论文摘要集

2023 年 5 月

目录

中文论文摘要

01 污泥生物炭强化好氧颗粒污泥特性研究

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摘　要　颗粒化时间长是制约好氧颗粒污泥技术工程化应用的关键瓶颈问题。本研究以低浓度城市污水为营养基质，曝气池絮体污泥为接种污泥，通过投加污泥生物炭在 SBR 反应器中强化好氧颗粒污泥的形成。考察了反应启动初期颗粒污泥的形成过程、颗粒属性及对污染物的去除效能。结果表明，添加生物炭的反应器中形成的污泥具有良好的沉降性能、较高的生物量保留率和良好的降解能力。SBR 反应器运行 7d 后，污泥浓度 MLSS 达到了 6000 mg/L，SVI_{30} 值稳定在 35 mL/g 左右；同时，颗粒污泥中胞外聚合物质(EPS)含量在生物炭的作用下显著增加，表明生物炭的投加刺激了 EPS 的分泌。反应器中 COD、TN 和 TP 的平均去除率分别提高 3.2%~5.1%、10%~13%和 10%~13%。污泥生物炭的投加不仅能够促进好氧颗粒污泥的快速形成，同时能够强化污染物的去除。

关键词　好氧颗粒污泥；污泥生物炭；晶核；胞外聚合物；序批式反应器

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02 针铁矿、赤铁矿和水锰矿对铊（I）的动态保留行为建模及机制研究

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摘 要 长江流域的重金属污染防治形势严峻，其中重金属铊（Tl）受到了高度重视。因此，研究 Tl 在环境介质上的迁移和转化规律对促进 Tl 污染控制与修复技术的发展具有重大意义。本研究通过吸附热力学和搅拌流动力学实验构建了统一动力学模型，以定量阐明不同水化学环境下 Tl（I）在广泛分布的铁/锰次生矿物（针铁矿、赤铁矿和水锰矿）上的动态保留和释放动力学。同时，采用光谱检测和理论计算揭示了铁/锰次生矿物对 Tl（I）的异质性表面络合和保留机制。实验结果表明，与环境 Tl 浓度相比，环境 pH 值对表面 Tl（I）结合物种的形成和分布有更大的影响。Tl（I）在铁/锰次生矿物上的保留主要涉及两种表面结合物种（≡MeOHTl^{+}和≡MeOTlOH^{-}）。表面羟基的水合作用诱导了 Tl（I）在矿物上的持久保留（$k_{d,\mathrm{MeOHTl}}$=0.005~0.018 min^{-1}）。碱性环境中的氢氧根离子和去质子化的羟基则提高了 Tl（I）在矿物表面的吸附能，增强了 Tl（I）的快速保留反应（$k_{d,\mathrm{MeOTlOH}}$=1.232~2.917 min^{-1}），并提高了矿物对铊的结合能力。

关键词 铊；保留；统一动力学模型；理论计算；界面反应

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03 基于双阶段注意力机制的污水处理过程自适应建模研究

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摘　要　污水处理厂普遍面临稳定达标难、运行碳排高的问题，其技术瓶颈在于调控精度有限、策略响应滞后。研究耦合双阶段注意力机制（Dual-stage Attention mechanism, DA）与长短期记忆网络（Long Short-Term Memory network, LSTM）算法构建污水处理厂出水水质预测模型。结果表明，DA-LSTM 对出水 COD、TP、TN 预测 R^2 分别为 0.98、0.95、0.87，相比对照组（LSTM）分别提升 5.10%、2.11%、14.77%，测试集 R^2 分别提升至 0.90、0.92、0.82，表明 DA-LSTM 具有良好的预测精度、泛化性、鲁棒性。解析 DA 结构发现，输入注意力可根据特征重要性自适应地调整权重来提高输入噪声的鲁棒性（相比 LSTM 提高 13.18%），降低特征筛选难度；时间注意力可改善长期记忆能力（由 96 h 增至 168 h），相比 LSTM 预测精度与训练速度分别提升 14.36%与 15.31%，注意力权重揭示 TA 能自适应聚焦关键历史信息进而捕捉长时依赖关系。综上所述，DA-LSTM 模型的长时记忆聚焦与特征自适应加权特点使其具备良好的预测精度、泛化性、鲁棒性与可解释性，能够支撑污水处理过程智能控制与低碳运行。

关键词　城镇污水处理厂；深度学习；注意力机制；多维时间序列；出水水质预测

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04 光催化、电磁场耦合垂直流人工湿地对水体氮磷有机物的净化效应

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摘　要　针对一些传统人工湿地主要依靠生物和基质的功能去除水体污染物，其出水水质常难以满足污水排放标准；一些强化方法在与人工湿地的联用中多为单一的物理措施。本试验将光催化技术、低强度电场与低频磁场技术耦合垂直流人工湿地，形成物理结合生物的处理系统。探究该系统对氨氮（$NH4^{+}$-N）、化学需氧量（COD）、总磷（TP）、正磷（PO_4^{3}-P）等指标在不同污染浓度、不同运行时间的去除效果，并从微生物门水平分布的群落结构特征等角度揭示该系统脱氮除磷机制。研究结果表明：（1）从去除率来看，系统运行时间与去除效果成正比，说明运行时间越长，其处理效果越好。（2）该强化系统在水力负荷为 1.8m．d，运行 72h 的条件下，处理废水中 $NH4^{+}$-N（31.2626~50.3649mg/L）去除率达 83%，COD（200~442.75mg/L）去除率达 68%，对 $NH4^{+}$-N、COD 有较好的去除效果。但对 TP、PO_4^{3}-P 的去除效果较差。（2）系统中通过光合作用自养的蓝菌门（Cyanobacteria）、变形菌门（Proteobacteria）、绿弯菌门（Chloroflexi）和在厌氧氨氧化过程中产生重要作用的浮霉菌门（Planctomycetes）的丰度较高。该研究可为多个物理措施引入人工湿地中的应用提供参考。

关键词　光催化;电磁场；微生物；人工湿地

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05 球磨改性生物炭促进厨余垃圾厌氧消化产甲烷关键官能团识别

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摘　要　生物炭作为导电介质被广泛应用于促进厌氧消化系统的产甲烷效率，但目前对于生物炭与微生物之间的相互作用及影响微生物菌群变化的关键材料特征尚不清晰。本研究通过利用两种不同的药剂（H_2SO_4、NaOH）对生物炭进行球磨改性（BMB-H_2SO_4、BMB-NaOH），探究其对厌氧消化过程的影响。批次实验中，添加 BMB-NaOH 厌氧消化组的甲烷产量为 454.04±7.50 mL/g VS_{added}，相比原始生物炭（359.13±3.76 mL/g VS_{added}）提高了 26.43%，而 BMB-H_2SO_4（115.89±5.67 mL/g VS_{added}）组甲烷产量分别下降了 67.73%。BET 结果表明，BMB-H_2SO_4 及 BMB-NaOH 较原始生物炭均降低，表明比表面积不是影响甲烷产量的直接因素。FTIR 及 XPS 分析结果表明，BMB-H_2SO_4 材料表面羧基显著增多，而 BMB-NaOH 表面羟基较原始生物炭更丰富。微生物分析结果表面，由于大量表面羧基可作为水解过程中的电子受体，BMB-H_2SO_4 组中负责碳水化合物的水解的微生物（*Georgenia*）较原始生物炭组（35.23％）被富集（38.82％）。同时，羟基可作为产甲烷过程中的电子供体，因此产甲烷菌（*Methanosaeta* 和 *Methanobacterium*）相对丰度较原始生物炭组（8.22%），在 BMB-NaOH 组（11.25%）及 BMB-H_2O_2 组（9.04%）上升，而在 BMB-H_2SO_4 组下降（8.14%）。H_2SO_4 和 NaOH 改性可分别使生物炭表面的羧基和羟基含量显著提升，羧基可促进厌氧消化的水解步骤，而羟基可促进厌氧消化的产甲烷步骤。本研究结果为导电介质影响厌氧消化过程的关键特征及关键作用机制提供了新思路，为实现厌氧消化导电介质的定向调控提供了研究基础。

关键词　厌氧消化；厨余垃圾；改性生物炭；羟基；羧基

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06 轻质磁黄铁矿生物滤池同步脱氮除磷性能研究

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摘　要　硫自养反硝化工艺(SAD)因无需外加有机碳源，符合“减污降碳，协同增效”的战略目标而受到关注，成为废水深度脱氮领域的研究热点。以单质硫(S0)作为电子供体，同时利用石灰石充当pH缓冲剂和无机碳源的硫-石灰石自养反硝化工艺(SLAD)拥有较好的脱氮能力，是最常见的硫自养反硝化工艺；但其除磷效率较差，出水SO42-及Ca2+含量较高，容易造成二次污染。以磁黄铁矿(FeS)作为电子供体的磁黄铁矿自养反硝化工艺(PAD)具备同步脱氮除磷的能力，且出水SO42-含量低，不易产生二次污染；但其脱氮速率较差，无法满足工程应用需求。Zhan等利用磁黄铁矿(150 μm)和单质硫(FeS和S0体积比为2:1)简单混合构建铁硫自养反硝化(PSAD)生物滤池，在HRT =1 h，进水NO3--N与PO43--P分别为40 mg·L-1和3 mg·L-1的条件下进行自养反硝化实验，结果表明，硝酸盐的最高去除速率为0.96 kg NO_3^--N·m^{-3}·d^{-1}，磷酸盐的去除率约为100%。但是利用细微磁黄铁矿与单质硫简单混合形成的PSAD容易发生堵塞，不利于实际应用。本研究以硫磺、磁黄铁矿等为原料，通过熔融混合等方式制备得到轻质磁黄铁矿材料(LPCM)，并构建生物滤池。实验证明，HRT=0.5 h的条件下，生物滤池可将人工配水中21.34±0.97 mg·L^{-1} NO_3^--N降至0.16±0.14 mg·L^{-1}。利用生物滤池处理生活污水。实验发现当进水pH较高（pH＞7.5) 时，生物滤池拥有较好的脱氮能力。HRT=1.5 h，进水NO3--N浓度为56.35 mg·L-1条件下，生物滤池容积负荷最高可以达到0.95 kg NO_3^--N·m^{-3}·d^{-1}。利用生物滤池处理生活污水。HRT=1.15 h条件下，生物滤池可将约50 mg·L-1的NO3--N可降至0.11±0.07 mg·L-1，去除率可达99.75±0.16 %。同等条件下，对于含101.53±1.91 mg·L-1 NO3--N、0.46±0.10 mg·L-1 PO43--P的工业废水，LPCM也具有较好的处理能力。出水NO3--N、PO43--P去除率分别为83.06±2.24 %、73.93±7.36 %，出水NO3--N浓度最低可降至12.87 mg·L-1，基本满足中华人民共和国城镇污水处理厂污染物排放

标准(GB18918-2022)一级A标准。最高容积负荷可以达到1.75 kg NO_3^--N·m^{-3}·d^{-1}，满足工程应用需求。实验证明，*Thiobacillus*，*Nitrosomonas*，*Bdellovibrio*和*Geothrix*等与脱氮相关属水平微生物群落丰度提高，*Sulfurimonas*属微生物丰度降低，可以有效提升LPCM颗粒脱氮能力及生物滤池抗高氮污水冲击能力。本研究利用LPCM构建的生物滤池，可以实现低碳、高效、深度同步脱氮除磷，并达到我国城镇污水处理厂污染物排放标准，为“减污降碳，协同增效”在工业废水深度处理领域提供技术支持。

关键词 磁黄铁矿；石灰石；改性硫磺；自养反硝化；同步脱氮除磷

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07 基于生化热力学的好氧颗粒污泥结构稳定机制研究

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摘　要　好氧颗粒污泥（AGS）具有结构致密沉降性能优异、抗冲击能力强等优势，被称为“下一代污水处理技术”。然而，现有研究主要关注单一运行条件优化与污泥菌群结构分析，颗粒污泥稳定机制仍不明晰、功能聚集体难以归一化调控。根据热力学第二定律，本论文提出污泥-水界面能（ΔGswa）表征 AGS 稳定性，选择有机负荷（OLR）和表面气速（SAV）作为两大能量输入关键操作参数。结果表明，适当提高 OLR 或 HSF 可降低 ΔGsw，分析发现影响 ΔGsw 的两条路径：直接影响污泥表面粗糙度（路径 I）； EPS 分泌菌富集，增加蛋白（类色氨酸蛋白）与疏水性官能团丰度，从而影响 ΔGsw（路径 II）。相关性与 PCA 分析，ΔGsw 与生化指标均显著相关，尤其是 *Paracoccus* spp.（-0.74**）与 Amide III （-0.81**），表明路径 II 对 ΔGsw 的影响更为显著。同时，ΔGsw 与物理稳定指标完整性系数（0.75**）、表面疏水性（-0.88**）、含水率（0.89**）、SVI_{30}（0.72**）显著相关。基于此，论文从生化热力学角度获得评价颗粒污泥结构稳定性的归一化指标，明晰典型工况下 AGS 稳定机制，为实际工程精准调控提供关键技术支撑。

关键词　好氧颗粒污泥；生化热力学；有机负荷；表面气速；颗粒稳定

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08 碳酸钙颗粒填充电化学沉淀系统：无膜电化学系统实现磷的高效及高纯度回收

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摘　要　废水中磷的去除与回收对预防水体的富营养化、缓解磷资源短缺、保障粮食安全具有重大意义。电化学诱导沉淀法在废水磷（P）回收领域拥有诸多优势，其通过阴极发生还原反应，构建局部高 pH 环境，从而诱导磷酸钙于阴极上沉淀并被回收[1]。然而，阳极发生氧化反应生成的 H+显著影响了 OH-的利用率。在此背景下，本研究提出碳酸钙（CaCO3）颗粒填充电化学沉淀系统的概念，评估了其提高磷去除效率及回收产物纯度的可行性，搭建并评估了两代 CaCO3 颗粒填充电化学沉淀系统，推进了该技术的研究及应用。

关键词　限域pH；磷酸钙填充；网兜阳极；电化学诱导沉淀

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09 黑臭水体阶段性治理成效研究——以仁怀市云聚雅苑黑臭水体治理点为例

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摘　要　黑臭水体的治理与修复是我国“十四五”规划水环境治理的重点工作,为落实《深入打好城市黑臭水体治理攻坚战实施方案》，仁怀市开展黑臭水体治理工作。依托贵州省遵义市仁怀市中心城区及北部乡镇水环境综合治理建设 PPP 项目，基于云聚雅苑黑臭水体治理点及其上下游开展溯源调查，通过控源截污、内源治理、生态修复等方式进行治理，结合氨氮、溶解氧、氧化还原电位等水质指标监测分析，进行阶段性治理成效研究，评估黑臭治理效果。结果表明：云聚雅苑黑臭水体治理效果良好，可为长江大保护项目黑臭水体治理提供技术参考。

关键词　黑臭水体；水环境治理；长江大保护

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10 基于细胞形态调控下厌氧氨氧化菌对盐度的适应机理研究

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摘　要　盐分对微生物有较高的抑制作用，传统的生物污水处理工艺对高盐废水的效果甚微。厌氧氨氧化菌因其优秀的耐盐能力而被广泛应用于高盐废水的处理，然而，厌氧氨氧化（anammox）细菌对含盐环境的适应机制尚未定论。近年来，细胞形态结构变化以适应恶劣环境的研究备受关注，本研究从厌氧氨氧化菌独特的代谢细胞器结构—厌氧氨氧化体（anammoxosome）作为切入点，利用透射电镜（TEM）和软 X 射线细胞三维成像（SX-CT）手段，通过研究盐度胁迫下厌氧氨氧化菌形态结构变化与生理代谢响应规律，提出以下微观机制：厌氧氨氧化菌通过改变形态大小来降低物质成本和能量消耗，管控形态的中央代谢网络尽可能将多的能量用于调节生理代谢活性，以提高在盐度突击时的适应能力，最终逐渐调控自身形态趋向于能够在恶劣环境下满足正常生理代谢的形态。本研究揭示了厌氧氨氧化细菌适应高盐环境的机制，对厌氧氨氧化工艺在含盐废水应用以及开发高效的生物处理技术提供了新思路。

关键词　厌氧氨氧化菌；盐胁迫；微观结构变化；生理代谢；适应机制

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11 降雨条件下山区河流污染物输移规律模拟研究

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摘　要　河流中污染物的输移过程受到地形、降雨-径流、水动力等诸多非线性因素的影响。本文以浅水方程(SWE）为基本框架，引入水深平均的 k-ε 紊流模型，并结合降雨和 Green-Ampt 下渗模型，开发了一套可模拟复杂条件下河流水动力特性的数值模型，实现对山区河流在降雨条件下的产汇流过程、污染物输移及水质变化的精细模拟。通过对比数值模拟结果、理论解和实验结果，验证了该模型在模拟下渗、径流以及溶质输移特性的准确性。

关键词　浅水模型；水质模型；山区河流；污染物输移

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12 三峡水库支流甲烷排放研究进展

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摘　要　甲烷（CH_4）对全球温室效应有着较大的贡献。三峡水库自 2003 年蓄水以来，其 CH_4排放问题已受到广泛关注。但三峡水库独特的运行方式，使得支流库湾 CH_4的产生和传输过程受到多方面的影响，进而导致其 CH_4排放效应尚不十分明确。本文综述了三峡水库支流 CH_4排放的研究进展，典型支流的 CH_4排放通量普遍高于干流，位于三峡水库库尾支流的 CH_4排放通量高于三峡水库库首及库中的支流。大多数典型支流的 CH_4通量在夏季均达到全年峰值，而在冬季高水位运行期均处于相对较低的水平。同时本文主要从藻类、气候因素、水动力条件及人类活动四个方面阐述了三峡水库支流 CH_4排放的影响因素。1）藻类：三峡水库蓄水后部分支流库湾出现了藻类水华现象，且藻类水华优势种已逐渐由蓄水初期的河流型藻类向湖泊型藻类演替，藻类的演替过程会加剧 CH_4的产生。此外，三峡水库支流优势藻种会发生季节性演替，其中以绿藻门和蓝藻门为主的藻类对 CH_4的贡献较大。2）气候因素：温度与支流 CH_4的生成与消耗速率呈显著正相关。较高的温度更有利于藻类的生长，但三峡水库反季节的调度运行方式使得更多的浮游植物在冬季产生，且干支流温度差导致的支流温度分层现象也会进一步加剧支流水华现象，为 CH_4的产生提供基质；降雨能增加支流水体中有机物及产甲烷菌含量，并对表层水体产生扰动，影响 CH_4的排放，但影响程度与降雨径流量级相关。3）水力条件：三峡水库低水位时期，CH_4在水体中的消耗较低，更有利于 CH_4传输。且水库运行导致的水位变化还会影响温度分层、藻类生长和有机物分布等因素，从而对支流 CH_4通量造成间接影响。4）人类活动：库

区人类活动导致的土地利用变化会增加支流水体中的营养物浓度，并增强细菌群落的营养相关代谢，从而导致 CH_4 排放通量的增加；支流区域的筑坝和水库运行改变了支流的水动力条件，对有机物的运输进行了阻拦，使得沉积物中的 TOC 含量增大，为 CH_4 的产生提供了更多基质。最后对未来的研究热点进行了展望，以期为三峡水库 CH_4 排放的控制和管理提供参考。

关键词 三峡水库；支流；甲烷排放；影响因素；水动力条件；藻类

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13 基于碳的空间治理绩效评估体系构建与初步应用——以浙江省为例

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摘　要：碳是社会经济活动的产物，国土空间则是社会经济活动的载体。不同的空间治理意味着在不同功能空间上社会经济活动规模、强度、效率以及能源资源消耗、碳排放等的差异，空间治理绩效应可通过碳相关指标表征。本文首先构建了基于碳的空间治理绩效评估理论模型以及包括“水平-进步-差距”三维或三个指数的评估方法，并选取浙江省及其11个地级市为研究区域进行初步应用，探究了差异化管控下浙江省的空间治理绩效与存在问题，并为推进空间治理绩效的提升与促进区域低碳发展提出政策建议。

关键词：碳；空间治理绩效；水平指数；进步指数；差距指数

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14 富磷废水作为磷源的MAP法回收沼液氮磷的研究

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摘　要　随着沼气工程的发展，沼液处理成为了解决污染问题和节约资源的重要途径。沼液中的氨氮和磷可用鸟粪石结晶法（MAP）回收，得到一种优质缓释肥，但沼液中氨氮含量一般远大于磷的含量，回收过程中需加入大量含磷试剂。本论文采用单因素实验法，以富磷废水作为含磷试剂的替代来源，结果表明，富磷废水能够作为磷试剂的替代来源，研究结果为解决沼液及富磷废水处理提供了新途径和理论参考。

关键词　沼液；富磷废水；MAP；单因素实验

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15 微气泡辅助液相低压等离子体处理工业污水

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摘要：本工作以罗丹明 B（RhB）为水污染模型，研究了超声空化的微气泡辅助低压等离子体工艺的废水处理性能。结果表明，与单独的低压等离子体技术相比，将超声辐射与低压放电等离子体相结合可以显著提高 RhB 的脱色效率。在相同的外加电压，微气泡的存在显著减少了能耗，1.0 min 可以实现 RhB 的完全脱色，而单一的低压等离子体技术处理则需 3.0-5.0 min。这项研究的结果表明，微气泡技术可协同扩展低压液相等离子体在污水处理研究和工业中的应用。

关键词：微气泡；超声空化；低压等离子体技术；污水处理

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16 污泥富铁生物炭厂内污泥调理深度脱水—厂外土地利用资源化新模式生命周期评价

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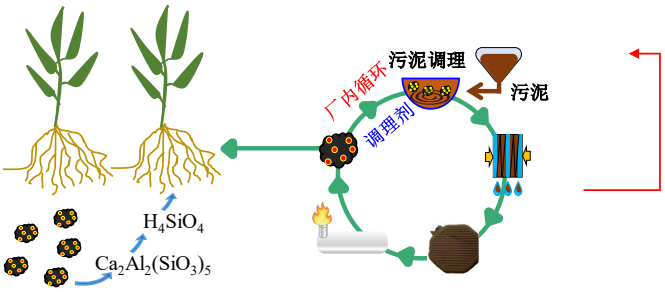
摘　要　市政污泥脱水困难是一项世界性难题。其中 Fenton 污泥复合调理技术因其能有效实现污泥深度脱水而受到广泛关注。然而在 Fenton 调理过程中，大部分铁元素会残留在脱水泥饼中，产生的大量富铁污泥后续如何处理处置是亟待解决的技术难题。研究团队前期研究结果表明，由 Fenton-赤泥调理得到的污泥深度脱水泥饼，热解制备的富铁生物炭能作为污泥调理剂进行回用，同时该污泥富铁生物炭也能作为硅肥进行土地利用。本研究基于上述成果，构建了污泥富铁生物炭污水厂内循环用于污泥调理—厂外土地利用的资源化新模式，如下图所示。



污泥富铁生物炭厂内污泥调理深度脱水—厂外土地利用资源化模式

通过对“Fenton-赤泥污泥调理深度脱水—卫生填埋”污泥处理处置模式与本研究提出的“污泥富铁生物炭污泥调理深度脱水—厂外土地利用”资源化新模式进行生命周期评价对比研究，发现本研究提出的新模式总环境影响潜值可降低 21.71%，为可持续的污泥处理处置技术提供新的思路和技术支撑。

关键词　市政污泥；深度脱水；污泥富铁生物炭；芬顿氧化技术；土地利用；生命周期评价

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17 磁铁矿投加与无机碳回流耦合强化产甲烷效能及其过程机制

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摘　要　在厌氧体系中，CO_2 还原型产甲烷菌作为末端电子受体，对有机物降解产甲烷性能具有决定性作用。研究从强化 CO_2 还原型产甲烷途径出发，提出磁铁矿投加与无机碳回流耦合强化产甲烷策略。结果表明，耦合策略具有协同强化产甲烷效果，36 kg COD/m^3/d 有机负荷下，相较于单策略施加反应器性能崩溃，其 COD 去除率稳定在 85% 以上。微生物群落与蛋白组分析发现，*Methanosaeta*（42.9%）和 *Methanosarcina*（38.8%）得到最大程度富集，同时它们中 CO_2 还原型产甲烷途径相关蛋白得到最大程度上调。结合电化学表征，磁铁矿可通过促进污泥微生物细胞色素 C、黄素等氧还介质分泌，以诱导种间直接电子传递（DIET）发生，*Methanosaeta* 和 *Methanosarcina* 中 $F_{420}H_2$ 脱氢/氢化酶、CoB-CoM 异二硫化合物还原酶等电子中介体蛋白显著上调；同时在无机碳回流条件下，它们更倾向通过 ABC 转运蛋白直接摄取 HCO_3^-，进一步还原其为甲烷。综上所述，耦合策略对 DIET 介导的 CO_2 还原型产甲烷途径具有协同强化作用，可为厌氧生物处理工程应用与过程碳中和提供可选择的技术路径。

关键词　磁铁矿；无机碳；种间直接电子传递；CO_2 还原型产甲烷；蛋白组

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18 循环经济背景下水务企业价值链优化研究——以北控水务为例

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摘　要　本文以我国水务龙头企业北控水务为例，探讨循环经济下水务企业价值链优化动因、途径及效果。本文的主要发现和结论是：首先，生态环境恶化与水务企业资源需求等因素加剧了水务企业价值链优化需求；其次，水务企业以循环经济建设及价值链优化为基础，协同优化产业链、供应链，逐步探索出保障企业的发展与生态平衡的有效途径；最后，循环经济理论能有效解决水务企业价值链优化中的各种矛盾，在进行不断优化后，可增强水务企业的核心竞争力，提升企业价值，促进水务企业健康循环，保障企业可持续发展。因此，现代化水务企业需建立循环经济水务企业价值链，在保障水务企业取得一定的经济效益的同时收获社会效益与生态效益。但由于水务企业的企业性质与地域性等原因，在优化转型中也存在着资金、技术等局限性。本文提供了一个循环经济下水务企业价值链优化的完整分析框架，丰富了水务企业价值链优化的相关文献，同时对水务企业的产业建设也有一定的借鉴意义。

关键词　循环经济；价值链；水务企业；北控水务

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19 基于分子网络技术的污水中药物转化产物识别与转化行为研究

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摘　要　环境介质中药物是广受关注的一类新污染物，污水处理厂是环境中药物的主要聚集地。污水中，转化产物是药物的另一种存在形式。研究表明，某些转化产物可能较药物母体化合物浓度更高、毒性更强。但受限于污水复杂基质中产物识别技术，目前尚存大量结构未知的药物转化产物未被揭示。本研究率先将分子网络技术引入环境领域，以解决污水复杂基质中药物转化产物非靶向识别过程中产物峰特异性识别和结构鉴定两个难题。产物识别方面，与传统的非靶向筛查策略相比，分子网络技术在产物峰识别方面假阳性结果较峰面积差异法和质量亏损法分别减小20.85和32.2倍。另外，相邻的已知节点可以提供质量差、谱图类似分值等信息，有利于未知产物的结构鉴定，这使得污水中西酞普兰的4个新的转化产物得以发现（图1）。转化行为方面，基于分子网络技术，识别出污水中氟西汀的11个转化产物，这些产物以7条转化路径进行转化。其中甲酰化、羟基化和脱氢反应在之前的研究中尚未报道，琥珀酸酰化是氟西汀在污水中的主要转化路径（图2）。使用分子网络技术对5种磺胺抗生素在污水中的转化行为进行探索发现，5种磺胺均会以5个路径—甲酰化、乙酰化、去甲基、蝶呤螯合、去氨基反应进行转化，其中甲酰化和蝶呤螯合反应是5种磺胺在污水中的主要转化路径，甲酰化作为磺胺的主要转化路径在之前的研究中尚未报道（图3）。本研究率先将分子网络技术用于污水中药物转化产物识别，有利于推进该技术在环境领域的应用，从而识别出更多结构未知的转化产物，所揭示的转化路径规律，有利于从转化路径层面调控工艺操作参数以强化污水中药物的去除。

关键词　分子网络；非靶向筛查；药物；污水；转化产物；转化路径

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20 纳滤在市政供水中研究及应用进展

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摘　要　近年来，纳滤膜分离过程在国内大型市政供水工程中如春笋般出现。水质标准的越发严格和人们生活水平的提高，大家越来越关注纳滤。始于巴黎的梅林奥赛 14 万吨/天纳滤膜水厂，后来国内建成了张家港 40 万吨/天（2019），武汉 10 万吨/天（2021），嘉兴 55 万吨/天（2022），同为深度处理，纳滤成为了 O_3-BAC 深度处理的竞争工艺。尽管当前大型纳滤工程上马较快，但纳滤工艺的实际应用中仍存在较多的科学技术问题亟需解决，如高性能国产纳滤膜的开发问题以及纳滤预处理的残余铝等问题。本文综述了纳滤在市政供水中研究及应用进展，分析了纳滤研究和工程应用中需注意的关键点，可望为纳滤膜深度处理饮用水工艺的发展、大型纳滤净水工程的设计、建设和运维，提供参考。

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21 光催化耦合垂直流人工湿地对农村污水的净化效果

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摘　要　本研究通过构建光催化—垂直流人工湿地耦合系统，探究了光催化的施加与人工湿地去除污染物效果的关系，确定光催化—垂直流人工湿地耦合系统的最佳参数。研究该系统对生活污水中总磷（TP）、正磷（$PO4^{3-}$-P）氨氮（$NH4^{+}$-N）和有机物（COD）净化效果，解析在光催化作用下垂直流人工湿地中微生物在不同水平下的相对丰度。结果表明：（1）光催化的施加对人工湿地中污染物的去除有强化作用，且强化效果与紫外灯管与催化材料的距离、紫外灯光照强度有关。本试验中在全送风曝气条件下，紫外灯管与催化材料的距离为 6cm 和光照强度为 3 组灯全开（5 盏/组）（23w/盏）时人工湿地去污效果最好。各项指标在高浓度进水的情况下，其去除率、累计削减负荷除 COD 外均优于对照组。COD 在平均进水浓度 366.17mg/L 的情况下，平均去除率可达 65.24%，与对照组平均去除率 65.06%持平。氨氮、总磷、正磷在平均进水浓度 65.00mg/L、5.06 mg/L、5.04mg/L 的情况下去除率分别提高 12.85%、83.07%、85.89%。（2）光催化的施加影响了湿地系统中微生物群落的相对丰度，与对照组相比，变形菌门（Proteobacteria）增多 8.43%；假单胞菌目（Pseudomonadales）增多 13.84%；不动杆菌属（Acinetobacter）增多 13.78%。

关键词　光催化；氮；磷；垂直流人工湿地；微生物

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22 2002-2020 年中国河流环境质量演变及驱动因子分析

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摘　要　基于 2002-2020 年河流环境质量、污染物排放和环境污染治理数据，采用典型相关分析和 Spearman 相关系数研究我国河流环境质量演变规律及其驱动因子，以期更科学地分析污染物排放和环境污染治理投资对流域环境影响。结果表明，2002~2020 年中国河流环境质量得到明显改善，I~III 类水比例由 29.1%提升至 87.4%，劣 V 类水比例由 40.9%下降至 0.2%；废水排放总量由 439.5 亿 t 增加到 849.1 亿 t，城镇生活污水排放量由 232.3 亿 t 增加到 659.8 亿 t，工业废水排放量由 207.2 亿 t 减少到 168 亿 t，环境治理投资由 1106.6 亿元增加到 10638.9 亿元。七大流域、浙闽片河流域、西南诸河流域和西北诸河流域 I~III 类水比例与工业源污染物排放呈负相关，与环境污染治理投资呈正相关；七大流域、浙闽片河流和西北诸河流域环境质量改善的首要措施是削减工业源污染物排放，污染物削减优先顺序均为：COD > NH_3-N > 废水总量；西南诸河流域水环境质量改善的首要措施是增加环境污染治理投资，环境治理投资增加优先顺序为工业污染源治理投资 > 城市环境基础设施建设投资/建设项目环保投资。研究结果可为“十四五”期间河流环境质量改善提供理论和决策依据。

关键词　河流环境质量；污染物排放；环境污染治理投资；驱动因子；相关性

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23 升流穿越式电化学氢自养反应系统对水中硝酸盐的去除研究

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摘　要　去除水中的硝酸盐已经成为目前水处理领域的研究热点。基于氢自养反硝化过程清洁、无副产物的优点，本研究采用电化学和生物氢自养相结合的方法，创新建立升流穿越式电化学氢自养反应系统，研究其对硝酸盐的去除效率。结果发现：HRT、循环比和电流强度与 NO_3^-去除均直接相关，其中电流强度是最重要的操作参数；HRT 为 8 h、电流强度为 20 mA、循环比为 3 是本系统的最佳操作条件，此时系统的 NO_3^-去除率达到 90.12%，出水 NO_2^-的积累量也相对较低（0.54 mg-N/L），电流效率为 75.94%，同时进水与出水 pH 均保持 7.00~8.00，证明该系统不需调节出水溶液 pH 值。而阴极区 ORP 处于-100 mV 以下，有利于反硝化细菌对硝酸盐的还原。此外，微生物群落分析结果表明：*Proteobacteria* 和 *Bacteroidetes* 是系统中丰度较高的微生物菌群，其中 *Proteobacteria* 菌门被证实在自养反硝化过程中占据优势地位；*Hydrogenophaga* 属氢自养反硝化菌的积累，表明电解产氢被很好的利用；功能基因 *nirK* 和 *nirS* 的分析结果证明反应系统中 NO_2^-结果的差异与微生物功能基因表达有关；更进一步的，阴极区附近弹性纤维填料上较大的细菌菌落丰度，表明该区域微生物的活性较高，系统的脱氮性能得到了有效的保障。本研究结果有望为水体中硝酸盐的高效去除提供方法参考。

关键词　生物反应器；硝酸盐；氢自养；电化学；微生物分析

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基金项目：国家自然科学基金项目(52070073，51878251，12205240)，河南省自然科学优秀青年科学基金项目（212300410034），河南省高校科技创新人才支持计划（22HASTIT009），郑州市科技协同创新专项重点项目（21ZZXTCX05）

24 山地中小城市水环境现状及治理措施建议-以重庆市某区县城市为例

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摘　要　以重庆市某区县城市为例，结合其水文、水质现状及山地城市特点，研究了山地中小城市水环境现状并提出了针对性治理措施和建议。研究表明，该区县中心城区部分区域存在积水问题，但无系统性内涝风险；区域范围内河流水质以III类水体为主，其氨氮（NH_3-N）、总磷（TP）含量季节性趋势明显，夏、冬两季浓度较高。同时，该城市存在雨水调蓄空间不足、排水管网破损或缺失、雨污混流等综合性问题；其中心城区范围内雨污混接、管道功能性缺陷问题突出，老旧城区及中心城区边缘居民聚居区的雨水管网缺失、雨污合流问题较为严重。本文从防洪提升、雨污管网改造、城市治理等方面提出山地中小城市水环境综合治理措施及建议。

关键词　山地城市；水环境现状；治理措施

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英文论文摘要

01 Facilely tuning the intrinsic catalytic sites of the spinel oxide for peroxymonosulfate activation: From fundamental investigation to pilot-scale demonstration

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Abstract Heterogeneous peroxymonosulfate (PMS)-based advanced oxidation processes (AOPs) have shown a great potential for pollutant degradation, but their feasibility for largescale water treatment application has not been demonstrated. Herein, we develop a facile coprecipitation method for the scalable production (~10 kg) of the Cu-Fe-Mn spinel oxide (CuFeMnO). Such a catalyst has rich oxygen vacancies and symmetry breaking sites, which endorse it with a superior PMS-catalytic capacity. We find that the working reactive species and their contributions are highly dependent on the properties of target organic pollutants. For the organics with electron-donating group (e.g., -OH), high-valent metal species are mainly responsible for the pollutant degradation, whereas for the organics with electron-withdrawing group (e.g., -COOH and -NO_2), hydroxyl radical (•OH) as the secondary oxidant also plays an important role. We demonstrate that the CuFeMnO-PMS system is able to achieve efficient and stable removal of the pollutants in the secondary effluent from a municipal wastewater plant at both bench and pilot scales. Moreover, we explore the application prospect of this PMS-based AOP process for large-scale wastewater treatment. This work describes an opportunity to scalably prepare robust spinel oxide catalysts for water purification and is beneficial to the practical applications of the heterogeneous PMS-AOPs.

Keywords Advanced oxidation process; Peroxymonosulfate; Catalysis; Water treatment; Large-scale

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This article has been published on PNAS (doi.org/10.1073/pnas.2202682119).

02 The preparation and anti-fouling performance of conductive CNTs-PVDF composite hollow fiber membrane for microalgae filtration

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Abstract Efficiently harvesting microalgae is vital to recover available energy and bio-products. Membrane filtration is a superior approach to separate microalgae from aqueous phase with little damage to the microalgae cell1-3. However, the existence of membrane fouling reduces the treatment efficiency and increases the production cost. Thus, it is of significance to fabricate a membrane with excellent anti-fouling performance. Herein, we fabricated CNTs-PVDF hollow fiber membrane by loading conductive CNTs coating on the surface of commercial PVDF membrane. The CNTs coating was stabilized on the PVDF membrane by the cross-linking reaction with polyvinyl alcohol and succinic acid, which enhanced the coating stability and the hydrophilicity. After filtrating high concentration microalgae, the permeance of membrane with -1.2 V bias was recovered above 95% by simple hydraulic cleaning, while that of membrane without bias was 57.98%. That exhibited the membrane fouling could be greatly mitigated by the assistance of electrical repulsion. Furthermore, this membrane also exhibited the outstanding flexibility and mechanical stability due to the commercial substrate, which is promising for the large-scaled fabrication and industrial application.

Keywords conductive membrane, anti-fouling performance, microalgae filtration, electric repulsion

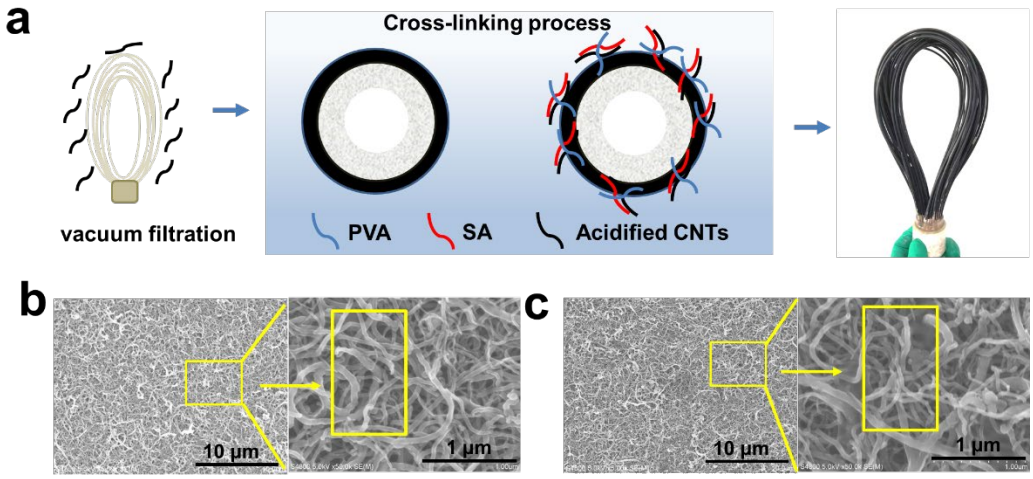

Figure. 1. a. The preparation process of CNTs-PVDF HFMs and the optical images of the membrane. b. The SEM morphologies of pre-CNTs-PVDF HFMs without cross-linking reaction. c. The SEM morphologies of CNTs-PVDF HFMs after cross-linking reaction. Herein, the parts of the yellow box were the magnified images.

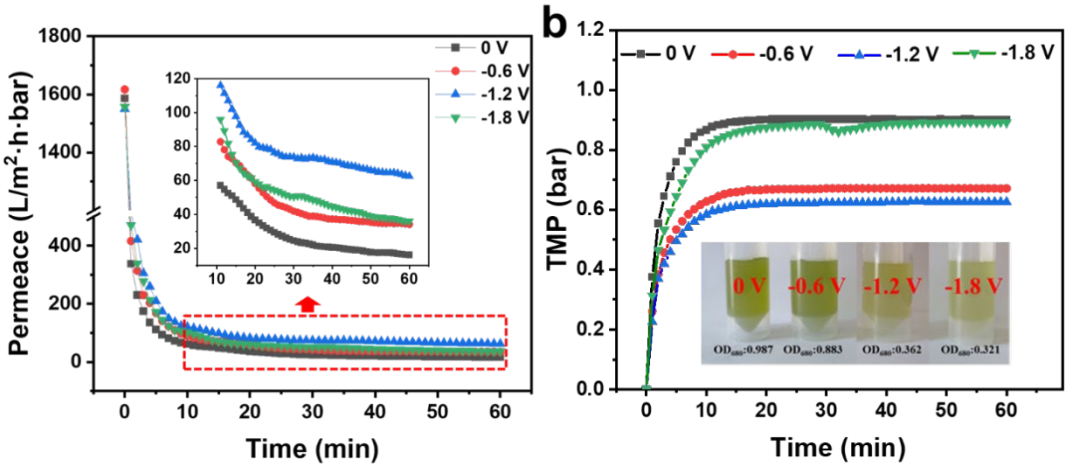

Fig. 2. The filtration performance of CNTs-PVDF HFMs. a. The permeance of membrane with different bias. b. The TMP of membrane with different bias, and inset was the microalgae solution recovered from the membrane surface.

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03 Easily biodegradable substrates are crucial for enhancing antibiotic risk reduction: Low-carbon discharging policies need to be more specified

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Abstract Governments have formulated stricter wastewater treatment plant (WWTP) discharge standards to address water pollution; however, with the cost of aggravating the refractory of the discharges. These policies are not in line with the classic co-metabolism theory; thus, we evaluated the effects of an easily biodegradable substrate on the removal efficiency of antibiotics and antibiotic resistance genes (ARGs) in the receiving water. In this study, reactor with 8 d of hydraulic retention time (HRT) was constructed to simulate a receiving river, and several antibiotics (0.30 mg/L each) were continuously discharged to the reactor (tetracycline, ciprofloxacin, amoxicillin, chloramphenicol, and sulfamethoxazole). Sodium acetate (NaAC) was used as a representative easily biodegradable substrate, and treatment protocols with and without a co-substrate were compared. The attenuation of the antibiotics in the simulated river and the production and dissemination of ARGs were analyzed. The results showed that 50 mg/L NaAC activated non-specific enzymes (a log2-fold change of 3.1-8.8 compared with 0 mg/L NaAC). The removal rate of the antibiotics was increased by 4-32%, and the toxicity of the downstream water was reduced by 35%. The upregulation of antioxidant enzymes caused by the intracellular reactive oxygen species (ROSs) decreased by up to 47%, inhibiting horizontal gene transfer and reducing mobile genetic element-mediated ARGs (mARGs) by 18-56%. Furthermore, NaAC also increased the alpha diversity of the microbial community by 5-15% (Shannon-Wiener Index) and reduced the abundance of human bacterial pathogens by 22-36%. In summary, easily biodegradable substrates in the receiving water are crucial for reducing antibiotic risk.

Keywords easily biodegradable substrates；antibiotic; antibiotic resistance genes；transfer；antioxidant enzymes；human bacterial pathogens

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This work was published in Water Research

04 Nitrogen-doped carbon nanotubes enhanced Fenton-like chemistry: Role of near-free iron(III)

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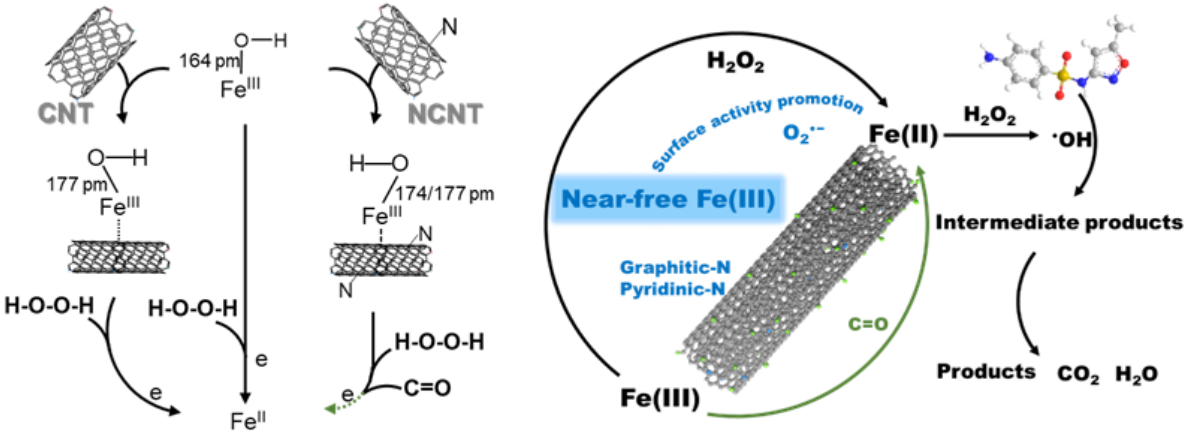
Abstract The sluggish kinetics of Fe(II) recovery strongly impedes the scientific progress of Fenton reaction (Fe(II)/H_2O_2) towards practical application. Here, we propose a novel mechanism that metal-free nitrogen-doped carbon nanotubes (NCNT) can enhance Fenton chemistry with H_2O_2 as electron donors by elevating the oxidation potential of Fe(III). NCNT remarkably promotes the circulation of Fe(III)/Fe(II) to produce hydroxyl radicals with excellent stability for multiple usages (more than 10 cycles) in the NCNT/Fe(III)/H_2O_2 system. Although carbonyl on NCNT can act as the electron supplier for Fe(III) reduction, the behavior of NCNT is distinct from common reductants such as hydroxylamine and boron. Electrochemical analysis and density functional theory calculation unveil that nitrogen sites of NCNT can weakly bind with Fe(III) to elevate the oxidation potential of Fe(III) (named near-free Fe(III), primarily $FeOH^{2+}$) at pH ranging from 2.0 to 4.0. Without inputs of external stimulations or electron sacrificers, near-free Fe(III) can promote H_2O_2 induced reduction of Fe(III) to initiate Fenton chain reactions for long-lasting generation of hydroxyl radicals. To our delight, it is a common property of N-doped carbon materials (e.g., graphene, carbon nanofibers, and acetylene black), our research thus provides a novel, sustainable, and green strategy for promoting Fenton chemistry.

Keywords Fenton chemistry; N-doped carbon nanotubes; Hydroxyl radicals; Near-free Fe(III)



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(Published: Water Research 210 (2022) 117984)

05 Regulation of free or surface hydroxyl radicals in MILs(Al)-Fe catalyzed Fenton-like systems by free carboxyl group on catalysts

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Abstract Iron based Fenton-like processes have been widely investigated, while how to regulate active species generation still is a problem of concern. In this study, MILs(Al) with various carboxyl group amounts were used as research tools, loading iron for Fenton-like oxidation, to investigate the effect of free carboxyl group on surface or free HO generation. Active species identification indicates that surface and free HO• were main active species for carbamazepine removal. Moreover, it was concluded that contribution of free HO• for the decontamination was positively correlated with carboxyl group amounts on MILs(Al). With free carboxyl group amounts increasing from 3.07 to 5.09 mmol/g on MILs(Al)-Fe, concentration of free HO• for carbamazepine removal increased from 47.4% to 62.5%. The mechanisms of carboxyl group amounts impact the chemical state of HO was proposed as steric hindrance effect and charge density near iron sites. The destruction of carbamazepine was proposed in different systems by intermediates determination, and the results indicate that the existing form of HO• mainly influenced the efficiency of pollutant degradation, rather than oxidation mechanisms of it. Various pollutants degradation in different MILs(Al)-Fe catalyzed Fenton-like systems were investigated as well, to understand the superiority of different HO• for decontamination. MILs(Al)-Fe with various carboxyl group amounts catalyzed Fenton-like processes could remove 34.2%-73.0% carbamazepine, 56.7%-93.8% sulfamethoxazole, 36.4%-75.6% bisphenol S and 43.8-79.7% salicylic acid. This study understood the regulation of active species by carboxyl group in MILs(Al)-Fe/H2O2 systems, and sheds new light on active species precise regulation in Fenton-like systems.

Keywords Fenton-like oxidation; MILs(Al)-Fe; Carboxyl group; hydroxyl radicals regulation; Catalytic mechanisms

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06 A Synergistic Platform Enables Co-oxidation of Halogenated Organic Pollutants with Zero Carbon Input

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Abstract While co-oxidation is widely used to biodegrade halogenated organic pollutants (HOPs), a considerable amount of organic primary substrate is required. Adding organic primary substrates increases the operating cost and also leads to extra carbon dioxide formation. In this study, we evaluated a two-stage Reduction and Oxidation Synergistic Platform (ROSP), which integrated catalytic reductive dehalogenation with biological co-oxidation for HOPs removal. 2,4-dichlorophenoxyactic acid (2,4-D) was used as a model HOP to verify the performance of ROSP. In the continuous operation of ROSP with HRT of 12 hours, 50 μM (or 11 ppm) 2,4-D was completely mineralized with effluent 2,4-D concentration < 0.2 μM (or 44 ppb). In the H_2-MCfR, over 80% of influent 2,4-D was reductively hydrodechloriated to POA. The produced POA was used as primary substrate to support the co-oxidation of 2,4-D in the O_2-MBfR. The community structure and gene encoding functional enzymes for POA, and 2,4-D co-oxidation were investigated through shallow metagenomic sequencing of biofilm DNA samples. The dominant bacterial genus *Variovorax* and various mono/di-oxygenase encoding genes may contribute to biodegradation. Compared with existing biological or advanced reducing methods, ROSP not only completely degrades HOPs, but also no extra carbon dioxide was produced by primary substrate oxidation.

Keywords Halogenated organic pollutants (HOPs); synergistic platform; catalytic dichlorination; biofilm co-oxidation

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07 Soft sensing of BOD in surface water using machine learning technology—— a case study

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Abstract Real-time monitoring of water quality is critical for the governance of surface waters. Although the development of the sensors for water quality parameters have advanced significantly, some water quality parameters are still challenging to obtain instantaneously. Among them, 5-day biochemical oxygen demand (BOD), which represents the concentration of biodegradable organic matter and is a vital indicator to measure the biodegradability of water, is still in lack of a satisfactory measurement tool. This study reports that soft sensing, which estimates BOD values using other readily-obtained water quality parameters, can be an alternative method for the accurate BOD monitoring. Two commercial machine models (Gradient Boosting and XGBoost) and a self-developed model based on 4-layered network (4LD) were used to predict BOD values of Lam Tsuen river in Hong Kong. The results showed that the mean square error (MSE) of the Gradient Boosting, XGBoost, and 4LD was 0.53, 0.37, and 0.29, respectively, indicating that the self-developed 4LD can serve as a soft sensor for BOD with a satisfactory accuracy. The model results showed that XGBoost can better estimate BOD. The important feature of water quality dataset is sparsity. Some water quality parameters, including chloride, salinity, *Chlorophyll-a*, and total organic carbon, showed no influence for the prediction results, while ammonia nitrogen and total *Kjeldahl* nitrogen were the key.

Keywords Water quality monitoring, soft sensing, Gradient Boosting, XGBoost, BOD, machine learning

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08 A novel low-carbon technology for advanced nitrogen removal from mature landfill leachate via PN-Anammox coupled with SdAD process

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Abstract: Mature landfill leachate, which is characterized with high-load ammonia and low C/N ratio, is the one of most challenges problems in wastewater treatment. Conventional biological nitrogen treatment from landfill leachate often needs dosing external carbon sources and resulting in operation cost increasing, huge sludge production and greenhouse gas emission. In this study, an innovative low-carbon process via partial nitrification and anaerobic ammonia oxidization (PN-Anammox) coupled with sulfur-driven autotrophic denitrification (SdAD) was developed to achieve high-efficient nitrogen removal from mature landfill leachate (NH_4^+-N of 2500 mg/L, C/N < 1.5). Over 99% total nitrogen (TN) of mature landfill leachate was effectively removed via the PN-Anammox coupled with SdAD process, and the concentration of TN in the effluent was decreased from 2600 mg/L to 10.3 mg/L. The results of the mass balance indicated that the PN-Anammox and SdAD processes contributed to 93.4% and 5.9% removal of TN, respectively. Comparing with conventional biological nitrogen removal process, the novel process reduced 25% oxygen consumption and 50% ecotoxicity of leachate without external carbon addition. Microbial community analysis indicated that *Candidatus Kuenenia* and *Thiobacillus* were dominant genera, which played critical roles in nitrogen removal in PN-Anammox and SdAD reactors, respectively. Therefore, the PN-Anammox coupled with SdAD process as an environmentally friendly technology has great potential for advanced nitrogen removal and promoting future low-carbon green watershed construction.

Keywords: Mature landfill leachate; Anammox; Sulfur-driven autotrophic denitrification; Advanced nitrogen removal

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09 Conductive materials can not overcome the limitation of biomass concentration in anaerobic digestion

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Abstract Conductive materials (CMs) have garnered significant interest in anaerobic digestion (AD) technology due to their potential to enhance methanogenic efficiency and maintain digester stability. However, methanogenic efficiency is intrinsically governed by the balance of substrate and inoculum. In this study, we assessed the impact of biochar and iron powder addition on anaerobic digestion at low, medium, and high inoculum-to-substrate (I/S) ratios. Protein was selected as the sole substrate since it is the principal component in typical substrates and is less likely to undergo acidification due to its high buffering capacity. Results indicate that the I/S ratio is the predominant factor in AD, irrespective of the conductive materials dosage. Methane yield potential increased stepwise as the I/S ratio escalated from 1:3 to 3:1, with 223±12, 301±10.6, and 339±7 mL CH4/g VS, respectively. The addition of CMs provided limited improvement (less than 19%), and iron even inhibited methanogenesis by 15% at low I/S ratios. Ammonia and volatile fatty acids (VFAs) variations were consistent with I/S ratios rather than CMs addition. Iron powder impeded acetate degradation at low and medium I/S ratios. Metagenomic analysis reveals that bacterial community dynamics during anaerobic digestion are contingent on the I/S ratio; i.e., *Clostridiaceae* and *Acetoanaerobium* dominate under low I/S ratios, while *Longilinea* and *Georgenia* proportions increase as the I/S ratio escalates. Comparatively, the influence of conductive materials on the bacterial community is limited, however, iron supplementation significantly elevates the proportion of hydrogenotrophic methanogen *Methanobacterium*. This study demonstrates that the addition of conductive materials can not overcome the limitation of biomass concentration in AD.

Keywords Anaerobic digestion; Inoculum to substrate ratio; Methane yield; iron powder; biochar;

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10 Risk assessment and response to flood disasters in China's coastal urban agglomerations under the background of carbon neutrality - A case study of Guangdong-Hong Kong-Macao Greater Bay Area

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Abstract Flood disasters caused by extreme precipitation events due to climate change cannot be underestimated, and have strong regional heterogeneity in disaster prevention and mitigation, especially for coastal cities in China. This paper focuses on the Guangdong- Hong Kong-Macao Greater Bay Area (GBA), evaluating its flood risk from three aspects: vulnerability, dangerousness, and sensitivity. The spatial distribution pattern of flood disaster risk in the GBA in 2030, 2060, and 2090 was projected in different development path scenarios, namely SSP 126/370/585. The results of the study show that although the Huizhou City in the east of the GBA and the Zhaoqing City in the northwest have the highest level of flood disaster risk, the central region of the GBA is most vulnerable to disaster-inducing environments and hazard-affected bodies, which means that the flood disaster risk and the impact of such risk in the GBA display regional differentiation characteristics and the spatial patterns of them are different. According to the SSP126 pathway,the flood risk in the GBA peaks in 2030, and decreases during 2030-2090. In contrast, under the SSP370 and 585 development paths, the risk peaks in 2060, and the overall risk by 2090 is roughly the same as that in 2060. In addition, the regions with the highest flood disaster risk are the cities of Guangzhou and Foshan along the Pearl River estuary, followed by Shenzhen, Zhuhai, Hong Kong and Macao with the next highest level of flood disaster risk. Overall, it shows that areas with higher levels of urbanization and more developed economies will face higher flood disaster risks. The “dangerousness- vulnerability-sensitivity” flood disaster risk assessment framework structure can reflect the spatial distribution pattern of flood disaster risks, identify the priority areas for flood prevention and control, and is conducive to risk management. At the same time, the research results show that ecological protection towards a sustainable development path have a positive effect on reducing flood risk.

Keywords Guangdong-Hong Kong-Macao Greater Bay Area (GBA), flood disaster, risk assessment, Geo-detector

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Aimed Journal: Resources, Conservation and Recycling

11 Construction of continuous-flow combined sulfur autotrophy with electrodialysis ion-exchange membrane bioreactor (CF-SEDIMB) for effective removal of nitrate in water

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Abstract Nitrate pollution is a key and hot issue in surface water around the world. In this study, a continuous-flow combined sulfur autotrophy with electrodialysis ion-exchange membrane bioreactor (CF-SEDIMB) was established by combining the electrodialysis reactor with the ion-exchange membrane bioreactor based on sulfur autotrophy. In the CF-SEDIMB system, the ion migration process and the removal efficiency of nitrate was enhanced under electric field. The water chamber and biological chamber are separated by the ion-exchange membrane to avoid secondary pollution of the effluent water, and realize the pollution-free transformation while enriching nitrate. The continuous operation of the CF-SEDIMB system showed that the nitrate concentration in the water chamber could reach below 10 mg-N/L at HRT_w (water chamber HRT) of 24 h, 20 h and 16 h, and the nitrate removal of the system was higher than 89.87%, but the decrease of HRT_w would lead to the increase of nitrate enrichment. Confocal laser scanning map (CLSM) showed that microbial community grew well and enriched onto the anion exchange membrane. High-throughput sequencing results showed that the microbial community differentiated in the biological chamber during long-term operation, and the denitrifying bacteria enriched and grew onto the outlet side of the biological chamber. Betaproteobacteria are the dominant bacteria on the surface of sulfur particles, while Gammaproteobacteria are the main bacteria in the space between sulfur particles. Fourier Transform infrared spectroscopy (FTIR) and scanning electron microscope (SEM) analysis showed that nitrate had a higher affinity for anion exchange membrane, nitrate was easy to enrich and adhere onto the anion exchange membrane surface, and microorganisms tended to grow on the anion exchange membrane surface. In the long-term continuous operation, hydraulic erosion, nitrate enrichment and attachment, erosion of microbial secreted products and other factors have caused certain damage to the anionic membrane surface, but the scaling phenomenon and the morphology change of the ion exchange membrane have no significant effect on the denitrification performance of the system.

Keyword Nitrate; Electrodialysis; Ion-exchange membrane bioreactors; Sulfur autotrophy; Microbial analysis

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12 Interpretable machine learning identifies eutrophication factors of a landscape lake recharged by reclaimed water

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Abstract The water quality of lakes recharged by reclaimed water is affected by both the fluctuation of reclaimed water quality and the biochemical processes in the lakes, so the main controlling factors of algae blooms are always difficult to identify. Taking a landscape lake recharged by reclaimed water as an example, the spatiotemporal distribution characteristics and correlation of water quality indexes were analyzed. It was found that the trend of lake water quality was highly consistent with but different from reclaimed water quality, and the lake alternated between hyper-eutrophication and eutrophication throughout the year by seasonally driven, but chlorophyll a (Chl-a) had no significant correlation with other indicators, except for a moderate negative correlation with NO_3^--N. Furthermore, taking nutrient difference indexes (NDIs) between reclaimed water and lake water into account, Chl-a concentration was predicted by random forest, and the relationship between Chl-a and each variable was analyzed by partial dependence plot. Results showed that the difference of NO_3^--N between reclaimed water and lake water (ΔNO_3^--N) was an important and positive NDI explanatory variable for Chl-a prediction, which proved that NO_3^--N input from reclaimed water was the dominant factor causing eutrophication, and the negative correlation between NO_3^--N and Chl-a in lake water was the result of algae blooms rather than the cause. Our study provides new insight into the identification of eutrophication factors for lakes recharged by reclaimed water.

Keywords Interpretable machine learning; reclaimed water; landscape lake; eutrophication; Chl-a prediction; random forest

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13 Effective removal of nitrate in water by combined sulfur autotrophy with electrodialysis ion-exchange membrane bioreactor: Reaction kinetics and microbial analysis

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Abstract Nitrate pollution is a hot issue in the field of water treatment. In this study, the combined sulfur autotrophy with electrodialysis ion-exchange membrane bioreactor (SEDIMB) in batch mode was established by combining the electrodialysis reactor with ion-exchange membrane bioreactor based on sulfur autotrophy. In SEDIMB system, the ion migration process was enhanced by electrodialysis and nitrate removal was accelerated. Using the advantages of ion-exchange membrane bioreactor, the water chamber and biological chamber were separated to avoid secondary pollution of effluent water and realize the pollution-free transformation while enriching nitrate. In addition, electro saturation method was used to pretreat the ion exchange membrane, which could effectively ensure the denitrification performance of the system. In this study, SEDIMB system was operated in batch mode at different voltages, different nitrate concentrations and different water conditions. Experimental results showed that the increase of voltage could effectively promote the nitrate migration in water chamber. When the voltage was 7 V, 20~60 mg-N/L nitrate could be effectively removed, and the removal efficiency was more than 93.54%, and the change of water type (tap water, lake water and deionized water) could not affect the denitrification performance of SEDIMB system. The nitrate removal process in water chamber of SEDIMB system accorded well with the first-order kinetic model (R^2=0.98), and the kinetic parameter K_1=0.0030 (min^{-1}). The microbial analysis showed that Betaproteobacteria (76.06%) was the dominant bacterium in the SEDIMB system. The confocal laser scanning microscope (CLSM) map showed that the microorganisms in biological chamber enriched and grew on the anion exchange membrane. In addition, fourier transform infrared spectroscopy (FTIR) and scanning electron microscope (SEM) analysis showed that the change of morphology of ion exchange membrane did not cause the change of nitrate removal efficiency.

Keyword Nitrate; Denitrification; Electrodialysis; Membrane bioreactors; Reaction kinetics

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14 Novel Strategies for Algae-laden Water Treatment by Peracetic Acid based Advanced Oxidation Processes

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Abstract: Harmful algal blooms pose great challenges to green watershed construction for producing microcystins, taste & odor compounds, leading to potential risks to human health and ecosystems. Firstly, the inactivation of algae by a combined process of peracetic acid and ultraviolet irradiation was systematically investigated. Both hydroxyl ($HO^{\bullet}$) and organic radicals ($RO^{\bullet}$) contributed to the cell integrity loss and **$RO^{\bullet}$ played the dominant role**. The algae **inactivation kinetics** can be well fitted by the typical Hom model, showing a type of shoulder and exponential reduction. The UV/PAA process **displayed better performance under the natural water background**, demonstrating the extensive potential for the practical application of this approach. After determining the feasibility of $RO^{\bullet}$ for algae inactivation, Fe(II)/PAA were applied as the combined preoxidation and coagulation process to enhance algae removal. A high removal rate of algae and turbidity could be achieved, **with most algal cells keeping intact**. The generated $RO^{\bullet}$, Fe(IV), and $HO^{\bullet}$ played major roles in the moderate oxidation of algal cells. Concurrently, the in-situ formed Fe(III) greatly promoted the agglomerating and settling of algae. These results offered novel strategies and some theoretical basis for algae-laden water treatment, favoring green watershed construction.

Keywords: Peracetic acid (PAA); Organic radicals ($RO^{\bullet}$); Algae; Cell integrity; Algal organic matter (AOM)

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Noted: Some results involving in this study have been published in ***Water Research*** (10.1016/j.watres.2021.117847) and ***Journal of Hazardous Materials*** (10.1016/j.jhazmat.2022.130571)

15 Inter-plant water integration considering water quality and water consumption costs

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Abstract Water scarcity and environment regulation increase the efforts required to reduce water consumption and prevent the water ecosystem degradation. Based on the park-wide water metabolism concept, this work explores the interactions among water reuse, total cost of the system, and water quality via the synthesis of inter-plant water networks. First, the park-wide water metabolism concept was designed to identify water reuse motivators, which included economic concerns, environmental regulations, water resource limitations, and receiving water quality. Second, a mixed-integer nonlinear programming model was developed for designing a water network to identify water reuse alternatives. Further, different scenarios were developed to consider the interactions between water reuse, total cost, and water quality. Comprehensive relationships between freshwater and wastewater flow, water networks, and an integrated diagram were designed to discuss the transition points and trends for water flow, quality, and cost. The minimum average annual total cost of the optimized water system was 29.77 million CNY, which was 27.43% lower than the average annual total cost of the park prior to optimization. The minimum consumption of freshwater at the lowest optimization cost was 113.7 m^3/h, which was 92.24% lower than the initial volume of the park. The findings indicate that system engineering and life cycle of water metabolism in chemical industrial parks could be combined for efficient water system management. Further, the results can provide technical support for effective decision-making by water consumers regarding water management.

Keywords: Inter-plant water network, Process integration, Water management, Mathematical programming

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16 Synergistic role of Fe_2O_3/SBA-15 surface in inducing ozone aqueous decomposition

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Abstract Catalytic ozonation is of interest to water treatment technology and the amount of active radical production is a primary objective of this process. To investigate synergistic role of Fe_2O_3/SBA-15 surface on ozone decomposition, the kinetics constant was measured and interface behaviors was discussed. The results indicated that Fe_2O_3/SBA-15 significantly increased the generation of active radical and the utilization efficiency of ozone relative to Fe_2O_3 in catalytic ozone decomposition. A synergistic role existed between Fe_2O_3 and SBA-15 in catalytic ozone decomposition by Fe_2O_3/SBA-15. The investigation indicated that SBA-15 had no catalytic activity for ozone decomposition. But, Si-OH of SBA-15 surface could adsorb ozone via hydrogen bonding, which was easily desorbed further into water. The interface behaviors resulted in significantly enhanced the reaction chances between ozone and Fe_2O_3 on Fe_2O_3/SBA-15 to initiate more active radical, which increased the removal of organics.

Keywords Fe_2O_3/SBA-15；catalytic ozone；active radical；kinetics; interface behaviors

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17 Recovery of phosphorus from municipal wastewater by a synchronous removal-enrichment biofilm process with low phosphorus concentration

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Abstract A biofilm sequential batch reactor (BSBR) was used to realize the synchronous removal and recovery of low concentrations of phosphorus (P) from municipal wastewater (P= 2.5 mg/L). The phosphorus concentration in the effluent is below 0.5 mg/L, which meets the discharge standard in most regions. The maximum phosphorus concentration in the recovery solution ($P_{recovery}$) reached 84.5 mg/L, which was 34 times that of the influent, and the P recovery efficiency of the system reached 72.80%. At the beginning of a harvest cycle, the release of phosphorus is driven by the biofilm phosphorus storage ($P_{biofilm}$) from the last cycle, and then the driving force turns into the consumption of carbon sources. The stoichiometric parameter C_{upt}/P_{rel} was adopted to measure the carbon source cost and utilization efficiency. Both the Pbiofilm and the C_{upt}/P_{rel} have a linear relationship with $P_{recovery}$. The extracellular polymeric substance (EPS) plays an important role in the absorption and release of P, contributing 65% of the $P_{biofilm}$. This work proved the possibility of synchronous removal-recovery of phosphate with a biofilm process, with lower influence phosphate concentration and higher efficiency.

Keywords phosphorus; recovery; biofilm; sequential batch reactor; EPS

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18 Spatial variation of dissolved organic matter in the Tuojiang River basin in Chengdu, China: Insights based on EEMs-PARAFAC analysis

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Abstract Three-dimensional excitation-emission matrix fluorescence spectroscopy coupled with parallel factor analysis was adopted to investigate the characteristics of DOM components in water samples collected from the Tuojiang River basin in Chengdu, including its main stream and tributaries. Four DOM components matched with three fluorescence peaks were identified in the whole river basin and tributaries; while three components corresponding to four fluorescence peaks were identified in the main stream. In all cases, humic-like components accounted for high proportions of the DOM. Correlation analysis revealed the same sources for four components in the whole river basin and its tributaries, whereas two components had different sources in the main stream. UV absorbance parameters ($SUVA_{254}$, S_R) and fluorescence parameters (BIX, HIX, FI, β:α) indicated the dominant autochthonous sources of DOM in the whole river basin. Higher terrestrial inputs of DOM were observed in the tributaries than in the main stream. In the areas influenced by human activities (6#, 17#, 18#), the sources of DOM showed strong terrestrial characteristics and high degrees of humification and aromatization, as well as serious pollution. The results of this study have potentially far-reaching implications for environmental water management in the area.

Key words Tuojiang River basin; fluorescence parameter; fluorescent components; parallel factor analysis; main stream–tributary difference

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19 Monitoring Selenite/Se^0 formation from biological elenate reduction for potential Se recovery in an H2-based reactor

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Abstract Selenium (Se) exists in the environment ubiquitously, and anthropogenic activities have dramatically increased Se emissions in recent years, bringing ecological hazards to aquatic systems (i.e., groundwater). Selenate bio-reduction can be successful for Se removal but usually needs carbon substrates for biomass activities. We investigated how H2, a clean, nontoxic-to-biomass and carbon-neutral electron donor, could be used in a reactor inoculated with microbial biomass previously enriched in ethanol and selenate. The results show that selenate was bio-reduced to selenite and crystalline Se0 , where the dominant formed species reversibly changed from selenite to Se0 depending on the selenate load. Calculations show that the formation of Se0 or selenite depends on the Gibbs free energy gained per mole electron or per mole selenate and is thus controlled by the selenate-H2 supply ratio. The correlation between ORP and the ratio of [selenite]: [selenate] based on the current process and other processes showed a concomitant increase. This study may lead to new carbon-neutral methods producing only selenite which can be converted to recoverable selenium abiotically

Keywords carbon-neutral bio-reduction；H2；selenate；selenite；selenium

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20 Screening and characterization of a novel Acid Orange 7 degrading *Microbacterium sp*. and bioaugmentation in an aerobic sequencing batch reactors

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Abstract: Acid orange 7 (AO7) is well known for its toxic and carcinogenic effects on human beings and the aquatic environment. In this study, a highly effective AO7-degrading bacteria strain, LX-1, was screened from the acclimated activated sludge of a dye wastewater treatment system. This strain, identified as *Microbacterium* sp., utilises AO7 as the sole source of carbon and energy for growth. The influences of culturing factors (initial concentration, pH, and temperature) on the bacterial substrate degradation were studied. The results showed that the optimal AO7 degradation occurred at an AO7 concentration of 50 mg·L^{-1}, 30 °C and pH8.0- 9.0. The decolorization of the bioaugmented SBR reactor was successful under long-term operation. This is the first report of AO7-degrading isolate from the genus of *Microbacterium*. Strain LX-1 could potentially be employed in bioremediation of AO7.

Key word: Acid Orange 7; azo dyes; *Microbacterium* sp.; Bioaugmentation

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21 Dynamic vitality characters of bacteria relating to bio-stability in drinking water

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Abstract Dynamic character of bacteria vitality in drinking water is of great significance to hygienic safety. The ATP detection was used to detect the change of bacteria vitality in drinking water. When the same bacteria quantity was added to a series of the diluted tap water samples with milli-Q water, there was a turning point in the relation curve between dilution ratios and bacteria vitality. Although the relation curve would become more and more fluctuant between bacteria vitality and dilution ratios as incubation period got longer and longer, the samples before the turning-point were still proved to be biological stable by these results of the long incubation tests. It was concluded that the nutrient concentration could be partly reflected at once by dynamic character of bacteria vitality in drinking water at the inoculation time, which is helpful to assess water bio-stability of drinking water.

Keywords vitality dynamic character; drinking water; bio-stability

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22 Combining homogenous oxidation with post-coagulation to recover organic carbon from chlorophenol-containing wastewater: Oxidative polymerization rather than mineralization

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Abstract This work provided a novel strategy to recover organic carbon from chlorophenol-containing wastewater. Colloidal manganese dioxides (cMnO2) coupled with periodate (PI) was selected as an efficiency homogenous oxidation process to oxidize chlorophenol from water, and a post-coagulation process using polyferric sulfate (PFS) was chosen to remove the cMnO2 after treatment. When analyzing the oxidation product of chlorophenol by the cMnO2/PI process, we observed the significant generation of polymeric products, which might be induced by the reactive manganese species via oxidative polymerization. Further, we found that the nascent floc generated in the post-coagulation process could effectively adsorb the polymeric products, which could be easily separated through precipitation. Compared with traditional degradation treatment process, the proposed oxidation-coagulation technology could recover carbon resources from wastewater to reduce CO2 emission with lower oxidant consumption.

Keywords Colloidal manganese dioxides, periodate activation, oxidative polymerization, carbon resource recover

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