

**FY 2023 Annual Report (4/1/23– 3/31/24)**  
**Biological Systems Unit**  
**Professor Igor Goryanin**



**Abstract**

Over the past few years, the Biological Systems Unit has been dedicated to the advancement of BioElectrochemical System (BES)/Microbial Fuel Cell (MFC) technology for wastewater treatment. This innovative approach harnesses the intricate interactions between microbial populations and electrodes to effectively remove organic pollutants while generating electricity. By integrating fundamental and practical objectives, our Unit aims to enhance BES/MFC systems through interdisciplinary methods such as biology, chemistry, engineering, and bioinformatics. Our ultimate goal is to optimize treatment efficiency and electricity production by developing ideal microbial communities and cost-effective materials. Sustainable wastewater treatment is particularly crucial for small islands like Okinawa. Scaling up the BES/MFC technology poses one of the significant challenges.

Continuing our research, the Unit (Drs Kainuma and Babiak, Ms Hiyane, Mr. Kometani) has focused on refining the biocathode system to remove organics and reduce nitrogen and phosphate levels in both raw and aerated swine wastewater. This year, we received two grants (Okinawa Prefectural Government and Proof of Concept from OIST Innovation) that helped us optimization of scaled-up biocathode reactors (525L) at the Okinawa Prefecture Grassland and Livestock Research Center. This effort, in partnership with Nikko Company and the Okinawa Prefecture Environment Science Center, aims to meet the needs of swine farmers. Nikko Company will further develop and commercialize this technology. Additionally, together with Dr. Sorokin conducted microbial analysis to understand the changes within the different chambers of the system.

## 1. Staff

1. Dr. Igor Goryanin, Professor
2. Dr. Mami Kainuma, Group Leader
3. Dr. Peter Babiak, Staff Scientist
4. Dr. Anatoly Sorokin, Staff Scientist
5. Mr. Takuro Kometani, Technician
6. Ms. Rie Hiyane, Technician
7. Ms. Shizuka Kuda, Research Unit Administrator

## 2. Collaborations

- ⇒ **Theme: An advanced wastewater treatment technology development for swine farms**
- Type of collaboration: Joint research and development
    - *Okinawa Prefecture Environment Science Center*
    - *Okinawa Prefecture Grassland and Livestock Research Center*
    - *NIKKO Company*
- ⇒ **Theme: Development of low-cost datalogger, potentiostat, and remotely accessible switch timers**
- Type of collaboration: Joint research and development
    - *Prof. Yasunori Osana, University of the Ryukyus, Faculty of Engineering (University of Kumamoto)*
    - *HugKun Company (Okinawa)*
- ⇒ **Theme: Technical discussion regarding organofluoride compounds (PFOS, PFOA) in Okinawa and its removal.**
- Type of collaboration: Technical advice
    - *Okinawa Environmental Engineering*
    - *Kadena Town Office*
- ⇒ **Theme: Optimal ethanol concentration to enhance microbial fuel cells**
- Type of collaboration: Technical advice (internship)
    - *Nagaoka University of Technology*

### 3. Activities and Findings

#### 3.1.1. R&D on swine wastewater treatment technology for simultaneous removal of nitrate and organics using bioelectrochemical systems (BES)

The amount of wastewater generated by intensive pig farming exceeds the available capacity for treatment and recycling. The global concern regarding the removal of nitrate from wastewater arises from its harmful impact on human and environmental health. Currently, the nitrate-nitrogen discharge limit for livestock wastewater is given special consideration at 400 mg/L in Japan. However, it is expected to be reduced to the general discharge standard of 100 mg/L shortly, aligning with regulations for other industries. Consequently, finding a cost-effective solution for nitrate removal in the livestock industry is an urgent matter.

To address these issues, our Unit has been developing biocathode technology that can simultaneously treat organics and nitrate in real swine wastewater. In this system, the raw wastewater, which contains high levels of organic compounds (2,000-6,000 CODcr mg/L after liquid-solid separation) and volatile fatty acids (~1200 mg/L) responsible for unpleasant odors, is oxidized by the anaerobic microbial community in the anode chamber. This reduces the required aeration time and the need for excess sludge removal. At the same time, nitrate (30-150 NO<sub>3</sub><sup>-</sup>-N mg/L) in the aerated wastewater acts as an electron acceptor and is converted to dinitrogen through denitrification by the cathodic microbial community. One advantage of this system is its ability to operate denitrification at a low wastewater COD/N ratio.

Since FY2021, we collaborated with Nikko Company and the Okinawa Prefecture Environment Science Center to operate and optimize the scale-up reactors of 525L at the Okinawa Grassland and Livestock Research Center, adjacent to the swine aeration system. We tested a configuration of two anode chambers (340L) and one cathode chamber (170L), more cost-effective organic removal from raw wastewater to meet farmers' needs. Throughout the year, among the on-site organic range we tested (1500-4500 CODcr mg/L) we achieved an average of 40% COD removal per day (Fig. 1) and 30-40% nitrate-nitrogen removal in 2 days.

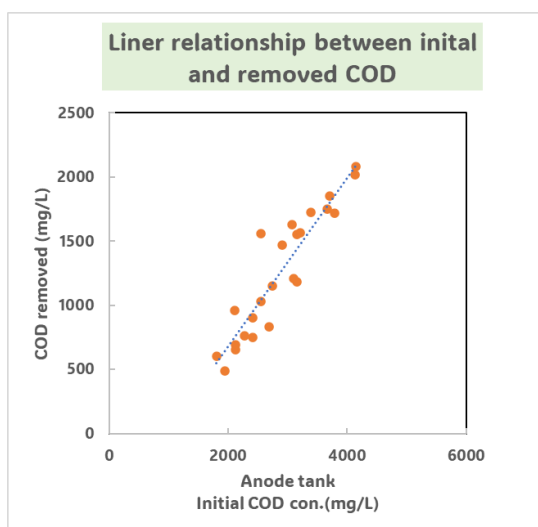


Fig. 1. The relationship between initial and removed CODcr of organics in raw wastewater treating (anode) chamber.

The anodic communities included electrogenic bacteria and microbes responsible for Direct Electron Transfer Systems (DIET). The cathodic communities included electrotrophic denitrifying bacteria and anammox.

The technology will be licensed to NIKKO Company to continue further development towards commercialization.

To make the new reactors more commercially viable, we worked with Professor Osana at the University of the Ryukyus to reduce the cost of the commercial data logger. We aimed to create an IoT (Internet of Things) prototype for field testing at a lower cost, serving as an alternative to the expensive scientific equipment used during development to demonstrate the potential cost reduction using customized electronics.

A video introduction of the system:

Revolutionizing Swine Farming: Cost-Effective Wastewater Treatment & Nutrient Recovery Innovation

<https://groups.oist.jp/ja/innovation/post/2024/03/07/revolutionizing-swine-farming-cost-effective-wastewater-treatment>

## 5. Grants

- Proof of Concept (POC)2 FY2022-23. Cost-effective and low-maintenance scale-up advanced wastewater treatment and nutrient recovery for swine farms.
- Okinawa Innovation Ecosystem Join Research Promotion Grant. FY2022-23 Development of environmentally concerned scale-up advanced wastewater treatment system.

## 6. Publications

1. Global sensitivity analysis for investigation of bacterial physiology in complex media with FBA-PRCC A Sorokin, I Goryanin, bioRxiv, 2024.02. 14.580207 2024
2. A novel platform for meta-omics analysis. Pilot study on inhaled corticosteroids in asthma patients with side effects A Sorokin, M Seitov, B Emilov, M Iskakov, B Osmonov, I Goryanin, Research Square 2023
3. Age-Related Changes in the Temperature of the Lumbar Spine Measured by Passive Microwave Radiometry (MWR) AV Tarakanov, AA Tarakanov, EG Skorodumova, N Roberts, T Kobayashi, ... I. Goryanin Diagnostics 13 (21), 3294, 2023
4. Using AI and BES/MFC to decrease the prediction time of BOD5 measurement I Medvedev, M Kornaukhova, C Galazis, B Lóránt, GM Tardy, A Losev, ..., I. Goryanin, Environmental Monitoring and Assessment 195 (9), 1018, 2023
5. Diagnostic of Patients with COVID-19 Pneumonia Using Passive Medical Microwave Radiometry (MWR) B Emilov, A Sorokin, M Seiitov, BT Kobayashi, T Chubakov, S Vesnin, ...Diagnostics 13 (15), 2585 2023
6. Diagnostics and prevention of sports-related traumatic brain injury complication OA Shevelev, AV Smolensky, MV Petrova, EM Mengistu, AA Mengistu, ...RUDN Journal of Medicine 27 (2), 254-264 2023

7. Concurrent raw and aerated wastewater treatment method using bioelectrochemical system M Kainuma, A Prokhorova, R Hiyane, M Kazeoka, I Goryanin, P Babiak, US Patent App. 18/076,860 2023
8. Correction of local brain temperature after severe brain injury using hypothermia and medical microwave radiometry (MWR) as companion diagnostics OA Shevelev, MV Petrova, EM Mengistu, MY Yuriev, IZ Kostenkova, ...Diagnostics 13 (6), 1159, 2023
9. FBA-PRCC. Partial Rank Correlation Coefficient (PRCC) Global Sensitivity Analysis (GSA) in Application to Constraint-Based Models A Sorokin, I Goryanin Biomolecules 13 (3), 5002023
10. Diagnostic of Patients with COVID-19 Pneumonia Using Passive Medical Microwave Radiometry (MWR). B Emilov, ...I. Goryanin Diagnostics 2023, 13, 2585

## 8. Invited talks

Mami Kainuma (Nov. 30, 2023) Diversity Symposium and Panel discussion organized by Japan Society for Bioscience, Biotechnology and Agrochemistry (Gender Equality and Diversity Promotion) “Rethinking Work: A 10-year future perspective on Career and Life Event”

「キャリアとライフイベントから考える働き方改革～10年後の自分を想像してみよう～」  
日本農芸化学会 2023 年度男女共同参画シンポジウム (講演とパネルディスカッション)