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IWA Webinar "Monitoring, Modelling and Mitigating Nitrous Oxide-Masterclass 2"
Post Webinar Report – 24/05/2022

Webinar available at: https://iwa-network.org/learn/process-emissions-masterclass-2/

Questions received from participants during registration:

#	Questions	Speaker	Answer
1	Would be interesting to know if the use of CFD for smart monitoring and sensor placement is already considered in the program.		There is some interesting CFD modelling being done on N2O and by some utilities/researchers – see page 232 of the book https://iwaponline.com/ebooks/book/844/Quantification-and-Modelling-of-Fugitive
2	Are deammonification processes (for treatment of ammonia-rich liquors) likely to result in elevated N2O emissions?	Vasilei a	Published literature and recent monitoring campaigns (e.g. Denmark) shows emissions from these processes to be substantially higher in sidestream applications on ammonia-rich liquors. The average EF based on review of data from full-scale nitritation and partial-nitritation reactors is equal to 4.3% of the influent N-load. One-stage granular anammox reactors have an average EF of 1.1% of the influent N-load. Emissions in lab and pilot-scale single-stage granular anammox reactors ranged from 0.1 to 12.19% of influent N-load. For more information, please refer to chapter 6.
3	How N2O emission from process like Nitrite Shunt is going to align with Net Zero		There is currently a lack of evidence for N2O emissions from mainstream nitritation/denitrification (aka nitrite shunt or short cut nitrogen removal) with evidence of unintentional mainstream processes causing significant emissions whilst some evidence that intentional bench testing offers lower emissions relative to conventional nitrogen removal. Watch this space!
4	Can N2O emissions be completed eliminated from waste water processes through the use of new	Vasilei a	MABR have shown lower emissions ~1 order of magnitude compared to conventional processes (i.e. https://doi.org/10.1016/j.watres.2017.07.058 which considers MABR and biofilm processes) though as noted in the article, the comparison of MABR with conventional biofilm was not with the same DO concentrations and ideally the two technologies

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	innovative technology?		should be compared with the same DO concentration at the bottom and top of the respective biofilms. We also refer to trial work in Denmark comparing conventional activated sludge and MABR (https://www2.mst.dk/Udgiv/publications/2020/08/978-87-7038-216-8.pdf) - but operation and control of processes is very significant to minimize emissions and whether comparisons are based upon 'optimised' plants (for N2O) is important to consider.
5	Is there any data regarding nitrous oxide emissions from combined partial nitritation/anammox reactors treating side-stream?	Vasilei a	One-stage granular anammox reactors have an average EF of 1.1% of the influent N-load. For more information, please refer to chapter 6. The following link has also useful information on the control of 1-stage granular partial nitritation/anammox reactors: https://doi.org/10.1016/j.scitotenv.2021.149092.
6	Are there any WWTP processes worse than others for N2O?	Vasilei a	For a comparison of different groups of processes, please refer to Chapter 6.

Questions received from participants via the Q&A:

#	Questions	Speaker	Answer
1	What frequency of off gas testing is appropriate? Daily? Hourly?		live answered
2	Is there a possibility that there is a biological oxidation pathway from N2O to NO3?		This is not a pathway identified by current research. Refer to Chapter 2, page 14 for currently understood pathways.
3	is it possible that all three major pathways coexist, especially HDN-N2O in a lump of water flow in aeration tank? thanks		yes based on hydrodynamic conditions and level of mixing there can be localized pockets in a reactor with different environmental conditions leading to different pathways
4	pH is a strong regulator of N2O emissions at the microbial level, can pH be modified to ensure the denitrification pathway is		pH between 7 and 8 were shown to be favourable for complete denitrification. pH below 7 seems to increase N2O accumulation. Reference papers are mentioned in the book.

Commented [LA1]: Liu please review.

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	completed and reduce N2O emissions?		
5	how reliable are measurements in small hood across a reactor? Have you found larger or multiple hoods are more accurate or see results from covered reactors?		Yes, multiple hood will give you more representative results. As Ben presented, there are strong spatial variations of N2O emissions.
6	Have you looked at the variability of N20 with different set ups of the ASP? e.g. optimised for low ammonia reduction or for Bio-P removal? Am interested in if a bio-P optimised process will increase or decrease gas production?		Hi Laura, we have been measuring in bio-P-tanks as well and we did not observed any N2O accumulation. But this can be site specific depending also on wastewater composition. I hope this help
7	Hi, As a practitioner looking to start monitoring N2O I found Chapter 5 of the book very useful- thank you. My question is, if you happen to have covered tanks with offgas directed through a pipe, gas monitoring is obviously a good way to monitor plant-wide emission- the book didn't have much guidance on this scenario; is this because it is simple? Any advice on monitoring successfully/accurately in this scenario?		Hello Emily - I would recommend reading up on the work at Viikinmäki in Finland https://pubmed.ncbi.nlm.nih.gov/27218458/
8	which method is most widely used?		live answered
9	What are the best tools for understanding which elements of the site's operation or external conditions have biggest impact on N2O?	Vasileia	Of course there are the mechanistic model Haoran presented and some are available in commercial process modelling software but as mentioned they are not straightforward and can be challenging to calibrate. You have to

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			know what you are doing. Alternatively, we have the N2ORisk DSS which uses Knowledge-based AI, machine learning and the data available to understand what is contributing to the emissions, what can be done to reduce, and what are the emissions. V: In the book chapter 10, we also report how data-driven techniques outliers detection, clustering, classification and regression were able to i) detect and isolate re-occurring process disturbances ii) provide insights in the long-term dynamic behaviour of N2O emissions, iii) link the behaviour of operational variables with specific ranges of N2O emissions, and iv) predict N2O emission fluxes and risks for elevated N2O emissions
10	due to temporal and spatial variation of N2O, how do you quantify total N2O emissions from grab sampling?		Hi Xiangjun, grab sampling is not recommended to quantify N2O emissions for exactly the reasons you say and would not likely provide a useful estimate of emissions. The book gives the background as to why this is in much more detail!
11	What factors were determined through PCA to be important for predicting N2O emissions?		Process control and automation (PCA?). We currently lack the ability to predict N2O emissions with accuracy and typical process control parameters do not provide surrogate information by which we can characterise N2O emissions. Aeration control, sludge age control, anoxic treatment cycling and carbon dosing have all been applied in academic and industry studies to date to mitigate emissions.
12	Hi, is it necessary to develop a two-phase model for predicting N2O emission, since the liquid concentration of N2O is		live answered

Commented [LA2]: Liu – please correct this as required!

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	normally monitored in full-plant industry?		
13	Hi, what about the COD fractionation on the N2O production by heterotrophic bacteria?		
14	Is there molecular work (qPCR, sequencing, metagenomics) data that can provide information on how to optimise the microbial communities present in the tanks to reduce N2O emissions?		Yes there is much ongoing work in this area
15	Reducing the AOR means bigger tanks. What about the operating costs? Do we have a cost-benefit assessment?		Hi Vincenzo - this is a great question, and we need to use tools like life cycle analysis to understand these cost benefits and carbon benefits. There is a very interesting LCA by Maria Farago, Mikkel Andersen and others here which doesn't cover the tankage question and tradeoff of cost and carbon (and wider LCA impacts) but does show what we need to be thinking about in my view - https://orbit.dtu.dk/en/publications/from-wastewater-treatment-to-water-resource-recovery-environmenta
16	Can we expect all N2O dissolved to be off gassed?		Hi Gustavo. As Liu has just noted in her response, in aerated zones is typically where the stripping occurs rather than anoxic zones where dissolved N2O will stay and could be removed or stripped once it gets to an aerobic zone - in anoxic is not typically stripped (unless very turbulent).
17	Was there any observation made on treated effluent quality and plant size if DO is reduced to 0.5 mg/L to reduce N2O emission?		Ben's presentation on the SBR mitigation study will answer this.
18	Is the dominant N2O production pathway specific at specific plants and we	Vasileia	Yes, we can determine the major pathway of N2O emissions. We can

Commented [LA3]: Liu – I guess this refers to understanding the links with carbon fractions or lack of rbCOD and N2O production – and there are studies on this though I am not sure whether they have focused in on COD fractionation?

Commented [LA4]: Liu could you comment further?

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	can develop specific minimizing strategy based on that? Or we have to account for all possible pathways at any situation?		then accordingly develop mitigation strategies. V: However, that emissions generation is dynamic (strong temporal variation) the triggering conditions (and thus the dominant pathways) can variate during the year.
19	Was there a seasonal variation in emissions?		Yes – seasonal variation is often observed in emissions at some sites; though at others it is not. Work remains to be done as to whether this is due to changing microbial communities, changing operational conditions or temperature differences.
20	To better quantify TOTAL N2O emissions for an open tank, is open-air spectrometer (like hyperspectral camera) method a better one than grab sampling method like hood or underwater sensor method? considering highly temporal and spatial variation of N2O. thanks		hood method or underwater sensor method are online methods, not grab sampling.
21	Did you also have results for the standard key indicators for operators such as SRT, SVI and required effluent quality for TSS and TN?		yes we do. happy to share the paper with these details
22	Does the Bolivar WWTP have total nitrogen treatment objective?		yes, a total N target <10mg/L
23	Is the plant equipped with Ammonia Based DO control?		DO control only. next steps we are looking to incorporate ammonia-based aeration control
24	Is it the low DO-setpoint that leads to low emissions or the lower flow of air that will reduce the stripping effect?		More resulted from less generation.
25	How does reducing the DO concentrations impact the nitrificaiton process? I am		live answered

Commented [LA5]: Liu – could you please review.

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	assuming the works needs to meet a final effluent ammonia consent.		
26	Could you talk us through how you changed DO (inc/dec) to reduce N20? would this be in one of your papers?		Hi James - the paper is here and does indeed discuss this. https://www.sciencedirect.com/science/article/abs/pii/S0043135420307338
27	Thanks Ben. Do you think you'd be able to claim emissions reductions? Or are we a little way off that in Aus.		good question. i think this is a little way off. at this stage we can only claim these reductions when reporting our emissions
28	Hi, is it necessary to develop a two-phase model for predicting N2O emission, since the liquid concentration of N2O is normally monitored in full-plant industry?		Answered live
29	What kind of model did QU develop for Bolivar? did this use a commercial simulation software or was it a bespoke model?		It was not carried out in commercial simulation software. We used AQUASIM.
30	in my question above I was referring to Strategy 2 where the DO concentration was reduced to 0.5 mg/l.		live answered
31	Any rules of thumb on NH4 and DO concentration in the reactor to minimize N2O? NH4 and DO are tricky.		Lower NH4+ should give you lower N2O emissions.
32	Was/is there an operational real time control system in the duration of your monitoring? Did you explore the effects of this in any detail?		I believe only DO control. we are hoping to move towards ammonium-based aeration control in the future
33	given how high you DO was - did you have a problem with your control system to		a good question, am unsure, but we did encounter problems with VSD drives tripping under high aeration/DO

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	start with? Did you look at using air flow rather than DO as an input control mechanism?		set points, which was another reason for us to modify aeration
34	How did the biology respond to operating at a continuous lower DO level?		live answered
35	Is even aeration a universal recommendation then to reduce N2O?		each case is different and has a different combination of factors. also, there can be even aeration of bad aeration since DO has such a big influence. The key is to have a framework to look at any combination of operating conditions and identify the best control action to reduce N2O
36	How was the more even supply of oxygen controlled?		through the adjustment of multiple DO setpoints that can be modified during the aeration phases
37	From your work, what would be your 'go to' strategies to minimise N2O emissions if you couldn't do all the monitoring work		live answered
38	are there technology for Nitrogen Capturing similar to Carbon Capturing?		
39	Why does emission go up during part of year?		live answered
40	Are there any studies monitoring and comparing N2O emission between mainstream MBR and MBBR? I know there is at least one for MBR lab scale, but have not seen any for MBBR (only MBBR sidestream, AnitaMOX)?	Vasileia	yes we do. happy to share the paper with these details This is an interesting review on N2O emissions in biofilm processes: https://doi.org/10.1007/s00253-018-9332-7 Table 1 in the following resource, provides a nice overview of the existing studies: https://doi.org/10.1016/j.scitotenv.2021.151394.
41	If you have seasonal variation in emissions, are there seasonal responses?	Vasileia	There are 'rule of thump' strategies to reduce the risk of N2O emissions described in the book but for a process

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			resilient to emissions during the whole year (N2O minimization) the response strategies should account for i) the temporal variability of operational and environmental conditions that result into changes of the N2O triggering mechanisms, ii) system disturbances that can influence short-term (i.e. 1 day) or even for longer periods (i.e. one week) both the system performance and the N2O generation and ii) the combined effect of the operational variables on N2O emissions.