First results of the On-Line Methane Measurement at Viikinmäki WWTP

Mari Heinonen

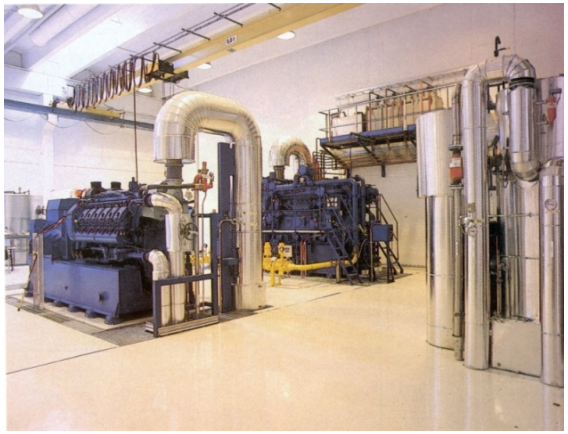
Green house gas emissions from wastewater treatment

Direct emissions:

- Wastewater treatment process emissions
- Sludge treatment process emissions
- Emissions of sludge based production (composting, thermal drying, etc.)
- Own energy production

Indirect emissions:

- Sewer system / incoming wastewater
- Energy (depends on the source)
- By chemicals, consumables, machinery, solid wastes etc.
- Transportation in general



Process gas emission mechanisms at treatment plant

Wastewater:

•NMVOC

•VOC-compounds

•SO_X, NO_x

Biological treatment process:

•N_2O

•$CO_{2\ (BIO)}$

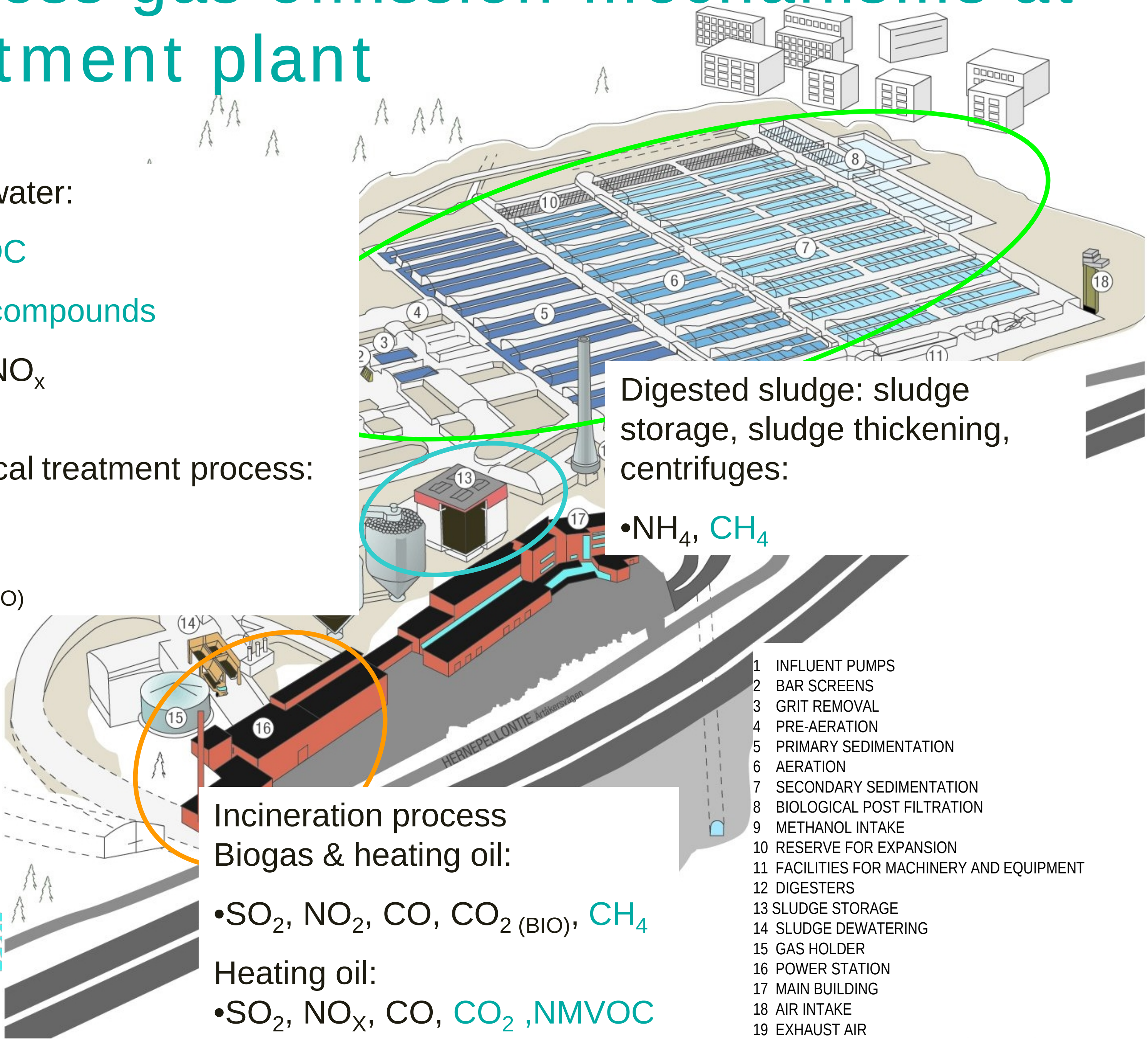
Digested sludge: sludge storage, sludge thickening, centrifuges:

•NH_4, CH_4

Incineration process
Biogas & heating oil:

•SO_2, NO_2, CO, $CO_{2\ (BIO)}$, CH_4

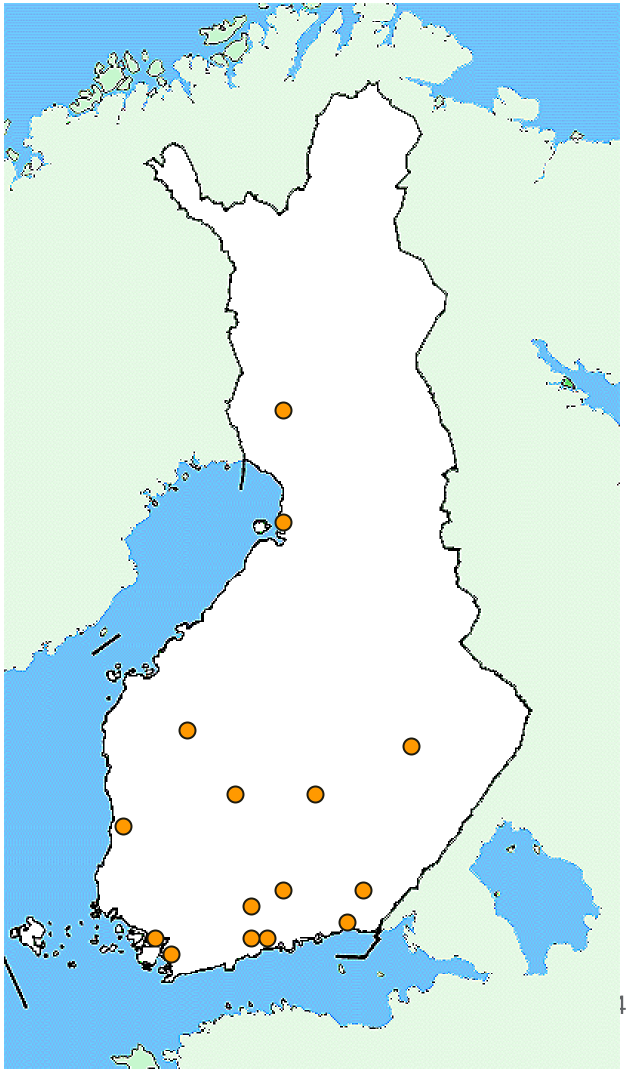
Heating oil:
•SO_2, NO_X, CO, CO_2 ,NMVOC



History of air emission research at Finnish WWTPs – case study

- 2006 Finnish Water and Wastewater Association VVY collected group of 15 large WWTP in Finland
- Basic question for the group was:
    - How to measure/calculate/estimate both water and air emissions for EU PRTR reporting purposes for 2007
- WWTPs decided to co-operate in both water and air emission research and join forces due to economical, knowhow and manpower reasons
- Similar task for wide analytic need in water emission side
    - Water emission samples was collected, analysed and reporting practises were developed during year 2007
        - Water emission results were rather homogeneous
        - Air emissions assumed to be homogeneous as well
- HSY Viikinmäki WWTP was selected as a pilot plant to study and develop a model for the air emission estimation due to covered underground plant facilities, size of the plant and personnel resources

Group of Finnish WWTPs



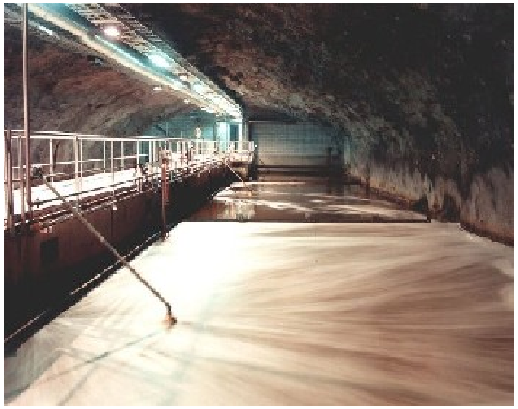
WWTP	Q_{ave} m^3/d	PE	BOD_7 t/d	$N_{influent}$ t/d	$N_{effluent}$ t/d	Digestion Y/N	Biogas Mm^3/a	Heating oil Y/N	Heating oil t/a
Helsinki	260 000	820 000	57,4	11,5	1,3	Y	10	Y	85
Espoo	90 000	260 000	18,2	4,8	1,2	Y	2,9	Y	295
Turku	67 000	200 000	14	2,8	0,9	N		N	
Jyväskylä	42 000	191 000	13,4	2,8	2	Y	1,2	N	
Tampere	63 000	172 000	12,1	2,7	1,9	Y	1,7	N	
Oulu	39 000	137 000	9,6	2,1	1,6	N		N	
Lahti	20 000	117 000	8,2	0,9	0,2	Y	1,5	N	
Kuopio	20 000	113 000	7,9	1,2	0,8	Y	1,2	Y	18
Pori	20 000	112 000	7,9	0,9	0,5	N		Y	81
Kotka	12 000	97 000	6,8	0,9	0,2	N		Y	18
Seinäjoki	17 000	93 000	6,5	0,7	0,3	N		Y	61
Rovaniemi	16 000	90 000	6,3	1	0,8	N		Y	140
Lappeenran	16 000	81 000	5,7	1,1	0,4	N		N	
Riihimäki	13 000	60 000	4,2	0,7	0,2	Y	0,5	N	
Rauma	13 000	26 000	1,8	0,4	0,4	N		N	

First step – Simplified Air Emission Model

- Underground plant construction was utilized as a large scale coverage for the measurements
  - All ventilation air is collected
- Based on the first air emission measurements of 2007 simplified emission model was innovated to develop
- Both utilities and authorities understand problem of traditional open air WWTP air emission measurements
  - Idea of the simplified model was accepted

How to study PRTR air emission compounds at WWTP

- VOC concentrations relatively low or below detection limit in Finnish municipal wastewater
- Model of air emissions can not be based on water phase concentrations

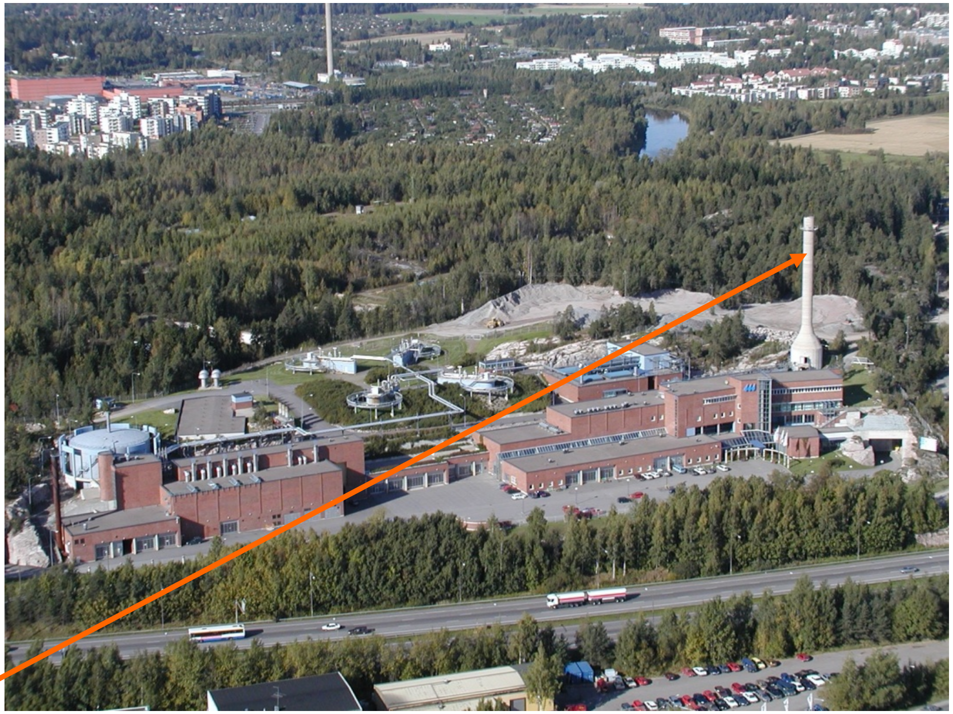


Effluent wastewater quality of PRTR compounds at urban Finnish WWTPs, 2006

Compound	Median, µg/l	Max, µg/l	Environmental Quality Standard*, Surface water, µg/l	Environmental Quality Standard*, Sea water, µg/l	WHO limitation for drinking water, µg/l
1,2-dichloroethane (EDC)	< 0.30	< 1	10	10	30
Dichloromethane (DCM)	< 0.3	2			20
Hexachlorobenzene (HCB)	< 0.05	< 0.25	0.03	0.03	
Pentachlorophenol (PCP)	< 0.1	< 0.1	2	2	9
Tetrachloroethylene (PER)	< 0.5	< 1	10	10	40
Trichloroethylene	< 0.5	< 1	10	10	20
Trichloromethane	< 0.3	< 0.5	12	12	300
Benzene	< 0.5	< 1			10

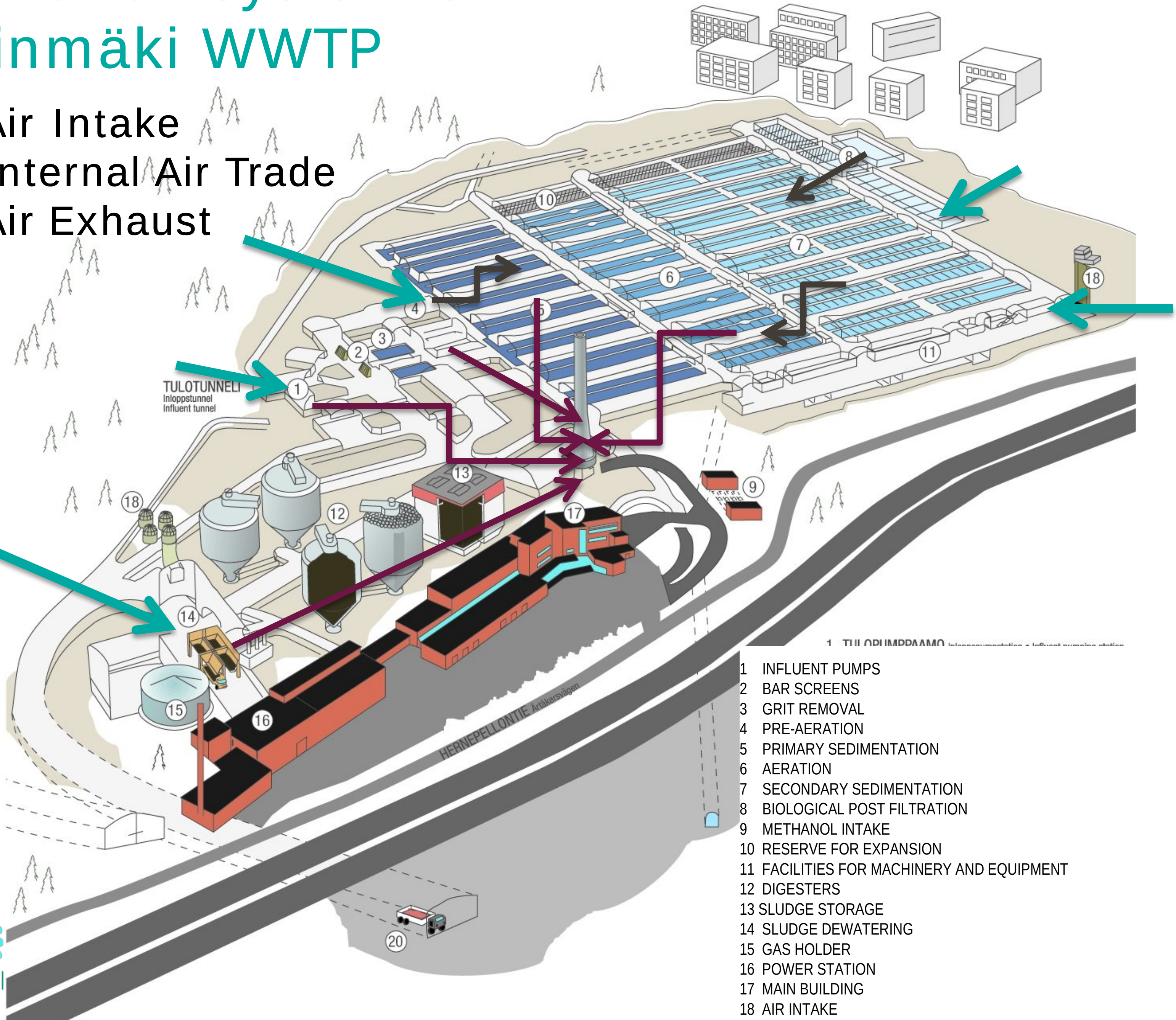
Case Viikinmäki WWTP

- Operated since 1994
- 780 000 PE
- Q_{ave} 280 000 m^3/d
- Q_{peak} 800 000 m^3/d
- All water process and sludge treatment areas have been tunneled in the bedrock
- Underground area 14 hectares, above ground 3 hectares
- Ventilation air flow 120 m^3/s – all ventilation air is collected to the chimney (50 m high)



Ventilation system of Viikinmäki WWTP

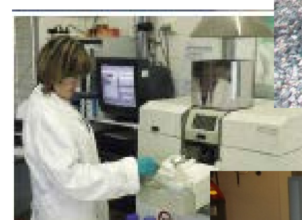
→ Air Intake
→ Internal Air Trade
→ Air Exhaust



1 INFLUENT PUMPS
2 BAR SCREENS
3 GRIT REMOVAL
4 PRE-AERATION
5 PRIMARY SEDIMENTATION
6 AERATION
7 SECONDARY SEDIMENTATION
8 BIOLOGICAL POST FILTRATION
9 METHANOL INTAKE
10 RESERVE FOR EXPANSION
11 FACILITIES FOR MACHINERY AND EQUIPMENT
12 DIGESTERS
13 SLUDGE STORAGE
14 SLUDGE DEWATERING
15 GAS HOLDER
16 POWER STATION
17 MAIN BUILDING
18 AIR INTAKE
19 EXHAUST AIR

Analyse methods for model

- Air phase measurement implemented MetropoliLab, the environmental laboratory of Helsinki
  - Inorganic compounds:
    - FT-IR-gas analyzer (GASMET DX-4010)
  - VOCs:
    - TD-GC/MSD-method (Markes Unity, UltrA, HP6890, HP5973)
- Power production emissions were performed by the consulting company Ramboll.
  - CO_2 and CO ABB's Uras-analyzer and IR absorption
  - NO_x chemiluminens method
  - SO_2 UV-fluorescence
  - Non-combusted residual by total organic analyzer equipped by FID



PRTR Emission model

- Emission mechanisms:
  - Water treatment process including sludge treatment
  - Power and heat production
- Correlation factors for PRTR compounds were determined
- Reference authored by Tommi Fred and Mari Heinonen "Air emissions at large municipal wastewater treatment plants in Finland for national E-PRTR reporting register" Water Practice & Technology © IWA Publishing 2009

Compound	CAS-number	Waste water kg/m³	BOD₇ kg/kg	Nitrogen kg/kg	Biogas kg/m³	Heating oil kg/kg
Methane	74-82-8		1,31E-02		7,31E-03	
Carbon monoxide	630-08-0				7,33E-03	1,70E-02
Carbon dioxide (bio)	124-38-9		8,78E-01		1,79	
Carbon dioxide (fossil)	124-38-9					3,13
Nitrous oxide (N_2O)	10024-97-2			2,57E-02		
Ammonia (NH_3)	7664-41-7		2,47E-5			
NMVOC		3,23E-05				2,03E-02
Nitrogen oxides (NOx)		6,72E-05			4,35E-03	6,72E-08
Sulphuric oxides (SOx)		5,28E-08			8,76E-05	1,12E-04
1,2-dichloroethane (EDC)	107-06-2	6,77E-09				
Dichloromethane (DCM)	75-09-2	2,68E-08				
Hexachlorobentzene (HCB)	118-74-1	8,33E-11				
Pentachlorobentzene	608-93-5	8,38E-11				
Tetrachloroethylene (PER)	127-18-4	2,09E-07				
Tetrachloromethane (TCM)	56-23-5	6,76E-09				
1,1,1-trichloroethane	71-55-6	7,88E-09				
Trichlorothene	79-01-6	1,78E-07				
Trichloromethane	67-66-3	2,18E-08				
Benzene	71-55-6	1,15E-07				

Calculation example for methane:

$$m(CH_4)[kg/a] = V_{BOD\_load}[kg/a] * K_1 + V_{bio\_gas}[m^3/a] * K_2$$

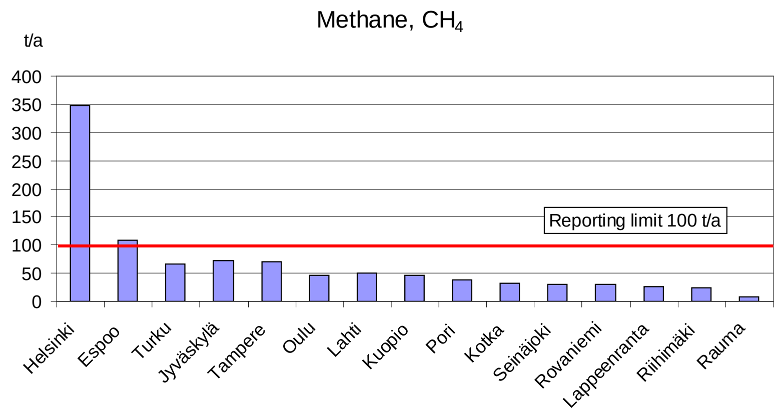
PRTR Reporting results at Viikinmäki

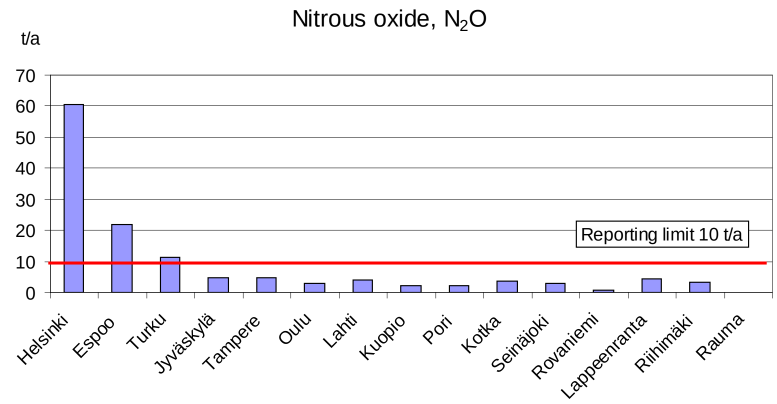
- Based on these measurements total emissions were determined
- Only methane and nitrous oxide emissions exceed the reporting limit (kg/a) at Viikinmäki WWTP (Helsinki)

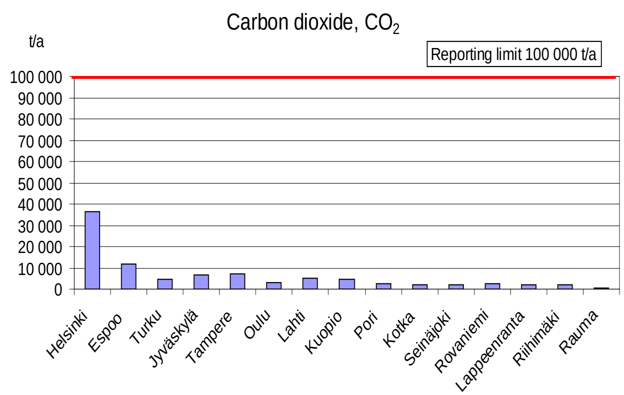
Compound	CAS-number	Total emission, kg/a	Reporting limit, kg/a	Emission / reporting limit ratio, %	Method
Methane	74-82-8	**350 000**	100 000	350 %	M
Carbon monoxide	630-08-0	76 000	500 000	15 %	M
Carbon dioxide[1)]	124-38-9	43 600 000	100 000 000	43 %	M
Nitrous oxide (N_2O)	10024-97-2	**68 000**	10 000	680 %	M
Ammonia (NH_3)	7664-41-7	520	10 000	5 %	M
NMVOC		4 700	100 000	5 %	M
Nitrogen oxides (NOx)		51 000	100 000	51 %	M
Sulphuric oxides (SOx)		900	150 000	0.6 %	M
1,2-dichloroethane (EDC)	107-06-2	0.63	1 000	0.1 %	M
Dichloromethane (DCM)	75-09-2	12	1 000	1.2 %	M
Hexachlorobentzene (HCB)	118-74-1	0.01	10	0.1 %	C
Pentachlorobentzene	608-93-5	0.01	1	1.0 %	C
Tetrachloroethylene (PER)	127-18-4	19	2 000	1.0 %	M
Tetrachloromethane (TCM)	56-23-5	0.6	100	0.6 %	M
1,1,1-trichloroethane	71-55-6	0.8	100	0.8 %	C
Trichloroethene	79-01-6	17.8	2 000	0.9 %	M
Trichloromethane	67-66-3	2.68	500	0.5 %	M
Benzene	71-55-6	11	1 000	1.1 %	M

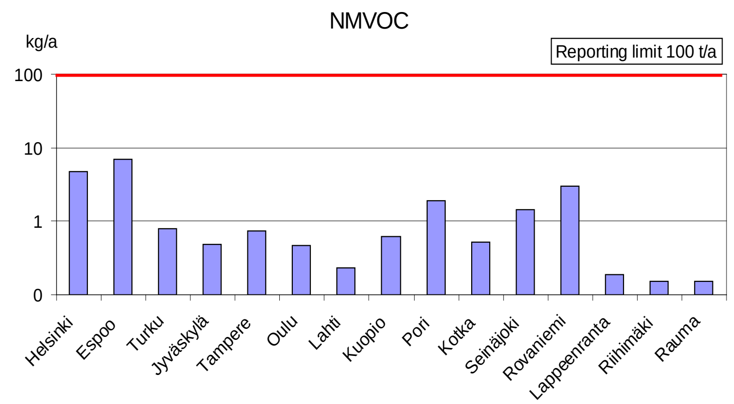
[1)] Includes both fossil and non-fossil sources

Example: Finnish green house gas emission reporting results





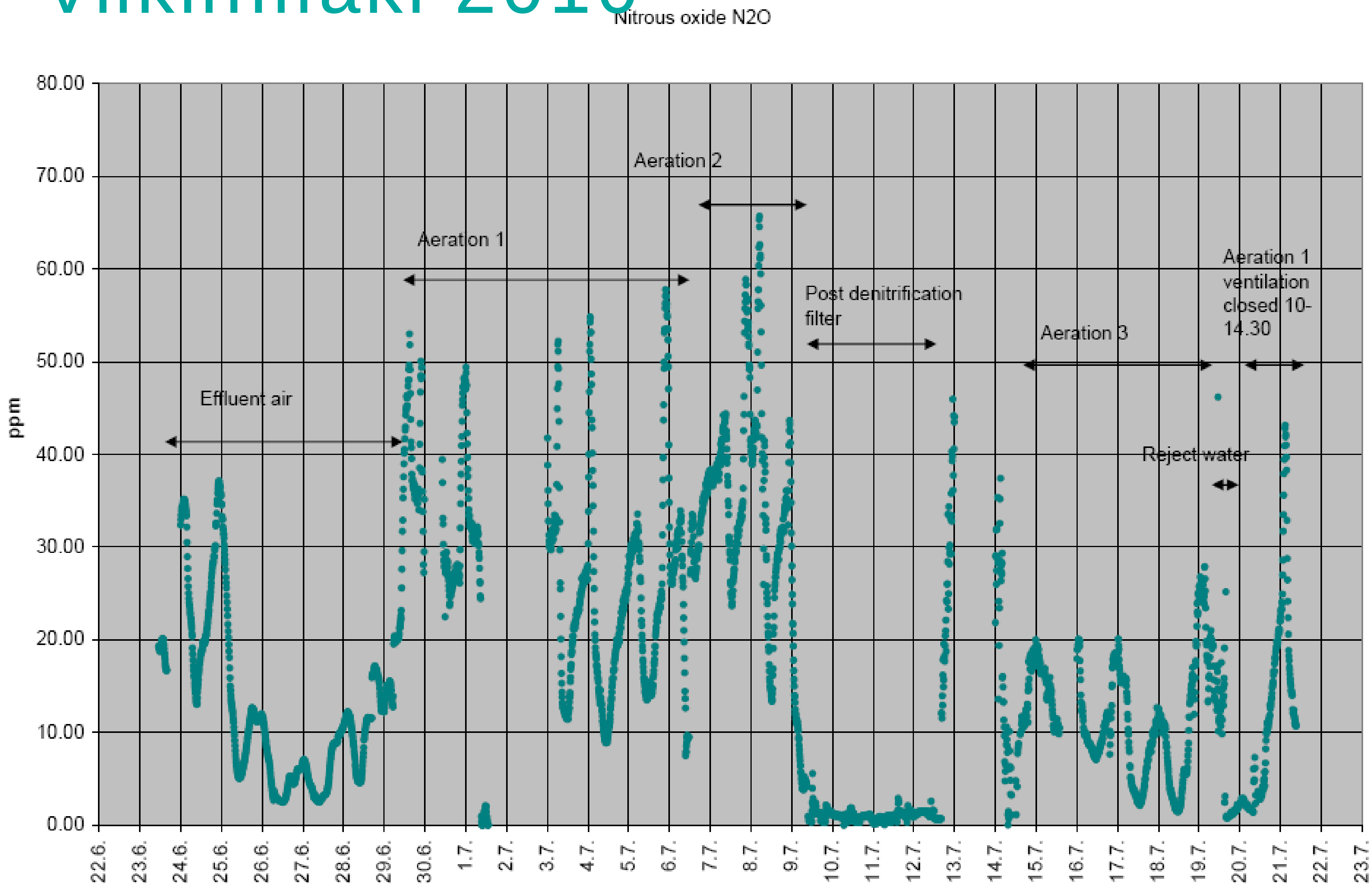




Second step –Air Emission Model development

- HSY Viikinmäki continued in situ air emission measurements
  - Simplified model should be developed
- Measurements showed high instability of emission levels and opened more questions about the seasonal and week variations
- Viikinmäki implemented by portable GASMET FTIR analyzer measurements periods in 2009, 2010
- Model was updated 2009 and 2010 (not published)
- 2011 Technical University of Helsinki measured N2O emissions as well

Some N2O result snapshots from Viikinmäki 2010

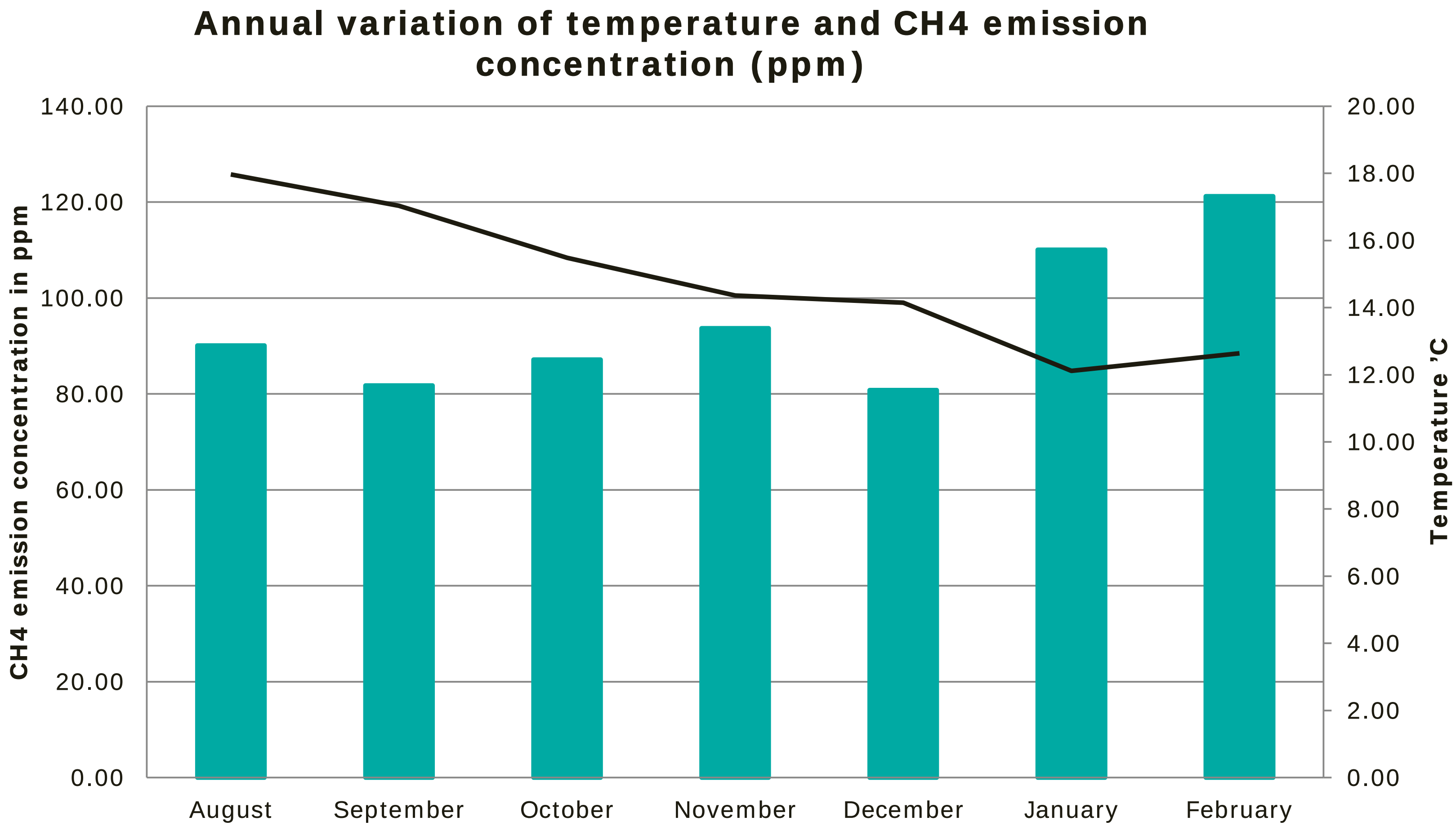


Third Step- On-line measurement by Gasmet FTIR

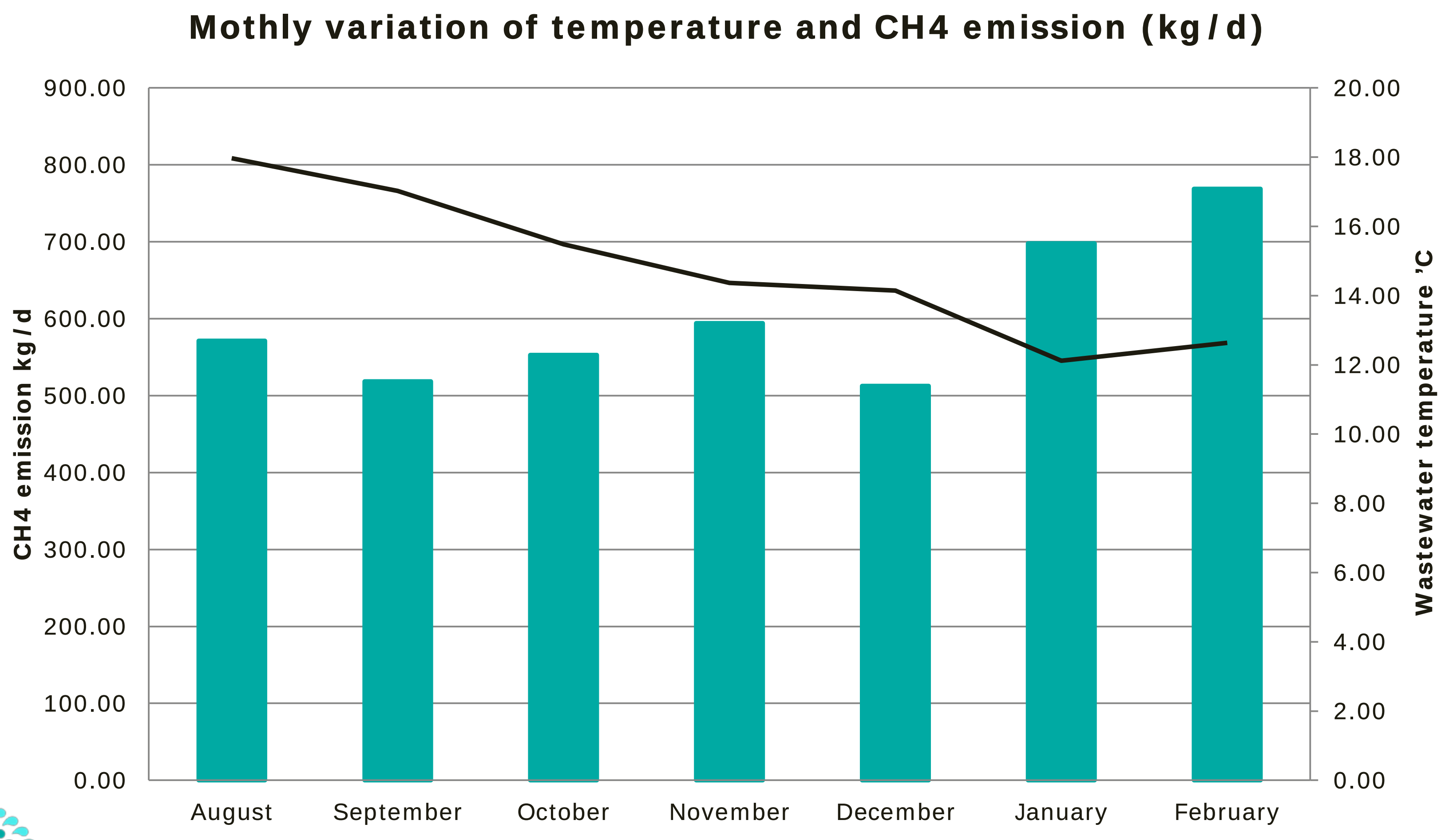
- Based on in-situ measurements, HSY decides to develop air emission control
  - HSY invested online air emission analyzer in the begin 2012
  - Analyzer was ready to implementation in July 2012

- Analyzer was produced by Finnish company GASMET Ltd. (www.gasmet.com)
- Gas analyses are based on FTIR sectromentry technology
  - Quality (50 gases) and quantity
- Quality of the analyses are excellent
- Analyzer collects both water and sludge treatment air emissions

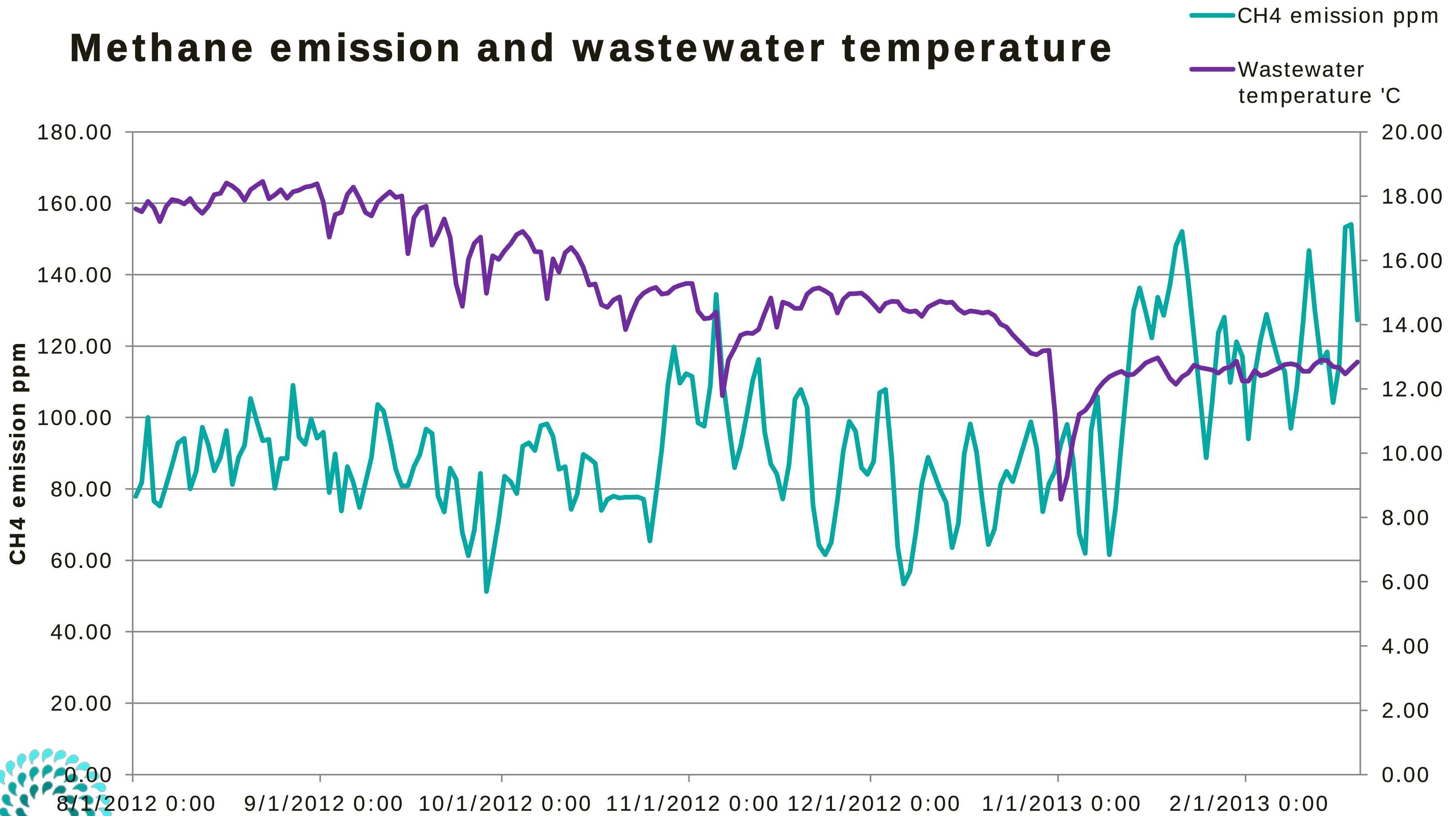
Monthly variation –temperature vs. CH4 ppm



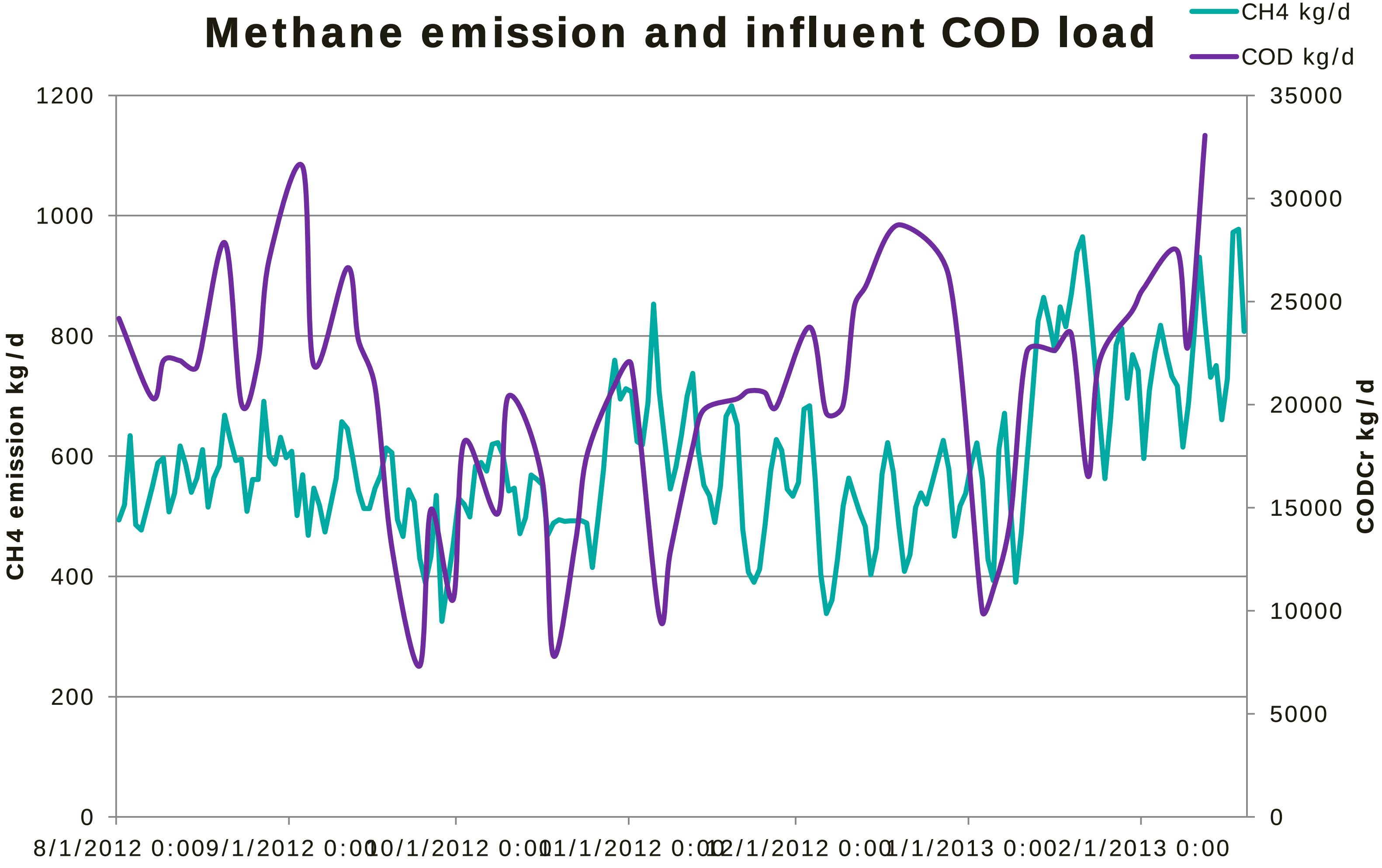
Monthly variation – temperature vs. CH4 kg d-1



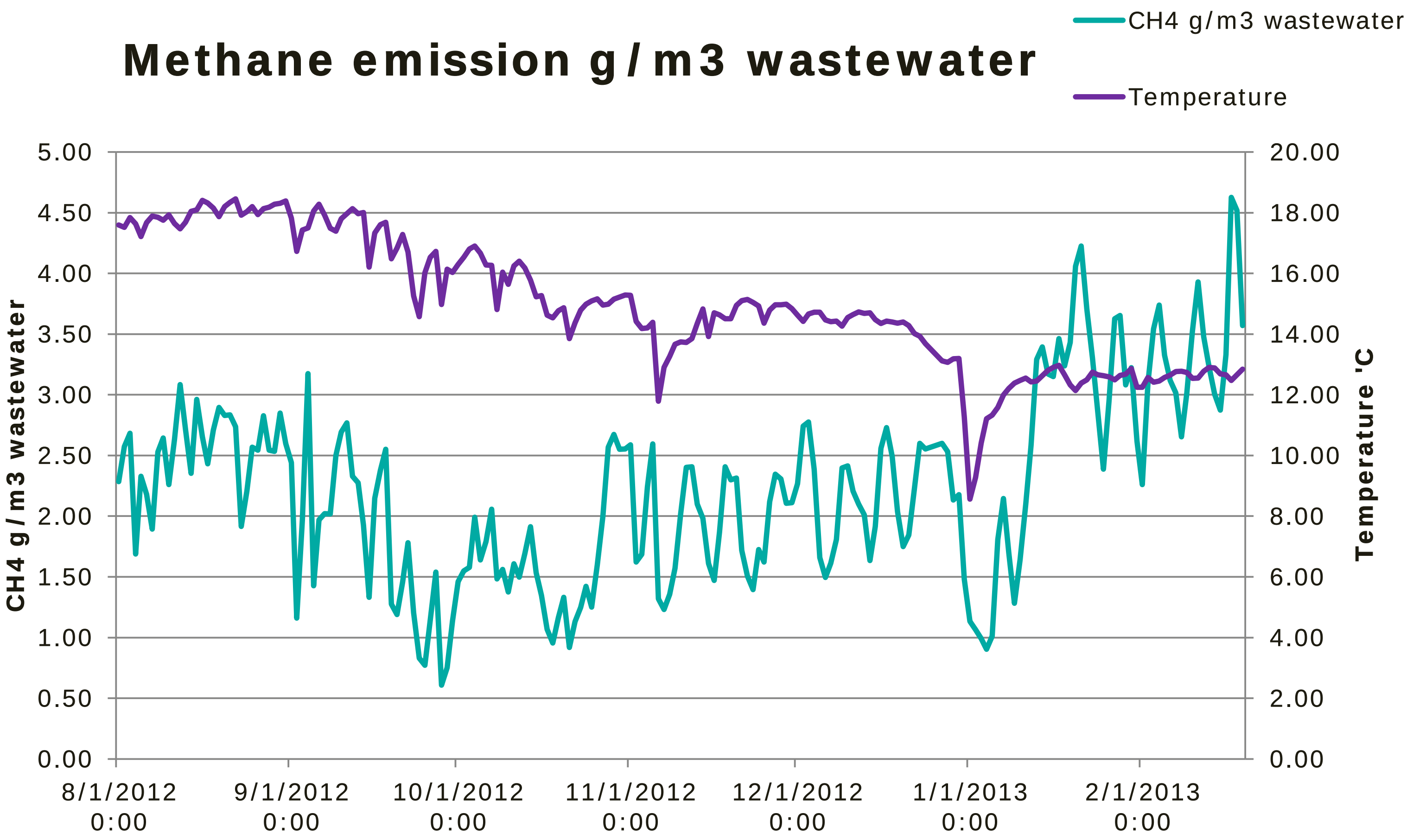
Annual variation –temperature vs. CH4 ppm



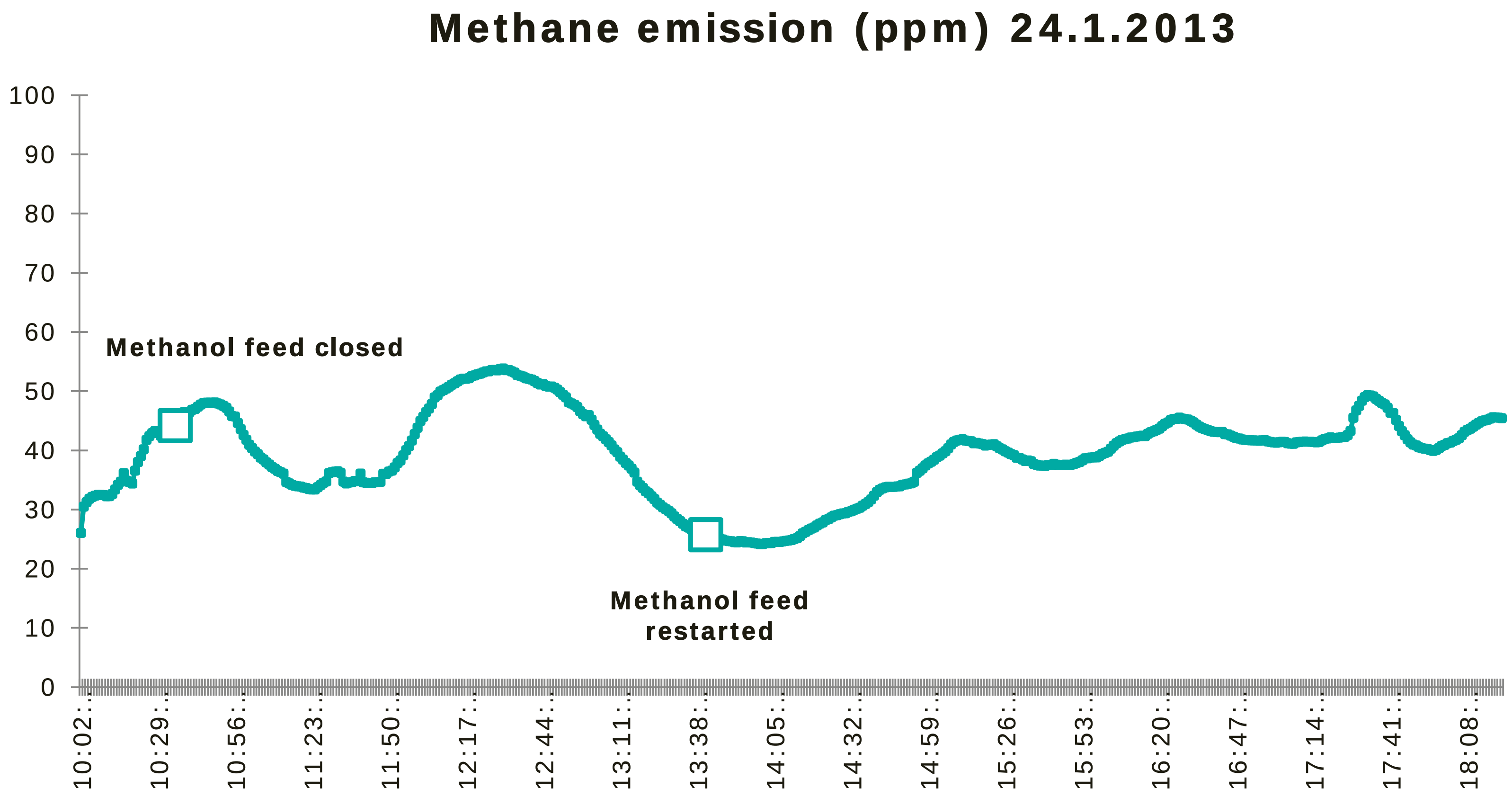
CH4 emission vs. COD load



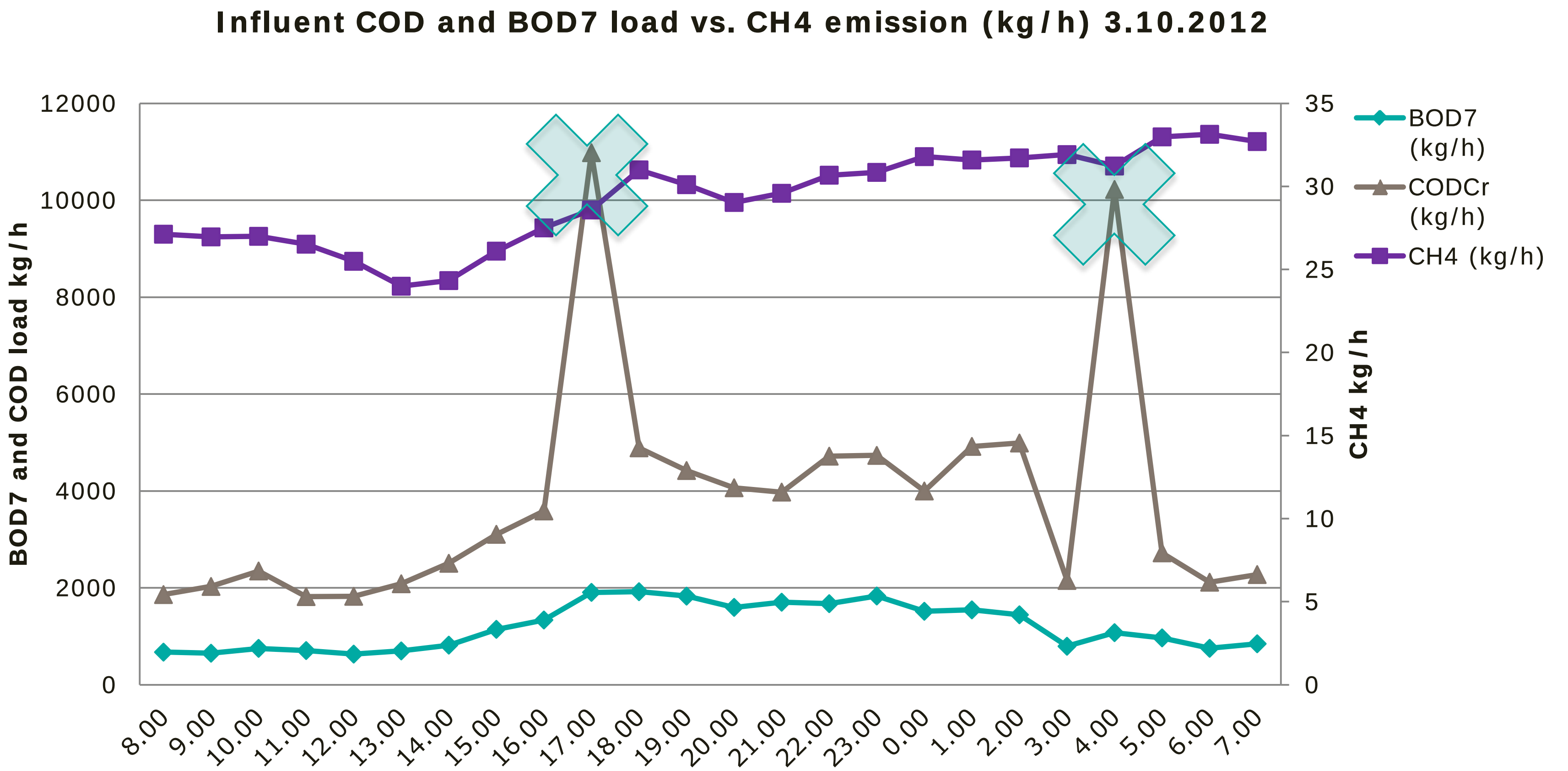
Annual CH4 emission per m3 vs. wastewater temperature



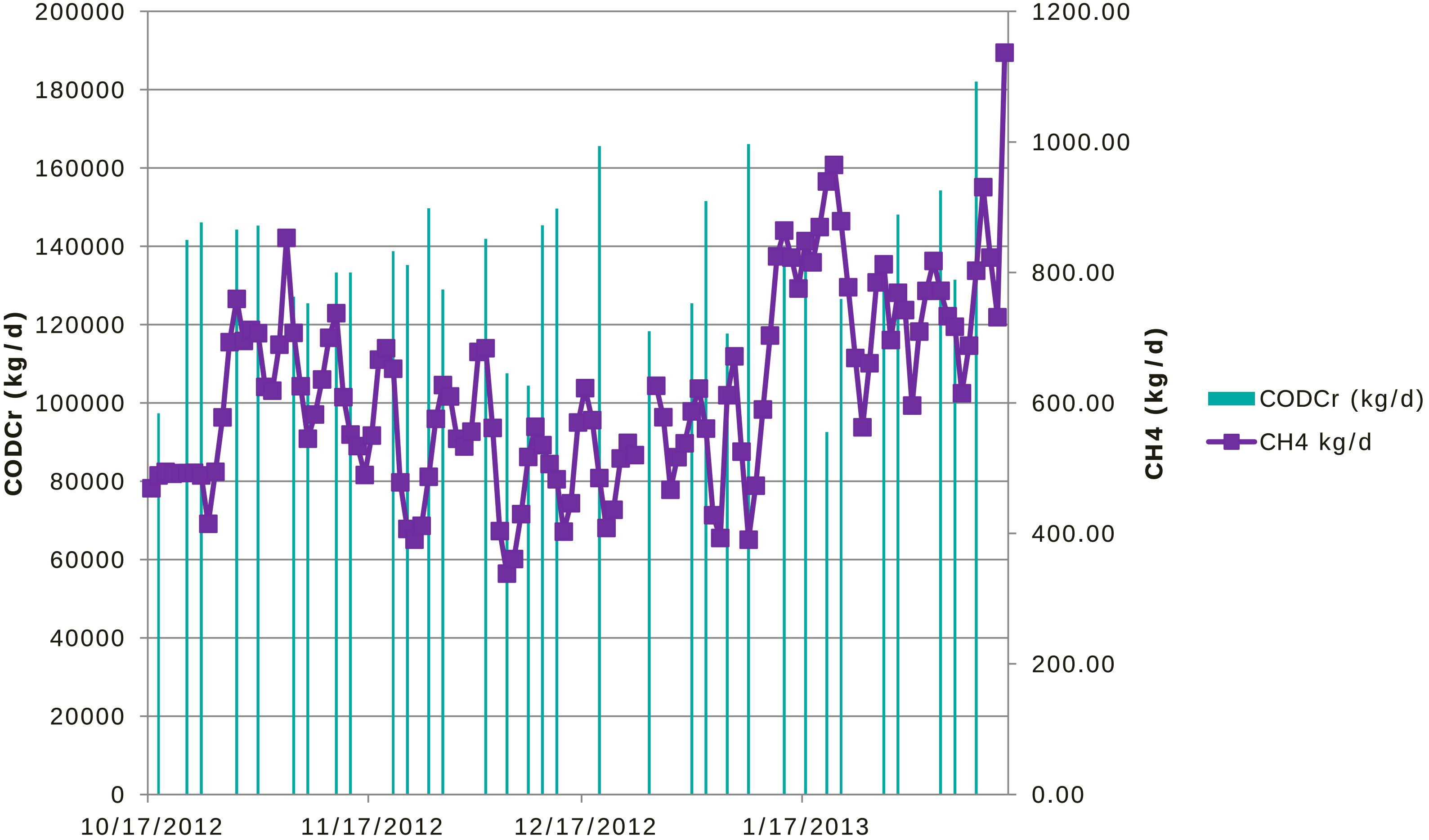
Biological post-filtration emissions



Daily variation in CH4 emissions



Daily COD load vs. daily CH4 emission



Preliminary results

Preliminary results from Viikinmäki WWTP 780 000 PE

CH4 t / a	CH4 kg / d	g CH4 / m3 wastewater	kg CH4 / PE / a	g CH4 / kg $COD_{influent}$
220	600 (513-768)	2,3	0,28	32

Results from Kralingseveer WWTP 360 000 PE

(Daelman et al, 2013), (Daelman et al, 2012),

CH4 t / a	CH4 kg / d	g CH4 / m3 wastewater	kg CH4 / PE / a	g CH4 / kg $COD_{influent}$
107	302 (211-429)	3,3	0,39	11

Daelman M.R.J., van Voorthuizen E.M., van Dongen L.G.J.M, Volcke E.I.P., van Loosdrecht M.C.M., (2013) Methane and nitrous oxide emissions from municipal wastewater treatment – results from long term study, Water Sci Technol., in press

Daelman M.R.J., van Voorthuizen E.M., van Dongen L.G.J.M, Volcke E.I.P., van Loosdrecht M.C.M., (2012) Methane emission during municipal wastewater treatment, Water Research

Future steps

- Full year data will be analysed after August 2013
- Simplified emission model will be calibrated based on one year data
  - Model is used by 12 Finnish WWTP for E-PRTR reporting
- Year 2013 Air emissions will be reported based on analysed data
- HSY Research work target will be in N2O emissions, but methane and CO2 emissions are easy to add for research schemas
  - Fractions of the methane sources at the plant – sources and sinks
  - Possibilities to decrease methane emissions

HSY

HSY

Kiitos! – Thank You!