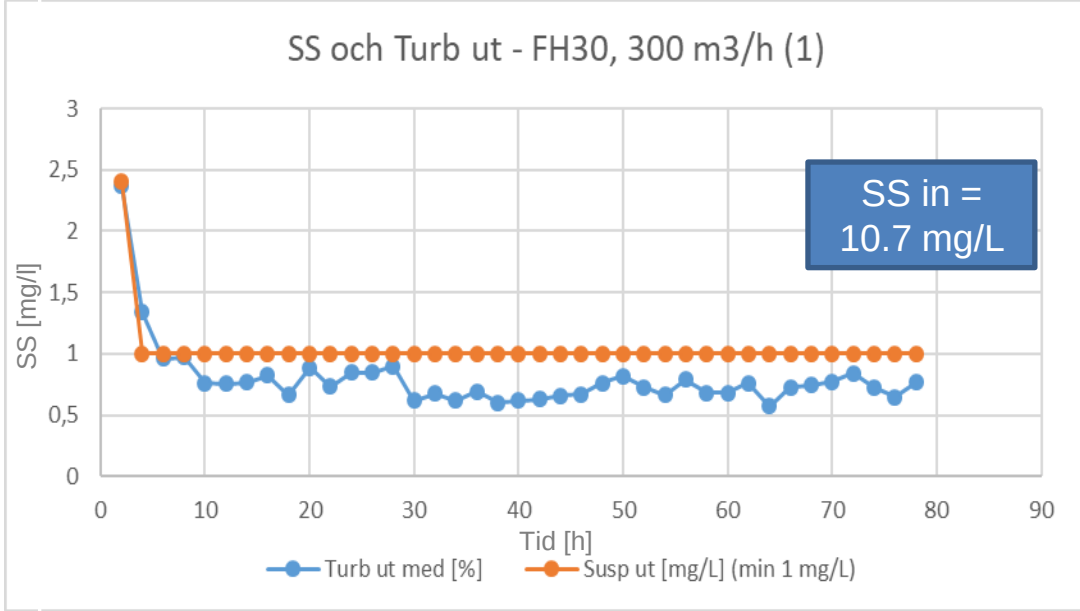
	Flow	SS in	SS out	Separation SS	P-tot in	P-tot out	Separation P-tot
Filter 30	300 m^3/h	10.9 mg/L	< 2 mg/L	90 %	0.69 mg/L	0.13 mg/L	81%
		10.9 mg/L	< 2 mg/L	90 %	0.68 mg/L	0.15 mg/L	77 %
	500 m^3/h	7.0 mg/L	< 2 mg/L	86 %	0.56 mg/L	0.18 mg/L	68 %
	600 m^3/h	8.0 mg/L	< 2 mg/L	88 %	0.61 mg/L	0.17 mg/L	72 %
Filter 17	300 m^3/h	10.0 mg/L	< 2 mg/L	85 %	0.72 mg/L	0.16 mg/L	78 %
	500 m^3/h	10.5 mg/L	< 2 mg/L	90 %	0.72 mg/L	0.19 mg/L	74 %
	600 m^3/h	7.0 mg/L	< 2 mg/L	86 %	0.73 mg/L	0.17 mg/L	77 %
Filter 8	300 m^3/h	14.2 mg/L	< 2 mg/L	93 %	0.85 mg/L	0.19 mg/L	78 %
	500 m^3/h	6.0 mg/L	< 2 mg/L	82 %	0.74 mg/L	0.26 mg/L	65 %
	600 m^3/h	7.3 mg/L	< 2 mg/L	86 %	0.77 mg/L	0.24 mg/L	69 %

Results: Sludge concentration out

Theory



Full scale results



- Detection limit for outgoing SS is 2 mg/L → results below is represented as 1 mg/L

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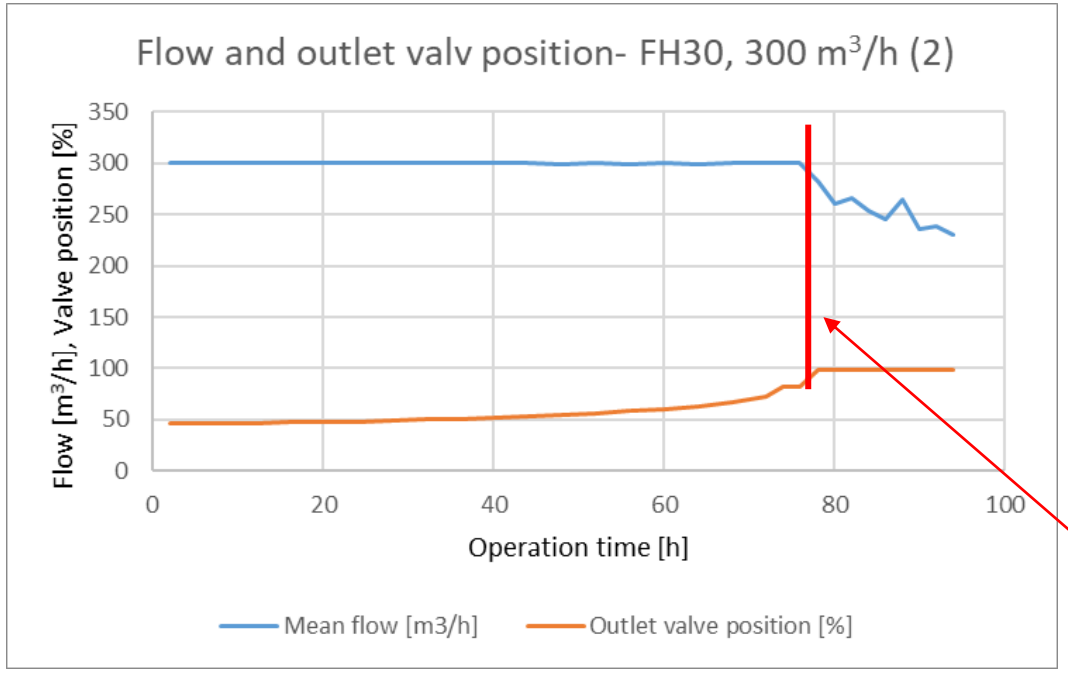
Redefinition of sludge capacity

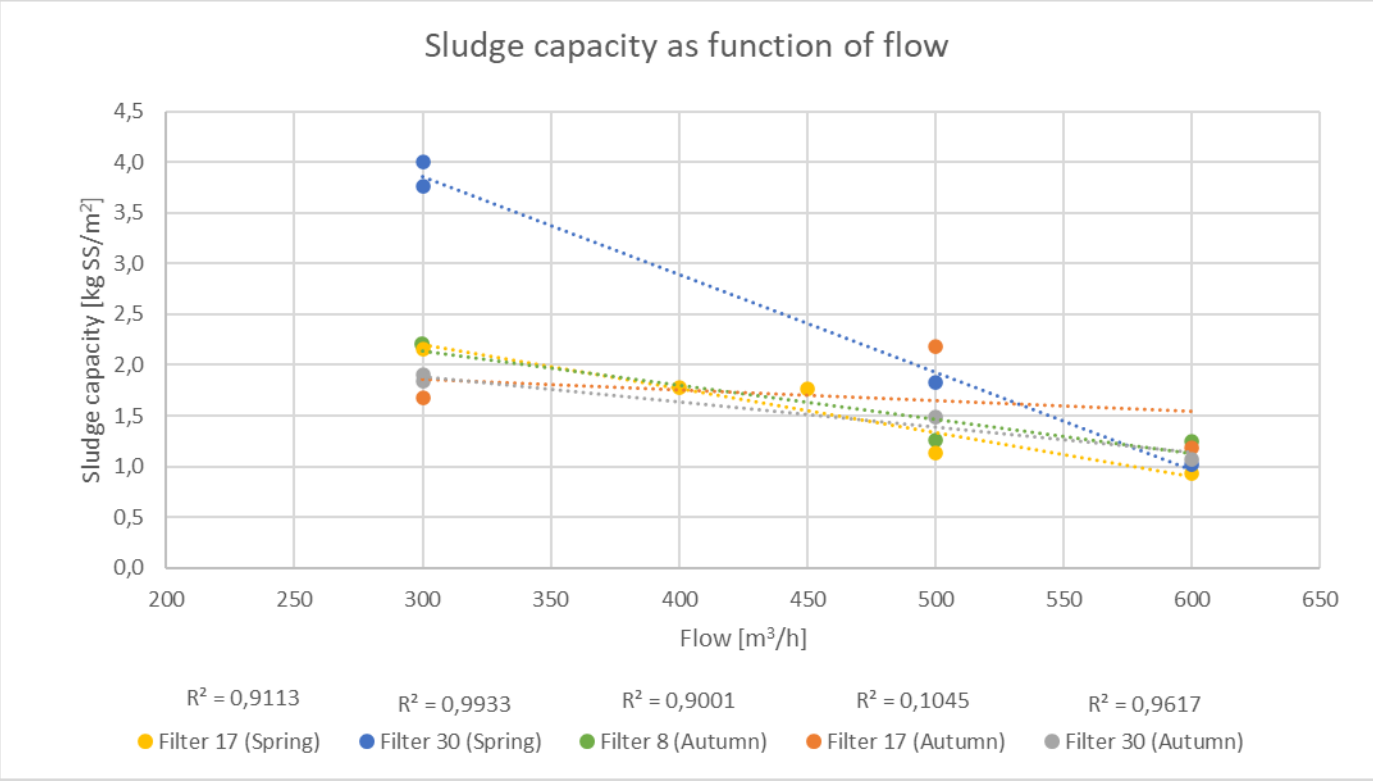


$$Sludge\ capacity\ [kg\ SS/m^2] = \frac{m_{SS\ in} - m_{SS\ out}}{Area_{filter}}$$

$$= \frac{Q_{filter}[m^3/h] * (c_{SS\ in} - c_{SS\ out})[mg/L] * t_{operation\ time}\ [h]}{Area_{filter}[m^2] * 1000}$$

Capacity reached

Results: Sludge capacity



	Flow	Operation time	Sludge capacity
Filter 30	300 m³/h	78 h	3.8 kg SS/m²
		78 h	4.0 kg SS/m²
	500 m³/h	20 h	1.8 kg SS/m²
	600 m³/h	10 h	1.0 kg SS/m²
Filter 17	300 m³/h	42 h	2.2 kg SS/m²
	400 m³/h	26 h	1.8 kg SS/m²
	450 m³/h	20 h	1.8 kg SS/m²
	500 m³/h	14 h	1.1 kg SS/m²
	600 m³/h	8 h	0.9 kg SS/m²

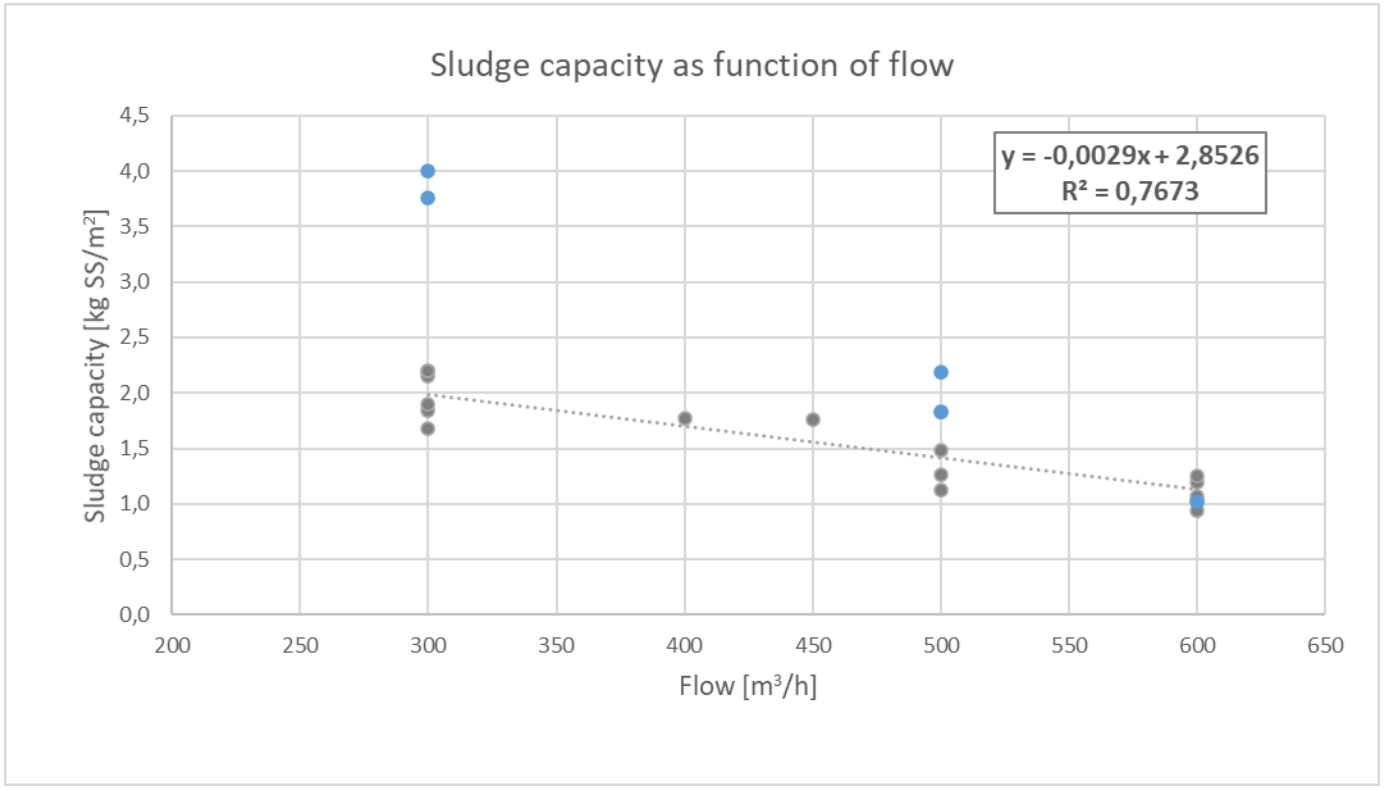
	Flow	Operation time	Sludge capacity
Filter 30	300 m³/h	36 h	1.8 kg SS/m²
		46 h	1.9 kg SS/m²
	500 m³/h	30 h	1.5 kg SS/m²
	600 m³/h	15 h	1.1 kg SS/m²
Filter 17	300 m³/h	52 h	1.7 kg SS/m²
	500 m³/h	28 h	2.2 kg SS/m²
	600 m³/h	20 h	1.2 kg SS/m²
Filter 8	300 m³/h	36 h	2.2 kg SS/m²
	500 m³/h	26 h	1.3 kg SS/m²
	600 m³/h	20 h	1.3 kg SS/m²

Conclusion

- Sludge capacity is dependent of the flow
- Relationship between sludge capacity and flow for Käppala WWTP:

$$Sludge\ capacity\ [kg\ SS/m^2] = -0{,}003 * Q_{Filter}\ [m^3/h] + 2.85$$

- No increase in outgoing sludge concentration could be detected.



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Further work

- Compare the results with high flow situations.
- Repeat the study to verify the relationship between sludge capacity and flow.
- Determine the filters sludge capacity and performance with other precipitation chemicals.
- Determine hydraulic bottle necks in sand filters – ongoing project

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