Inhibitor	Inhibitory dose Ammonia oxidation	Inhibitory dose Nitrite oxidation	Type	Mechanism	System tested in	Reversible/Lower effect	Source
1,1,1,2-Tetrachloroethane (CCl3CH2Cl)	1.2 mM		Chlorinated hydrocarbon (pesticide)	Suicide substrate	*N. europaea* ATCC 19718 @ 30C	Irreversible	Keener & Arp 1993
DDD [1,1-dichloro-2,2-bis (p-chlorophenyl) ethane]		5 ug/ml	organochlorine (pesticide)		*Nitrobacter agilis*		Winely & San Clemente 1970
Lindane (gamma isomer of 1,2,3,4,5,6-hexachlorocyclohexane)	10 ug/ml		Pesticide		*Nitrobacter agilis*		Winely & San Clemente 1970
Allylthiourea (ATU)	5 mg/L		Chemical compound	suppress oxygen uptake			Hu et al., 2003
Allylthiourea (ATU)	0.12 mg/L		Chemical compound	suppress oxygen uptake			Bejarano-Ortiz et al., 2015
Allylthiourea (ATU)	20 mg/L		Chemical compound	suppress oxygen uptake			Fox et al., 2006
Allylthiourea (ATU)	0.018 mg/L		Chemical compound	suppress oxygen uptake			Cui et al., 2005
Aluminum (Al^{3+})	12.5 mg	12.5 mg	Metal		Unitank process		Zhou et al., 2012
Ammonia (NH_3)		6.0 mg/L	Inorganic compound		*Nitrobacter*		Vadivelu et al., 2007
Ammonia (NH_3)		30-50 mg/L	Inorganic compound		*Nitrobacter* Airlift bioreactor , pH 7.5, 26-28C, DO3-5mg/	Reversible when NH_3 declined	Kim et al., 2008
Ammonia (NH_3)		0.04-0.08 mg/L	Inorganic compound		*Nitrospira* Airlift bioreactor , pH 7.5, 26-28C, DO3-5mg/	Reversible when NH_3 declined	Kim et al., 2008
Ammonia (NH_3)	290-1600 uM	46 uM	Inorganic compound				Park & Bae 2009
Ammonia (NH_3)		0.7 mg/L	Inorganic compound				Kim et al., 2006
Aniline	< 1 mg/L		organic compound		*Nitrosomonas* sp.		Hockenbury & Grady 1978
Azide		0.03 mg/L	Inorganic compound	react with nitrite			Bejarano-Ortiz et al., 2015
Benzethonium chloride (QAC)		0.023 g/g MLSS	Disinfectant		Activated sludge		Cui et al., 2020
Cadmium (Cd^{2+})	1-10 mg/L		Metal	displaces Zn(II) and Fe(II) from metalloproteins	lab scale continuous-flow enriched nitrificaiton system	reversable when cadmium loading stopped	Mertoglu et al. 2008

Inhibitor	Inhibitory dose Ammonia oxidation	Inhibitory dose Nitrite oxidation	Type	Mechanism	System tested in	Reversible/Lower effect	Source
Cadmium (Cd^{2+})		>>1.0 mM	Metal	displaces Zn(II) and Fe(II) from metalloproteins	activated sludge A2O and SBR systems, pH 7.2, DO 2.0 mg/L		You et al., 2008
Cadmium (Cd^{2+})	1 mM		Metal	displaces Zn(II) and Fe(II) from metalloproteins		Addition of complexing agents	Hu et al., 2002
Cadmium (Cd^{2+})	0.03-1 mg/L		Metal	displaces Zn(II) and Fe(II) from metalloproteins			Kapoor et al., 2015
Cadmium (Cd^{2+})	0.01-0.2 mM		Metal	displaces Zn(II) and Fe(II) from metalloproteins	*N. europaea* batch cultures exponential or stationary phase	reversible with 5 mM NAC (N-acetyl-L-cysteine)	Chandran & Love 2008
Carbon disulfide (CS2)	0.5 ug/ml		Organosulfurr compound	chelators of metal ions	*N. europaea*	partially reversible by washing CS2-treated cells in buffer containing NH4+	Hyman et al., 1990
Chlordane (1,2,3,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene)		5 ug/ml	Chlorinated hydrocarbon (pesticide)		*Nitrobacter agilis*		Winely & San Clemente 1970
Chromium [Cr(III)]	300 mg/L		Metal	substitution-inert complexes with a number of cell components	SBR, 24h HRT. Exposure for 12h		Kapoor et al., 2016
Chromium [Cr(VI)]	30 mg/L		Metal	substitution-inert complexes with a number of cell components	SBR, 24h HRT. Exposure for 12h		Kapoor et al., 2016
CIPC [isopropyl N-(3-chlorophenyl) carbamate]		10 – 110 ug/ml	carbamate ester (pesticide)		*Nitrobacter agilis*		Winely & San Clemente 1970
Cobalt (Co^{2+})		200 nM	Metal		*N. winogradskyi* NBRC 14297 grown in mineral medium w/ trace elements, 28C, 100 rpm, dark	Reversible with applied Ca^{2+}, Mg^{2+}, or L-histidine	Metzner et al., 2019

Inhibitor	Inhibitory dose Ammonia oxidation	Inhibitory dose Nitrite oxidation	Type	Mechanism	System tested in	Reversible/Lower effect	Source
Copper (Cu^{2+})	8 uM $CuCl_2$		Metal	causing losses of intracellular K^+, loss of membrane integrity	*N. europaea* mid- to late-exponential phase, pH 7.8, 30C		Park & Ely 2008
Copper (Cu^{2+})	5 mg/L		Metal		*Nitrosomonas* sp. in CSTR		Lee et al., 1997
Copper (Cu^{2+})	0.28-0.61 mg/L		Metal		MBBR during long term operation		Schopf et al., 2018
Copper (Cu^{2+})	25 mg/L		Metal	disruption of enzyme structure in the cell	continuous flow lab-scale activated sludge reactors , 25C, HRT 12h		Lee et al., 2009
Copper (Cu^{2+})	200 mg/kg		Metal		grassland or cultivated land soil from china		Li et al., 2009
Copper (Cu^{2+})	0.5 mg/L		Metal				Aslan & Sozudogru 2017
Copper as nano-Cu	19.6 mg/L in biofilms, 49.0 mg/L in planktonic cells		Metal		planktonic and biofilm-gown *Nitrosomonas europaea*		Reyes et al., 2014
Copper as nano-CuO	50 mg/L Cu(II) ion and 399 mg Cu/L nano-CuO	200 mg Cu/L of Cu(II) ion	Metal	Cell membrane disruption			Liu & Wang 2012
Cyanide	0.34 mg/L		chemical compound		lab-scale SCTR steel-processing waste, HRT 10d, 28C, pH 7.5, DO 2 mg/L	Irreversible, but constantly exposed systems can develop tolerance	Do et al., 2008
Dithiol (toluene-3,4-dithiol)	1 mM		organic sulfur compound		*N. europaea* (Schmidt strain) in 0.05M phosphate, pH 7.5		Hooper & Terry 1973
Dodecylamine	< 1mg/L		fatty amine (disinfectant)		*Nitrosomonas* sp.		Hockenbury & Grady 1977
DTPA	3.1 mM		Chelant		Nitrifying biomass in CSTR, SRT 20d, HRT 1d, pH 7.4		Hu et al., 2003
EDA	0.6 mM	cytoplasmic membrane rupture	Chelant		Nitrifying biomass in CSTR, SRT 20d, HRT 1d, pH 7.4		Hu et al., 2003

Inhibitor	Inhibitory dose Ammonia oxidation	Inhibitory dose Nitrite oxidation	Type	Mechanism	System tested in	Reversible/Lower effect	Source
EDTA	2.4 mM		Chelant		Nitrifying biomass in CSTR, SRT 20d, HRT 1d, pH 7.4		Hu et al., 2003
Eptam (S-ethyl-di-N, N-propyl-thiocarbamate)		275 ug	Herbicide		*Nitrobacter agilis*		Winely & San Clemente 1970
Heptachlor (1,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-4,7-endo-methanoindene)		10 ug/ml	Herbicide		*Nitrobacter agilis*		Winely & San Clemente 1970
Hydrocyanic acid (HCN)	0.1 to 0.2 mg/L		chemical compound				Hu et al., 2003
Lead (Pb^{2+})	1000 mg/L		Metal				Kapoor et al., 2015
Light 400-430nm	400-430nm		Environment		*N. europaea* (Schmidt strain) and cell-free extracts	Less sensitive without oxygen, or with high ammonia or hydroxylamine	Hooper & Terry 1974
Magnesium as nano-MgO	>240 mg Mg/L of nano-MgO		Metal	hydrolyze in water to generate hydroxide and increase pH to max pH 10			Liu & Wang 2012
MAST (2-amino-4-methyl-6-trichloromethyl-1,3,5-triazine)	0.5 to 2.0 uM		organic compound (herbicide)	inhibit formation of hydroxylamine	*Nitrosomonas europaea* ATCC 25978		Matsuba et al., 2003
Mercury (Hg^{2+})	6 uM		Metal			Reversible with increased time	Park & Ely 2008
Nickel (Ni^{2+})	50 mg/L		Metal		*Nitrosomonas* sp. in CSTR		Lee et al., 1997
Nickel (Ni^{2+})	1.5 mM		Metal		continuously operated lab-scale nitrifying bioreactor	Reversible with added metal complexing agent (e.g. EDTA) at appropriate concentration	Hu et al., 2001
Nickel (Ni^{2+})	1.0 mM		Metal		activated sludge A2O and SBR systems, pH 7.2, DO 2.0 mg/L	somewhat reversible with strong chelant	You et al., 2008
Nickel (Ni^{2+})	1 mM		Metal			Completely reversible with 1mM EDTA	Hu et al., 2002

Inhibitor	Inhibitory dose Ammonia oxidation	Inhibitory dose Nitrite oxidation	Type	Mechanism	System tested in	Reversible/Lower effect	Source
Nickel (Ni^{2+})	0.03-3 mg/L		Metal				Kapoor et al., 2015
Nickel (Ni^{2+})	0.2-0.4 mg/L		Metal				Aslan & Sozudogru 2017
Nitrapyrin [2-chloro-6-(trichloromethyl)pyridine]	0.5 to 2.0 uM		organic compound (fertilizer nitrification inhibitor)	inhibit formation of hydroxylamine	*Nitrosomonas europaea* ATCC 25978		Matsuba et al., 2003
Nitrous acid	12 uM	1.7-6.8 uM	Acid				Park & Bae 2009
Nitrous acid	0.40-0.63 mg/L	0.02 mg/L	Acid		*Nitrosomonas* , *Nitrobacter*		Vadivelu et al., 2007
n-methylaniline	< 1 mg/L		organic compound		*Nitrosomonas* sp.		Hockenbury & Grady 1977
Peracetic acid (PAA)	1/0.14 to 3/0.42 mg/L PAA/H2O2		organic compound (disinfectant)	enzyme inhibition			Chen et al., 2022
Phenol	60 uM		organic solvent		*N. europaea* biofilm & suspension		Lauchnor & Semprini 2013
Phenol	20 uM		organic solvent	inhibiting AMO oxidation of NH3	*N. europaea* in batch reactors, 30C, 150rpm, pH 7.8		Lauchnor & Semprini 2013
Phenol		1.10 mg/L	organic solvent				Cui et al., 2005
Phenol	5 uM		organic solvent		*Nitrosomonas europaea*		Radniecki et al., 2009
Potassium chlorate ($KClO_3$)		5 mM	chemical compound (Pesticide)		SBR with aerobic granules, pH 7.8-8.2		Xu et al., 2011
Quaternary Ammonium Compunds (QACs)	2 mg/L		Disinfectant	destabilize membranes		Microbial acclimation can reduced inhibition	Conidi et al., 2019
Silver (Ag^{+})	0.05-0.50 mg/L		Metal	damage membrane integrity of cells	nitrifying sludge		Giao et al., 2017
silver as nano-Ag	1-100 mg/L		Metal	damage membrane integrity of cells	nitrifying sludge		Giao et al., 2017

Inhibitor	Inhibitory dose Ammonia oxidation	Inhibitory dose Nitrite oxidation	Type	Mechanism	System tested in	Reversible/Lower effect	Source
Sodium sulfide	10^{-4} M		chemical compound	scavage oxygen	*N. europaea* (Schmidt strain) in 0.05M phosphate, pH 7.5		Hooper & Terry 1973
sulfide	> 0.5 mg/L S		chemical compound	inactivate the AMO enzyme	Nitrifying biomass in continuous-flow 10-1 reactor covered with opaque hood, HRT 1 day, SRT of 25 days, pH 7.2, VSS 2,000 mg/L	recovered after sulfide addition stopped	Sears et al., 2004
sulfide	3.1-112.0 mg HO- -S/L		chemical compound				Ortiz et al., 2013
sulfide	> 5 mg S/L		chemical compound		CSTR under steady-state operation, 30C, pH 7.0, 200 rpm, HRT 3.5 d, DO, 4.0 mg/L		Bejarano-Ortiz et al., 2015
Thioacetamide		0.027 mg/L	organosulfur compound				Cui et al., 2005
Thiourea		0.01 mg/L	organosulfur compound				Cui et al., 2005
Thiourea	2% by weight of nitrogen		organosulfur compound				Hauck 1980
Toluene	20 uM		aeromatic hydrocarbon		*Nitrosomonas europaea*		Radniecki et al., 2008
Zinc (Zn^{2+})	1.5 mM		Metal		continuously operated lab-scale nitrifying bioreactor	Reduce inhibition by adding metal complexing agent (e.g. EDTA) at appropriate concentration	Hu et al., 2001
Zinc (Zn^{2+})	50 mg/L	10 mg/L	Metal				Fox et al., 2006
Zinc (Zn^{2+})	0.1-10 mg/L		Metal				Kapoor et al., 2015
Zinc (Zn^{2+})	0.04 to 3.28 mg/L		Metal	binding to the active site of ammonia monooxygenase (AMO)	CSTR, 300mg NH4+-N/L from local steel-processing industry, 10d HRT, 28C, pH 7.5, Do 2.0 mg/L	keep AOB population above a certain level	Lee et al., 2011
Zinc (Zn^{2+})	3.4uM		Metal				Park & Ely 2008

Inhibitor	Inhibitory dose Ammonia oxidation	Inhibitory dose Nitrite oxidation	Type	Mechanism	System tested in	Reversible/Lower effect	Source
Zinc (Zn^{2+})	30 uM		Metal	inhibits AMO enzyme	*N. europaea* continuously grown in a bioreactor	Mg2+ and Ca2+ provided some protection against inhibition	Radniecki et al., 2009
Zinc as $ZnCl_2$	10 uM		Metal	inhibits the electron transport chain	*N. mobilis*		Radniecki & Ely 2008

References:

Aslan, S., & Sozudogru, O. (2017). Individual and combined effects of nickel and copper on nitrification organisms. *Ecological Engineering* 99:126-133.

Bejarano-Ortiz, D.I., Huerta-Ochoa, S., Thalasso, F., Cuervo-Lopez, F.M., & Texier, A.C. (2015). Kinetic Constants for Biological Ammonium and Nitrite Oxidation Processes Under Sulfide Inhibtion. *Applied Biochemistry and Biotechnology* . Doi:10.1007/s12010-015-1844-3.

Bejarano-Ortiz, D.I., Huerta-Ochoa, S., Thalasso, F., Cuervo-Lopez, F.M., & Texier, A.C. (2015). Kinetic Constants for Biological Ammonium and Nitrite Oxidation Processes Under Sulfide Inhibtion. *Applied Biochemistry and Biotechnology* . Doi:10.1007/s12010-015-1844-3.

Chandran, K. & Love, N.G. (2008). Physiological State, Growth Mode, and Oxidative Stress Play a Role in Cd(II)-Mediated Inhibition of Nitrosomonas europaea 19718. *Applied and Environmental Microbiology* 74(8):2447-2453.

Chen, J., Song, T., Long, S., Zhu, K.J., & Pavlostathis, S.G. (2022). Effect of peracetic acid solution on a nitrifying culture: kinetics, inhibition, cellular and transcriptional responses. *Water Research* 219:118543.

Conidi, D., Andalib, M. Andres, C., Bye, C., Umble, A., & Dold, P. (2019). Quaternary Ammonium Compound Inhibition of Biological Nutrient Removal Activated Sludge: The Significance of Good Modeling Practice on Process Design. *WEFTEC* 2019 Proceedings *(2018 Water Environmental Federation: 2484-2496)* .

Cui, R., Chung, W., & Jahng, D. (2005). A rapid and simple respirometric biosensor with immobilized cells of Nitrosomonas europaea for detecting inhibitors of ammonia oxidation. *Biosensors and Bioelectronics* 20(9):1788-1795.

Cui, Y., Gao, J., Zhang, D., Zhao, Y. & Wang, Y. (2020). Rapid start-up of partial nitrification process using benzethonium chloride-a novel nitrite oxidation inhibitor. *Bioresource Technology* 315:123860.

Do, H., Lim, J., Shin, S.G., Wu, Y., Ahn, J., & Hwang, S. (2008). Simultaneous effect of temperature, cyanide and ammonia-oxidizing bacteria concentrations on ammonia oxidation. *J Ind Microbiol Biotechnol* 35:1331-1338.

Fox, J.T., Brandriff, C.J., & Bott, C.B. (2006). Assessing the Potential for Nitrification Inhibition at Wastewater Treatment Facilities as a Result of Zinc Orthophosphate addition to potable water distribution systems. *WEFTEC .06 (2006 Water Environment Foundation)* 6593-6622.

Giao, N.T., Limpiyakorn, T., Kunapongkiti, P., Thuptimdang, P., & Siripattanakul-Ratpukdi, S. (2017). Influence of silver nanoparticles and liberated silver ions on nitrifying sludge: ammonia oxidation inhibitory kinetics and mechanism. *Environmental Science and Pollution Research* 24:9229-9240.

Hauck R.D. (1980). Mode of Action of Nitrification Inhibitors. *Nitrification Inhibitors - Potentials and Limitations* . https://doi.org/10.2134/asaspecpub38.c2

Hockenbury, M.R. & Grady, C.P.L. (1977). Inhibition of Nitrification-Effects of Selected Organic Compounds. *Water Pollution Control Federation 49(5):768-777*

Hooper, A.B. & Terry, K.R. (1973). Specific Inhibitors of Ammonia Oxidation in Nitrosomonas. *J of Bacteriology* 115(2):480-485.

Hooper, A.B. & Terry, K.R. (1974). Photoinactivation of Ammonia Oxidation in Nitrosomonas. *J of Bacteriology* 119(3):899-906.

Hu, Z., Chandran, K., & Smets, B.F. (2001). Evaluation of Nitrification Inhibition by Heavy Metals Nickel and Zinc. *Proceedings of the Water Environment Federation 2001(11):581-595.*

Hu, Z., Chandran, K., Grasso, D., & Smets, B. (2002). Effect of Nickel and Cadmium Speciation on Nitrification Inhibition. *Environmental Science and Technology* 36:3074-3078.

References Cont:

Hu, Z., Chandran, K., Grasso, D., & Smets, B.F. (2003). Nitrification Inhibition by Ethylenediamine-Based Chelating Agents. *Environmental Engineering Science* 20(3):219-228.

Hyman, M.R., Kim, C.Y., Arp, D.J. (1990). Inhibition of Ammonia Monooxygenase in Nitrosomonas europaea by Carbon Disulfide. *J of Bacteriology* 172(9):4775-4782.

Kapoor, V., Li, X., Elk, M., Chandran, K., Impellitteri, C.A., & Santo Domingo, J.W. (2015). Impact of Heavy Metals on Transcriptional and Physiological Activity of Nitrifying Bacteria. *Environ. Sci. Technol.* 49(22):13454-13462.

Kapoor, V., Elk, M., Li, X., Impellitteri, C.A., & Santo Domingo, J.W. (2016). Effects of Cr(III) and Cr(VI) on nitrification inhibition as determined by SOUR, function-specific gene expression and 16S rRNA sequence analysis of wastewater nitrifying enrichments. *Chemosphere* 147:361-367.

Keener, W.K. & Arp, D.J. (1993). Kinetic Studies of Ammonia Monooxygenase Inhibition in Nitrosomonas europaea by Hydrocarbons and Halogenated Hydrocarbons in an Optimized Whole-Cell Assay. *Applied and Environmental Microbiology* 59(8):2501-2510.

Kim, D., Lee, D., & Keller, J. (2006). Effect of temperature and free ammonia on nitrification and nitrite accumulation in landfill leachate and analysis of its nitrifying bacterial community by FISH. *Bioresource Technology* 97(3):459-468.

Kim, D.J., Lee, D.I., Cha, G.C., & Keller, J. (2008). Analysis of Free Ammonia Inhibition of Nitrite Oxidizing Bacteria Using a Dissolved Oxygen Respirometer. *Environmental Enginering Research* 13(3):125-130.

Lauchnor, E.G. & Semprini, L. (2013). Inhibition of phenol on the rates of ammonia oxidation by Nitrosomonas europaea grown under batch, continuous fed, and biofilm conditions. *Water Research* 47(13):4692-4700.

Lauchnor, E.G. & Semprini, L. (2013). Inhibition of phenol on the rates of ammonia oxidation by Nitrosomonas europaea grown under batch, continuous fed, and biofilm conditions. *Water Research* 47(13):4692-4700.

Lee, Y., Ong, S., & Sato, C. (1997). Effects of heavy metals on nitrifying bacteria. *Water Science and Technology* 36(12):69-74.

Lee, Y.W., Tian, Q., Ong, S.K., Sato, C., & Chung, J. (2009). Inhibitory Effects of Copper on Nitrifying Bacteria in Suspended and Attached Growth Reactors. *Water Air Soil Pollution* 203:17-27.

Lee, S., Cho, K., Lim, J., Kim, W., & Hwang, S. (2011). Acclimation and activity of ammonia-oxidizing bacteria with respect to variations in zinc concentration, temperature, and microbial population. *Bioresource Technology* 102:4196-4203.

Li, X., Zhu, Y.G., Cavagnaro, T.R., Chen, M., Sun, J., Chen, X, & Qiao, M. (2009). Do ammonia-oxidizing archaea respond to soil Cu contamination similarly asa ammonia-oxidizing bacteria?. *Plant Soil* 324:209-217.

Liu, G. & Wang, J. (2012). Effects of Nano-Copper(II) Oxide and Nano-Magnesium Oxide Particles on Activated Sludge. *Water Environment Research* 84(7):569-576.

Matsuba, D., Takazaki, H., Sato, Y., Takahashi, R., Tokuyama, T. & Wakabayashi, K. (2003). Susceptibility of Ammonia-Oxidizing Bacteria to Nitrification Inhibitors. *Zeitschrift fur Naturforschung C, A Journal of Biosciences* . 58(3-4):282-287.

Mertoglu, B., Semerci, N., Guler, N., Calli, B., Cecen, F., & Saatci, A.M. (2008). Monitoring of population shifts in an enriched nitrifying system under gradually increased cadmium loading. *Journal of Hazardous Materials* 16(2-3):495-501.

Metzner, R., Nomura, T., Kitaoka, N., Ando, A., Ogawa, J., & Kato Y. (2019). Cobalt-dependent inhibition of nitrite oxidation in Nitrobacter winogradskyi. *Journal of Bioscience and Bioengineering* 128(4):463-467.

Ortiz, D.I.B., Thalasso, F., Lopez, F.M.C., & Texier, A. (2013). Inhibitory effect of sulfide on the nitrifying respiratory process. *Journal of Chemical Technology and Biotechnology* 88(7):1344-1349.

Park, S. & Bae, W. (2009). Modeling kinetics of ammonium oxidation and nitrite oxidation under simultaneous inhibition by free ammonia and free nitrous acid. *Process Biochemistry* 44(6):631-640.

Park, S. & Ely, R.L. (2008). Candidate Stress Genes of Nitrosomonas europaea for Monitoring Inhibition of Nitrification by Heavy Metals. *Applied and Environmental Microbiology* . 74(17):5475-5482.

Radniecki, T.S. & Ely, R.L. (2008). Zinc Chloride Inhibition of Nitrosococcus mobilis. *Biotechnology and Bioengineering* 99(5):1085-1095.

References Cont:

Radniecki, T.S., Dolan, M.E., & Semprini, L. (2008). Physiological and Transcriptional Responses of Nitrosomonas europaea to Toluene and Benzene Inhibition. *Environ. Sci. Technol.* 42(11):4093-4098.

Radniecki, T.S., Semprini, L., & Dolan, M.E. (2009). Expression of merA, amoA and hao in Continuously Cultured Nitrosomonas europaea cells Exposed to Zinc Chloride Additions. *Biotechnology and Bioenginerring* 102(2):546-553.

Reyes, V.C., Opot, S.O., & Mahendra, S. (2014). Planktonic and biofilm-grown nitrogen-cycling bacteria exhibit different susceptibilities to copper nanoparticles. *Environmental Toxicology and Chemistry* 34(4):887-897.

Schopf, A., Delatolla, R., Mathew, R., Tsitouras, A., & Kirkwood, K. (2018). Investigation of copper inhibition of nitrifying moving bed biofilm (MBBR) reactors during long term operations. *Bioprocess and Biosystems Engineering* 41:1485-1495.

Sears, K., Alleman, J.E., Barnard, J.L., & Oleszkiewicz, J.A. (2004) Impacts of reduced sulfur components on active and resting ammonia oxidizers. *Journal of Indian Microbiology and Biotechnology* . 31:369-378.

Vadivelu, V.M., Keller, J., & Yuan, Z. Free ammonia and free nitrous acid inhibition on the anabolic and catabolic processes of Nitrosomonas and Nitrobacter. *Water Sci Technol* . 56(7):89-97.

Vadivelu, V.M., Keller, J., & Yuan, Z. Free ammonia and free nitrous acid inhibition on the anabolic and catabolic processes of Nitrosomonas and Nitrobacter. *Water Sci Technol* . 56(7):89-97.

Winely, C.L. & San Clemente, C.L. (1970). Effects of Pesticides on Nitrite Oxidation by Nitrobacter agilis. *Applied Microbiology* 19(2):214-219.

Xu, G., Xu, X., Yang, F. & Liu, S. (2011). Selective inhibition of nitrite oxidation by chlorate dosing in aerobic granules. *Journal of Hazardous Materials* 185(1):249-254.

You, S.J., Tsai, Y.P., & Huang, R.Y. (2008). Effect of heavy metals on nitrification performance in different activated sludge processes. *Journal of Hazardous Materials.* Doi:10.1016/j.jhazmat.2008.10.112.

Zhou, Z., Chen, Y., Xing, C., Chen S.W., Tong, F., & Wang J.R. (2012). Inhibitory Effects of Simultaneous Chemical Phosphorus Removal on Microbial Activity in the Unitank Process. *Advanced Material Research* 610-613:1672-1675.