

Calibration and Validation of Real time Calculation of the N₂O emission from Activated Sludge Tanks

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Overview

- Measuring Offgas flow
- Measuring Nitrous Oxide in Offgas
- Measuring Nitrous Oxide in activated sludge
- Real Time Calculations (Software sensors)
- Compare Measured and Calculated
- Conclusions





Equipment for Offgas measurements











Calibration of offgas flow

Offgas Flow Calibration





Nitrous Oxide Measurement





Nitrous Oxide Instrument Set-up



- Keep the Flow rate (2G) at 60 L/hr.
- Cal gas = N2O gas at maximum (span) concentration in N2 gas.
- Zero gas = pure N2 gas.



Nitrous Oxide Instrument Calibration and Linearity





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Offgas measurements/calculations

 $N_2O-N [mg/m^3] = N_2O [ppm] * (N_2O_{Mw} / 24.45) * N_{2,Mw} / N_2O_{Mw}$

→ $N_2O-N [mg/m^3] = 1.145 * N_2O [ppm]$





N2O(liq) Sensor, Flow Meter and Hood Locations



- Flow direction
 - $N_2O(liq)$ sensors
 - Flow Meters
 - Hood







N₂O(liq) Sensor and Flow Meter



Thermal Gas Mass Flow Meters in Aeration Manifold



Aerated area – diffusor area



Distance Diffusor to Bottom: 0.3 m

Avg. Distance Diffusor to Surface: 5.125 m

Area of Diffusor cluster: 45 m²

Number of Diffusor Clusters: 6

Observed Aerated Area at Surface per Diffusor Cluster: Approx. 65 m² (\rightarrow Total = 390 m²)

Total Area per Tank: 960 m²





Calculations from N_2O_{liq} to N_2O Emission





Calculation of $k_L a$ for $N_2 O$

In the aerated reactor the size of the total aeration field (m^2) and the total air flow Q_A (m^3s^{-1}) for the aerated reactor is known. The superficial gas velocity of the aerated reactor is calculated by dividing the total air flow with the aeration field size:

$$v_g \cong \frac{Q_A}{Aeration \ field \ size}$$

From the superficial gas velocity of the aerated reactor the N₂O mass transfer coefficient $k_{L}a_{N2O}$ can be calculated using the empirical formula 1.2 based on laboratory experiments at 20°C in mixed WWTP liquorⁱ:

$$k_L a_{N_2 0 \ 20 \ C} = \left\{ \frac{D_R}{D_L} \right\}^{-0.49} \times 34500 \times (v_g)^{0.86}$$

 v_g : Superficial gas velocity of the reactor (m³m⁻²s⁻¹) D_L : Depth of the laboratory reactor (0.815 m) D_R : Depth over the diffuser of the reactor (m) $k_L a_{N20}$: N₂O mass transfer coefficient (d⁻¹)

The $k_L a_{N2O}$ calculated above is temperature corrected to the process temperature $T_{Process}$:

$$k_L a_{N_2 O T_{Process}} = k_L a_{N_2 O 20 \mathcal{C}} \times (1.024)^{(T_{Process} - 20 \mathcal{C})}$$

ⁱ Foley, J., de Haas, D., Yuan, Z.; Lant, P. (2010) Nitrous oxide generation in full-scale biological nutrient removal wastewater treatment, plants. Water Res. 44, 831-844.



Calculation of Henry's Const.

The dimensionless Henrys constant $H_{N_2O,T_{Process}}$ is dependent on the process temperature

$$H_{N_2O,T_{Process}} = \frac{1}{\mathbf{k}_{\mathrm{H}} \cdot \mathbf{R} \cdot (\mathbf{T}_{\mathrm{Process}} + 273.15) \cdot 10^3 \frac{\mathrm{L}}{\mathrm{m}^3}}$$

$$\mathbf{k}_{\mathrm{H}} = \mathbf{k}_{\mathrm{H}}^{\theta} \times \ \mathrm{e}^{\left(\frac{-\Delta \mathrm{solnH}}{R} \cdot \left(\frac{1}{\mathrm{T}_{\mathrm{Process}^{+} 273.15}} - \frac{1}{\mathrm{T}^{\theta} + 273.15}\right)\right)}$$

 k_{H}^{θ} : Henrys constant at the std. temp. (mol·L⁻¹·bar⁻¹) $T_{Process}$: Mixed liquor temperature (°C) T^{θ} : Standard temperature = 25°C -ΔsolnH/R: The enthalpy of the solution (K)

From literature the N₂O mean values for k_{H}^{θ} , - Δ solnH/R and supporting constant numbers are given in the below table:

k _H ^θ (mol·L ⁻¹ ·bar ⁻¹)	$\frac{-\Delta \text{solnH}}{R}$ (K)	$C_{N_2O,air}$ (g-N/m ³)	R (m³·bar·mol ^{−1} ·K ^{−1})	$k_L a_{N_2 0 T_{Process}}^{Non-aerated}(d^{-1})$
0.0247	2675	0.0003	8.314 x 10 ⁻⁵	2 – 4 *

*) A typical figure of 2 in an anoxic tank is reported by Siegrist and 'Gujer, 1994



Real Time Calculations

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🔽 — Luftflow T4 [m3/h] 🔽 — Luftflow T4, filt. [m3/h] 🔽 — KLa N2O v. 20 gr. C T4 [pr. d] 🔽 — KLa N2O T4 [pr. d] 🔽 — Temperatur T4 [C] 🔽 — Temperatur T4, filt. [C] 🔽 — Henry's konstant T4 [-]



Calculation of the Specific N₂O Emission

Aerated zones:
$$r_{N_2O,T_{Process}} = H_{N_2O,T_{Process}} \times S_{N_2O} \left[1 - e^{-\frac{k_L a_{N_2O}}{H_{N_2O}} \cdot \frac{V_R}{Q_A}} \right] \times \frac{Q_A}{V_R}$$

Non – aerated zones:
$$r_{N_20,T_{Process}} = k_L a_{N_20,T_{Process}}^{Non-aerated} \times \left[S_{N_20} - \frac{C_{N_20,air}}{H_{N_20,T_{Process}}} \right]$$

 $\mathbf{r}_{N_2O,T_{Process}}$: N₂O emission rate (g-N N2O m⁻³ d⁻¹) $\mathbf{H}_{N_2O,T_{Process}}$: Henrys constant (dimensionless) \mathbf{S}_{N2O} : N₂O concentration (g-N N2O m⁻³) Q_A: Total air flow through reactor per day (m³d⁻¹)
V_R: Volume of aerated part of reactor (m³)
k_La_{N20}: N₂O mass transfer coefficient (d⁻¹)

ⁱⁱ Schulthess, R. & Gujer W. (1996) Release of nitrous oxide (N2O) from denitrifying activated sludge: Verification and application of a mathematical model, Water Res. 30, 521-530.



N2O

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emission

Real Time Calculations





N2O Emissions compared





Conclusions



- Working with the Hood
 - Offgas flow difficult to measure
 - Offgas N2O concentration stable
- Comparing Emissions
 - Aerated area (and volume) difficult to estimate
 - Calculation over estimates at higher N2O (liq) concentrations
 - Calculated emission from non-aerated vol. here constitute 10-15 % of the total
- Further Work
 - Uncertanties of estimates for existing formula
 - Introducing correction terms or suggest new formula.



Thank you for your attention

