

Research Project Report

Program for Asia-Japan Research Development, Asia-Japan Research Institute

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Environmental Engineering for Supporting Agriculture, Livestock, and Fisheries

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Background and Significance of this Research

Vietnam has attained the highest GDP growth rate among developing nations in the East Asia-Pacific region. Japan, as the largest donor of Official Development Assistance (ODA), also contributes significantly to economic cooperation. With a growing number of Japanese small- and medium-sized enterprises seeking to establish operations in Vietnam, addressing environmental pollution of the atmosphere, rivers, and oceans resulting from industrial development is the shared responsibility of both Vietnam and Japan. Vietnam's primary industries include agriculture, livestock, and fisheries, with the environmental preservation of farmland and fishing grounds being crucial for sustainable economic development, food safety, and security.

In Vietnam, the excessive application of pesticides, chemical fertilizers, and antibiotics to boost yields has led to contamination of the agricultural, livestock, soil, and water environments. Additionally, there has been an increase in violations of the Food Sanitation Act concerning pesticides and veterinary medicines in foods imported from Vietnam to Japan. Moreover, as Vietnam's primary industry workers possess a low level of safety awareness, there is an urgent need to disseminate safe and secure agricultural, livestock, and fishery production methods among producers. In response to requests for enhancing the quality of education in Vietnam, the Japan International Cooperation Agency (JICA) signed an implementation agreement with the Vietnam Japan University (VJU) to establish a master's course in 2015, with Ritsumeikan University collaborating as a lead institution in the Environmental Engineering course, inaugurated in 2016. Students who graduated from VJU and enrolled in the doctoral program of Ritsumeikan University have shown an interest in livestock wastewater treatment and the effective utilization of fishery waste since their time at VJU.

It is anticipated that Japan's environmental technology, informed by its own experiences with pollution issues, will be applied in Vietnam, exemplified by initiatives such as the Ministry of the Environment's Asian Water Environment Improvement Model Project and Shiga Prefecture's Water

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Environment Business Overseas Expansion Model Project Subsidy. Although some progress has been made in the treatment of urban sewage and industrial wastewater, the current efforts are insufficient to address Vietnam's specific agricultural, livestock, and fishery challenges, which is the primary objective of this project.

Objectives

This research aims to solve environmental problems related to agriculture, livestock, and fisheries in Vietnam, and to develop elements of sustainable environmental technology, propose systems, and evaluate them from three perspectives: water circulation, resource circulation, and food production. Building upon previous research accomplishments and established human resource networks, this project aims to train graduate students from Vietnam at our university to become emerging researchers. This initiative seeks to contribute to the future enhancement of amicable relations between Vietnam and Japan.

Actual Activities

(1) Constructed Wetlands for Treating Livestock Wastewater

In northern Vietnam (e.g., Hoai Duc District, Hanoi), pig farming is thriving, resulting in the generation of large amounts of highly concentrated wastewater. Anaerobic biological treatment is mainly used, but it is not sufficient to prevent water pollution. Therefore, advanced treatment using constructed wetlands and duckweed-based oxidation ponds is promising. This process is expected to contribute to water purification by absorbing nitrogen and phosphorus, and also to enable recycling into feed and fertilizer resources since aquatic plants such as duckweed and water spinach accumulate starch.

(2) Development of an Artificial Wetland System Using Recycled Fishery Waste

Vietnam has an active aquaculture industry, and a large amount of waste such as clam shells is generated in Thai Binh and other provinces. The goal of this project is to develop a technology to remove heavy metals from mine wastewater by using constructed wetlands that utilize clam shells as filtering material.

Result and Perspectives

(1) Soil Adsorption, Photodegradation, and Removal of Antibiotics from Water by Duckweed:

Case Studies Examining Erythromycin, Lincomycin, and Others

For obtaining fundamental data about the treatment of ampicillin (ABPC), oxytetracycline (OTC), erythromycin (EM), and lincomycin (LCM) in water environments, distributions of resistant bacteria, soil adsorption, photodegradation, and removal by duckweed were studied. Against the total population of heterotrophic bacteria in a water sample from Lake Biwa, bacteria resistant to 50 mg/L ABPC, OTC, EM, and LCM were, respectively, 4.3, 19, 2.5, and 26%. During the soil adsorption test, ABPC and OTC at 10 mg/L decreased respectively to 81% and 15% in 2 days. Under sunlight, 1.0 mg/L OTC and EM decreased respectively to <0.5% and 58% in 5 days. The duckweed uptake test results showed that 0.1 mg/L ABPC and EM decreased respectively to 28% and 21% in 7 days. These

results are summarized in Figure 1 and demonstrate that LCM was only slightly adsorbed into soil, photodegraded, or removed by duckweed, indicating its persistence in water environments.

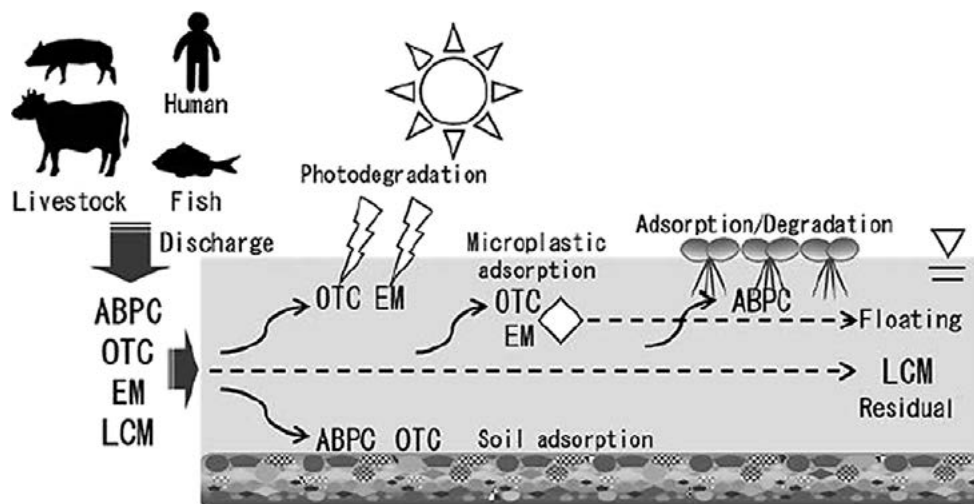


Figure 1. Possible behaviors of ABPC, OTC, EM, and LCM in water environment

(2) Image Analysis for Estimation of Biomass and Nutrient Removal of Duckweed *Lemna aoukikusa*, *Spirodela polyrhiza*, and *Wolffia globosa* in Lab-Scale Cultivation

Image analysis was applied for the non-destructive measurement of the respective frond areas of three duckweed species. As shown in Figure 2, the dry biomass (y , mg) was found to be proportional to the frond area (x , cm^2) measured by image analysis as follows: $y = 1.99x - 0.24$ for lesser duckweed *Lemna aoukikusa*, $y = 2.36x - 3.22$ for giant duckweed *Spirodela polyrhiza*, and $y = 1.17x + 0.91$ for rootless duckweed *Wolffia globosa*. These duckweed species were cultivated separately for 7 days in a modified Hoagland medium under laboratory batch conditions. Biomass growth and nitrogen and phosphorus removal in the medium could be quite accurately predicted from the changes in the frond areas and from the typical biomass yields of nutrients without disturbing the batch operations.

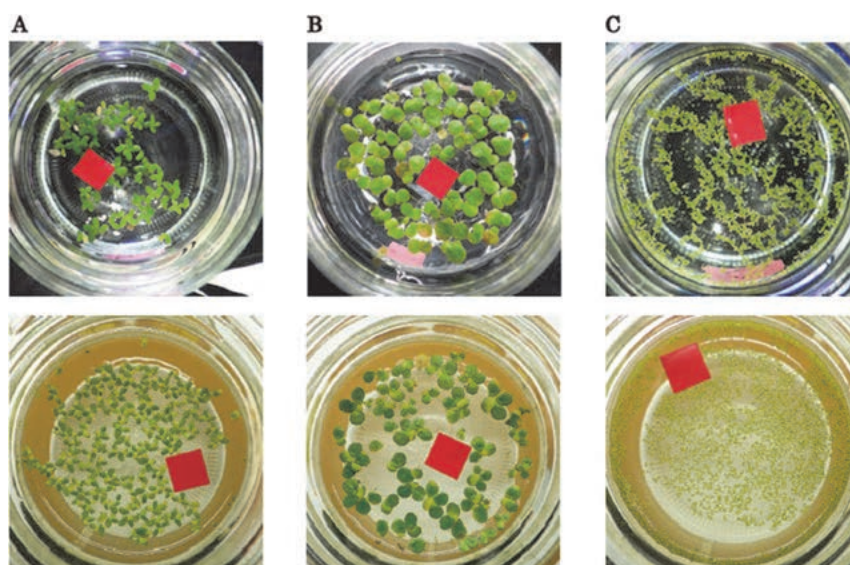


Figure 2. Duckweed used for this study. Healthy (upper) and withered (lower) conditions of *L. aoukikusa* (A), *S. polyrhiza* (B), and *W. globosa* (C). Red squares are 1.0 cm^2 area markers.

(3) Recycling Clamshells as Substrate in Lab-scale Constructed Wetlands for Heavy Metal Removal from Simulated Acid Mine Drainage

The feasibility of clamshells as a substrate in constructed wetlands (CWs) for removing heavy metals from acid mine drainage (AMD) was evaluated as summarized in Figure 3. Column-type CWs (ID 12.5 cm, H 50 cm) filled with clamshells or gravel were planted with cattails. Synthesized AMD containing 20 mg/L zinc (Zn), 0.3 mg/L cadmium (Cd), 20 mg/L copper (Cu), 1.1 mg/L lead (Pb), 0.6 mg/L manganese (Mn), and other minerals (pH=4.1) was fed to CWs (1 L/column) with hydraulic retention times of 2–7 days in sequencing batch mode. Results indicated higher metal removal in clamshell-based CWs with the pH neutralization than in gravel-based CWs. The removal efficiencies were 85.3–92.6%, 84.1–98.3%, 96.5–99.7%, 98.3–99.1%, and 64.0–83.8%, respectively, for Zn, Cd, Cu, Pb, and Mn. During 6 months of operation, 790.7 mg of Zn, 10.6 mg of Cd, 762.4 mg of Cu, 40.1 mg of Pb, and 19.9 mg of Mn were fed to each CW. Of those, the main metal-removal route was retention in the substrate, representing 49.7–82.5%, followed by plant uptake (16.1–39.0%), and other processes (0.6–3.2%). After treatment, the metal content of the clamshells had increased, while the calcium content was lower. The clamshell-based CWs extended the cattail root and incubated sulfate-reducing bacteria, increasing the population. These findings suggest a way of recycling clamshells as filter media in CWs for heavy-metal-rich wastewater treatment.

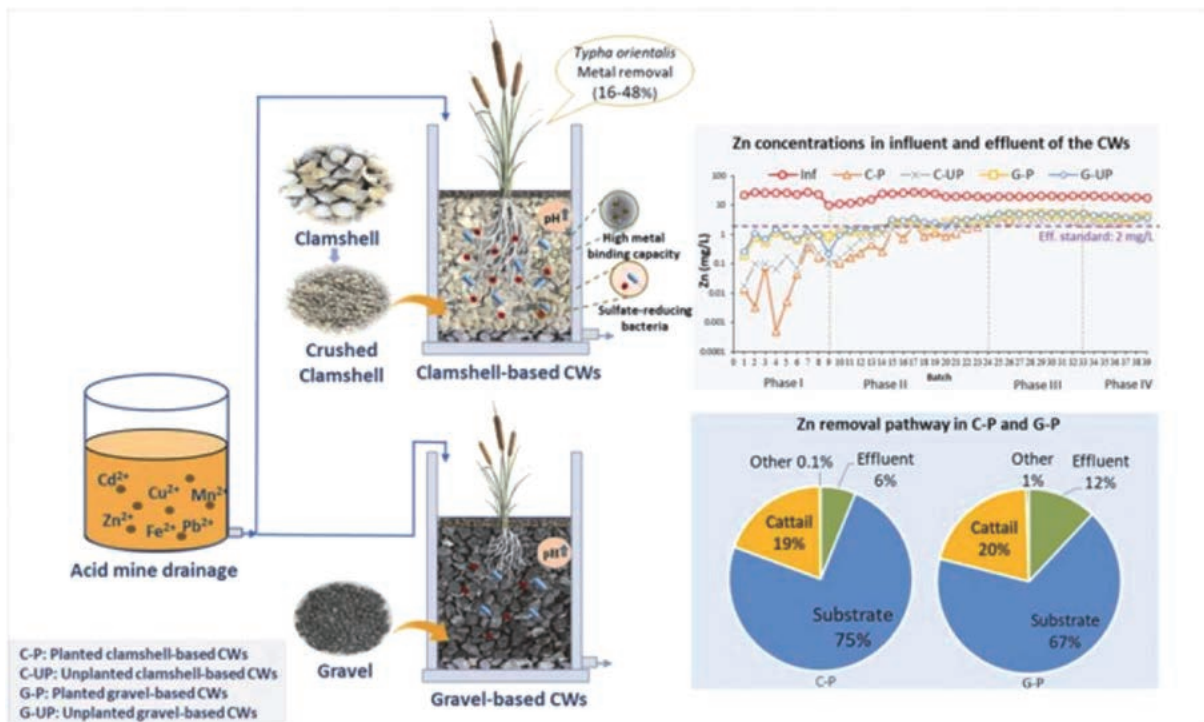


Figure 3. Diagram of lab-scale CWs for removing heavy metals from synthetic AMD

(4) Greywater Treatment Using Lab-scale Systems Combining Trickling Filters and Constructed Wetlands with Recycled Foam Glass and Water Spinach

A low energy-consuming system for greywater treatment was developed with a trickling filter (TF) followed by constructed wetlands (CWs), as summarized in Figure 4. The roles of substrates, plants, and microorganisms were intentionally explored. TFs and CWs were filled with recycled foamed glass. Water spinach and parsley planted in the CWs provided additional value. Microorganisms in the

system were characterized through carbon-utilization tests and 16S rRNA gene next-generation sequencing. In 5.5 months, TOC, TN, and TP removals from greywater were, respectively, 83.5, 85.5, and 92.1 %. TOC was removed in the TF at 22.6 g-C/m²/d. The CWs exhibited TN and TP removals at 0.44 g-N /m²/d and 0.19 g-P/m²/d. Water spinach was harvested at 792 g-wet/m²/week, accounting for 7.1 % and 12.6 % for TN and TP removals. Denitrification, microbial diversity, and carbon source utilization potentials were enhanced by water spinach. This is a sustainable wastewater treatment model that uses recycled materials and edible plants.

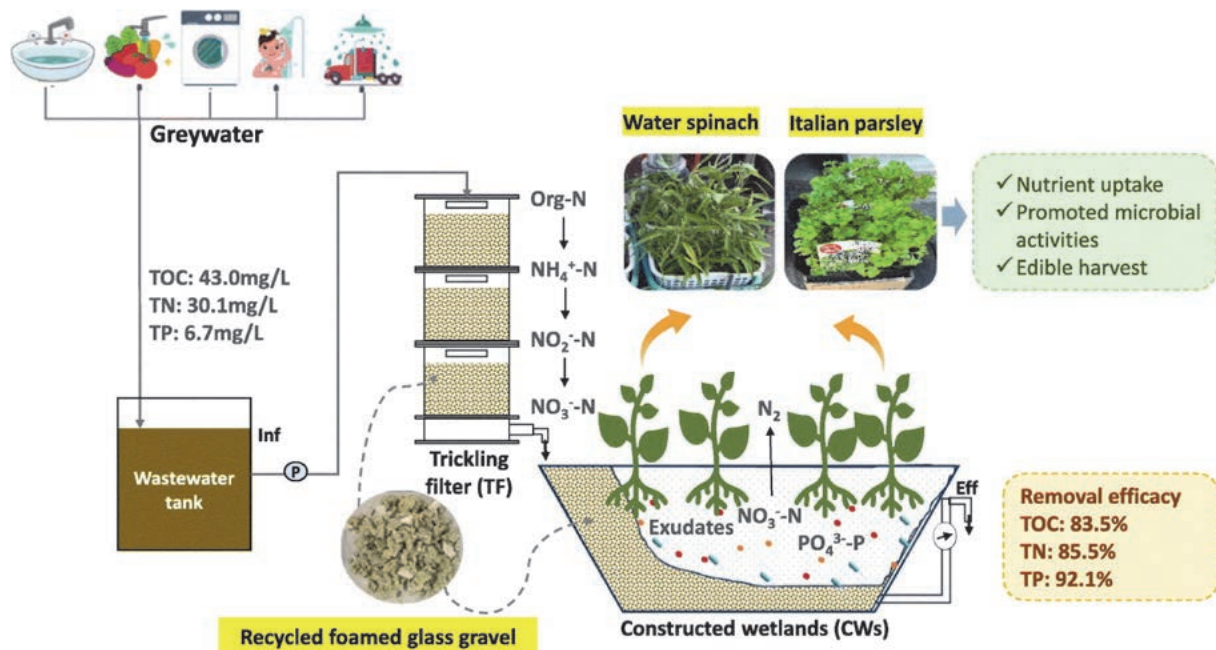


Figure 4. Diagram of the trickling filter (TF) and constructed wetland (CW) systems used for greywater treatment. CW-A was planted with water spinach (Phases 1–3) and parsley (Phase 4). CW-B was left unplanted during the whole process.

Project Members and Roles

- SODA Satoshi. Professor, College of Science and Engineering, Ritsumeikan University. Project leader. Supervising and designing wastewater treatment systems.
- NAKAJIMA Jun. Professor Emeritus, College of Science and Engineering, Ritsumeikan University. Environmental systems engineering.
- AMANO Koji. Professor, College of Gastronomy Management, Ritsumeikan University. Environmental systems engineering, food and water consumption.
- CHIKAMOTO Tomoyuki. Professor, College of Science and Engineering, Ritsumeikan University. Building engineering and natural energy.
- LI Asuka. Associate Professor, College of Science and Engineering, Ritsumeikan University. Building engineering and natural energy.
- SATO Keisuke. Associate Professor, College of Science and Engineering, Ritsumeikan University. River basin environment information engineering.
- HASEGAWA Tomoko. Associate Professor, College of Science and Engineering, Ritsumeikan University. Climate change impact assessment.
- SHIMIZU Toshiyuki. Associate Professor, College of Science and Engineering, Ritsumeikan University, 2018–2022. Associate Professor, Fukuyama City University. Water and wastewater engineering.

- YOTSUI Saki. Assistant Professor, College of Science and Engineering, Ritsumeikan University, 2020–2022. Natural disaster science/disaster prevention science.
- KAWASAKI Etsuko. Visiting Researcher, Ritsumeikan University. Hiyoshi Corporation. Environmental analytical chemistry.
- NGUYEN Thi An Hang. Associate Professor, Vietnam-Japan University. Environmental engineering.
- ISHIMOTO Chikako. Ph.D. course student, 2019–2021, Visiting Researcher in 2021–present, Ritsumeikan University. Shizuoka Prefectural Livestock Technology Research Institute Small and Medium-sized Livestock Research Center. Animal husbandry and wastewater treatment.
- DINH Thi To Uyen. Ph.D. course student, 2018–2022, Ritsumeikan University. Environmental systems engineering.
- NGUYEN Thi Thuong. Ph.D. course student, 2019–2022 and Researcher from 2023–present, Ritsumeikan University. Environmental systems engineering.
- PHAM Thi Kieu Chinh. Ph.D. course student, 2021–2024, Ritsumeikan University. Environmental systems engineering.
- WANG Rongxuan. Researcher, 2023–2025, Ritsumeikan University. Environmental systems engineering.

Selected List of Publications

Peer-reviewed papers

- 1) 惣田訓, 清水聡行, 芳野浩志, 中島淳 (2022) 「微細気泡オゾン処理—生物処理によるフミン酸試薬の3次元励起—蛍光スペクトルの変化」. 『日本水処理生物学会誌』, 58(2), 55–60.
- 2) Nguyen, T.T, Huang, H., Nguyen, T.A.H., Soda, S. 2022. Recycling Clamshell as Substrate in Lab-scale Constructed Wetlands for Heavy Metal Removal from Simulated Acid mine Drainage. *Process Saf. Environ. Prot.*, 165, 950–958.
- 3) Dinh, T.T.U., Semba, S., Nakajima, J., Soda, S. 2022. Image Analysis for Estimation of Biomass and Nutrient Removal of Duckweed *Lemna aoukikusa*, *Spirodela polyrhiza*, and *Wolffia globosa* in Lab-scale Cultivation. *Jpn. J. Water Treat. Biol.*, 58(1), 35–43.
- 4) Rose, S.K., Popp, A., Fujimori, S., Havlik, P., Weyant, J., Wise, M., ...Hasegawa, T., et al. 2022. Global Biomass Supply Modeling for Long-run Management of the Climate System. *Climatic Change*, 172, Article 3.
- 5) Nyairo, R., Hasegawa, T., Fujimori, S., Wu, W., Takahashi, K. 2022. Socio-economic Trajectories, Urban Area Expansion and Ecosystem Conservation Affect Global Potential Supply of Bioenergy. *Biomass and Bioenergy*, 159, 106426.
- 6) Nguyen, T.T., Soda, S., Horiuchi, K. 2022. Removal of Heavy Metals from Acid Mine Drainage with Lab-scale Constructed Wetlands Filled with Oyster Shells. *Water*, 14 (20), 3325.
- 7) Pramugani, A., Shimizu, T., Goto, S., Argo, T. A., Soda, S. 2022. Decolorization and Biodegradability Enhancement of Synthetic Batik Wastewater Containing Reactive Black 5 and Reactive Orange 16 by Ozonation. *Water*, 14 (20), 3330.
- 8) 加藤慎之介, 中條明人, 野村快斗, 惣田訓 (2022) 「散水ろ床フォトリアクターによる合成廃水の処理: 有機物除去と硝化への水理学的滞留時間の影響」. 『環境技術』, 51, 308–315.
- 9) 和木美代子, 石本史子 (2022) 「養豚排水からの窒素除去における従来技術とアナモックス処理の現状と課題」. 『日本水処理生物学会誌』, 58, 115–126.
- 10) Soda, S., Fujii, D., A, D., Ike, M. 2023. Chemical and Biological Assay-based Characterization of Leachate before and after Treatment at Waste Landfills in Ho Chi Minh City, Vietnam. *Asia-Japan Research Academic Bulletin*. 4, 4.0_33.
- 11) Soda, S. and Nguyen, T. T. 2023. Classification of Mine Drainages in Japan Based on Water Quality: Consideration for Constructed Wetland Treatments. *Water*, 15(7), 1258.
- 12) 惣田訓, 児島直美 (2023) 「平野川底質改善実証実験における南弁天橋地点の底質微生物叢の変化」. 『水環境学会誌』, 46(9), 141–148.
- 13) 後藤慎平, 清水聡行, 惣田訓 (2023) 「リアクティブオレンジ 16 とリアクティブブラック 5 を含む模擬廃液の脱色と生分解性の向上のためのオゾン処理」. 『日本水処理生物学会誌』, 59(3), 33–37.

- 14) Fujimori, S., Oshiro, K., Hasegawa, T., Takakura, J., Ueda, K. 2023. Climate Change Mitigation Costs Reduction Caused by Socioeconomic-technological Transitions. *npj Climate Action* volume 2, Article number: 9.
- 15) Park, C. Y., Takahashi, K., Li, F., Takakura, J., Fujimori, S., Hasegawa, T., Thiery, W. 2023. Impact of Climate and Socioeconomic Changes on Fire Carbon Emissions in the Future: Sustainable Economic Development Might Decrease Future Emissions. *Global Environmental Change*, 80, 102667.
- 16) Yazawa, T., Morita, A., Shimizu, T. 2023. Assessment of Basin-scale Water Stress Using Geographic Information System in Southeast Asian Countries with Megacities. *The Journal of Indonesia Sustainable Development Planning (JISDeP)*, 4(1) 1–20.
- 17) Pham, C. T. K., Sawada, K., Soda, S. 2023. Characterization of a Moderately Halotolerant Antimony-removing *Desulfovibrio* sp. Strain Isolated from Landfill Leachate. *Water*, 15(22), 3872.
- 18) Srivastava, P., Marquez, G. P., Gupta, S., Mittal, Y., Soda, S., Dwivedi, S., Odedishemi, A. F., Freguia, S. 2024. Diversity of Anaerobic Ammonium Oxidation Processes in Nature. *Chem. Eng. J.*, 483, 149257.
- 19) 澤田和子, 北條雄大, 清水聡行, 惣田訓 (2023) 「水中の抗菌薬の土壌吸着, 光分解, ウキクサによる除去: エリスロマイシンやリンコマイシン等を例として」. 『環境技術』, 52(6), 296–304.
- 20) 清水聡行, 神子直之, 奥田康洋, 藤原柊斗 (2023) 「物質毎の 222nm 紫外線吸収エネルギーに着目した促進酸化法による LAS 分解の評価」. 『土木学会論文集』, 79(25), 23-25003.
- 21) 矢澤大志, 庄司純音, 清水聡行 (2023) 「地域総合化による琵琶湖・淀川流域の降水日および雨日継続特性の空間分析」. 『環境システム計測制御学会 (EICA) 誌』, 28, 2/3, 46–55.
- 22) Mishima, I., Yoshikawa, N., Asakawa, S., Noguchi, Y., Amano, K. 2023. Life-cycle Analysis of Environmental Loads from Household Septic Systems in Japan Focusing on Effluent Water Discharge. *Water Science & Technology*, 88(11), 2719–2732.
- 23) Nguyen, T.T., Zhang, Z., Wang, R., Sawada, K., Soda, S. 2024. Greywater Treatment Using Lab-scale Systems Combining Trickling Filters and Constructed Wetlands with Recycled Foam Glass and Water Spinach. *Bioresour. Technol. Rep.*, 27, 101915.
- 24) Yamamoto, A., Eguchi, H., Soda, S. 2024. Removal of Reactive Yellow 86 from Synthetic Wastewater in Lab-scale Constructed Wetlands Planted with Cattail and Papyrus. *Appl. Sci.*, 14(15), 6584.
- 25) Pham, C.T.K., Aoyama, Y., Sawada, K., Soda, S. 2024. Antimony Removal in a Lab-scale Anaerobic Upflow Fluidized Bed Reactor Packed with PVA Gel-beads Inoculated with a *Desulfovibrio* sp. Strain. *Jpn. J. Water Treat. Biol.*, 60(3), 39–49.
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- 27) Deng, Y., Liu, W., Nguyen T. T., Di, H. J., Lian, Y., Yang, J., A, D., Qiu, R. 2024. Exploring the Efficiency of Tide Flow Constructed Wetlands for Treating Mariculture Wastewater: A Comprehensive Study on Antibiotic Removal Mechanism under Salinity Stress. *Water Research*, 258, 121738.
- 28) Nguyen, T.T., Huang, H., Oda, M., Soda, S. 2024. Constructed Wetlands Planted with Iris for Treatment of Wastewater Simulating a Typical Mine Drainage in Japan: Effects of Organic-feeding on Removal of Zn and Cd. *J. Asia-Japan Res. Inst. Ritsumeikan U.*, 6, 35–50.
- 29) 惣田訓, 片岡弘貴, ZHOU Xinge, SEBASTEIN Blessen, 佐藤由也, 羽部浩 (2024) 「人工湿地による坑廃水からの亜鉛除去と土壌細菌へのヨシの影響」. 『環境技術』, 53 (6), 306–313.
- 30) 惣田訓, 澤田和子 (2025) 「合流式下水道越流水の放流時の平野川表層水の微生物叢の調査」. 『水環境学会誌』, 48, 11–18.

Other articles

- 1) Soda, S. 2022. Book Review: Modern Asia and Environmental Issues: Diversity and Dynamism Edited by Tomoyo TOYOTA, Yasuhiro HAMADA, Yuji FUKUHARA, Shintaro YOSHIMURA, Tokyo, Kadenshya, 2020. *Asia-Japan Research Academic Bulletin*, 3(3), 73–74.
- 2) 石本史子 (2023) 「養豚廃水処理施設におけるアナモックスを用いた窒素除去」. 『環境技術』, 52(3), 162–166.
- 3) 惣田訓 (2023) 「書評『現代適正技術論序説 —近代科学技術に代わる技術体系をめぐって—』」. 『環境技術』,

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- 4) 惣田訓、グエン ティ トゥオン (2024) 「人工湿地によるカドミウム含有坑廃水の現地処理実験」.『環境技術』, 53, 76–79.
- 5) 小田柿喜暢, 木下盛年, 堤幸一, 佐藤圭輔, 惣田訓 (2024) 「ベトナムにおける微生物・植物による水質浄化 —滋賀県水環境ビジネス海外展開事業化モデル事業における取組み—」.『環境技術』, 53(5), 253–256.
- 6) 惣田訓 (2024) 「書評『トイレからはじめる防災ハンドブック 自宅でも避難所でも困らないための知識』」.『環境技術』, 53(5), 273.
- 7) 清水聡行, 木村昌弘, 米谷直晃, 山口岳夫 (2025) 「奄美群島の水供給の現状と課題」.『環境技術』, 54(2) 66–71.
- 8) 惣田訓, Nagarajan GANAPATHY, Debraj BHATTACHARYYA (2025) 「立命館大学とインド工科大学ハイデラバード校の相互学生短期派遣 2023, 2024」.『立命館大学理工学部紀要』, 83, 51–59.

Books

- 1) 惣田訓 (2023) 「第 13 章 環境都市工学分野における留学生の短期研修プログラム」. pp.235–250. 太田亨、安龍沫、村岡貴子、門倉正美 編：『日本で学ぶ理工系留学生. ココ出版.
- 2) Nguyen, T. A. H., Bui, T. H., Nguyen, T. T., A, D., Soda, S. 2025. Constructed Wetlands for Sustainable Bioremediation of Antibiotics from Wastewater: Potential and Challenge. P. Lens & B. X. Thanh (Eds.). In *Nature-Based Solutions for Urban Sustainability*. pp. 61–95, IWA Publishing.

Selected list of Research Funding/Grant

惣田訓, 清水聡行. 公益財団法人大林財団研究助成. インドネシア地方都市の環境保全を目指したバティック廃水処理装置. 2022 年度

惣田訓, 清水聡行. 公益財団法人前田記念工学財団研究助成. 散水ろ床と人工湿地を組み合わせた難分解性有機物除去機能を強化した省エネルギー型下水処理システム. 2022 年度

惣田訓. 令和 4 年度休廃止鉱山における坑廃水処理の高度化技術調査事業に係るパッシブトリートメント導入に向けた調査研究. 人工湿地方式のメカニズム解明と処理条件の最適化の検討. 2022 ~ 2023 年度

清水聡行 (代表者) 基盤研究 (C) 人口減少が進む中小規模の水道事業を対象とした持続的可能な水供給システム. 2021 ~ 2023 年度

李明香 (代表者) 若手研究 自然エネルギーと天井裏空間の蓄熱容量を利用した空気循環システムの提案. 2022 ~ 2024 年度

長谷川知子 (代表者) 研究活動スタート支援 食料安全保障と生態系保全を考慮した世界規模の植林吸収ポテンシャルの推計. 2022 ~ 2023 年度

川越保徳 (代表者), 惣田訓 (分担者) 基盤研究 (B) 海水・淡水 Anammox 混合培養系の部分亜硝酸化 -Anammox- 脱窒法への展開. 2022 ~ 2025 年度

清野純史 (代表者), 四井早紀 (分担者) 基盤研究 (B) 多様な発生形態を有する南海トラフ地震に対応可能なライフライン防災に関する研究

伊津野和行 (代表者), 四井早紀 (分担者) 基盤研究 (B) 橋梁の対水害設計法の構築と桁流失防止対策の開発に関する研究.

惣田訓, 澤田和子 : ((株) 日吉共同研究) 琵琶湖内湖・西の湖における環境変動に対応した水質浄化・管理技術の研究開発 ~淡水真珠稚貝養殖手法および水道水カビ臭原因プランクトン 特定システム~. 2023 年度

惣田訓: 科学技術振興機構さくらサイエンスプラン「日印のインフラ環境と科学技術」2023 年度

惣田訓 : ((株) 水 ing) 食物連鎖を利用した水処理及び余剰汚泥減容化. 2024 年度

Nguyen Thuong Thi (代表者) 科研費研究活動スタート支援. Development of Hybrid Multi-stage Constructed Wetlands Based on Indigenous Adsorptive Materials for Sustainable Heavy Metal Treatment from Mine Drainages in Japan. 2023 ~ 2024 年度

惣田訓: 受託事業 (キョーラク (株)) 活性汚泥法の効率改善に関する技術開発. 2023 ~ 2024 年度

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