

Challenges and Applications of Nitrate-Reducing Microbial Biocathodes

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Supplementary Material

List of abbreviations

Table S1. List of literature report about denitrification experiments made in batch.

Table S2. List of literature report about denitrification experiments made in flow.

List of abbreviations:

BES: Bioelectrochemical System

BOD: Biological Oxygen Demand

DO: Dissolved Oxygen

COD: Chemical Oxygen Demand

CV: Cyclic Voltammogram

DNRA: Dissimilatory Nitrate Reduction to Ammonium

HRT: Hydraulic Retention Time

MEC: Microbial Electrolysis Cell

MES: Microbial Electrochemical Snorkel

MFC: Microbial Fuel Cell

NCC: Net Cathodic Compartment

NRB: Nitrate-Reducing Biocathode

NRR: Nitrate Reduction Rate

SMFC: Sediment Microbial Fuel Cell

SCE: Saturated Calomel Electrode

SHE: Standard Hydrogen Electrode

SND: Simultaneous Nitrification and Denitrification

TCC: Total Cathodic Compartment

TN: Total Nitrogen

Table S1. List of literature report about denitrification experiments made in batch. (NI: no information)

Type of BES	Cathodic medium	Cathode material	Bacteria source	Atmosphere	Applied cathode potential	Resistance	Starting nitrate concentration	Nitrate reduction rate	Energy production	Ref
MFC	Buffer synthetic wastewater	graphite-Fe(III) electrode	Anaerobic digester sludge	N ₂	/	10 or 1000Ω	65 mg N-NO ₃ ⁻ L ⁻¹	0.084 mg NO ₃ ⁻ -N cm ⁻² (electrode surface area) day ⁻¹	Max 1.7 mW m ⁻²	[1] (2008)
MFC	Buffer synthetic wastewater	non wet-proof carbon paper	A mixed culture of denitrifying bacteria	Anaerobic	/	1000Ω	117 - 134 mg N-NO ₃ ⁻ L ⁻¹ 2g/l NaHCO ₃	2.3 - 4%	9.4mWm ⁻² of anode surface 0.19Wm ⁻³ of TAC	[2] (2008)
SMFC	Synthetic lake water	Carbon paper	Sediment	He	/	470 Ω	10 mg N-NO ₃ ⁻ L ⁻¹	62%	Max 38 mW m ⁻²	[3] (2012)
Bioelectrochemical denitrification system	Phosphate buffer with nitrate and bicarbonate	Carbon paper	Sludge cake	NI	-150 or -300 mV vs Ag/AgCl	Applied cell voltage: 0.5, 0.7, 1V	50 mg N-NO ₃ ⁻ L ⁻¹	0.204 mg NO ₃ ⁻ -N cm ⁻² d ⁻¹ (for voltages 0.7 and 1V)	2.8 mA	[4] (2013)
Soil MFC	Groundwater	Graphite bars	Sediment and groundwater	Aerobic or anaerobic (N ₂)	NI	3000Ω	Around 180 mg N-NO ₃ ⁻ L ⁻¹	55 mg NO ₃ ⁻ L ⁻¹ d ⁻¹	24 mW m ⁻² 129 mA m ⁻² (anaerobic conditions)	[5] (2015)

BES	Modified DSM medium 113	Carbon cloth	<i>Thiobacillus denitrificans</i>	CO ₂	-500, -300, -100, +250 mV vs SHE (poised)	Potential applied to biocathode	14 mg N-NO ₃ ⁻ L ⁻¹ (2 mM NO ₃ ⁻)	21.12 mmol NO ₃ ⁻ -N L ⁻¹ d ⁻¹ m ⁻² (for potential -500 mV vs SHE)	160.83 μA (for potential -500 mV vs SHE)	[6] (2015)
MES	Solution of nitrate	Iron rod	Sediment	NI	NI	0 Ω (shortcut)	2 mg N-NO ₃ ⁻ L ⁻¹	98% in 16 days	No power production (MES)	[7] (2015)
BES	Synthetic nitrate-contaminated water	Graphite felt	Sludge from wastewater treatment process (WWTP)	NI	From +0.5V to +0.05V vs Ag/AgCl	1000 Ω	50 mg N-NO ₃ ⁻ L ⁻¹	75.4% 2.39 mg N L ⁻¹ d ⁻¹	NI	[8] (2015)
MFC	Wastewater	Carbon felt	Sediment and wastewater	NI	NI	50 Ω	18.7 mg NO ₃ ⁻ -N L ⁻¹	96% (14 days)	353 mA m ⁻² (shortcut current) 88 m ²	[9] (2016)
MFC	Buffer medium	Graphite rod	Cow manure and soil	N ₂	NI	100 Ω	69 to 966 mg NO ₃ ⁻ -N L ⁻¹ (initially 345 mg)	Up to 8.2 kg m ⁻³ d ⁻¹ (highest C/N ratio)	190 mA m ⁻² 31.92 mW m ⁻²	[10] (2016)
BES	Buffer media	Graphite rod	Switched anodic biofilm	N ₂	-303 mV vs SHE	Potential applied to biocathode	30 mg N-NO ₃ ⁻ L ⁻¹ 1.398 g L ⁻¹ NaHCO ₃	Max 532 mgN m ⁻² d ⁻¹	NI	[11] (2016)
SMFC	Lake water	Graphite felt	Lake sediment and water	DO, 2.3 mg L ⁻¹	NI	1000, 510, 100, 51, 10 or 1 Ω	2.5 mg N-NO ₃ ⁻ L ⁻¹ (lake conditions)	60% in 115h for 1 Ω	From 1.6 mW m ⁻² (1000 Ω) to	[12] (2016)

										$0.85 \text{ mW m}^{-2} (1\Omega)$
Microbial Electrochemical Denitrification System	Synthetic buffer groundwater	Graphite felt	Sludge from WWTP	Ar	Applied potential -300; -500; -700 or -900 mV vs SHE	Potential applied to biocathode	50 mg N-NO ₃ ⁻ L ⁻¹ 2 g L ⁻¹ of NaHCO ₃	3.5 mg N-NO ₃ ⁻ L ⁻¹ d ⁻¹ (-700mV vs SHE)	NI	[13] (2016)
BES	Synthetic buffer groundwater	Graphite felt	Anaerobic sludge from WWTP	Ar	Applied potential: -0.7 V vs. SHE	Potential applied to biocathode	50 mg N-NO ₃ ⁻ L ⁻¹ 2 g L ⁻¹ NaHCO ₃	831.5 mg m ⁻² d ⁻¹ of N- NO ₃ ⁻ (biocathode in water)	NI	[14] (2016)
BES	Medium	Carbon felt	Activated sludge from WWTP	Ar	-0.2 V vs SCE	Potential applied to biocathode	440 mg N-NO ₃ ⁻ L ⁻¹	86.1% (5 days)	NI	[15] (2017)
Bioelectrochemical reactor	Medium	Graphite felt + graphite granules	Mixed culture from sludge-based reactions	NI	-0.5 V vs SCE	Potential applied to biocathode	40 mg N-NO ₃ ⁻ L ⁻¹	Up to 16.5 mg N-NO ₃ ⁻ L ⁻³ day ⁻¹	Up to -2.25 mA	[16] (2017)
Biofilm-electrode reactor	Medium	Graphite granules with different surface oxygen content	Liquid from suspended sludge reactor	NI	-0.5 V vs SCE	Potential applied to biocathode	40.0 mg L ⁻¹ NO ₃ ⁻ -N 2.70 g L ⁻¹ NaHCO ₃	Up to 27.36 mg NO ₃ ⁻ -N L ⁻¹ d ⁻¹	Up to 2mA	[17] (2017)
SMFC	River water	Graphite felt	Sediment from lake	NI	From 200 to 250 mV vs Ag/AgCl	1000Ω or open circuit	2.87 mg NO ₃ ⁻ N / l	Up to 79.1% (no plant)	9.82 mW/m ² (R=400Ω)	[18] (2018)

BES	Synthetic buffer groundwater	Granular graphite	Effluent of parent BES	NI	-0.303 V vs SHE	Potential applied to biocathode	30 mg N-NO ₃ ⁻ L ⁻¹ 0.551 g L ⁻¹ NaHCO ₃	39.7 g N m ⁻² d ⁻¹	NI	[19] (2019)
Microbial Electrochemical System	Buffer media	Graphite brush	Domestic wastewater	NI	-0.5 V vs SCE	Potential applied to biocathode	22.5 mg N-NO ₃ ⁻ L ⁻¹ 1 g L ⁻¹ bicarbonate	98%	NI	[20] (2019)
MFC for nitrate and uranium removal	Phosphate-free medium	Graphite felt	Consortia from previously operating MFC	N ₂	No information	1000Ω	680 mg N-NO ₃ ⁻ L ⁻¹	0.130 kg N-NO ₃ m ⁻³ d ⁻¹	2.91 W m ⁻³ & 29.7 A m ⁻³	[21] (2020)
Biocathode photo-bioelectrochemical system	Phosphate buffer medium 0.48 g/L NaHCO ₃	Nickel foam	Aerobic sludge and <i>Chlorella vulgaris</i>	Aerobic	From -0.37 to ~-0.47 V vs SCE	50 or 500Ω	330 mg N-NO ₃ ⁻ L ⁻¹	86% (192h)	40mW m ⁻² (while reducing nitrate)	[22] (2019)
Algal-bacterial biocathode photo-bioelectrochemical fuel cell	Phosphate buffer medium 0.4 g L ⁻¹ NaHCO ₃	Carbon felt	Aerobic sludge and <i>Chlorella vulgaris</i>	Anaerobic	From -0.3 to ~-0.5 V vs SCE (dark)	500Ω	500 mg N-NO ₃ ⁻ L ⁻¹	From 150 to 200 mg N-NO ₃ ⁻ L ⁻¹ in effluent after 160h	8.5 mW m ⁻² (while reducing nitrate)	[23] (2019)
Single-cathode three-anode microbial fuel cell	Buffer artificial wastewater	Graphite felt	Sewage treatment plant and sludge system	NI	From ~120 to 50 mV vs SCE	1000Ω	110 mgNO ₃ ⁻ · N · L ⁻¹	Up to 75.52%	795.70 mW m ⁻³	[24] (2020)

Mediator less SMFC	River water	Carbon fiber brush	River sediment and water	Aerobic	No information	1000 Ω	125.59 mg N-NO ₃ ⁻ L ⁻¹	99% in ~60 days	Up to 86.06 mW m ⁻³	[25] (2019)
Double-chamber bioelectrochemical system	DSM medium	Carbon felt	T.denitrificans	Anaerobic	-500mV vs SHE	Potential applied to biocathode	2 mM NO ₃ ⁻ -N	54.47 mmol NO ₃ ⁻ -N L ⁻¹ m ⁻² d ⁻¹	NI	[26] (2020)
MFC with different external circuits/operation modes	Phosphate buffer	Graphite felt	Mixed bacterial cultures from previous MFC	NI	///	Alternative charging and discharging (ACD), intermittent charging (IC) and constant external resistance (R)	140 mg N-NO ₃ ⁻ L ⁻¹ 1.92 g/L NaHCO ₃	15.5 mg NO ₃ ⁻ L ⁻¹ d ⁻¹	Up to 0.91 W m ⁻³	[27] (2013)
BES	Wetland water unriched with sodium bicarbonate	Graphite granules + stainless steel grid	Sediment from wetland	Aerobic	-0.5 vs SCE (applied)	Potential applied to biocathode	90 or 113 mg N-NO ₃ ⁻ L ⁻¹	Up to 2.04 g N-NO ₃ ⁻ d ⁻¹ m ⁻²	Max -0.4 A	[28] (2021)
Two chamber BES	Synthetic medium	Carbon cloths	Anaerobic sludge from WWTP	Anaerobic	0.7 V vs. SCE	Potential applied to biocathode	60 mg N-NO ₃ ⁻ L ⁻¹	89.6% in 4h, 100% in 12 h	2.13 mA (max) 0.18 mA (steady state)	[29] (2022)
MFC	Synthetic medium	Graphite felt	Consortium from	NI	/	NI	20 mg N-NO ₃ ⁻ L ⁻¹	77.40% in 2 d	564 mV	[30] (2022)

denitrification MFC										
Three-chambered cell	Synthetic medium	Carbon graphite fiber brushes	Domestic WW	Aerobic	/	50 Ω	30.0 mg NH_4^+ -N L^{-1} , 600 mg N-NO_3^- L^{-1}	88.2% in 10 h	6.6 W m^{-3}	[31] (2021)
Wetland coupled with microbial electrochemical system	Synthetic medium + sediment	Carbon fiber brush	Domestic sewage	Aerobic	/	NI	7.4 mg N-NO_3^- L^{-1}	96.9% at 21 h	1.6 mW m^{-2}	[32] (2022)
BES	Synthetic medium	Carbon cloth	Freshwater sediment	Anaerobic	-0.5 V vs. Ag/AgCl	Potential applied to biocathode	0.18 g NaNO_3 L^{-1}	>95% in 3 d	0.95 A m^{-2}	[33] (2023)
Biofilm electrode reactor	Synthetic municipal WW	Ppy coated graphite felt	Mixed culture from previous reactor	Anaerobic	NI	NI	20 mg N-NO_3^- L^{-1}	4.96 mg N-NO_3^- L^{-1} .h	Applied current 10 mA	[34] (2022)
MFC	Phosphate buffer medium	Vulcanized carbon cloth	Eggshell + groundwater	Aerobic	/	500 Ω	150 mg N-NO_3^- L^{-1}	97 % in 3 weeks	228 mW m^{-2}	[35] (2022)
BES	Synthetic medium	Carbon fiber + biochar supported nano zero-valent iron	Anaerobic sludge	NI	-0.40 V (vs. SCE)	Potential applied to biocathode	100 mg N-NO_3^- L^{-1}	100% in 28h	0.280 A	[36] (2022)

Sulfur-packed biocathode system	Synthetic medium	Carbon cloth	Anaerobic activated sludge	NI	-0.5 V vs SCE	Potential applied to biocathode	60 mg N-NO ₃ ⁻ L ⁻¹	95.9% in 12 h	1.76 mA (max) 0.19 mA (stabilized)	[37] (2022)
Bidirectional electron transfer system	Modified PBS	Graphite plates	Domestic wastewater	N ₂	-0.5 V vs. SCE	Potential applied to biocathode	NaHCO ₃ (1 g L ⁻¹) + NO ₃ ⁻ -N (0.1 g L ⁻¹)	93 ± 5.9 % within 96 h	-0.72 mA	[38] (2023)
Bidirectional BES	NH ₄ Cl-free M9	Hydrophilic carbon paper	Brewery anaerobic digestion sludge	NI	0.5 V vs Ag/AgCl	Potential applied to biocathode	50 mg N-NO ₃ ⁻ L ⁻¹	44.84 g m ⁻³ d	-2.19 A m ⁻²	[39] (2022)
MFC	Stock medium	Carbon cloth	Anoxic sludge from a moving biofilm reactor	N ₂	/	230 Ω	100 mg N-NO ₃ ⁻ L ⁻¹	56.5-79.8 %	3432-3847 mW m ⁻³	[40] (2023)
MFC	Synthetic medium	Air cathode	<i>Halomonas</i> strains	Aerobic	/	500 Ω	58.7 mg N-NO ₃ ⁻ L ⁻¹	88.26 % in 72 h	24.2 mW m ⁻²	[41] (2021)
MFC	Synthetic medium	Granular Activated Carbon	Anaerobic sludge from WWTP	NI	/	1000 Ω	100 mg N-NO ₃ ⁻ L ⁻¹	90 % in 4 d	0.32 V output voltage	[42] (2023)
MFC	Synthetic wastewater	carbon felt	active bacterial consortium from seawater	NI	/	100 Ω	KNO ₃ (2.5 g/L)	89 % in 4 d	162.09 mW m ⁻²	[43] (2023)
Sediment MFC	Synthetic wastewater	Granular Activated Carbon	Sediment from a fish culture pond	Aerobic	/	1000, 500, 200, and 100 Ω	10 mg N-NO ₃ ⁻ L ⁻¹	72-91 %	0.181, 0.217, 0.240, and 0.238 mA	[44] (2021)

Table S2. List of literature report about denitrification experiments made in flow. (NI: no information)

Type	Cathodic medium and flow	Cathode material	Bacteria source	Atmosphere	Cathode potential	Resistance	Inflow nitrate concentration	Nitrate reduction rate	Energy production	Ref
MFC	Modified M9 medium 6 L ⁻¹	Granular graphite	Mixed sludge and sediment	Ar	Varying depending on R and NO ₃ ⁻ concentration	5-50Ω	Up to 0.160 kg N m ⁻³ NCC d ⁻¹	Max. 0.146 kg NO ₃ ⁻ -Nm ⁻³ NCC d ⁻¹ or 0.080 kg NO ₃ ⁻ -Nm ⁻³ TCC d ⁻¹	Max 8 W m ⁻³ NCC (R = 25Ω)	[45] (2007)
MFC	Adapted M9 medium 200mL min ⁻¹	Granular graphite	Mixed denitrifying sludge	No information	From around -0.3 to -0.1 V vs SHE (after stabilization, day 16)	5-100 Ω	55-66 mg N-NO ₃ ⁻ L ⁻¹	Up to 0.41 kg NO ₃ ⁻ -N m ⁻³ NCC d ⁻¹ (R = 5Ω)	Max 34.6 W m ⁻³ NCC (R = 20Ω)	[46] (2008)
MFC	Modified M9 medium 0.700 L · d ⁻¹	Granular graphite	Microbial consortium from previous MFC	He, (tests of produced gas product)	100, 0, -100, -200 mV vs SHE	5Ω	0.652 g NaNO ₃ L ⁻¹ 1.119mM-N h ⁻¹	-0.484 mM-N · h ⁻¹ (continuous feeding conditions)	12.4 mA (E _{cath} applied = -100 mV vs SHE)	[47] (2009)
BES	Medium 0.79 L d ⁻¹	Granular graphite	NI	N ₂	NI for MFC	1.1 Ω	From 0.137 to 0.684 kg NO ₃ ⁻ Nm ⁻³ NCC d ⁻¹	Up to 0.50 kg NO ₃ ⁻ Nm ⁻³ NCC d ⁻¹ (adjusted pH)	NI for MFC	[48] (2009)
MFC	Synthetic wastewater 1.3ml/min	Granular graphite	Sludge from WWTP	Air	-435 mV vs Ag/AgCl	30Ω	2.5 g NO ₃ ⁻ /l	35.21%	1.92 W/m ²	[49] (2010)
MFC	Medium with varying ionic strength 1.44L/day	Granular graphite	Effluent from previous MFC	N ₂	From -0.09 to -0.15 V vs SHE	25Ω	From 14.42 to 15.64 mg N-NO ₃ ⁻ /L	From -0.076 to -0.105 mM N h ⁻¹ (increasing	4,4 W/m ³ NCC	[50] (2012)

Membrane-less MFC	Growth medium 0.633 L d ⁻¹	Carbon cloth	Denitrifying consortium	N ₂	NI	100Ω	32,4 mg/L	with ionic strength) 0.186 g N-NO ₃ ⁻ m ⁻³ day ⁻¹	Max 71,2 mW m ⁻³	[51] (2013)
MFC	Groundwater 1.21 L d ⁻¹	Granular graphite	Effluent from previous MFC	N ₂	From 53 to -122 mV vs SHE	25Ω	28.32 mg N-NO ₃ ⁻ /L	Max 51.37 gN m ⁻³ NCC d ⁻¹	No information	[52] (2013)
MFC	Nitrate-enriched mineral medium or effluent from other MFC From 1.2 to 1.5 L day ⁻¹	Rod graphite	Effluent from previous MFC	NI	NI	100Ω	26.6 mg N-NO ₃ ⁻ /L (autotrophic denitrification)	17% (autotrophic conditions)	15 A m ⁻³ NCC (autotrophic conditions)	[53] (2013)
MFC	Freshwater, bicarbonate buffered media HRT: 318–1250 min, initially no flow	Graphite rod	Freshwater sediment or denitrifying biomass, enriched with Fe oxidizing, NO ₃ ⁻ reducing bacteria	N ₂ /CO ₂	0 and -0.25 V vs Ag/AgCl	Potential applied to biocathode	64.8 mg N-NO ₃ ⁻ L ⁻¹	Up to 11.4 g NO ₃ ⁻ -N m ⁻² day ⁻¹	Max -3200 mA m ⁻²	[54] (2014)
BES	Medium NI	Graphite rod	Inoculum from cathode from previous MFC	N ₂	-0.32 V vs Ag/AgCl	Potential applied to biocathode	14.28 mmol NO ₃ ⁻ ·L ⁻¹ (200 mgN·L ⁻¹)	Up to 2.78 mmol NO ₃ ⁻ ·L ⁻¹	NI	[55] (2014)
MFC	Modified M9 medium (with ammonium)	Graphite felt	Sludge from WWTP	N ₂	NI	100Ω	37.9 mg N-NO ₃ ⁻ L ⁻¹	7.89 g N-NO ₃ ⁻ m ⁻³ day ⁻¹	176.1 mA/m ² of electrode surface area	[56] (2014)
BES	Synthetic wastewater HRT: 2-24h	Carbon felt/multiwall carbon	Sludge from WWTP	N ₂	-100 mV	Potential or current applied to biocathode	50 mg N-NO ₃ ⁻ L ⁻¹ (0.303 g NaNO ₃ L ⁻¹)	92.7%	NI	[57] (2015)

								nanotube composite		
BES	Nitrate contaminated groundwater Or tap water From 1.26 to 2.76 L day ⁻¹	Granular graphite	Inoculum from previous MFC	N ₂	from +597 to -703 mV vs SHE	Potential applied to biocathode	33.11 mg N-NO ₃ ⁻ L ⁻¹	2.59 mg N-NO ₃ ⁻ L NCC ⁻¹ h ⁻¹ (93.9%) (E = -123mV vs SHE, conversion to N ₂)	Up to 24.6 (E = -123mV vs SHE)	[58] (2015)
MFC	Synthetic buffer medium 0.93 mL/min	Activated carbon flakes	Anaerobic mixed cultures sludge from WWTP	Anaerobic	NI	1000Ω	NH ₄ NO ₃ (0.176 g/L) 141 ± 14 mg NO ₃ ⁻ L ⁻¹	88%	Max 669 mW/m ³ 3487 mA/m ³	[59] (2016)
MFC	Buffer media 1.25 ml min ⁻¹	Granular graphite	Aerobic and anaerobic sludge and sediments	NI	NI	12.5Ω	From 12.5 to 45 mg N L ⁻¹ 2 g NaHCO ₃	88.93 g NO ₃ ⁻ -N m ⁻³ NCC day ⁻¹	6.6 W m ⁻³ NCC (for 37 mg N/L)	[60] (2016)
MFC	Synthetic wastewater Lagging time: from 44 to 72h	Carbon felt	Sludge from WWTP	Anaerobic	NI	1000Ω	From 0.08 to 0.64 mmol L ⁻¹ (in presence of different concentrations of perchlorate)	Up to 87.05% (for C ₀ ≤ 0.32 mmol NO ₃ ⁻ /L)	Up to 0.66 W/m ³ (only nitrate)	[61] (2017)
Controlled biocathodic denitrification	Synthetic buffer wastewater From 2 to 9 L d ⁻¹	Granular graphite	Culture from parent CBD	NI	-0.303 V vs SHE	Potential applied to biocathode	40 mgNO ₃ ⁻ L ⁻¹	Close to 100% for lower loading rates	Up to 70 A m ⁻³ NCC	[62] (2018)
MFC	Buffer medium 36 ml/min for circular MFC	Carbon felt	Enriched inoculum	N ₂ and Ar	NI	1500Ω	100mg NO ₃ /L	100% in 2 days	2.1W/m ³ and 26.6 A/m ³	[63] (2018)

BES	Buffer synthetic groundwater HRT from 1.6 to 7.5h	Graphite granules	Effluent from a denitrifying BES reactor	N ₂	-0.123 V vs SHE	Potential applied to biocathode	33 mg N-NO ₃ ⁻ L ⁻¹ 420.0 mg L ⁻¹ NaHCO ₃	519 g N-NO ₃ ⁻ m ⁻³ Net Cathodic Compartment d ⁻¹	NI	[64] (2021)
Denitrifying biocathode-electrocatalytic reactor	Buffer cathodic medium 10 mL min ⁻¹	Graphite felt	Active sludge and a previously enriched denitrifying biocathode consortium	N ₂	No information	Applied voltage: 1.3 and 1.5 V	5.05 g/L KNO ₃ 1.92 g/L NaHCO ₃	0.45 kg NO ₃ ⁻ N/m ³ NCC/d	NI	[65] (2021)
single chamber biocathode-TiO₂/g-C₃N₄ nanosheet/graphene composite photoanode	Buffer nutrient medium 150 mL d ⁻¹	Carbon paper	Effluent from a bioelectrochemical reactor and active sludge	No information	-0.5 V vs Ag/AgCl	100 Ω	From 6 to 18 mgN L ⁻¹	Final concentration : less than 1 mg N/L in 21h	NI	[66] (2020)
Microbial desalination cell	Nutrient medium 0.6 L d ⁻¹ HRT=1.3 days	Granular activated carbon	Denitrifying sludge from the wastewater treatment system	Anoxic	NI	560, 100 and 22 Ω	0.05 g NO ₃ ⁻ L ⁻¹ 2.5 g NaHCO ₃	99.85%	0.425 W m ⁻³	[67] (2020)

MFC combined with anaerobic sequencing batch reactor	Phosphate buffer solution 1.7 ml min ⁻¹	Carbon fiber brush	Dewatered sludge	NI	NI	10.5 Ω	From 7 to 70 mg NO ₃ ⁻ -N per L 2 g NaHCO ₃	125.7 g NO ₃ ⁻ -N/m ³ NCC/d	40.69 ± 0.8 A/m ³ NCC (C= 49.35 mg NO ₃ ⁻ -N per L)	[68] (2020)
MFC	Buffer medium 1 g NaHCO ₃ L ⁻¹	Carbon bush	Inoculated sludge	1.5, 3.4 or 4.4 mg DO L ⁻¹	NI	1000 Ω	0.722 g/L KNO ₃	Up to 1.565 mg NO ₃ ⁻ -N (L·h) ⁻¹	Max 1776 mW m ⁻³	[69] (2019)
Bioelectrochemical denitrification system	Phosphate buffer solution NaHCO ₃ (2 g) HRT from 41.6 to 8.3 h	Carbon brush	Sludge from WWTP	Ar	~-0.5 V vs Ag/AgCl	15 Ω (applied voltage 0.7 V)	From 0.031 to 0.132 kg NO ₃ ⁻ -\ N/m ³ · D	Max 0.121 kg NO ₃ ⁻ -\ N/m ³	Up to 4.38 kWh/kg NO ₃ ⁻ -N	[70] (2019)
MFC	Buffer catholyte HTR = 120h	Carbon felt	Activated sludge	0.2-0.5 mg of DO L ⁻¹	Around 0.1V vs Ag/AgCl (200Ω)	200 or 500 Ω	1.5 mM NaNO ₃	92.5 % (200Ω)	1.5 mA (200Ω)	[71] (2015)
BES	Anaerobic mineral medium 0.24 mL/min (HRT 12 h)	Carbon fiber felt	Soil sample	N ₂	500 mV (vs. SHE)	21.52 Ω	28 mg N-NO ₃ ⁻ L ⁻¹	23.52 g N m ⁻³ d	-400 μA	[72] (2021)
Electrified secondary settlers	WW 25 L·d ⁻¹	graphite-coated stainless steel mesh	Effluent from denitrifying BES reactor	Anaerobic	- 0.321 V vs Ag/AgCl	Potential applied to biocathode	33 mg N-NO ₃ ⁻ L ⁻¹	248 g N m ⁻³ d	4.9·10 ⁻¹ kWh g _{Nremoved} ⁻¹	[73] (2023)

MFC	Synthetic medium HRT 24-96h	Graphite felt	Anaerobic sludge	Anaerobic	NI	NI	30 mg N- NO ₃ ⁻ L ⁻¹	Up to 96.56 % (HRT 48h, COD/N = 0.75)	NI	[74] (2022)
MFC	Synthetic wastewater	Carbon fiber brush	denitrifying sludge from reactor	Ar	/	13.5 - 47.37 Ω	40-45 mg N- NO ₃ ⁻ L ⁻¹	0.0055 kg N m ⁻³ d	540 mV output voltage	[75] (2022)
MEC	Synthetic nitrate-contaminated groundwater 1.08 L/d (HRT 3.3 h)	Granular graphite	microbial cultures from denitrifying BES	N ₂ /CO ₂	-0.333 V vs Ag/AgCl	Potential applied to biocathode	33 mg N- NO ₃ ⁻ L ⁻¹	233.8 g N- NO ₃ ⁻ m ⁻³ d	-18.3 mA	[76] (2021)
biofilm-electrode denitrification reactor	Synthetic WW HRT 24h	Nano-α-Fe ₂ O ₃ on Granular Activated Carbon	Sludge from WWTP	NI	NI	Current applied to biocathode	60 mg N- NO ₃ ⁻ L ⁻¹	Close to 100%	NI	[77] (2022)
sulfur-driven denitrification coupled with MFC	Synthetic WW	Carbon brush	Anaerobic sludge	Ar	/	NI	100.0 mg N- NO ₃ ⁻ L ⁻¹	87.7% in 12 h, 100% 24h	output voltage of 360 mV	[78] (2022)

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