The SyDE Program Student Essay Collection No.1 (FY2024)

Introduction of my research topic / The link between sustainable societies and my research

Tohoku University

WISE program for Sustainability in the Dynamic Earth

2024

SyDE
WISE Program for Sustainability in the Dynamic Earth

CONTENTS

Understanding Mechanisms of Electron Acceleration in Aurora Generation

Koseki Saito (Dept. Geophys., Grad. Sch. Sci., D3)

Auroras are beautiful light displays seen in the Earth's polar regions, occurring at altitudes between 90 and 500 km. Although these lights appear in the atmosphere, their origin is strongly influenced by the sun and the magnetosphere, and the region of space around the Earth dominated by its magnetic field. The energy that powers auroras originates from the sun. The sun emits a flow of charged particles, known as solar wind, which travels through space along with a magnetic field. Some solar winds collide with Earth's magnetosphere, transferring energy into the magnetosphere and causing disturbances that accelerate charged gases, known as plasma, within the magnetosphere. This accelerated plasma then collides with atmospheric particles toward Earth's atmosphere. These collisions excite atmospheric particles, and as they return to their ground state, they release light, which we refer to as auroras. This process involves complex interactions between the Sun and the Earth's environment. However, several aspects of these processes, such as the exact mechanism of plasma acceleration in the magnetosphere, are not fully understood.

Researchers have studied the processes that generate auroras using various methods, including developing observation equipment such as satellites and ground-based radar, analyzing the data obtained, constructing theoretical models, and performing numerical simulations. Our research focuses on understanding how plasma, particularly electrons, is accelerated within Earth's magnetosphere and then falls into the atmosphere. We address two main research questions: understanding the spatial distribution of plasma within the magnetosphere and examining how electromagnetic waves within the magnetosphere accelerate electrons.

In the first research topic, plasma within the magnetosphere is distributed according to forces such as the centrifugal force from Earth's rotation, gravity, and the force exerted by the magnetic field. Electromagnetic waves propagate through the plasma in the magnetosphere. The propagation speed of these waves is determined by the plasma density and temperature, similar to how quickly sound travels through air, which is determined by the atmospheric temperature. Because electromagnetic waves accelerate plasma, constructing a theoretical model that determines the spatial distribution of plasma and the propagation speed is an important research topic for understanding how these waves accelerate plasma. We developed a new theoretical model that

considers the spatial variation in the magnetic field and the electrical balance between ions and electrons in the plasma, improving upon existing models [Saito et al., 2023, DOI: 10.1029/2023JA031660].

The second research topic is the electron acceleration by electromagnetic waves in the magnetosphere. Energy from the sun disturbs the magnetosphere, generating electromagnetic waves that accelerate electrons and cause them to fall into the Earth's atmosphere. One key acceleration process involves the electric field component of these waves, which can trap and transport electrons toward Earth. As these waves propagate closer to the Earth, their speed increases, allowing the trapped electrons to accelerate along with the waves and eventually descend into the atmosphere. This acceleration process is well understood for simple cases with uniform magnetic fields. However, in the real magnetosphere, where the magnetic field weakens with distance from Earth, the process is more complex and is not fully understood. We clarify these processes using theoretical studies and numerical simulations to enhance our understanding of the conditions under which electrons are significantly accelerated.

In conclusion, our research focused on the electron acceleration processes related to aurora generation. These processes are not only important for understanding magnetospheric science, including auroras, but also have broader implications in fields such as astronomy and nuclear fusion science, where similar plasma acceleration processes occur. The detailed theories developed in this study contribute significantly to these fields.

Development of an Energy-Efficient and Energy-Generating Treatment Method for Swine Wastewater Using a Combination of UASB and Anammox Processes.

SHEN Junhao

Research Background:

Creating a "circular society" is an urgent task, and biomass energy is gaining attention as a renewable energy source. Livestock manure is a significant biomass resource, and its proper treatment can transform it into a valuable resource. Swine wastewater, with its high organic matter and nitrogen content, can cause environmental issues, such as bad odors, pests, and water pollution, if not properly treated. Additionally, antibiotic use in intensive farming poses risks to water systems and human health, requiring effective, low-cost, and highly efficient removal methods.

Research Objective:

The objective of this study was to assess the effectiveness and sustainability of combining methane fermentation and anammox technologies for swine wastewater treatment. Methane fermentation breaks down organic matter under anaerobic conditions to produce biogas, which offers benefits such as low energy use and stable performance. However, nitrogen was not effectively removed. Anammox is a promising technology for nitrogen removal, but it faces challenges such as long cultivation times and difficulty in handling organic matter. By combining these processes, their limitations can be addressed to enhance overall system performance.

Methodology:

The system was designed using two upflow anaerobic sludge blanket (UASB) reactors and one Air-Lift Reactor(ALR) connected sequentially: a methane fermentation UASB reactor, a partial-nitritation ALR reactor, and an Anammox UASB reactor. The setup was tested for efficiency and stability. Organic concentrations and antibiotic levels were measured in the wastewater before and after the methane fermentation process to evaluate their performance. The PN (Partial Nitritation) reactor aimed to stabilize the substrate supply for the anammox reactor, with adjustments made to the sludge concentration and aeration based on the organic and nitrogen levels. The Anammox reactor focuses on promoting the formation of hydroxyapatite (HAP) granules and studying the conditions influencing granule formation and treatment efficiency.

Methane Fermentation Results:

The UASB reactor maintained stable effluent quality despite changes in the organic concentration of the substrate, which varied seasonally between 2 g/L and 8.5 g/L. During colder months, COD

concentrations averaged approximately 7.5 g/L, whereas in warmer months, they dropped to approximately 2 g/L. The reactor's effluent COD remained steady at approximately 2 g/L. The granule size in the UASB reactor was correlated with the Organic Loading Rate (OLR), with larger granules observed at higher OLRs.

Antibiotics in wastewater include sulphonamides, macrolides, and hormones, with sulphonamides being the most common. Hormone concentrations were particularly high, exceeding 40 µg/L. The methane fermentation process was effective in removing hormones (up to 97%) but less effective for macrolides. It showed up to 81% removal efficiency for some sulfonamides.

In conclusion, the methane fermentation process effectively digested most of the organic matter, except for compounds resistant to biological degradation. It also showed moderate antibiotic removal with high efficiency for hormone reduction.

PN/Anammox Process Results:

The PN/anammox process included a PN reactor and an anammox reactor. The PN reactor provided a consistent ammonia-nitrite ratio for the anammox reactor. During the operation, an unexpected increase in the organic concentration was noted, likely due to the growth of other organisms and sludge dissolution.

The Anammox reactor used effluent from the PN reactor as its substrate, and its nitrogen removal performance was monitored. Strategies have been developed to maintain efficiency and stable nitrogen levels.

Conclusion:

The combined UASB and Anammox system offers a promising solution for swine wastewater treatment, achieving high performance with a low energy input. This system effectively removed organic matter and antibiotics, making it a sustainable and efficient method for swine wastewater management.

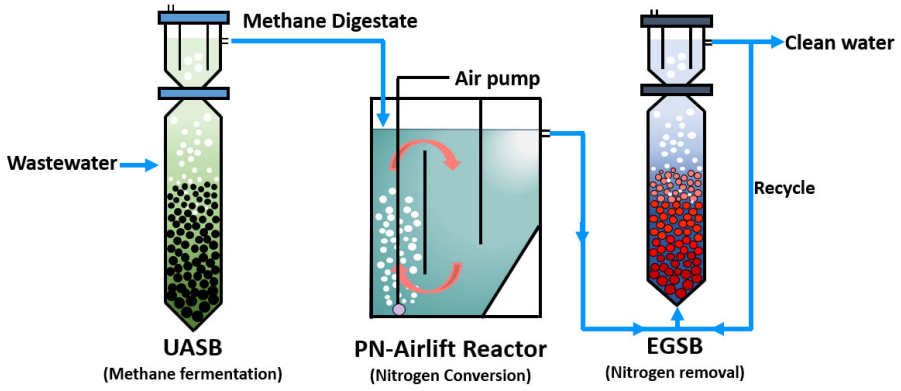

Figure. Swine wastewater treatment system combining methane fermentation with Anammox

Analysis of the topographic and backscatter strength characteristics of petit-spot volcanoes using seafloor acoustic survey data

Yuki Matamura

Petit spots are small monogenetic volcanoes observed in the outer-rise system prior to the subduction of oceanic plates (Fig. 1). Their geochemical variations in lava have provided new information about the Earth's interior, such as melt-ascending processes, asthenospheric components, and lithospheric metasomatism. Recent discoveries of primitive and silica-undersaturated petit spots indicate direct ascension from the upper mantle without the formation of magma reservoirs in the lithosphere. They are called direct ascending petit spots (DAPs) because they erupt in a highly limited area, specifically at the top of the outer rise, where the melt ascends within a shorter duration than that of previously reported petit-spot melts.

In addition to chemical composition, morphological parameters (such as volume, aspect ratio, distribution, and shape) may define petit spots morphologically, as the edifices are characterized by being quite small and amorphous in their morphology compared to other intraplate edifices (i.e., seamounts). Furthermore, the morphological definition of petit-spots enables us to clarify their broad distribution, leading to a better understanding of the bias and universality of petit-spot volcanism. Determining the types of petit spots and their distribution is important in estimating the global-scale heterogeneity of the upper mantle (Machida et al., 2009), the mass of CO_2 emissions from global petit spots (Okumura and Hirano, 2013), and identifying regions of intraplate coseismic slip propagation (Fujie et al., 2020). In this study, I show the relationship between petit-spot morphology and melt viscosity derived from in situ rock chemical composition and the potential for statistical classification of petit spots based on morphological information.

Multibeam echosounding (MBES) is an acoustic survey technique that transmits multiple directional acoustic beams in a fan shape from a vessel and measures the depth based on the time taken for sound waves to travel back and forth. It includes not only the topography of the ocean floor but also the backscatter strength of the sound waves (Fig.1, right). The characteristics of the seabed surface reflected in the backscatter strength include the sediment covering the seabed, which absorbs sound waves and weakens them. Conversely, if there are hard surfaces such as lava, a stronger intensity is observed. If the seabed surface is rough, sound waves are scattered more strongly, resulting in greater strength. Therefore, petit-spot volcanoes that occur on older sediment-covered plates show strong acoustic backscatter, which may originate from lava.

The MBES data were analyzed to identify petit spots using three morphological parameters: volume, surface area, and maximum specific relative height. Based on the area and volume, petit-

spot-like topographic highs were divided into two groups: high areas with high volume and high areas with low volume. The DAP belongs to the high area with a low-volume group. The melt viscosity of the petit-spot volcanoes was estimated based on the major elemental compositions of the collected samples (Sato Ph.D., 2018). The data show a correlation between magma viscosity and the aspect ratio of the volcanic edifices, revealing a quantitative relationship between morphological parameters and chemical composition through viscosity. Based on the morphological knowledge obtained from the new acoustic data and viscosity analysis, a clear possibility for the statistical classification of petit spots is proposed. The application of this concept to large datasets could accelerate further understanding of the spatial distribution of petit-spot volcanoes in deep-ocean basins.

The insights gained from this study on petit-spot volcanoes have important implications for a sustainable society. First, by clarifying the distribution of petit-spot volcanoes and estimating their CO2 emissions more accurately, we can better understand the impact of climate change and contribute to the development of policies to mitigate global warming. Furthermore, as future research sheds more light on the relationship between seismic activity and petit-spot volcanoes, it will aid in reducing disaster risk and improving disaster preparedness measures. Thus, the study of petit-spot volcanoes has the potential to contribute not only to the understanding of the Earth's internal structure but also to climate change mitigation and disaster risk management, which are crucial for achieving a sustainable society.

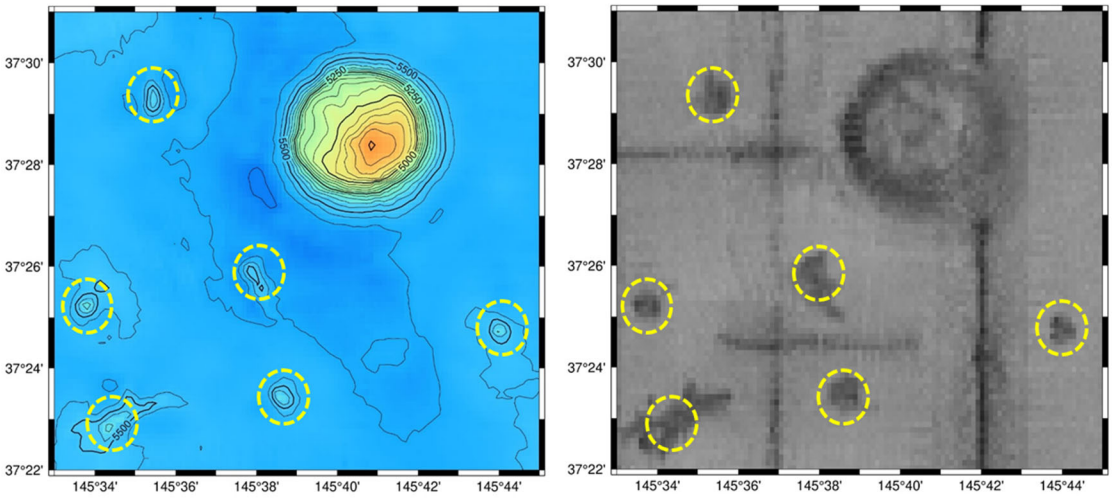

Figure 1. Topography map (left) and backscatter strength map (right). The dashed yellow circles are petit spots.

Efficient Nitrogen Removal by Using Partial-Denitrification/Anammox Process for Mainstream Wastewater Treatment

LUO ZIBIN

Sewage discharged from human activities contains a variety of toxic and harmful substances. If this sewage is continuously discharged into the ecosystem, the Earth's environment will continue to deteriorate, making it difficult for human beings to survive. The development of modern sewage treatment technology began in the Industrial Revolution of the late 19th century. In the early 20th century, the invention of the activated sludge process marked the beginning of modern biological treatment technologies. This process involves the metabolism of microorganisms to remove organic pollutants from the sewage. By the second half of the 20th century, wastewater treatment technologies were further improved and diversified, especially for the removal of nutrients such as nitrogen and phosphorus. Other nutrient removal technologies have been rapidly developed, such as the emergence of nitrification/denitrification and other processes, which make the wastewater treatment process more efficient. Nevertheless, the current implementation of this process is seen as economically and environmentally unsustainable because of concerns regarding energy usage, sludge generation, and greenhouse gas emissions.

In the 1990s, a novel method called anaerobic ammonium oxidation (anammox) was developed that converts ammonia (NH_4^+-N) and nitrite (NO_2^--N) into nitrogen gas (N_2) and nitrate (NO_3^--N) under completely anaerobic conditions. Compared with traditional nitrification-denitrification, anammox approach was pursued because aeration consumption was reduced by 60%, organic carbon requirements were reduced by 100%, sludge production was reduced by 90%, and greenhouse gas emissions were reduced by 90%. Moreover, the recently discovered partial denitrification reaction, which reduces NO_3^--N to NO_2^--N, provides a stable and efficient substrate for anammox reactions. Therefore, the partial denitrification/anammox (PDA) process (Figure 1) is expected to replace conventional biological nitrogen removal processes, resulting in cost reduction, reduced energy consumption, and greenhouse gas emissions.

However, coupling two seemingly simple biochemical reactions to denitrify wastewater is not as easy as one might think because of the constraints of environmental conditions and the complex microbial relationships involved. Most studies have shown that the PDA process needs to be further investigated in terms of initiation and stability.

In contrast to previous studies, this study utilized anammox granular sludge as the seed sludge and controlled the appropriate substrate ratio to investigate the startup of the PDA process.

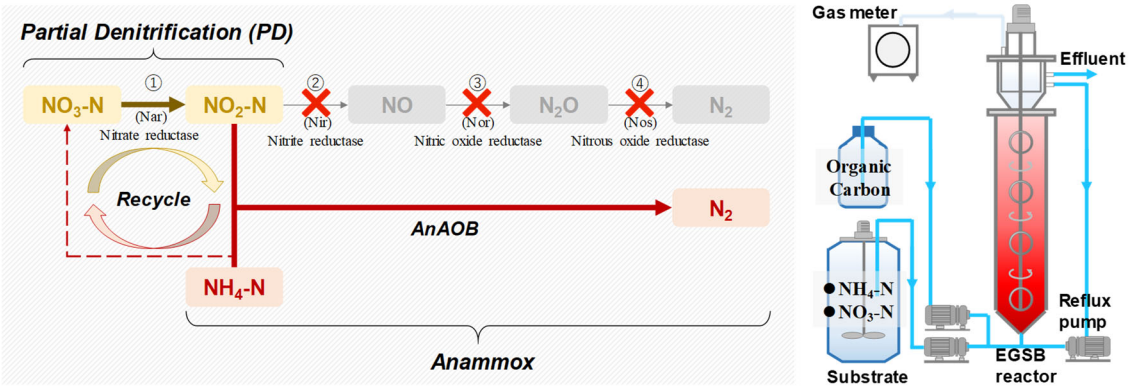

Figure. 1 Concept of partial denitrification/anammox process and experimental setup

This study employed an expanded granular sludge bed (EGSB) reactor, which enables continuous water intake, making it more representative of actual wastewater treatment than previous studies while also allowing for more efficient wastewater treatment. In addition, we used three different organic carbons to simulate the organic pollution components in actual sewage to analyze reactor performance under different conditions and stresses. By comparing the experimental groups, we explored the optimal operating conditions and influencing environmental factors. In addition, high-throughput sequencing is regularly performed to analyze the relationships between microorganisms and changes in microbial communities. Finally, based on existing experience and results, this process was used to treat sewage and investigate the feasibility of its practical application.

This study involved the start-up, optimization, and application of the process and adopted experimental methods that were completely different from those of previous studies, such as the selection of seed sludge and the configuration of the reactor. This study is expected to provide an experimental case with a reference value for the PDA process, thereby promoting its full-scale practical application.

Analysis of Mars Orbiter Data

Akira Kazama

Overview of the Mars Atmosphere Study

Our research analyzes the Martian atmosphere by leveraging observational data obtained from the European Space Agency (ESA)'s Mars Express orbiter. Using these data, we aim to better understand Martian meteorological phenomena and atmospheric fluctuations.

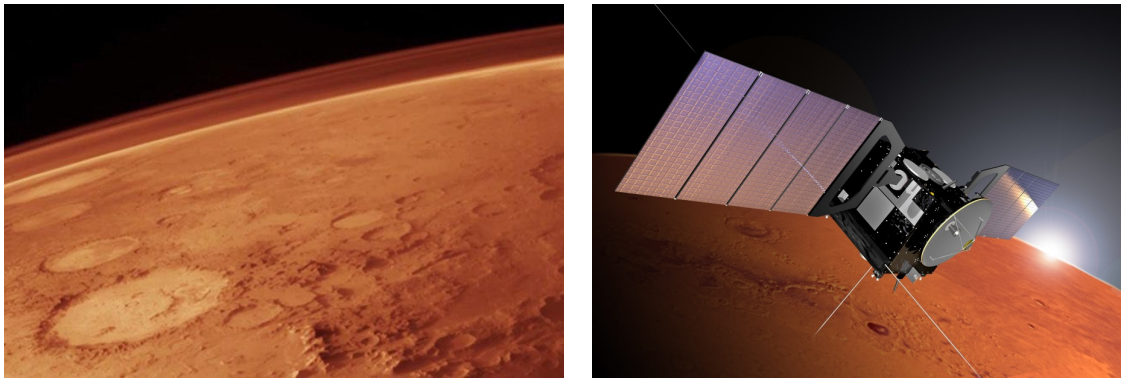

Figure. (Right) Image of Martian atmosphere ©NASA, (left) Image of Mars Express ©ESA

The focus of the Research: Dust and Surface Pressure

This study focuses on observing dust and surface pressure on Mars.

-Why do we focus on the dust?

Martian dust plays a crucial role in the Martian atmosphere, similar to water clouds on Earth. Dust not only affects the climate on Mars but also causes global-scale dust storms (Mars occasionally experiences dust storms so large that they cover the entire planet). This can cause significant changes to the Martian environment. Therefore, observing the behavior of dust is essential to understanding the Martian meteorology.

-Why do we focus on surface pressure?

Surface pressure is the key to understanding the meteorology and climate of Mars. By observing fluctuations in the surface pressure, we can track the movement of the Martian atmosphere, which also aids in predicting future weather conditions.

Development of Observation Tools

To increase the amount of data from these observations, we are developing tools that can measure changes in dust and surface pressure on Mars. These tools aim to analyze data from orbiters, allowing us to monitor fluctuations in the Martian atmosphere in real-time.

Importance of the Research

This research is crucial for gaining a deeper understanding of the Martian environment. Particularly, in future Martian exploration missions or habitat construction, being able to accurately predict dust storms and surface pressure changes will greatly contribute to the safety and success of exploration activities. Furthermore, understanding the meteorology and atmospheric fluctuations on Mars will help us to better prepare for long-term human activities on the planet.

Conclusion

Dust and surface pressure are indispensable elements in studying the Martian atmosphere. Through the development of tools to observe these fluctuations, we aim to better understand Martian meteorological phenomena and contribute to the success of future Martian exploration and human activity.

Cyanobacteria threaten sustainable drinking water supply

Yohei Miura

Cyanobacteria, which are capable of photosynthesis, are widely found in water bodies and are often grouped with algae. These microscopic organisms, although invisible to the naked eye, can multiply rapidly under favorable conditions, leading to a phenomenon known as cyanobacterial blooms or algal blooms. During these blooms, cyanobacteria form scum on the surface of the water, often turning the water green and making it visible. Cyanobacterial blooms have been reported in freshwater and seawater environments in Japan. Although marine cyanobacterial blooms can harm aquatic life, freshwater cyanobacterial blooms, which occur in rivers, lakes, and reservoirs, pose a significant threat to drinking water quality. This essay explores the risks that cyanobacteria pose to sustainable drinking water supply from three perspectives: production of harmful substances, reduction in water treatment efficiency, and financial burden on water management authorities.

First, cyanobacteria produce substances that can emit foul odors and may be harmful to human and animal health. Many visitors to lakes or reservoirs may experience unpleasant odors in the air. These odors often result from substances produced by cyanobacteria during algal blooms. Even after water treatment, odors can persist, reducing the quality of drinking water. Cyanotoxins, toxic substances produced by cyanobacteria, can cause serious health issues such as liver damage, neurological disorders, and, in severe cases, death. There have been instances in which toxic cyanobacterial blooms have caused the death of fish and livestock and illness in humans. Although water treatment plants are designed to remove harmful substances, the presence of cyanotoxins complicates this process. Additional steps, such as the use of activated carbon, are required to ensure that toxins are completely removed. If not adequately treated, cyanotoxins can pass through the treatment process and enter the drinking water supply, posing a serious public health risk.

Secondly, cyanobacterial blooms can significantly reduce the efficiency of water treatment plants, making it more difficult to provide clean drinking water to residents. Water treatment involves several steps. Water is first extracted from a source such as a river or reservoir and transported to a treatment plant, where chemicals are added to promote the agglomeration of particles. These particles form flocs that settle at the bottom of the tank as the water flows through. The cleaner

water is then passed through a filtration system made of gravel and sand to remove any remaining particles, after which chlorine is added to disinfect the water and ensure its safe distribution. However, this process becomes more complicated when large quantities of algae are present. Water requires additional chemicals to ensure that the algae settle properly, and small particles may pass through the filters, clogging them and necessitating frequent cleaning. This not only reduces the volume of clean water that can be supplied to residents but also increases operational costs and the workload of the treatment plant.

Finally, the financial burden of managing cyanobacterial blooms places significant pressure on water management authorities. For example, addressing such blooms in Japan requires substantial financial resources for their treatment and analysis. For instance, the Kyoto City Water Supply and Sewage Bureau spent over 0.5 billion yen in 2023 to remove odor-causing substances from the drinking water supply. Advanced equipment and reagents are required to detect and quantify cyanotoxins and other harmful compounds; however, not all water management authorities can afford this investment. Smaller water bureaus struggle with these costs, especially considering Japan's declining population, which has led to reduced water consumption and, consequently, less revenue for water management services.

Cyanobacterial blooms in freshwater pose a serious threat to the sustainable supply of drinking water. The substances produced during these blooms not only degrade water quality but also complicate the water treatment process and place significant financial burdens on water management authorities. To ensure a sustainable drinking water supply for future generations, it is essential to develop new technologies and strategies for managing cyanobacterial blooms in freshwater sources.

Research on foreshock activities of 2016 Kumamoto earthquake
To understand the occurrence processes of large earthquakes

Masaki Orimo

The foreshock which is an active seismicity prior to large earthquakes may help us understand their mechanisms of occurrence. Compared to large earthquakes with no remarkable foreshocks, we can obtain information about what occurred before the mainshock. Previous studies have suggested that crustal fluid, which exists in the crust or the uppermost mantle, plays an important role in the generation of foreshocks. However, the relationship between foreshocks and crustal fluids has not yet been investigated in detail.

The scaled energy (e_R) is a key parameter for understanding these relationships. This is related to the fault motion. Previous studies have indicated that if earthquakes related to crustal fluids occur, the e_R tends to be systematically lower than other earthquakes.

The 2016 M7.3 Kumamoto earthquake occurred approximately 28 h after the occurrence of the M6.5 largest foreshock. Many earthquakes were observed after the M6.5 largest foreshock, making it possible to study their characteristics. In this study, we refer to earthquakes observed during the two earthquakes as foreshock activities prior to the M7.3 mainshock. We estimated the e_R for earthquakes with magnitudes in the range of 1.5 to 2.5 observed after the M6.5 largest earthquakes to reveal the generation mechanism of foreshocks.

The e_R was computed using observed seismic waveforms. Although the waveforms contain information about fault motion, they are contaminated by path effects during propagation. Thus, we removed the path effects from the observed waveforms and estimated the e_R.

We obtained the e_R for 9,118 earthquakes. We found that the e_R for earthquakes during the foreshock periods was systematically lower than that for other earthquakes. This suggests that crustal fluids may have been associated with the occurrence of earthquakes prior to the M7.3 mainshock. In addition, crustal fluid may have contributed to the generation of the M7.3 mainshock.

Although the immediate contribution of the study results is difficult to evaluate seismic hazard assessment, I believe that continued research on this topic can help to develop a sustainable society.

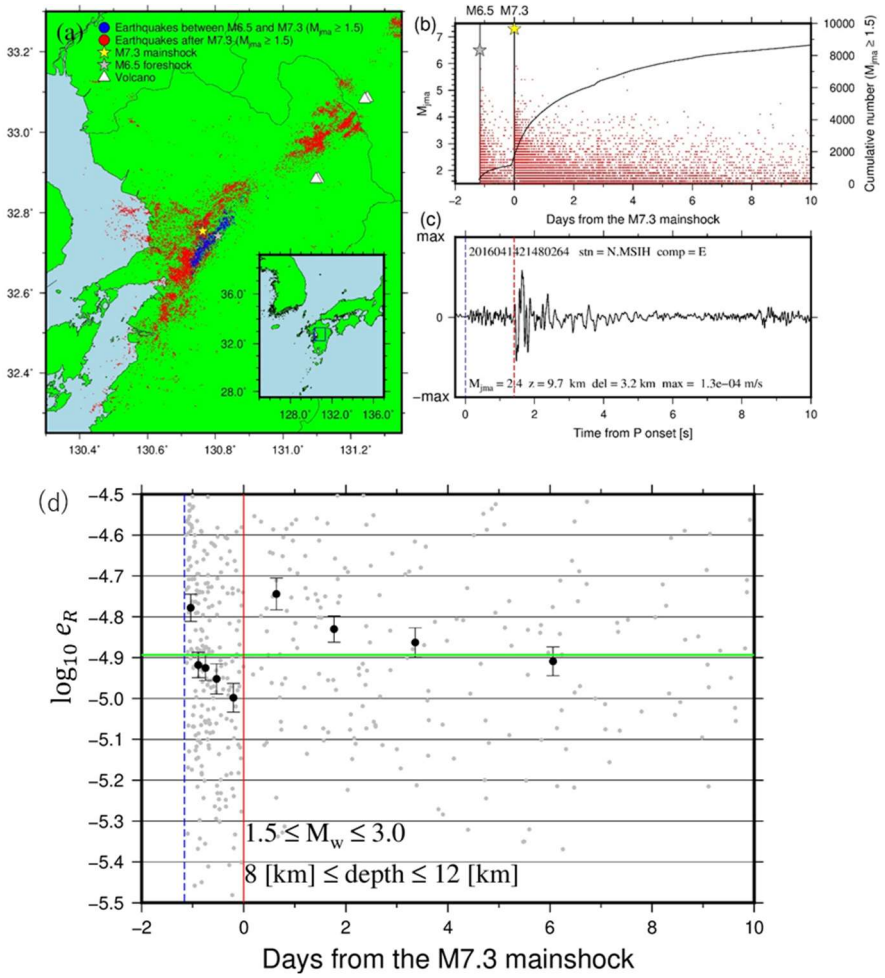

Figure 1. Seismicity in the focal area of the 2016 Kumamoto earthquake. (a) Map of the source area. The red and blue dots indicate earthquakes that occurred after the M7.3 mainshock and earthquakes that occurred during the M6.5 largest foreshock and the M7.3 mainshock, respectively. The yellow and gray dots indicate the M7.3 mainshock and the M6.5 largest foreshock, respectively. The white triangles indicate volcanoes. (b) Magnitude and cumulative number of earthquakes within 10 days of the M6.5 largest foreshock. The red dots indicate corresponding earthquakes. The black line indicates the cumulative number of earthquakes with magnitudes greater than 1.5. (c) Example of observed waveforms used in this study. The blue and red dashed vertical lines indicate the onsets of P- and S-waves, respectively. (d) Temporal changes in the estimated e_R. Gray dots indicate individual data. Mean e_R and time are shown by black dots. Each bin has 50 earthquakes. Error bars indicate the standard errors of the mean e_R for each bin. Blue and red lines indicate the occurrence time of the M6.5 largest foreshock and M7.3 mainshock, respectively. Green lines indicate the mean e_R of all earthquakes in the focal area of the M6.5 foreshock.

Development of a novel N_2O removal process

Ryota Maeda

Nitrous oxide (N_2O) is a greenhouse gas and an ozone-depleting substance. N_2O has a global warming potential approximately 273 times greater than that of CO_2, and its atmospheric concentration has increased significantly in the last 100 years. The main source of N_2O emissions is the agricultural sector, which accounts for half of human activity-related emissions. Although their contribution is much lower, the waste and wastewater treatment sectors are sources of N_2O.

During wastewater treatment, N_2O is generated by both aerobic (with oxygen) and anaerobic/anoxic (without oxygen) processes. Previous studies have reported that N_2O generation from anaerobic/anoxic processes is related to the nitrogen removal process, and the concentrations of N_2O in off-gas can reach 1,300 ppm in lab-scale reactors. Several factors have been found to affect N_2O generation in wastewater treatment (e.g., dissolved oxygen (DO), NO_2^-, and NH_4^+ concentrations, and the carbon-to-nitrogen ratio (COD/N ratio)). N_2O emission mitigation approaches, such as DO and COD/N ratio control, have been reported. However, these approaches are not necessarily universal because they are only effective under specific conditions. Alternatively, processes that use microbial reactions to remove N_2O from gases, such as biofilters filled with polyurethane foam, have been developed. This method targets 100–300 ppm of N_2O in nitrogen (anaerobic) or air (aerobic) and successfully reduces N_2O in gas. In contrast, wastewater treatment processes generate much higher concentrations of N_2O (>1,300 ppm).

To remove high concentrations of N_2O generated from anaerobic/anoxic wastewater treatment processes, we focused on a down-flow hanging sponge (DHS) reactor. DHS was originally developed for wastewater treatment, maintaining a high sludge biomass in sponge media and resulting in effluent water quality comparable to that of conventional activated sludge processes. DHS allows aerobic treatment without aeration by supplying oxygen from the air owing to gas-liquid equilibrium, while wastewater flows from top to bottom by gravity.

In this study, we developed a process to remove high concentrations of N_2O quickly using a DHS. We tested the N_2O removal performance of the DHS reactors by feeding them with different N_2O concentrations (5–2,000 ppm). Microelectrode experiments were conducted to assess the kinetics of the N_2O reduction. Finally, microorganisms that may be involved in N_2O removal were identified using 16S rRNA gene amplicon and metagenome analyses.

As a result, our proposed process successfully removed high concentrations of N_2O. The maximum N_2O removal rate was obtained when 2,000 ppm N_2O was supplied, which is much

faster than those reported in previous studies. Microelectrode experiments indicated that the N_2O dissolution rate is an important factor in determining the N_2O removal rate. Amplicon and metagenome analyses showed that the microorganism *Azonexus* played a key role in N_2O removal.

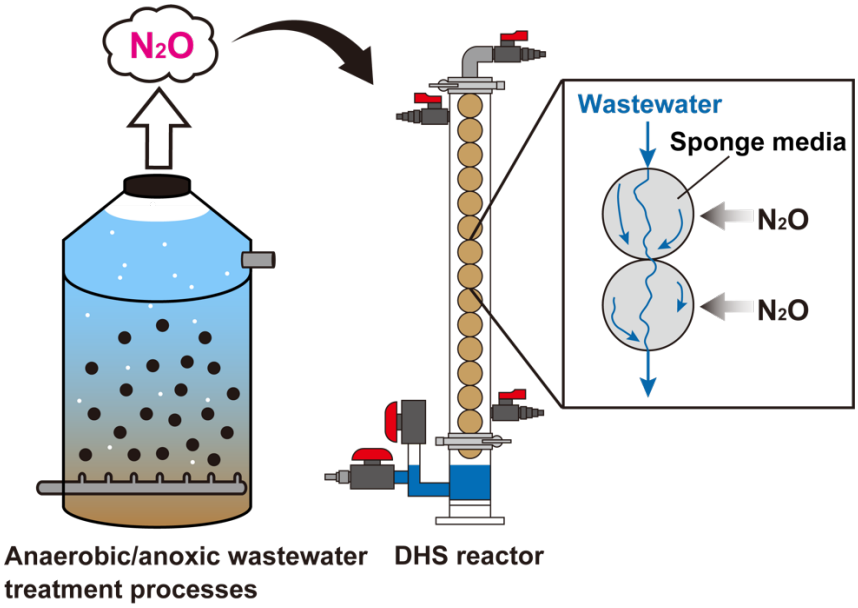

Figure 1. Overview of this study.

A New Remote Observation of the Plasma Environment around Europa

Shinnosuke Satoh

Europa is a moon of Jupiter that is covered by a thick ice shell. It does not possess internal thermal or energy sources to heat its unique environment, but charged particles (electrons and ions) in Jupiter's magnetosphere provide Europa's atmosphere and surface with energy through collisions between particles. The energy alters the atmospheric and surface particles through physical and chemical reactions. It is important to investigate the entire process of interaction between Europa and the Jovian magnetospheric plasma because it leads to a better understanding of Europa's environment.

One of the research questions has been, "how variable are the plasma density and temperature around Europa?" Previous spacecraft missions have measured plasma parameters close to Europa on several occasions, but we do not fully understand the variation in the plasma environment. A significant investment in a dedicated spacecraft mission was required to investigate Europa and its plasma environment. Our research (Satoh et al., 2024) developed a new method to measure the plasma parameters around Europa using remote observations of ultraviolet aurorae.

The interaction between Europa and the magnetosphere generates magnetohydrodynamic wave, the Alfvén wave, which can carry energy along the magnetic field lines. The Alfvén wave launched at Europa propagates along the field line and ultimately induces ultraviolet aurora in Jupiter's atmosphere, called footprint aurora. Europa's footprint aurora is bright and relatively easy to observe using the Hubble Space Telescope.

To answer this question, we analyzed images of Europa's footprint aurora taken by Hubble Space Telescope in two observing campaigns in 2014 and 2022. We measured the position of Europa's footprint aurora because it changes in response to variations in the plasma density and temperature around Europa. Using a theoretical model, we retrieved the plasma density and temperature around Europa from the measured footprint positions. We found that the plasma density and temperature increased during the 2022 campaign. The temporal variation in the plasma parameters is consistent with previous observations conducted by the Galileo spacecraft.

This study successfully introduced a unique and effective method to measure plasma parameters around Europa using remote observations. Remote observations by Hubble Space Telescope are expected to provide clues to better understand the interaction between Europa and Jupiter's magnetosphere.

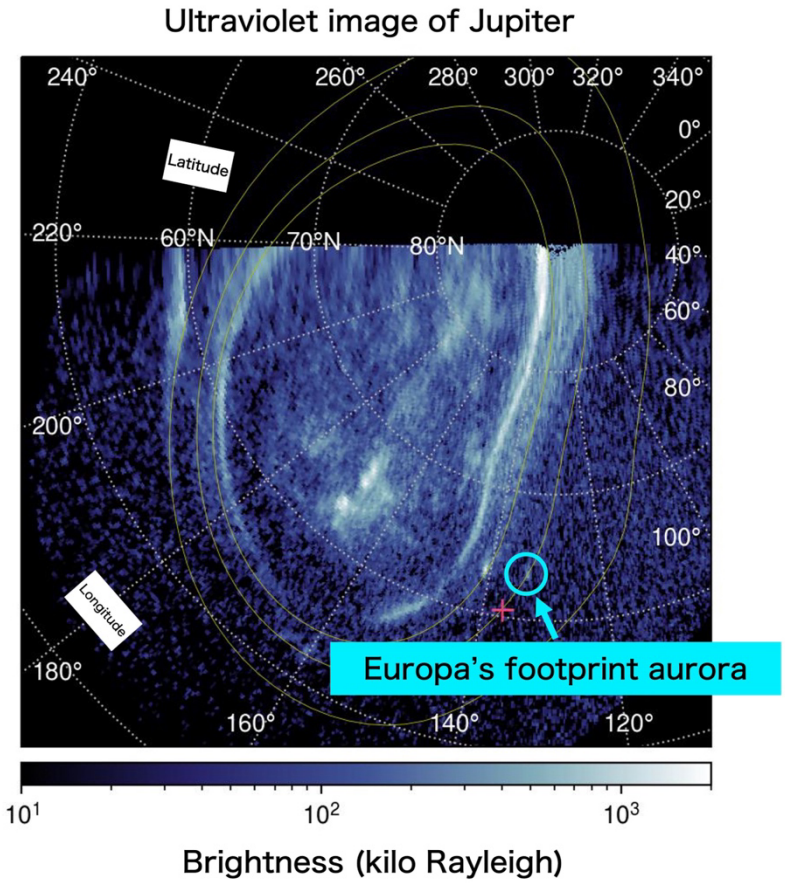

Figure. An ultraviolet image of Jupiter's northern hemisphere obtained by Hubble Space Telescope. Europa's footprint aurora is in the blue circle.

Reference

Satoh, S., Tsuchiya, F., Sakai, S., Kasaba, Y., Nichols, J. D., Kimura, T., Yasuda, R., & Hue, V. (2024). Changes in the plasma sheet conditions at Europa's orbit retrieved from lead angle of the satellite auroral footprints. Geophysical Research Letters, 51, e2024GL110079. https://doi.org/10.1029/2024GL110079

Petrological research on Fukutoku Oka-no-Ba 2021 eruption

Taisei Ukita (Department of Earth Science)

Japan has 111 active volcanoes, approximately one-third of which are located at sea. These volcanoes are called volcanic islands or submarine volcanoes. Submarine volcanoes located far from land may seem irrelevant to our daily lives. However, when these volcanoes erupt, the extremely hot magma (~900℃) meets the seawater, sometimes causing more explosive eruptions than those on the land. For example, the 2022 huge eruption of the Hunga Tonga-Hunga Ha'apai submarine volcano in Tonga triggered a massive tsunami that spread across the entire Pacific Ocean. In 1952, the eruption of the submarine volcano Myojin-sho affected a ship and resulted in over 30 deaths. These examples demonstrate the importance of studying submarine volcanoes, particularly for disaster prevention.

I am researching the 2021 eruption of Fukutoku Oka-no-Ba, a submarine volcano, focusing on the chemical composition and structure of the erupted materials. Fukutoku Oka-no-Ba is a submarine volcano located 1,300 km south of Tokyo in the southernmost area of the Ogasawara Islands. In August 2021, a large-scale eruption occurred at this volcano, estimated to be the largest volcanic event in Japan in the 21st century. The erupted materials contained a large amount of pumice, which is less dense than seawater, forming a "pumice raft" that covered the sea surface. This pumice raft drifted westward with ocean currents for over 1,000 km and reached the Okinawa Islands by autumn of the same year. The pumice rafts disrupted fishing operations in Okinawa, and beaches, which are vital for tourism, were covered in the pumice, resulting in a decline in visitors. Consequently, the local economy of the prefecture has suffered significant damage.

Following the 2021 eruption, three research cruises were conducted; I participated in two of them. Each expedition required a three-day voyage to reach sea areas near Fukutoku Oka-no-Ba. During the 1-2 days stationed in the research area, we collected seafloor sediment samples, which were then transported back over another three-day return journey. The collected samples were distributed among researchers in our collaborative research group on shore, and various ongoing studies are currently underway. This research focuses primarily on obsidian collected from the seafloor.

Obsidian, which is a material typically formed during volcanic eruptions, consists primarily of volcanic glass. This glass forms when magma cools rapidly during an eruption. It has a uniquely low mineral crystal content compared to other volcanic rocks. Obsidians often retain

valuable information about the pre-eruption magma. As they are commonly formed during explosive eruptions, it is crucial to understand the processes leading to these volcanic events. In our research, we are gradually uncovering the magma processes that led to the 2021 explosive eruption by analyzing the chemical composition and amount of water dissolved in obsidian glass compared with other volcanic materials.

Through a series of research cruises and analyses of obsidian and other eruption products collected from the sea bottom, the magma processes that led to the explosive eruption of Fukutoku Oka-no-Ba in 2021 are gradually being uncovered. This research is not limited to the specific event at Fukutoku Oka-no-Ba but has the potential to contribute to a better understanding of the magma behavior leading to explosive eruptions in other submarine volcanoes. Furthermore, these findings are expected to significantly enhance our understanding of volcanic activity in submarine regions, which is challenging to monitor, and contribute to volcanic disaster prevention efforts.

Photo of eruption column taken from an airplane by 3rd Regional Coast Guard Headquarters, Japan Coast Guard. August 13, 2021. (https://www1.kaiho.mlit.go.jp/kaiikiDB/kaiyo24-2.htm)

Mechanisms of inland earthquakes from the basic physical property of minerals

Yukiko Kita

An inland earthquake is a phenomenon in which stress that has accumulated in shallow crustal faults dissipates instantaneously. This can result in tremendous damage. The Noto Peninsula earthquake in January 2024 caused extensive damage, recently. How do inland earthquakes occur? The current dominant theory for the mechanism of inland earthquakes is that ductile deformation is locally dominant in the lower crust below the fault and that stress is concentrated in the upper crust directly above its ductile deformation zone, leading to rupture (Iio et al., 2009PEPI; Fig. 1(a)). Therefore, studying the strength of the lower crust is important for understanding inland earthquakes.

Geophysical observations and geological surveys of the fault zone have been used to investigate the strength of the lower crust. These studies have revealed the presence of ductile shear zones composed of fine-grained plagioclase (Jamtveit et al., 2017 Nature) and water (Wannamaker et al., 2009 Nature) only in the lower crust immediately below the faults. Plagioclase is the main component of the lower crust and is the hardest mineral in the crust; therefore, it dominates the strength of the crust. Rock experiments have shown that the deformation mechanism changes depending on the grain size of the mineral, with finer grains becoming softer, and the presence of water significantly reduces the strength of the mineral (Rybacki et al., 2006; Fig. 1(b)). Therefore, it is crucial to understand the effects of water on plagioclase strength to understand the mechanisms behind inland earthquakes. The objective of this study is to elucidate the basic physical properties of fine plagioclase, which constitutes a fault zone in the lower crust, using rock experiments.

How do you investigate the basic physical properties of minerals? The first thing that comes to mind is the collection of natural stones and conducting experiments using them. However, as natural rocks contain minerals other than plagioclase, it is difficult to investigate the physical properties of plagioclase alone. Therefore, in this study, plagioclase-only rocks were artificially synthesized to create synthetic samples that simulated the lower crust and were used in deformation experiments. The advantage of creating synthetic samples is that the complex composition of the Earth can be simplified to its utmost limit. When natural rocks with complex compositions are used in experiments, various factors are involved, and it is difficult to consider them. However, using synthetic rocks as experimental samples, we can examine complex phenomena individually.

Plagioclase is difficult to synthesize because of its unique characteristics. However, I succeeded in developing a method for synthesizing artificial plagioclase rocks based on the synthesis method for fine ceramics. Currently, I have synthesized plagioclase rocks. In the future, rock deformation experiments will be conducted using artificial plagioclase rocks to reveal the physical properties of the lower crust.

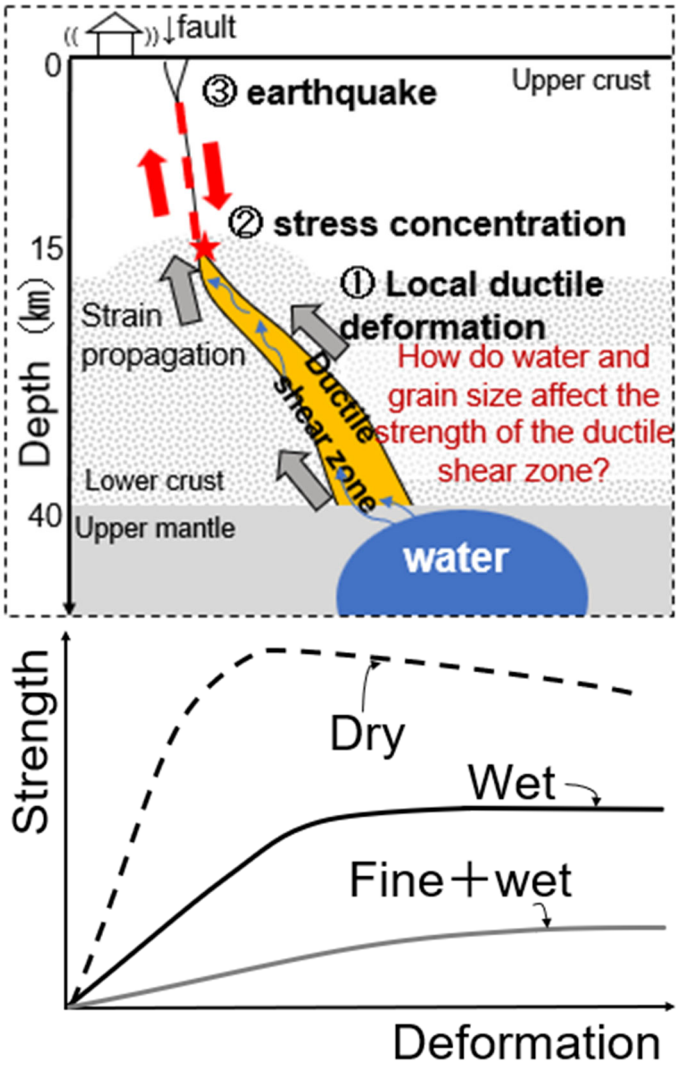

Fig.1 (a) Schematic image of the mechanism of inland earthquake generation. (b) Change in rock strength due to water

Inferring the origin of tsunamis from various observations

Hidetoshi Masuda

My research topic is the inverse analysis of tsunami observations. Inverse analysis is a modeling method for determining the cause (tsunamigenic earthquakes or tsunami flow conditions) from the results (i.e., observations). Tsunamis can be destructive, and some, such as the 2004 Indian Ocean tsunami in Indonesia and the 2011 Tohoku-oki tsunami in Japan, can cause catastrophic disasters. The most extreme classes of tsunamis rarely occur; their recurrence intervals can be hundreds of years. Therefore, researchers have attempted to obtain as much fundamental information as possible on the size, source, and recurrence of tsunamis. The latest observational networks have enabled us to measure tsunami wave heights at various locations worldwide. However, only information on recent tsunamis can be obtained in this manner. To reconstruct tsunamis that occurred in the historic and geologic past, tsunami information must be obtained from historical documents, traditions, or geological records of tsunamis. My research has consistently focused on developing methods to determine the characteristics of tsunami sources from various tsunami records.

The most common type of tsunami record is the mareogram. Mareograms are recorded at tide gauges worldwide to measure tidal variation. If tsunamis attack tide gauge stations, they should be recorded on a mareogram. It is an analog of seismograms for earthquakes. A methodology to invert mareogram records into tsunami source characteristics has been in development since the late 1980s; therefore, the method is almost completely established. However, mareogram records sufficient to understand the tsunami sources cannot always be obtained. In such situations, another type of tsunami record called the tsunami trace height must be used. Tsunami trace heights are onshore traces of tsunami inundation, such as watermarks or washed debris. These were collected through post-tsunami field surveys along a damaged coastline. Because trace heights may be obtained wherever they are accessible by researchers, the use of trace heights in tsunami source investigations can complement the scarcity of mareograms. However, the nature of onshore tsunami behavior is very complex. Owing to this complexity, the response of trace heights to the tsunami source size is also complex, making their use difficult. To overcome this bottleneck, numerous tsunami simulations have been conducted to determine the optimal tsunami source. Tsunami simulations usually take dozens of hours, but I avoided the computational time problem by using a much simpler and faster model specializing in predicting specific outcomes, called the surrogate model. As a case study, my research group applied the novel method to the 2024 Noto

Peninsula earthquake and tsunami in Japan and obtained a refined tsunami source model that accounted for both mareograms and tsunami trace heights.

My focus also extends to ancient tsunamis that occurred hundreds or thousands of years ago. We are trying to obtain tsunami source information from a new medium, that is, tsunami deposits, because only geological records are available for such old events. Tsunami deposits are sedimentary deposits transported by and deposited from tsunamis. If we can estimate tsunami source characteristics from tsunami deposits, our knowledge of tsunamis can be broadened to include the geological past. This may significantly extend our understanding of giant tsunamigenic earthquakes. Conventionally, tsunami simulations have mostly focused on hydrodynamic aspects. We coupled a model of sediment transport by fluids with a hydrodynamic tsunami model to simulate tsunami-induced sediment transport. This coupled model can extend the conventional inverse analysis framework using sedimentary tsunami records. Our new topic is the establishment of a framework for deposit-based tsunami source inferences. Our group has completed a preliminary numerical experiment and obtained reasonable results. We are also moving forward in achieving their application to ancient tsunamis.

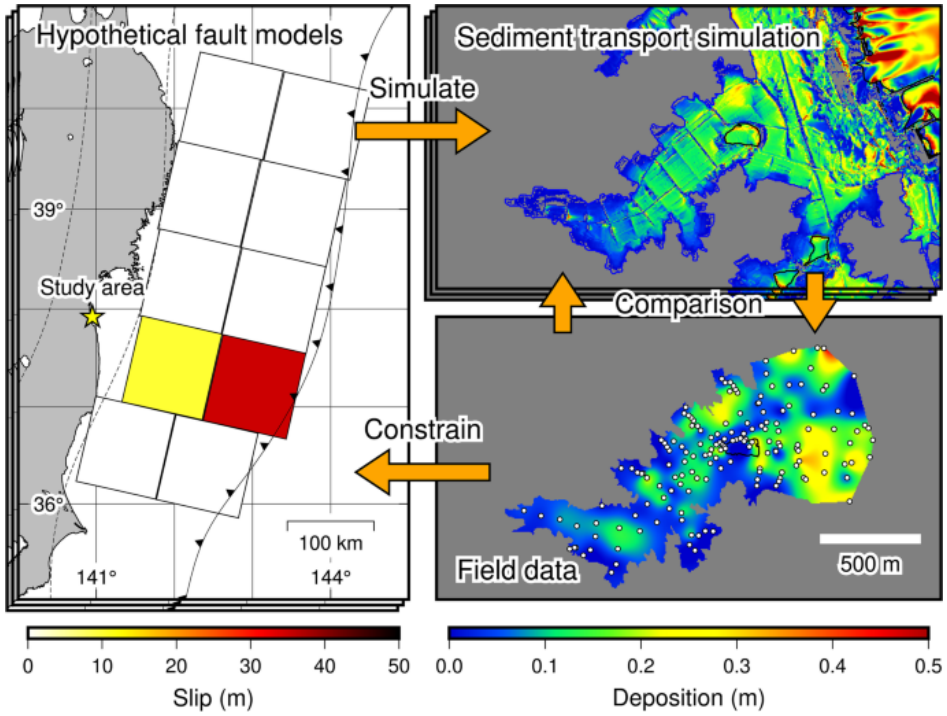

Figure: Conceptual illustration of deposit-based tsunami source inference (Masuda et al., 2022, *Progress in Earth and Planetary Science*). This example uses the total volume of tsunami deposit as a proxy for tsunami size.

The development of the new copper alloy for future fusion reactors

Toshiki Saito

In the future, climate crises will be one of the biggest problems that must be solved. Greenhouse gases (GHG), the main cause of the climate crisis, are emitted by human activities, especially through power generation. However, electricity is essential to our daily lives, powering many items on which we depend, such as electric vehicles, smartphones, and computers. Therefore, power-generation methods with lower GHG emissions are required.

One of the candidates is the use of renewable energy such as solar, wind, or wave energy. Renewable energy emits almost no GHG during power generation, and it is virtually unlimited. However, renewable energy faces a challenge in terms of its demand-following capabilities. As renewable energy power generation depends on natural phenomena, the amount of electricity generated cannot be controlled by humans. Electricity demand is not uniform throughout the day. It changes depending on time, temperature, and other factors. Renewable energy must be used along with other energy sources that can meet changes in electricity demand.

Then how about using nuclear energy? Nuclear energy can generate electricity with lower emissions and can follow a change in demand. Nuclear energy may be a good energy source when combined with renewable energy. However, nuclear energy suffers from the problem of high-level nuclear waste (HLW) produced during power generation. HLW has been radioactive for years, so it must be managed properly for more than ten thousand years. Nuclear energy emits near-zero GHG, but it forces future generations to take care of HLW.

Is there no good solution for reducing GHG emissions and providing sufficient electricity in our daily lives? Fusion energy is now focused as a new solution, and considerable research has been conducted on its practical applications. In fusion energy, the energy produced by the fusion reaction of hydrogen isotopes is extracted in the form of heat, which is then converted into electricity. Fusion energy has the following advantages compared to other energy sources:

1. Zero GHG emission through power generation.
2. Be able to follow the change in demand.
3. The fuel for the fusion reaction is abundant on the Earth.
4. No production of HLW.

To generate electricity from fusion reaction, we need fusion reactors. They confine fuels of

fusion reaction and control it, although there are many challenges in making this possible. A major challenge is the materials used. For fusion reaction, the fuel must be heated up to 150 million degrees Celsius and in the state called “plasma.” Although the reactor components do not touch the plasma directly, they are exposed to a high heat flux from it. The divertor was among the components exposed to the highest heat flux in the reactor, so the material used in the component needs to keep high strength even in high temperatures. High durability in the high temperature is required for the divertor materials.

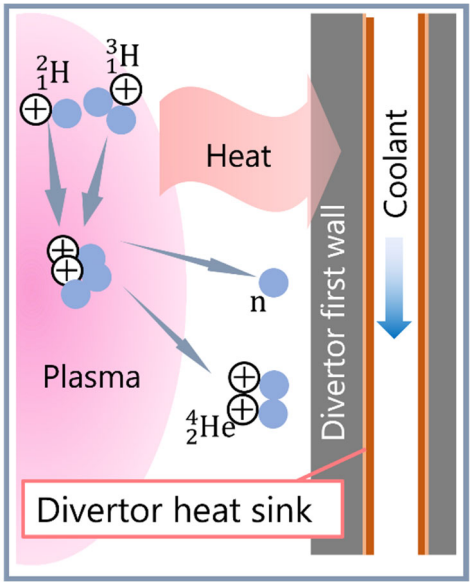

Fig. 1 The environment surrounding the divertor heat sink

The divertor emits helium gas, the fusion reaction byproduct, and maintains the quality of the plasma. As the component is exposed to the high heat flux, cooling is necessary to keep its strength. Therefore, a cooling pipe called a “divertor heat sink” is installed inside the divertor. Since the divertor heat sink’s major mission is to remove heat from the divertor, a material with high thermal conductivity is required.

The divertor is exposed to high levels of neutron and helium ion bombardment (“irradiation”). When the material is irradiated, it loses strength and becomes brittle. The divertor heat sink must also be durable against such irradiation events.

Typically, there is a tradeoff between high thermal conductivity and durability. The new copper material developed by our research group is expected to overcome this issue. Our copper material is one of the “oxide-dispersion strengthened copper alloys (ODS-Cu),” but with a new composition. This material was produced by solidifying alloy powders using the sintering method. Our research group has successfully produced ODS-Cu with high strength and thermal conductivity. My current goal is to reveal the relationship between alloy powder microstructures and the final bulk material properties. Understanding this relationship will be effective in establishing a production method for ODS-Cu with high durability and thermal conductivity.

Initiation and growth of stress corrosion cracking in carbon steel overpacks for high-level radioactive waste disposal

Tomohiro Takita

1. Introduction: The importance of the management of high-level radioactive waste

As the world faces challenges such as climate change and energy sustainability, the importance of nuclear power is increasing. Nuclear energy offers advantages such as a stable electricity supply and zero carbon emissions. However, the management of spent fuel remains a significant challenge. In Japan, the current approach involves processing spent fuel into glass waste forms (high-level radioactive waste) and then disposing of it in deep geological formations, specifically at depths of 300 m or more.

In this disposal method, glass waste forms are stored in thick metallic containers known as overpacks, made of carbon steel, and further encased in clay as a buffer material (a man-made barrier). These overpacks must be able to contain radioactive materials reliably for more than 1,000 years. One of the most critical factors affecting their integrity is corrosion owing contact with groundwater.

Although the design of overpacks anticipates uniform corrosion and sets the wall thickness accordingly, the potential for localized corrosion, including stress corrosion cracking (SCC), has not been adequately considered. Considering this, this study aims to evaluate whether stress corrosion cracking occurs in carbon steel overpacks in an environment that simulates geological disposal, and if so, to assess the growth of such cracking.

2. Understanding of stress corrosion cracking (SCC)

Stress corrosion cracking (SCC) occurs in metals when a tensile stress is applied in a corrosive environment. SCC occurs because of the interplay of three factors: stress, material properties, and environment. Thus, eliminating at least one of these factors could prevent the occurrence of SCC. If SCC develops in the overpack designed for geological disposal, it may lead to short-term failure. Therefore, evaluating the SCC susceptibility and growth rate of carbon steel in geological disposal environments, such as those containing carbonate/bicarbonate, chlorides, and sulfate ions—is crucial for enhancing the reliability of the geological disposal of high-level radioactive waste.

3. Connection of my research to a sustainable society

Successful management of high-level radioactive waste is closely related to the principles of sustainable development. A sustainable society is meets the present needs without compromising

the ability of future generations to meet their own needs. Effective radioactive waste management is essential to protect human health and the environment, thereby supporting a sustainable energy infrastructure. If the risks associated with nuclear waste are not adequately addressed, public apprehension can hinder the expansion of nuclear power and ultimately affect global efforts to reduce carbon emissions.

Furthermore, the findings of this research could inform regulatory frameworks and best practices for global nuclear waste management. As different countries grapple with their own challenges related to high-level radioactive waste, the insights gained from this study can serve as valuable resources for policymakers and engineers. Collaborative efforts across borders are essential for advancing the safe and sustainable management of radioactive waste, ultimately supporting global sustainability goals.

4. Conclusion

In conclusion, my research on stress corrosion cracking (SCC) in carbon steel overpacks is important for the effective management of high-level radioactive waste. As nuclear power continues to play a crucial role in the transition to sustainable energy, ensuring the long-term integrity of waste containment systems is essential. The potential for localized corrosion, particularly SCC, poses significant risks that could undermine the safety of geological disposal methods. By evaluating the susceptibility and growth rates of SCC under simulated geological conditions, this study aims to enhance the reliability of overpacks, thereby safeguarding public health and the environment.

Moreover, the findings of this research will provide valuable insights for policymakers and engineers globally by promoting best practices in radioactive waste management. Collaborative international efforts are vital for addressing the challenges associated with nuclear waste and ensuring that nuclear energy can be used sustainably. Ultimately, by advancing our understanding and management of radioactive materials, we can contribute to a more sustainable society that meets current energy needs while protecting future generations.

Balancing Agriculture and Energy: A Sustainable Approach to Using Agricultural Reservoirs for Power Generation in Japan

Atsuya Ikemoto

Sustainability involves using resources in a manner that does not harm future generations. Water and energy are essential resources, and this research focuses on finding new ways to manage them effectively. Specifically, I studied how water can be used from agricultural reservoirs to generate electricity without affecting food production. In this essay, I explain how my research contributes to a sustainable society by providing clean energy while preserving agricultural needs.

Agricultural reservoirs are used to store water for farming, particularly during dry periods. These reservoirs play a vital role in ensuring that crops can grow, even when rainfall is limited. They are essential for food production in many regions. However, the water stored in these reservoirs is often underused because it is used only when needed for irrigation. This provides opportunities for innovation. This research explored the possibility of using stored water to generate electricity, thereby offering a new source of renewable energy.

Hydroelectric power, which uses water flow to generate electricity, is a well-known form of renewable energy. Large dams such as the Hoover Dam are examples of this technology. However, these large projects can have significant environmental impacts, such as disruption of ecosystems and displacement of communities. In contrast, this research focuses on small-scale hydropower, which uses water in existing agricultural reservoirs. Electricity can be generated with a minimal environmental impact by releasing water through small turbines when irrigation is not required. Because reservoirs are already in place, no major infrastructure changes are required, making this approach more sustainable.

One of the main challenges in this research was to balance the need for energy with the need for water in agriculture. The primary purpose of these reservoirs is to provide water for crops; therefore, it is crucial not to divert too much water for electricity generation. This research used computer models to simulate different scenarios, considering factors such as rainfall, crop water needs, and electricity demand. This helps to determine the best time to generate electricity without affecting the water supply for farming. The goal was to create a system in which energy and agriculture could thrive together.

Therefore, there are significant potential benefits of using agricultural reservoirs for energy generation. First, it helps reduce reliance on fossil fuels, which contribute to climate change. Hydropower is a clean energy source that does not produce greenhouse gases. Using water that is

already stored in agricultural land, electricity can be generated without increasing the carbon footprint. This will contribute to slowing global warming and improving air quality.

In addition to the environmental benefits, small-scale hydropower can provide energy independence to rural communities. Many rural areas rely on electricity from distant power sources, which are expensive and unreliable. By locally generating electricity from reservoirs, these communities can become more self-sufficient and reduce their dependence on external energy sources. This strengthens rural areas' resilience and supports sustainable development.

In conclusion, this study closely connects with the idea of sustainability by finding a way to generate clean energy from agricultural reservoirs without affecting food production. This approach reduces the reliance on nonrenewable energy sources, protects the environment, and supports rural communities. By using resources wisely, we can create a sustainable future for everyone. My work is just one example of how innovative thinking can help solve sustainability challenges and I hope that it can inspire others to explore similar solutions.

Exploring the Future of Data-Driven Geotechnical Engineering with Statistical Machine Learning: Foundations for Accelerating Construction DX

Taiga Saito

The construction industry is at a pivotal moment, facing new societal challenges and rapidly advancing technologies. One of the most significant developments has been the integration of Information and Communication Technology (ICT) into construction processes. This integration offers significant opportunities to improve the efficiency, quality, and safety of construction projects. However, it also introduces challenges, especially in dealing with the uncertainties of geotechnical materials, such as soil and rock, which are highly variable and require complex planning and execution.

Engineers have traditionally relied on their experience and intuition to address these uncertainties. Although this has worked to a certain extent, it is becoming less effective as construction projects grow in complexity and scale. There is a growing need for systematic and data-driven methods to improve decision-making. Although ICT has brought about innovations such as unmanned construction and automated quality checks, there is still heavy reliance on human judgment. This reliance can limit the potential benefits of ICT technologies can offer in terms of efficiency and risk reduction.

To address these challenges, this research focuses on developing statistical machine-learning models specifically designed for geotechnical engineering. The main goal is to replace or enhance human intuition with insights derived from data, thereby improving decision-making in areas such as understanding site conditions and ensuring quality. By modeling the decision-making processes of experienced engineers using advanced machine learning techniques, we aim to make more accurate and reliable predictions of soil behavior and other important geotechnical properties.

A key aspect of this study is the creation of a comprehensive geotechnical database. This database is a valuable resource that enables more precise predictions and better-informed engineering decisions. We used advanced statistical methods, such as hierarchical Bayesian models and minimum information dependence models. These models enable a better understanding of complex data structures and result in more efficient and robust predictions. These models need to be interpretable so that engineers can understand and trust them in real-world applications. Engineers may hesitate to use a model that is too complicated to understand despite its accuracy. By ensuring that the models are understandable, we can eliminate a major obstacle to adopting machine-learning technologies in the construction industry.

Sustainability was another crucial aspect of this study. Sustainability in construction is closely related to the efficiency of resource use and time management. Accurate predictions of geotechnical properties allow for more efficient use of materials, reduce waste, and lower the environmental impact of construction projects. For example, knowing precisely how soil behaves can lead to foundation designs that use less material without sacrificing safety or performance, thereby reducing the carbon footprint.

Automating decision-making processes can help address labor shortages, which are significant issues in countries such as Japan, owing to aging populations and declining birth rates. By moving toward more automated and less labor-intensive construction methods, workforce shortages can be alleviated. Automation enhances safety by reducing the need to work in potentially dangerous environments. Automated systems can handle repetitive or hazardous tasks with high accuracy and consistency, thereby improving the overall quality of construction projects.

In the future, the application of statistical machine learning in geotechnical engineering has the potential to dramatically transform the construction industry. By developing models that are both reliable and easy to understand, we aim to encourage the widespread adoption of ICT in construction, thereby accelerating the digital transformation of the industry. This can result in more efficient project management, cost savings, and improved safety measures. It also allows for improved risk management through a more accurate prediction of geotechnical challenges, thereby enabling proactive steps to prevent costly delays and accidents.

In summary, integrating statistical machine learning models into geotechnical engineering represents a significant step forward in addressing the challenges posed by the variability of geotechnical materials. The construction industry can improve efficiency, quality, safety, and sustainability by relying solely on human intuition to make data-driven decisions. This study plays a vital role in this transformation by developing models that are both accurate and understandable, ensuring that they can be effectively used in the field. As the industry continues to embrace ICT and machine learning, it stands to gain from increased automation, better resource management, and improved responses to societal challenges, such as labor shortages and environmental concerns. Ultimately, this research not only advances technology in the construction industry but also aligns with the broader goals of sustainability, preparing the industry to meet future demands.

Effects of pH Control and Sludge Recirculation on Two-Phase Anaerobic Digestion of Food Waste and Paper Waste

ZENG QINGKANG

According to 1983 statistics for Japan, the total volume of this waste was 368 million tons/year, of which approximately 30% was reused or recycled, while the remaining 70% was treated or disposed of. Current treatment and disposal methods include incineration, which is highly effective for volume reduction, and direct landfilling, which generates toxic chemicals and makes it difficult to secure landfill sites. In December 2022, the IEA report announced that "renewable energy will overtake coal as the world's largest power source by the beginning of 2025. Methods for generating hydrogen and methane from organic waste through the action of anaerobic microorganisms have attracted attention from the perspective of preventing global warming, soaring fossil fuel prices, and building a decarbonized society. Anaerobic digestion is of great significance for the conservation of the global environment because of its advantages in terms of energy recovery from wastewater.

The two-phase anaerobic digestion system separates the hydrogen-producing phase from the methane-producing phase, realizing the simultaneous generation and recovery of hydrogen and methane, which has high practical value. However, many operational and systemic questions remain regarding the two-phase anaerobic digestion process. Therefore, it is important to investigate the factors responsible for the stable and efficient operation of two-phase anaerobic digestion systems.

In this study, the operating effects of the two-phase anaerobic digestion of paper waste and food waste for hydrogen and methane production were investigated, and the effects of pH control on the hydrogen-producing phase were systematically investigated. Under different operating conditions, the gas production capacity, organic matter utilization efficiency, and energy yield of the two-phase anaerobic fermentation system were investigated to optimize the operation mode of the two-phase anaerobic fermentation system, which will lay the foundation for large-scale industrial applications of the two-phase anaerobic fermentation system in the future. This study also compared the effects of two pH control methods (addition of alkaline solution and sludge recirculation) to determine the optimal pH control method.

The inoculum for both the hydrogen and methane production reactors were obtained from the anaerobically digested sludge obtained from the Senen Purification Center. After loading into the reactors, the air inside the reactors was expelled using a nitrogen aeration blow-torch to make the reactor anaerobic. The food waste used in this study was artificially prepared, and the paper waste

used was copy paper from the laboratory. The prepared artificial food waste and paper waste were mixed in a TS-based ratio of 7:3, and some water was added to adjust the total TS of the mixed substrate to approximately 10%.

The three comparative experimental processes are illustrated in Fig. 1. In case 1, the pH was controlled between 5.0 and 6.0 by adding Na_2CO_3 solution. In Case 2, 600mL of methane sludge was recirculated into the hydrogen fermentation tank every day, and in Case 3, neither an alkaline solution nor sludge recirculation was used. Each patient underwent continuous surgery for at least 18 days.

Temperature-phased TPAD systems with paper and food waste as substrates for hydrogen and methane production can be operated continuously and stably. The optimal mixing ratio of food waste to paper waste was 7:3 (based on TS), under which the hydrogen and methane production was the best, with hydrogen and methane concentrations of 49.59% and 57.52%, respectively, and gas yields of 0.07 m^3-H_2/kg-input TS and 0.4 m^3-CH_4/kg-input TS, respectively. The removal rate of VS in the entire AD process was 84%; 3.29% of the input COD was converted to hydrogen, and 68.1% was converted to methane.

It is generally believed that the optimal pH value of the hydrogen production phase is between 5.0 and 6.0, at which the main types of VFAs in the AP reactor are acetic acid and butyric acid, which are favorable for hydrogen production. The concentrations of acetic acid and butyric acid in the hydrogen production phase rapidly decreased when the pH dropped below 5.0, leading to a decrease in the rate of methane production.

In a TPAD system, controlling the pH of the hydrogen-producing phase is necessary for continuous and stable production of hydrogen and methane. When the pH value of the hydrogen production phase was controlled to be 5.0-6.0, the hydrogen and methane production rates were stable, which were 1.18 L/L/d and 1.52 L/L/d, respectively. When the pH of the hydrogen-producing phase was not controlled, the conversion rate of hydrogen in the input COD was 2.23%, and the conversion rate of methane was 53.92%, which was lower than that when the pH of the hydrogen-producing phase was controlled.

In the TPAD system, after adding sludge recirculation in a 1:1 ratio, stable operation can be achieved, and there is no need to add alkali to the hydrogen phase to control the pH of the hydrogen-producing phase. The hydrogen and methane concentrations were 41.61% and 58.41%, respectively, and the gas production rates were 1.25 L/L/d and 1.69 L/L/d. Compared with pH control by alkaline solution, the VS removal rate increased by 1.74%, and the utilization efficiencies of the input substrate increased by 15.47% and 20.56%, respectively. Adding recirculation significantly increased anaerobic reactions in the hydrogen fermentation tank, and

the gas production rates increased by 6% and 11% for hydrogen and methane, respectively.

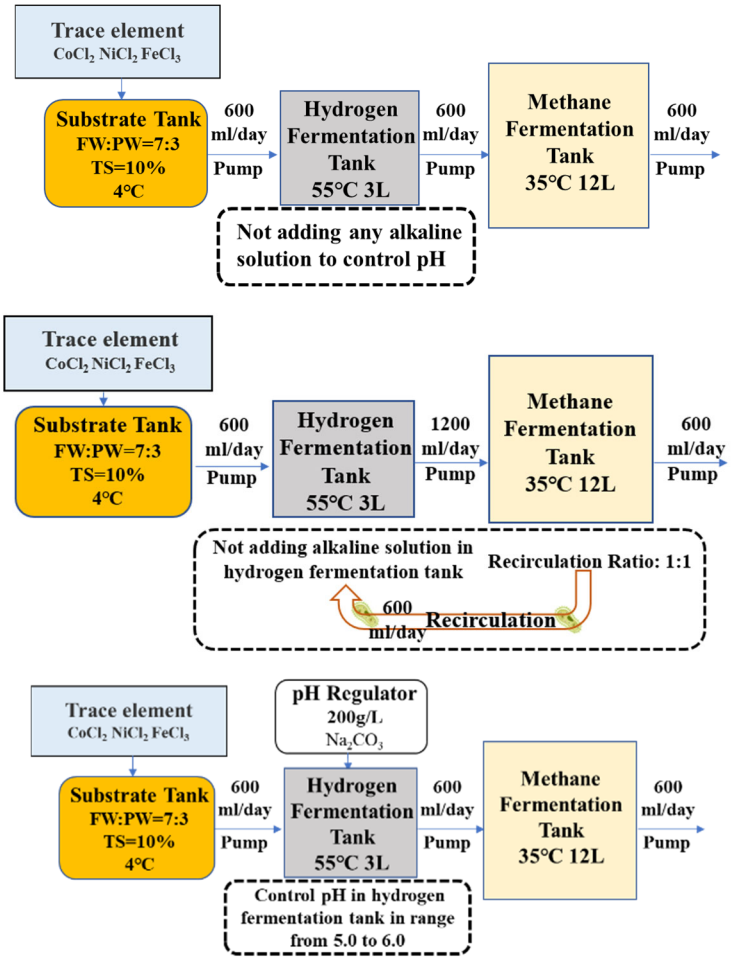

Fig.1 Long-term continuous experiment process with pH control by alkaline solution, without pH control and with pH control by sludge recirculation.

Assessing the Differential Impact of Air Pollution on Child Growth in Myanmar: Insights from 2015-2016 DHS and Satellite Data

SOPHIA

Introduction

Air pollution has emerged as a significant global health challenge, causing an estimated seven million premature deaths annually. Low- and middle-income countries bear this burden, with Myanmar being particularly affected. According to the World Health Organization (WHO), the recommended safe level of PM2.5 (particulate matter with a diameter of less than 2.5 micrometers) is 5 µg/m³. However, in Myanmar, the average annual concentration of PM2.5 is around 30 µg/m³, which is six times higher than the WHO standard. Such elevated pollution levels pose severe health risks, particularly for children, whose developing organs make them more vulnerable to the effects of air pollution.

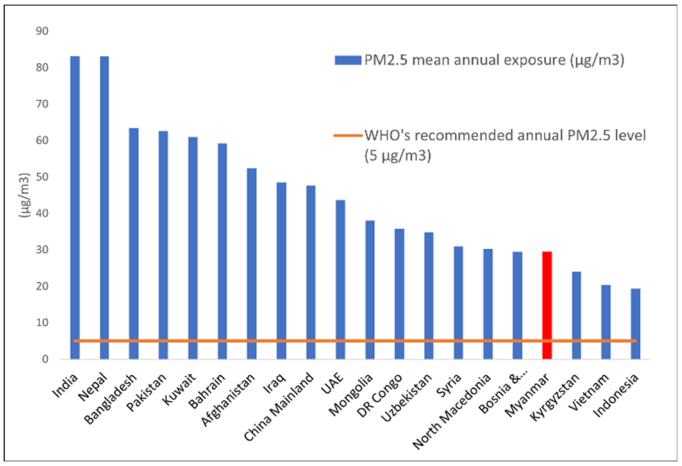

Figure 1. PM2.5 mean annual exposure in top 20 countries in 2019

Research Objectives

The overall goal of this research is to investigate how accumulated exposure to PM2.5 affects HAZ and stunting rates among children under five years of age in Myanmar. I also intend to explore whether the effects of PM2.5 differ by age and sex. Specifically, I ask the following questions: (1) How does postnatal accumulated PM2.5 exposure influence child growth outcomes? (2) Are there significant differences in the impact of PM2.5 based on the child's age and gender? To answer these questions, I used data from the 2015–2016 Myanmar Demographic and Health Survey (DHS) combined with satellite-derived pollution estimates. My study focuses primarily on long-term postnatal exposure to PM2.5, distinguishing it from earlier research that often emphasized average exposure over shorter periods.

Literature Review

Previous studies have demonstrated a strong correlation between air pollution and adverse health outcomes. Jayachandran (2009) found that exposure to smoke from forest fires in Indonesia led to higher infant mortality rates. Similarly, Arceo et al. (2016) showed that higher pollution

levels during pregnancy are associated with lower birth weights. In a more recent study, Balietti et al. (2022) found that higher PM2.5 exposure levels significantly increased stunting rates among children in India. However, most of the existing literature focuses on mean PM2.5 exposure over a specific period rather than the accumulated exposure experienced throughout early childhood. My research contributes to the field by analyzing the accumulated PM2.5 exposure from birth to the survey date, providing a more comprehensive picture of its long-term impact on child growth. Additionally, this study analyzes gender-specific effects and how they evolve as children age.

Methodology

To analyze the differential impact of air pollution on child growth, Ordinary Least Squares (OLS) and instrumental variable (IV) regression techniques were employed. OLS serves as a baseline estimation, while the IV approach addresses potential endogeneity issues such as measurement errors and omitted variable bias. For the IV model, the distance to Dhaka, Bangladesh, was used as an instrument for postnatal accumulation of PM2.5. The high pollution levels and proximity of Dhaka to Myanmar make it a suitable exogenous determinant of PM2.5 exposure. The analysis was structured into three models.

Model 1 examines the interaction between age and PM2.5 exposure.

Model 2 looks at the interaction between gender and PM2.5 exposure.

Model 3 combines both age and gender interactions.

By estimating the effects of postnatal PM2.5 while controlling for other factors such as socioeconomic conditions, maternal health, and additional pollutants (carbon monoxide and ozone), I sought to isolate the true impact of air pollution on child growth outcomes.

Results

The results of this analysis revealed a significant negative relationship between postnatal accumulated PM2.5, exposure, and child growth, as measured by HAZ and stunting rates. Specifically, exposure to higher levels of PM2.5 increases the likelihood of stunting in young children, with the effect diminishing as children age. This suggests that infants are more vulnerable to the harmful effects of air pollution than are older children. Sex-specific effects were also observed. Male children are more adversely affected by PM2.5 exposure than female children, particularly during early childhood. However, as children grow older, the sex difference decreases. One possible explanation for this finding is that boys in Myanmar, especially in rural areas, may spend more time outdoors, exposing them to higher levels of pollution than girls, who are more likely to stay indoors.

Conclusion and Policy Implications

The findings of this study highlight the urgent need for targeted interventions to reduce PM2.5, particularly in vulnerable populations such as infants and young children. Regulatory measures should be strengthened to improve air quality monitoring and limit emissions from industrial and agricultural activities, which are the major sources of PM2.5. In addition, public health programs focusing on maternal and child health should be prioritized to address the long-term consequences of stunting and growth impairment. In conclusion, this study provides valuable insights into the differential impacts of air pollution on child growth in Myanmar. By focusing on the postnatal lifetime accumulated PM2.5, this study contributes to a deeper understanding of how sustained exposure to air pollution affects health outcomes. These findings underscore the importance of implementing comprehensive policies to reduce air pollution and protect children's health and development in Myanmar.

Connection Between Sustainable Society and My Research

Jingwen Zhong

Research Introduction

This study aimed to explore the connection between family social class and children's non-cognitive abilities through multivariate analysis. Research has shown that differences in upbringing, which are often influenced by parental social class, contribute significantly to gaps in children's development, educational success, and eventual outcomes in adulthood. In postwar Japan, the issue of "problematic" discipline was prevalent, especially in rural areas and among the working class. As a result, efforts to address this issue became central to societal reform, with the goal of promoting "family democratization" and improving children's prospects for the future.

With the equalization of educational opportunities and the transformation of families, ways of raising children have become more diverse. The data used in this study were obtained from the Parent-Child Survey on Children's Lives and Learning, conducted in 2015 by the Institute of Social Science at the University of Tokyo and the Benesse Institute of Education. This survey focuses on parent-child involvement and considers the non-cognitive skills that the OECD (2015–2018) points out as important in terms of parenting outcomes, allowing for a more comprehensive exploration of the effects of the upbringing method.

This study categorized parenting based on questions about "family conversations" and "family rules" and used exploratory factor analysis to examine children's noncognitive abilities. Descriptive analyses indicated that children who grow up in families where "both parents have college degrees" have higher non-cognitive abilities than children where "both parents have non-college degrees.

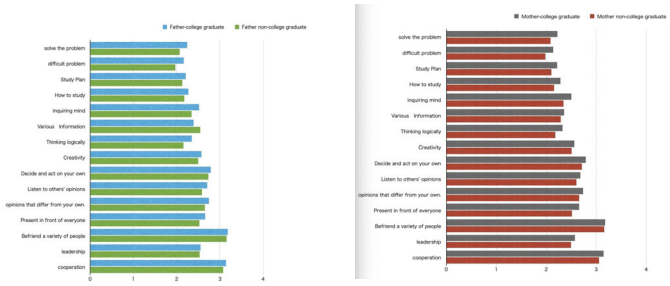

Figure: Parental Educational Background and Children's Non-Cognitive Ability

Based on the result that children who grew up in families where "both father and mother have college degrees" have higher non-cognitive abilities than children who grew up in families where "both father and mother have college degrees," it can be predicted that the mother's educational background (cultural capital) has a significant impact on the development of her children. Although it was confirmed that parents' social class, especially cultural capital, affects children's non-cognitive ability, it is necessary to examine whether this effect is mediated through child-rearing. In addition, we deny that the hierarchical differences in child-rearing are segmented in Japan as they are in the West and find that there are gradational differences according to maternal educational background. Therefore, it can be said that we should discuss whether the child-rearing disparity is becoming established as one hierarchical culture.

With Sustainable Society

High-quality family education is closely linked to the United Nations' Sustainable Development Goals (SDGs), particularly in education, gender equality, poverty eradication, and social inclusion. Family education is fundamental to achieving the goal of "ensuring inclusive and equitable quality education." In addition to supplementing schooling, home education plays a critical role in children's early development. The learning environment, support, and value-shaping that parents provide for their children at home have a direct impact on their cognitive and non-cognitive abilities and lay the foundation for lifelong learning.

In addition, high-quality home-based education includes the development of children's life skills and emergency response capabilities. Through home education, parents can help their children understand the basics of natural disasters and enhance their awareness of disaster prevention. For example, parents can teach their children how to protect themselves from earthquakes, floods, or fires and familiarize them with emergency escape routes. In this way, the family can not only become a place for the dissemination of knowledge but also improve the overall capacity of the community to respond to disasters. Addressing climate change requires the participation of all people, and family education plays a key role in this process. Parents can increase their awareness of global issues by educating their children on the causes of climate change and its impact on natural disasters.

In conclusion, high-quality family education plays an important role in raising awareness and capacity for disaster prevention and contributes to the realization of Sustainable Development Goals (SDGs). By fostering awareness of disaster preparedness and climate change in the next generation, family education not only improves the coping capacity of individuals and communities but also contributes to global sustainable development.

Small meteors and their impact on planetary atmospheres

HASEBE Akinori

When you think of a meteor, what types of objects do you imagine? Some of you will recall the science fiction movie “Armageddon.” People who are interested in dinosaurs are aware of the meteor that caused their mass extinction. However, not only destructive meteors but also smaller meteors have attracted the interest of scientists.

Small meteors, also called “interplanetary dust particles (IDP),” are ubiquitous in the solar system and collide constantly with the Earth. Analyses of ground-based observations, detectors onboard spacecraft, computer simulations, and collections of meteorites have revealed that hundreds of tons of IDPs strike the Earth per day. Considering the different collision frequencies between large meteors and IDPs, the latter has a greater daily impact on the global environment.

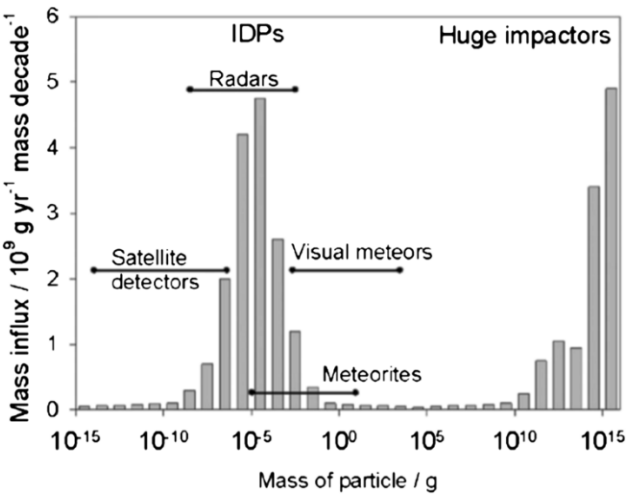

Fig. 1 Mass influx distribution of meteors to Earth. Horizonal lines indicate detection methods and their coverage. [Plane, 2012]

The formation of metallic layers in the upper atmosphere is an example of the environmental change caused by IDPs. When they enter the atmosphere, they are heated by collisions with atmospheric molecules and gradually “evaporate. Metal atoms such as Mg and Fe are released into the atmosphere to form the metallic layer. This metallic layer sometimes significantly alters the structure of the upper atmosphere, negatively affecting radio communications. This example demonstrates the scientific and technological importance of understanding the interactions between IDPs and planetary atmospheres.

In our study, we used simulation models that reproduced the changes in IDPs in the atmosphere and an atmospheric chemistry model to elucidate the interaction process between IDPs and the atmosphere. The atoms released during vaporization react chemically with materials in the upper atmosphere to form various substances. The simulation models can quantitatively reproduce the changes in atmospheric composition caused by these reactions. Thus, it is possible to predict the possible future effects of IDPs on Earth and estimate their importance in planetary history.

Our laboratory is particularly focused on studying the long-term evolution of planetary atmospheres, and we consider this in our research on IDPs. We expect that IDPs have had a significant impact on the evolution of planetary water environments. Some IDPs contain plenty of water in the form of hydrous minerals that would have evaporated in the upper atmosphere to supply water to the planet. So far, it is uncertain how much of an impact it would have, and few previous studies have focused on water in IDPs. Therefore, as our research progresses, a new IDP factor will be added to the evolution of planetary water environments, thereby bringing significant changes to this research area.

Furthermore, we plan to apply these studies to Martian science in anticipation of further exploration. The world's first Mars-area sample return mission, the Martian Moons eXploration (MMX), is currently underway by JAXA. This spacecraft is expected to provide information on the amount and composition of IDPs present around Mars. We will have to wait a few more years to obtain the results of this mission, but we are now developing simulation models so that we can use them immediately.

These small meteors may not have the same power as giant meteors, which could cause mass extinction. However, they certainly have an impact on the environment of Earth and other planets. We are now studying IDPs as a part of large-scale planetary science, but they will also have an impact that cannot be ignored by science and technology on a scale that concerns human activity. Fortunately, many students in this SyDE program study such things, and we would like to explore ways in which our research can be applied more broadly through interactions with them.

Enhancing Irradiation Resistance of Silicon Carbide Ceramics: A Step Toward Safer Nuclear Energy

Taichi Miyagishi

Introduction

Nuclear power holds significant potential as a clean and efficient energy source that is essential for reducing greenhouse gas emissions and combating climate change. Silicon carbide (SiC) ceramics are widely regarded as promising materials for nuclear reactor components owing to their high-temperature strength, low activation, and resistance to corrosion. However, under particle irradiation, SiC experiences increased corrosion rates, which can compromise the integrity of reactor systems over time. To address this challenge, this research focused on the development of a double-layer ceramic coating to enhance the irradiation resistance of SiC, thereby improving the safety and durability of nuclear reactors.

Research Overview

This study investigates the application of a double-layer coating system consisting of a mullite bond layer and an alumina top layer on SiC ceramics. Both materials were chosen because of their unique properties: alumina is known for its excellent resistance to corrosion, while mullite serves as a reliable bond coat that enhances the adhesion between the SiC substrate and the alumina layer. This coating system aims to improve the stability and performance of the material under irradiation, which is a critical factor in the nuclear environment.

The coatings were applied to SiC samples by laser chemical vapor deposition and subjected to irradiation experiments. The tests were conducted at a temperature of 300°C with 5.1-MeV silicon ions to simulate conditions similar to those in a nuclear reactor. To assess the durability of the coatings, a novel testing method, the double-notch shear compression test, was developed. This method enabled the precise measurement of the interfacial strength of the coating layers after irradiation, providing insights into the ability of the coatings to withstand extreme conditions.

Key Findings

The results of the irradiation tests are promising. Contrary to expectations, the irradiation improved the interfacial strength at both the SiC/mullite and alumina/mullite interfaces. This suggests that the structural changes induced by irradiation contributed to an increase in the

bonding strength, making the coated SiC more resilient under harsh conditions. Microstructural analysis revealed that the irradiation led to the formation of a transition layer at the SiC/mullite interface, which may have been responsible for the enhanced strength. This finding is significant because it demonstrates the potential of these coatings for improving the performance and longevity of SiC ceramics for nuclear applications.

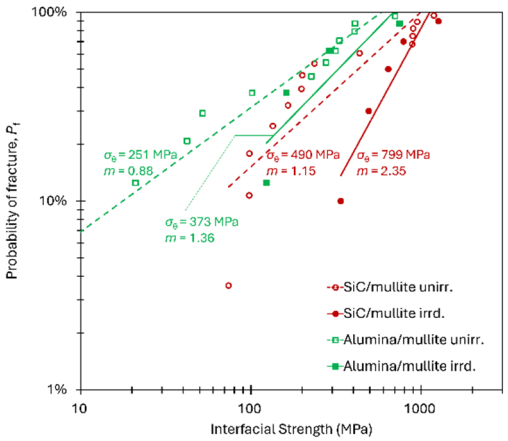

Fig. Irradiation effects on interfacial strength of SiC/mullite and alumina/mullite.

Broader Impact – How Does My Research Connect to a Sustainable Society?

Nuclear power is an essential part of the global effort to combat climate change because it generates electricity without directly emitting CO_2. However, the risk of severe accidents remains a challenge with potentially devastating consequences. Accident-tolerant fuels (ATFs), such as those investigated in this study, are designed to enhance the safety of nuclear reactors by maintaining their structural integrity and resisting corrosion under extreme conditions. By improving the irradiation resistance of SiC with double-layer ceramic coatings, this study helps minimize the damage to reactor components during accidents, potentially limiting the release of harmful substances.

Because renewable energy sources, such as wind and solar, are not yet sufficient to meet global demands, nuclear energy plays a vital role in providing reliable and clean power. Improving the safety and durability of nuclear reactors supports the continued use of this energy source, thereby ensuring its role in the transition to a low-carbon economy. Thus, this study contributes to both the advancement of nuclear technology and global sustainability goals by making nuclear power safer and more resilient.

Conclusion

In conclusion, this research on double-layer ceramic coatings for SiC ceramics contributes to the ongoing efforts to make nuclear energy safer and more sustainable. By enhancing the irradiation resistance of SiC, we can extend the lifespan of critical reactor components, reduce the risk of accidents, and support the broader adoption of nuclear power as a clean energy solution. As the world seeks to transition away from fossil fuels, such innovations will be essential to ensure

that nuclear energy can play a role in securing a sustainable future.

Revealing Trace Chemical Species in Materials Science

Shunsuke Shimizu

Introduction

Imagine trying to find a single diamond grain in a large desert. This is similar to what scientists encounter while attempting to detect trace amounts of chemical species in solid materials. Our research focuses on developing new methods to find and analyze trace chemical species such as nitrogen and hydroxyl groups in materials such as carbon and oxides.

Background

Materials such as carbon and oxides are crucial in technologies ranging from energy storage to catalysis and semiconductors. Even small amounts of chemical species (10 ppm) in these materials can alter their work. Therefore, it is important to determine what these tiny chemical species are and how many of them are present. However, conventional analytical methods lack the sensitivity to detect and quantify these trace elements. Measuring (quantifying) and identifying (qualifying) all the trace chemical species in a material is challenging.

Our Research

In our work, we use a special device called an "Advanced Temperature-Programmed Desorption" (Advanced TPD) system, which we developed ourselves. TPD is an important thermal analytical method in which a sample is heated at a constant rate, and the gases desorbed from the sample are detected using a mass spectrometer or high-speed gas chromatography. For example, when TPD is applied to carbon materials, each oxygen functional group can be quantified based on the desorbed gas species and their desorption temperatures (Fig. 1). However, commercial TPD equipment cannot detect all hydrogen, nitrogen, sulfur, and phosphorus species in carbon because conventional TPD is not sensitive enough and cannot reach high temperatures (sensitivity: ~1000

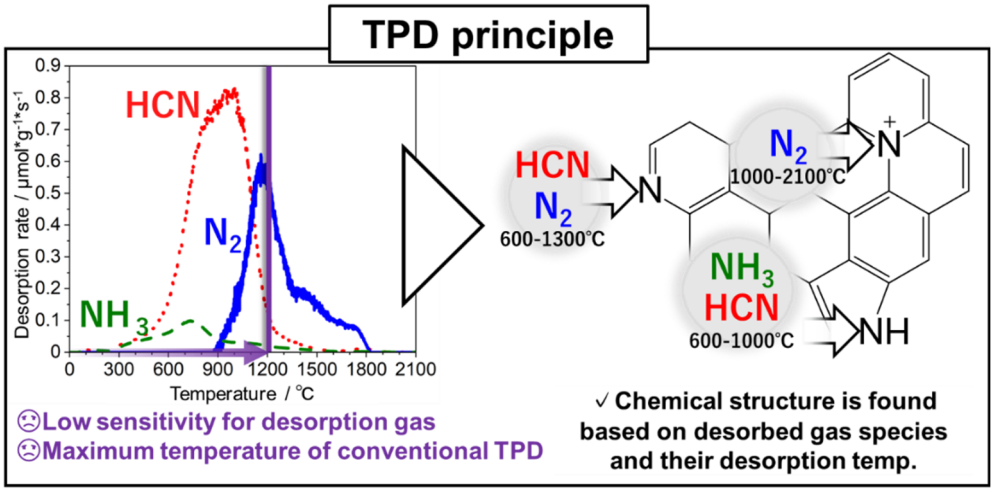

Fig. 1 The principle of TPD. Our advanced TPD is different from conventional TPD from the perspective of gas sensitivity and heating maximum temperature.

ppm, max temp.: 1200 °C). We developed an advanced TPD device that can heat up to 2300°C and has high sensitivity (~10 ppm), allowing us to measure all these species[1–3]. Recently, we applied TPD to other materials, such as oxides and nitrides. In the following section, we describe a recent study.

Perovskite-Type Oxides

Perovskite-type oxides are used in photocatalysis to accelerate chemical reactions using light, such as generating hydrogen gas or purifying water with solar power. The addition of small amounts of nitrogen (nitrogen doping) improved the performance. Measuring and identifying nitrogen inside a material is important but challenging using conventional methods. Using advanced TPD, we can measure and identify all nitrogen species in bulk oxides, helping us understand how nitrogen doping improves the material[4].

Zeolites

Zeolites, which are crystalline materials used in catalysis and adsorption, contain hydroxyl groups that play crucial roles in their catalytic activity and stability. These hydroxyl groups can exist in different environments, such as on the surface or at defect sites, which can significantly affect the zeolite properties. Conventional methods struggle to distinguish between these types of hydroxyl groups and provide detailed information on their behavior. Using advanced TPD, we can measure the gas species released during heating—either hydrogen (H_2) or water vapor (H_2O)—and determine their desorption temperatures. This analysis allowed us to differentiate between the types of hydroxyl groups and provided insights into the strength of the hydrogen bonds formed between them, which is critical for understanding the performance of the material in catalytic applications.

Conclusion

By developing these new methods, our research will help us to better understand and improve the materials that power our world. Whether it is making batteries last longer or creating more efficient catalysis, knowing what is inside these materials is key, and our work helps to uncover these hidden secrets.

References

1 T. Yoshii, G. Nishikawa, V. K. Prasad, **S. Shimizu**, R. Kawaguchi, R. Tang, K. Chida, N. Sato, R. Sakamoto, K. Takatani, D. Moreno-Rodríguez, P. Škorňa, E. Scholtzová, R. K. Szilagyi and H. Nishihara, *Chem*, 2024, **10**, 2450–2463.

2 D. Tanaka, N. Takemori, Y. Iba, K. Suyama, **S. Shimizu**, T. Yoshii, H. Nishihara, Y. Kamimura, Y. Kubota and S. Inagaki, *Microporous Mesoporous Mater.*, 2024, **379**, 113294.

3 L. Merkel, A. Setaro, C. E. Halbig, **S. Shimizu**, T. Yoshii, H. Nishihara, T. Hilal, G. Algara-Siller, C. Koch and S. Eigler, *Carbon*, 2024, **229**, 119454.

4 **S. Shimizu**, T. Yoshii, G. Nishikawa, J. Wang, S. Yin, E. Kobayashi and H. Nishihara, *Chem. Sci.*, 2024, **15**, 10350–10358.

A Study of the Social Contribution Activities of Religion in Times of Crisis—Focusing on the Pandemic

GONG XIYAN

Research Background

Since the mid-20th century, there has been a growing interest in religious social contributions, both in practice, such as “liberation theology” and “engaged Buddhism,” and theoretically, as seen in José Casanova's “public religion theory.” These interests arose primarily against the backdrop of social issues such as poverty, discrimination, war, disasters, and environmental destruction. However, there has not been a sufficient examination of how religion can address pandemics on a global scale. Following the Great East Japan Earthquake, research and practice in this field developed rapidly in Japan, but both still lag behind those in the West. This study aims to clarify the challenges faced by religions in Japan during pandemics that threaten the world and their contributions.

Current State of Research

There is a considerable body of research on the connection between religion and infectious diseases. When modern medical knowledge is scarce, religious responses such as festivals are held to ward off epidemics and seek healing, leading to the spread of faith based on these practices. Additionally, in the Edo period, diseases became deified and represented in imagery, as seen in "pox pictures," "measles pictures," and "cholera pictures" (Tanaka 2022, Park 2021).

With the introduction of Western medicine in the Meiji era and advancements in pharmacotherapy in the 20th century, a significant transformation in the response to infectious diseases occurred. The religious community's response to the early 20th-century Spanish influenza outbreak in Japan has been examined. Kaino (2020) argued that Christian churches at the time did not consider disasters and social problems to be their concern and scarcely mentioned the faith-based and theological significance of infectious diseases. Yumiyama (2021) noted that religious events continued during the Spanish flu pandemic. Research in Japan regarding the role of religion in the COVID-19 pandemic focused on the provision of solace to people (Park 2021, Wakamatsu, Shimazono, Yumiyama 2021).

Previous research on the intersection between religion and infectious diseases has focused on religious perspectives on the cause of diseases, that is, religious views on illness. In addition, the psychological function of spiritual healing by religion in the face of infectious diseases has been emphasized, while the social role of religion in solving broader social problems caused by infectious diseases has been overlooked.

Research Purpose

This study aims to clarify how religions in Japan responded to the pandemics since the 20th century, and their related social contributions. By comparing the social contributions of religion in Japan during these pandemics, this study seeks to examine how the role of religion in such crises has changed. The topic can also be examined from a broader perspective, considering the social response of religion to other types of emergencies, such as disasters and wars. This study elucidates the uniqueness and commonalities of religion in Japan in response to the pandemics. It also explores how religious institutions can be used to address pandemics and disasters and enhance social resilience in modern society.

Ripple effects on academic fields and society

This study suggests that the significance of religion in contemporary society should not be limited to personal spiritual healing but that attention should also be paid to its social significance by examining the role of religion in society. Through social contribution activities, the role of religion has been redefined, offering insights into the research on modern religion. Furthermore, by highlighting the role of religious institutions as social resources in response to the pandemic, it is evident that religion can be utilized as a means of disaster preparedness when facing unknown risks. Religion brings new hope to human society, demonstrating its role in creating resilient societies, even for disaster prevention.

References

Kaino, Nobuo. (2020). "The Spanish Flu and the Japanese Church: How Did the Church Respond 100 Years Ago?" *Gospel and World*, pp. 30–35.

Park, Byung-Do. (2021). "Epidemics as Disasters in Early Modern Japan and Religious Responses: From Smallpox, Measles, Cholera to COVID-19." *Contemporary Religion 2021: Special Issue on Religion and Infectious Diseases*, pp. 103–125.

Tanaka, Jin. (2022). "Epidemics in Classical Japanese Literature: Examples of Visualization, Personification, and Narrativization." *Journal of Research Society of Buddhism and Cultural Heritage*, pp. 23–30.

Wakamatsu, Eisuke, and Shimazono,Susumu; Moderator: Yumiyama,Tatsuya. (2021). "Dialogue: The Expected Role of Religious Leaders Amid the COVID-19 Pandemic." *Contemporary Religion 2021: Special Issue on Religion and Infectious Diseases*, pp. 5–31.

Yumiyama,Tatsuya.(2021). "Why Were Religious Ceremonies Held During the Spanish Flu Pandemic?" *Journal of Religious Studies*, Vol. 95, No. 2

Cathode Design for Next-Generation Energy Storage Devices with Ultra-High Energy Density

Zhaohan Shen

Among secondary batteries, lithium-air batteries (Li-O_2 batteries), which have the highest theoretical energy density, are gaining significant attention as next-generation batteries, leading to a global race in their development. However, a major challenge lies in battery degradation under high overpotential. Solid catalysts are widely used to address this issue.

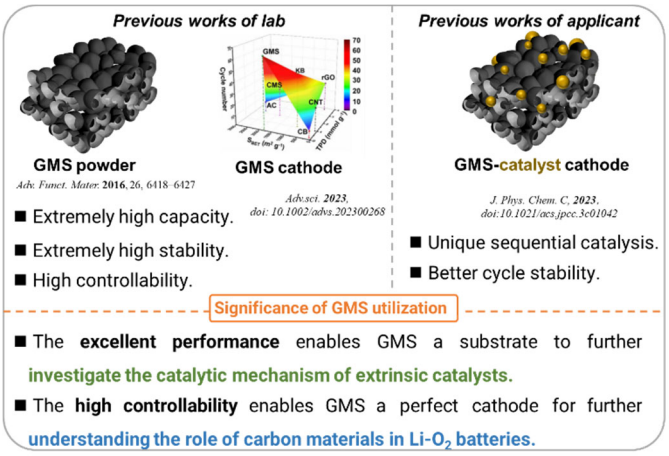

Figure 1. Current background of this research.

According to recent studies, a lower overpotential does not necessarily improve cycle performance, yet the relationship between overpotential and the performance of Li-O_2 batteries remains unclear. The applicant's research aims to clarify the true impact of overpotential on batteries and explain its relationship with cycle performance.

In the laboratory that I belong to, a novel carbon material with high oxidation resistance and excellent porosity, graphene mesosponge (GMS, Fig. 1), has been developed (Adv. Funct. Mater. 2016, 26, 6418). Li-O2 batteries using GMS as the cathode have achieved extremely high capacity and cycle stability (Adv. Sci. 2023, in press). The applicant has previously found that combining GMS powder with a solid catalyst (Ru nanoparticles) can significantly improve cycle stability through sequential catalytic effects (J. Phys. Chem. C, 2023, 13, 6239) (Fig. 1).

According to the recent research, it has been believed that addressing the challenges shown in Fig. 2 is essential to further improving cathode design performance.

Challenge 1: The relationship between the structure of the carbon cathode and the performance of Li-O_2 batteries remains unclear.

Challenge 2: The reaction mechanism of solid catalysts is not well understood.

Challenge 3: Liquid-phase catalysts (redox mediators, RM) migrate to the anode, causing degradation reactions (shuttle effect).

The primary cause of Challenge 1 is the need to fabricate working electrodes by mixing binder with conventional carbon cathode powders. To address this, the present research will clarify the

relationship between the structure of the carbon cathode and the performance of Li-O_2 batteries by creating a binder-free electrode through the self-supporting membrane fabrication of GMS.

To enhance energy efficiency, solid catalysts are widely used in Li-O_2 batteries. However, their intrinsic catalytic mechanisms remain unclear. In the applicant's previous research, it was found that conventional hcp-type Ru combined with GMS achieved sequential catalytic effects. Therefore, to address Challenge 2, this research will bridge the gap in applying the previously unreported fcc-type Ru to Li-O_2 batteries, summarizing the catalytic mechanism based on the properties of the catalyst's crystal structure. This novel Ru catalyst also has the potential to exhibit unprecedented ultra-high catalytic performance. During the study of GMS cathodes fixed with solid catalysts, side reactions caused by the solid catalysts were observed. Building on this, the application of soluble redox mediators (RMs) with superior selective catalytic performance without inducing side reactions is proposed. However, it is crucial to prevent reactions with the Li anode (shuttle effect). Due to its unique structure, GMS has a fixing effect on modified RMs.

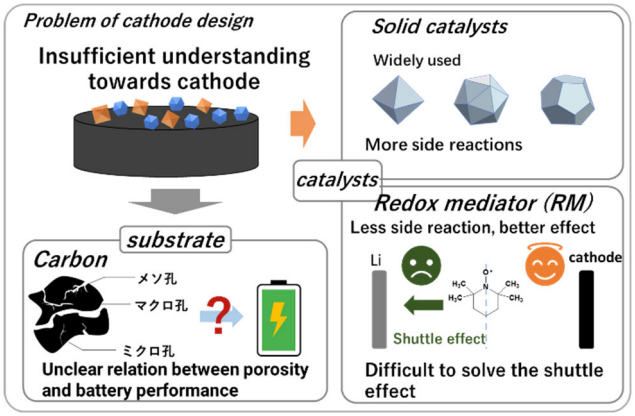

Figure 2. Challenges in the cathode design.

Ultimately, by combining ultra-high-performance carbon support materials (Challenge 1) with highly catalytic solid catalysts (Challenge 2) or liquid catalysts (Challenge 3), it is expected that a cathode with practical-level high capacity, high catalytic performance, and highly stable cycle performance can be designed.

The carbon material developed in this research allows for highly controlled hierarchical pore structures. This unique, designable carbon cathode enables the construction of cathodes for Li-O_2 batteries based on the fundamental structure of carbon materials. Moreover, previous studies on solid catalysts in Li-O_2 batteries have not addressed the core mechanisms involved. This research aims to elucidate the catalytic mechanisms based on crystal surfaces. Simultaneously, by flexibly designing GMS for liquid catalysts, we aim to resolve the shuttle effect of RMs in Li-O_2 batteries. Ultimately, by combining high-performance carbon supports and catalysts, we intend to develop a high-performance Li-O_2 battery that has not been reported in prior research.

Development of Force-Driven Power Generation Using Elastic Carbon Materials

XIA TIAN

As global environmental problems become more serious, there is increasing urgency to find clean energy sources to replace traditional fossil fuels and reduce environmental pollution. Modern electronic products tend to be portable and lightweight and typically rely on traditional batteries (such as dry batteries and lithium batteries). While batteries provide high energy density, they also pose significant environmental risks owing to the use of heavy metals and toxic electrolytes. To address these challenges, researchers are exploring innovative alternatives, and carbon nanomaterials have emerged as promising solutions. Owing to their exceptional electrochemical properties, stability, and diverse structural forms, including powders, tubes, fibers, films, and 3D foams, carbon nanomaterials are well-suited for power generation applications at the carbon-electrolyte interface. Their designable nanoscale dimensions, large surface areas, high electrical conductivities, and tunable chemical reactivities make them ideal candidates for the development of new lightweight and environmentally friendly energy sources.

In a recent study, we synthesized a unique elastic mesoporous carbon with a pore size of approximately 7 nm. This material, which we named carbon mesosponge (CMS), exhibited a sponge-like mesoporous structure and remarkable mechanical flexibility (Fig. 1a). During our experiments, we observed an intriguing phenomenon: when pressure was applied to elastic porous carbon immersed in an electrolyte, a significant electrical signal was generated. This process is analogous to squeezing a sponge, which causes the electrolyte within the pores to flow out. Based on this discovery, we developed a force-driven power-generation system using a CMS as a model material (Fig. 1b). The system produces strong electrical signals upon compression and release (Fig. 1c). The current exhibited a negative response to compression, indicating that electrons flowed from the counter electrode to the CMS, accompanied by an increase in the potential. Upon pressure release, the

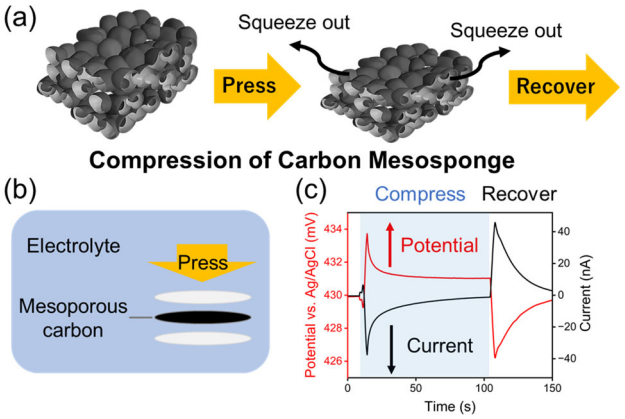

Fig. 1. (a) The compression processes. (b) Schematic of the device. (c) Force-responsive electrical signals.

current response becomes positive, and the potential returns to its initial level.

This force-driven power generation phenomenon is not limited to CMS but rather is also observed in other porous carbon materials. We tested various porous carbons, including commercial activated carbon, and found that the output power of the force-driven power-generation system was strongly correlated with the flexibility of the material. We investigated the influence of different electrolytes by applying various cations and anions to a force-driven power generation system. Interestingly, the electrical signals generated using different electrolytes exhibited similar characteristics, and the output was positively related to the diffusion coefficients of both cations and anions. This suggests that the deformation of mesoporous carbon leads to ion movement and redistribution. Due to the high mobility of OH^- ions, the force-driven system achieved its highest output when using NaOH as the electrolyte. Additionally, the output power was significantly affected by electrolyte concentration, increasing from 0.1 to 3.8 $\mu W/cm^2$ as the concentration increased from 1 to 4 M. The system's output power also rose from 3.8 to 7.1 $\mu W/cm^2$ with a temperature increase from 25 to 35°C due to the higher mobility of ions at elevated temperatures.

In conclusion, we discovered a unique force-driven power-generation phenomenon in which the application and release of pressure on porous carbon immersed in an electrolyte generates a strong, responsive electrical signal. This simple design allows for the harvesting of electrical energy from periodic applications and the release of pressure. The system output was positively related to the flexibility of the porous carbon, temperature, and electrolyte concentration. The maximum output power of the system can reach up to 7.1 $\mu W/cm^2$, which is comparable to existing carbon-electrolyte power generation systems.

The development of innovative energy sources, such as the force-driven power generation system described in this study, is closely linked to the goal of building a sustainable world. Traditional energy sources such as fossil fuels are primary contributors to environmental degradation, air pollution, and climate change. By transitioning to clean and sustainable energy technologies, greenhouse gas emissions can be significantly reduced, and the adverse impacts of climate change can be mitigated. The use of carbon nanomaterials in power generation is a promising advancement. Unlike conventional batteries, which involve environmentally harmful components, such as heavy metals and toxic electrolytes, carbon nanomaterials are generally safer and more sustainable. Moreover, they can be sourced from abundant renewable materials, further reducing the environmental footprint associated with their production and use. This not only reduces reliance on disposable batteries but also aligns with the principles of sustainable energy harvesting and the circular economy.

How My Research Contributes to Building a Sustainable Society

Riichi Sugai

I am conducting research to develop a numerical simulation method that can reproduce the flow of sediment and the damage or collapse of structures such as buildings and bridges. You may wonder how it is possible to calculate the behavior of both the sediment flow and the collapse of structures. These two phenomena can be described based on the same physical principle, which is the equation of motion. Equations were derived to describe the deformation of objects. Using computers, we solved the equations to simulate the deformation and destruction of objects. Briefly, my research involves developing the methods necessary for solving the equations of motion on computers and predicting the complex behaviors of objects.

The subject of this research was the prediction of damage caused by natural disasters. You may have seen news that heavy rain or earthquakes cause sediment to flow into residential areas and cause the collapse of buildings. Natural disasters can lead to loss of human life and destroy property and assets, significantly impacting human society. Because it is impossible to prevent heavy rain or earthquakes from occurring, it is crucial to take measures against natural disasters to avoid damage. Specifically, one of the countermeasures against sediment flow is to design and build retaining walls or dams that can properly contain sediment from a landslide and withstand even the strongest earthquakes.

To implement these measures properly, an accurate prediction of the phenomena involved is essential. However, we do not fully understand them because of their complexity. Let us consider the difficulties involved in understanding landslides. There are two main approaches to studying mechanics: experiments and numerical simulations. In experiments, soil is placed on a slope in a laboratory and showered with water to simulate rainfall and trigger a landslide. Although such experiments can reproduce realistic results, they are costly and time-consuming, and therefore, they cannot be conducted frequently. Furthermore, it is extremely difficult to assess what is happening inside the collapsing soil based on visual observations. Indeed, determining the water content within the soil is significant because the resistance of soil structures against collapse strongly depends on the amount of water they contain. Unfortunately, the amount of detail that can be measured experimentally is limited. However, if we can reproduce phenomena using numerical simulations, the time and cost issues can be significantly alleviated. Although high-performance computers are necessary, the annual cost of using a supercomputer is often lower than that of a single experiment. Furthermore, numerical simulations can visualize all the internal information of objects, allowing us to examine details that cannot be observed experimentally.

Therefore, numerical simulations can be considered a powerful tool for understanding the mechanisms behind complex phenomena such as sediment flow and the collapse of structures.

Although the advantages of numerical simulations have been previously explained, they are not without limitations. Though numerical simulations are widespread and many engineers have access to them, the commonly used simulation methods are not capable of addressing the following phenomena: 1) the process by which soil transitions from a solid-like cohesive state to a state of collapse and flow and 2) cases where the soil collapses and deforms discontinuously, such as crack formation. Without integrating these factors, it is difficult to accurately reproduce sediment flows and the resulting damage or collapse of structures owing to their impact.

To address these challenges, this research focuses on enhancing simulation methods. Specifically, I attempt to expand the functions of the material point method (MPM), which has been applied in sediment flow analyses, to simulate the damage and destruction of structures. In this process, I aim to integrate the two fields of geotechnical and computational solid mechanics. Additionally, reproducing sediment flow over actual terrain using numerical simulations requires a vast amount of computational resources. This is because of the need for large-scale, detailed terrain data and the necessity of calculating the sediment flow and collapse of structures at very short time intervals to obtain precise results. To address the issue of computational cost, my research also includes efforts to improve computational efficiency through techniques such as parallel computing, thereby reducing the time and resources required for these simulations.

Finally, I describe how this research contributes to building a sustainable society. I believe that by enabling the accurate reproduction of sediment disaster damage through numerical simulations, my research can contribute to the achievement of SGDs Goals 3, 9, and 11. Goal 3 aims to ensure overall health and well-being. To build safe healthcare facilities and water supply systems, we must design them robustly against external forces such as earthquakes and terrorism. Numerical simulations help predict damage in such situations, allowing us to provide safer facilities. Goal 9 focuses on building disaster-resilient infrastructures and ensuring stable access. Numerical simulations during pre-assessments are beneficial for the design and construction of resilient roads, power transmission towers, and communication base stations. Goal 11 emphasizes building disaster-resilient cities and infrastructure, particularly reducing human loss and property damage from disasters, such as floods. This research potentially serves as a powerful tool for predicting flood damage, including landslides, and for implementing appropriate countermeasures to reduce economic losses. I aim to apply my research in order to achieve these goals.

Biosensor development for the detection of infectious disease biomarkers in wastewater

WANG YILEI

An outbreak of an infectious disease can be regarded as a sudden disaster event, and its far-reaching impact is thought to be provoked. In addition to medical testing, methods that can predict and alert patients about infectious disease outbreaks need to be developed. One innovative approach involves the use of wastewater epidemiology to detect biomarkers. This approach allowed us to obtain predictive information before confirming cases of infection. Various biomarkers can be detected in wastewater, such as the pathogen itself, secretions in human excreta (including antibodies), and the genetic material of the virus. Biosensors have the advantage of faster and real-time detection and the effectiveness of early warning systems. Targeting proteins can eliminate the need for sample pretreatment, reduce detection time, and enable on-site real-time monitoring.

During my master's studies, my target for detection was SARS-COV-2 specific IgA antibodies. Some studies have shown that IgA antibodies dominate the early response to SARS-CoV-2, occurring faster and more strongly than the other antibodies. In addition, there are two types of IgA: serum IgA and secretory IgA, which are mainly found in exocrine fluids, such as saliva, tears, and gastrointestinal fluid; therefore, SIgA can be detected in wastewater. I use an aptamer as the recognition element of a biosensor, and a short piece of a single-stranded oligonucleotide molecule (RNA or DNA) can be screened using the SELEX (Systematic Evolution of Ligands by EXponential enrichment) method from randomly synthesizing an oligonucleotide nucleic acid library through folding to form a specific three-dimensional structure that interacts with target molecules with high affinity and specificity. Aptamers have wide applicability and can bind to a variety of biological elements, such as ions, compounds, drugs, proteins, and nucleic acids. In my master's degree, I am conducting aptamer screening for SARS-COV-2 specific IGA antibodies. At the same time, I plan to propose a general aptamer screening method to cope with the diversity of biomarkers in wastewater.

During my doctoral studies, I have focused on the construction of sensors and their practical applications. Paper-based analytical devices (PADs) were introduced in the 20th century and rely on capillary action for passive fluid transport. Over the past few decades, numerous researchers have reported the applications of PADs in areas such as food safety, clinical

diagnostics, drug development, and environmental monitoring. PADs offer a promising solution for infectious disease diagnosis and are characterized by their cost-effectiveness, rapidity, high sensitivity, high specificity, and simplicity of use. They can meet the
Substantial demand for on-site testing in resource-limited communities. Some paper-based sensors employ optical principles, including colorimetric, fluorescence, and chemiluminescence assays, to achieve visual, non-quantitative, or semi-quantitative results. To predict the number of infections based on biomarker concentrations in wastewater, it is essential to obtain quantitative results. I aim to achieve high-sensitivity quantitative detection using aptamer paper-based biosensors by conducting in-depth investigations and assessments of various potential quantification methods in a future study.

This innovative research plan will bring new ideas to biosensing technology, not only introducing new methods in the field of wastewater monitoring but also providing an earlier disease warning system and promoting interdisciplinary cooperation. This has far-reaching impacts on society, including the improvement of resource management efficiency and the formulation of precise public health policies. It is expected to provide advanced and sustainable disease monitoring and prevention methods for the scientific community and social health.

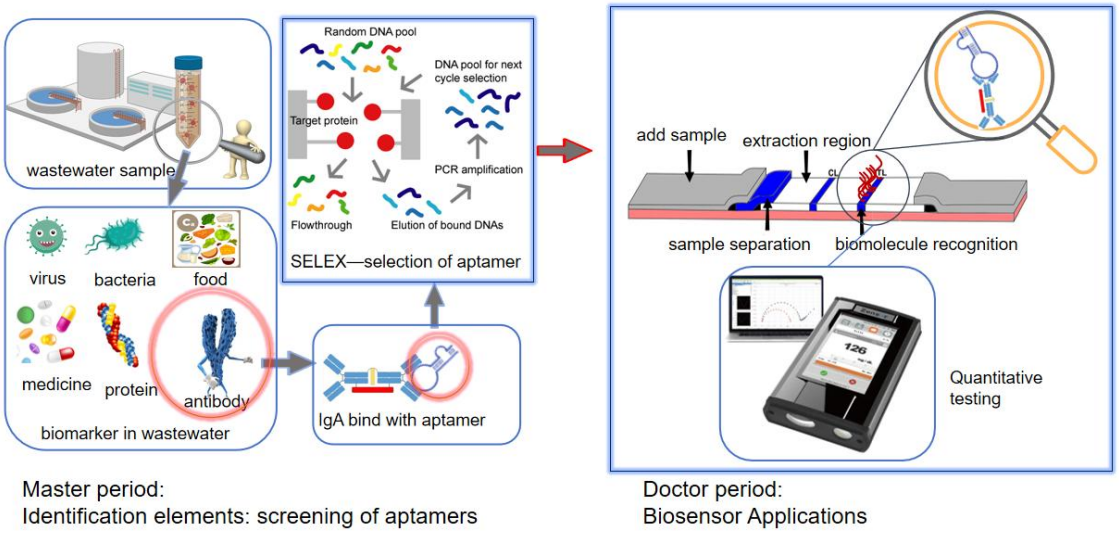

Figure 1 Graphical abstract

Relationships among fatigue, risk-taking, and risk perception.

Kaho Suzuki

Risk-taking often endangers our lives by causing injuries, traffic accidents, or industrial accidents. Furthermore, risky group decision-making can lead to tragedy, such as the 1986 space shuttle Challenger disaster. How can you avoid risk-taking? Some findings have revealed that tired people tend to make riskier decisions (Hockey et al., 2000), so getting adequate rest may prevent risk-taking due to fatigue. However, people cannot rest whenever they want to. Therefore, it is necessary to find ways to encourage fatigued individuals to make safer decisions.

Additionally, there is a need to examine the effects of individual fatigue on group decision-making. Fatigue and group decision-making are both common in daily life. In other words, you often engage in group decision-making in the workplace or at home with fatigue. Therefore, an increase in risk-taking, a change in mood state, or a decrease in cognitive ability due to fatigue may affect the process and outcomes of group decision-making.

To this end, we plan to conduct four studies. In Study 1, we will measure risk-taking and risk perception in fatigued people to elucidate the mechanism behind the relationship between fatigue and risk-taking. To evoke fatigue, we will ask the participants to perform cognitive tasks for long hours. To measure risk-taking, we will use the Automatic BART (Pleskac et al., 2008). We will ask participants to decide how many times they would pump up a balloon without informing them about the balloon's limit. The more the balloon is pumped, the larger the monetary reward will be. However, if a participant pumps too much air into the balloon, it will burst, and the participants will not gain a reward. Thus, the number of times the participants pump up the balloon represents risk-taking. To measure risk perception, we will ask participants to guess the probability of a balloon bursting and estimate the severity of failure to gain a reward.

In Study 2, we will ask participants to perform Automatic BART in a group to examine how group decision-making will change as the number of fatigued people will increase. Each group will consist of three fatigued participants.

In addition to these studies, we plan to investigate the relationship between fatigue and risk-taking in natural disasters. In Study 3, we will induce participant fatigue using the same procedure as in Study 1. Then, we will have participants read about a fictional scenario in which a local government issues a natural disaster warning, and we will ask the participants to decide at what level of warning they would take evacuation actions. In Study 4, participants will be asked to engage in group decision-making during a fictional natural disaster.

Reference

Hockey, G. R. J., John Maule, A., Clough, P. J., & Bdzola, L. (2000). Effects of negative mood states on risk in everyday decision making. Cognition & Emotion, 14(6), 823-855.

Pleskac, T. J., Wallsten, T. S., Wang, P., & Lejuez, C. W. (2008). Development of an automatic response mode to improve the clinical utility of sequential risk-taking tasks. Experimental and clinical psychopharmacology, 16(6), 555.

Estimating the size of rocks in the lunar subsurface using ground penetrating radar

Keitaro Kanda

I am working on estimating the size of rocks beneath the Moon using an observation technique called “Ground Penetrating Radar (GPR).

The Moon is covered with fine sand-like particles called “regolith”. Earth's soil is formed and evolves through the influence of wind, water, and life. However, the Moon has no such effect. Instead, the regolith was formed and evolved by meteorite impacts and high-energy cosmic rays from space. Meteorite impacts break up and stir up lunar bedrock (generally formed by ancient volcanic activity), gradually reducing the particles to finer particles. High-energy cosmic rays act on fine particles and cause changes in their chemical composition. The regolith covers the entire lunar surface. The average depth of the regolith is in the range of 4–5 m in mare regions, which are characterized as relatively dark-colored areas and appear as a rabbit pattern in Japan, and in the range of 10–15 m in the highland regions, which are characterized by relatively light color.

Most particles in the regolith are very small (less than 1 mm in diameter); however, relatively large rocks (several centimeters to several tens of centimeters in diameter) also exist. The sizes of these particles and rocks reflect the duration for which the surface of the Moon has been exposed to meteorites and cosmic rays. Therefore, I would like to study the size of the rocks in the regolith to understand the age of the subsurface strata containing the rocks and the evolution of the lunar surface. This research requires observation of rocks beneath the surface of the Moon, and GPR is a useful tool for this purpose.

GPR is a convenient method for surveying subsurface structures that can be performed easily and quickly without digging directly into the å. In a GPR survey, a GPR antenna transmits radio waves below the surface of the ground (see ① in the figure). The transmitted radio waves travel through the ground and are reflected at boundaries where physical properties change, such as the boundary between strata (e.g., between layers of regolith and lava) and rocks buried in the regolith (see ② in the figure). The reflected radio waves travel toward the ground and are finally measured by a receiving antenna of GPR (see ② in the figure). The depth of the reflected object can be estimated by multiplying the speed of light by the time taken from the transmission of the

radio wave to its reception and dividing by 2. By repeating this measurement while moving the antenna, a two-dimensional cross-sectional view of the subsurface structure can be created (see ④ in the figure). Typically, GPR is used to survey roads or tunnels and to search for anti-personnel mines and archaeological sites.

GPR has also been used in lunar and planetary exploration. In China's lunar exploration program called “Chang’E” a GPR is mounted on an exploration rover to investigate the subsurface structure of the Moon. I am working on analyzing observation data from the Lunar Penetrating Radar (LPR) onboard the Yutu-2 rover of the Chang'E-4 mission. There are two types of GPRs on the Yutu-2 rover, and the one I am using can observe up to about 40 meters below the surface.

GPR observations are quick and easy to perform, but they are difficult to analyze and interpret GPR observation data. This is because GPR observations can only tell us that there is an irregular object with different physical characteristics, and we cannot know what that object is directly. Although the location of a foreign object can be determined, the details of its shape are often unknown. Therefore, in our study, simulations were performed to investigate the relationship between the subsurface structure and the results of GPR observations. The simulations allowed us to freely set the subsurface structure (e.g., the location and size of rocks buried in the regolith) and helped us understand the real lunar subsurface structure by providing referential information to the LPR observations.

In summary, lunar regolith and rocks are important research targets that reflect the history of the lunar surface, and I am trying to investigate the subsurface structure of the Moon by analyzing data from the GPR on board the Chinese lunar rover and simulating GPR observations to reveal the lunar history.

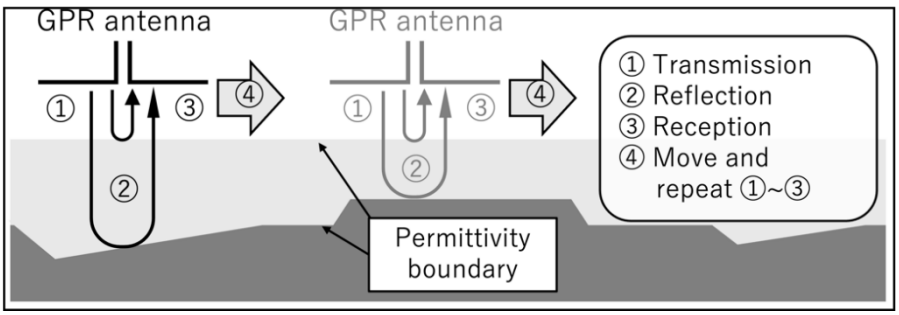

Figure. Basic principle of GPR observation.

Development of landslides forecasting model using ensemble precipitation for extremely heavy rainfall due to “senjo-kosuitai”

Kosei Osamura

1. Introduction

In recent years, the frequency of landslides and floods caused by extremely heavy rainfall has increased. For example, in the latter stage of the Baiu season, the western part of Japan including the Kyushu area experiences an accumulated rainfall of more than 150 mm/3 h. A “senjo-kosuitai” is the extreme heavy rainfall with a width 20-50km and a length 100-300km, produced by successively formed and developed convective cells and passing and stagnating at almost the same place for few hours. senjo-kosuitai often cause large-scale disaster. An extremely heavy rainfall event in 2018, caused more than 280 deaths in the western and eastern parts of Japan. This extremely heavy rainfall event was characterized by 24 h accumulated precipitation amounts exceeding 500 mm and caused multiple flood disasters around the Oda River in Okayama. In 2020, multiple flood disasters occurred around the Kuma River in southern Kumamoto causing more than 70 deaths, and emergency heavy rainfall warning were issued in south Kumamoto, Kagoshima, Fukuoka, and other areas.

Meso-scale (atmospheric scale 2 -2000 km) events including senjo-kosuitai have an associated degree of chaos, i.e. nonlinearity. For this reason, the meso-scale is sensitive to initial conditions and long-term unpredictability. Thus, the initial errors increase as the forecast time increases. However, in a recent study, weather model research has examined the initial sensitivity conditions due to atmospheric chaos.

In 2009, the Japan Meteorological Agency been implemented the use of the soil water index (SWI) in deciding when to issue heavy rainfall warning and assessing landslide risk since 2009. The SWI has a horizontal resolution of SWI 1 km and is forecasted after 6 h using 1 h precipitation data examined every 10 min. However, short-term forecasting is not possible for senjo-kosuitai, which exhibit rapidly increasing hazard risk. In this study, we developed a long-term landslide hazard risk forecasting system for heavy rainfall events caused by senjo-kosuitai in Nigata in 1998.

An outline of this study is shown in Figure 1. One-hour precipitation forecasting of landslide risk was conducted using ensemble prediction, which is a method for calculating precipitation scenarios that considers sensitivity to initial conditions due to atmospheric chaos. Ensemble predictions are useful for considering chaos at the meso-scale and probabilistic assessments of landslides risk.

2. For sustainability

The Sendai Framework for Disaster Risk Reduction 2015-2030 was adopted at the Third World Conference on Disaster Risk Reduction, which was held from March 14 to 18, 2015, in Sendai, Miyagi. It states that reducing deaths due to disasters is one of the most important factors and reduces disaster risk and deaths through multi-hazard early warning systems.

The Japan Meteorological Agency has been operating early warning systems for heavy rainfall, floods, strong winds since 1952. Early warnings are issued by the Japan Meteorological Agency for high-disaster-risk regions, 6 h disaster event occurs. Heavy rainfall due to senjo-kosuitai, increases the hazard risk rapidly. Consequently, people who live in high-disaster-risk areas may not have time to escape. This study showed that a long-term hazard risk forecasting system for landslides using ensemble prediction that could issue warning more than 72 h in advance could facilitate people being evacuated, which would reduce the number of deaths and the hazard risk, which set a target for Sustainability in Sendai Framework for Disaster Risk Reduction 2015-2030. The result of this study is expected to be useful in improving the efficiency of evacuations, and train services (transportation) before and during natural disasters and reducing the damages caused by weather-related natural disasters.

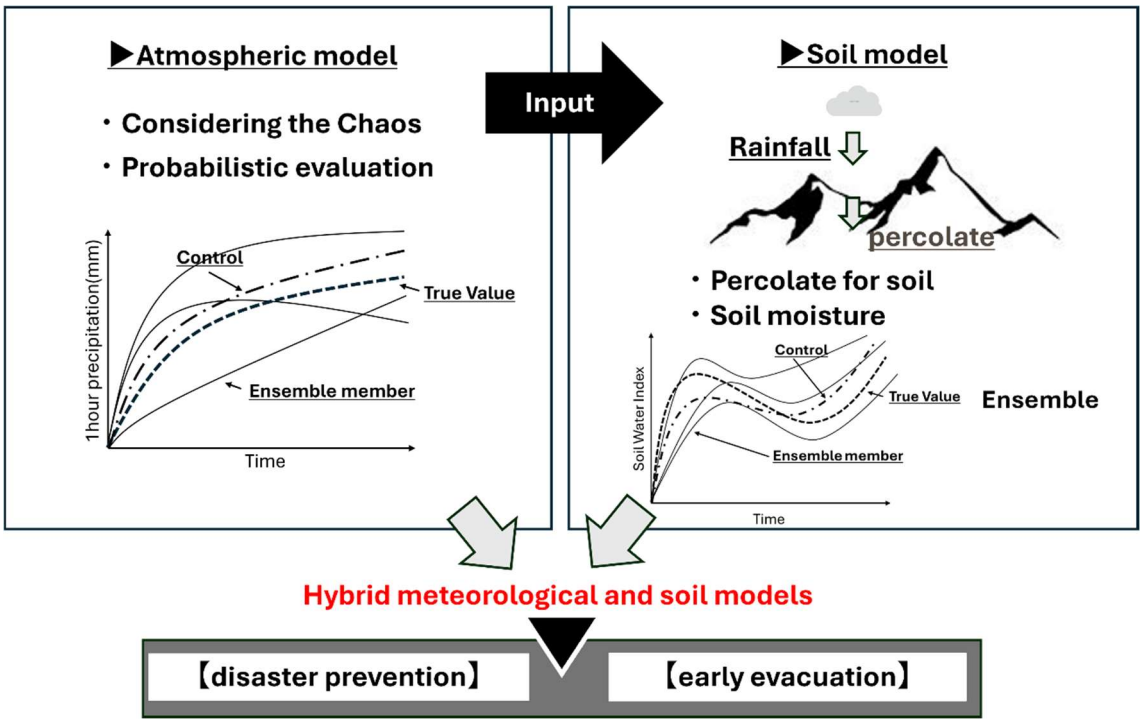

Figure. 1 Outline of this study

Toward Understanding the Factors Influencing Magma Discharge Rate Variations in Volcanic Eruptions

Shuhei Hotta

In volcanic eruptions, the pressure within the magma chamber is the primary driving force for magma ascent and is released during an eruption. As an eruption progresses and the pressure in the magma chamber decreases, the intensity of the eruption, typically characterized by the magma discharge rate, is expected to decline. Indeed, in some eruptions, exponential decreases in the magma discharge rate have been observed, which is consistent with this physical model. However, not all eruptions follow such a monotonic evolution, and magma discharge rates can vary widely with time. In certain eruptions, the discharge rates increased as the eruptions progressed, whereas in others, they fluctuated in a more complex manner.

Examples of eruptions with fluctuating discharge rates include the 1977 eruption of Usu Volcano and the 2011 eruption of Kirishima-Shinmoedake. In the latter case, both the magma chamber pressure changes and variations in the discharge rate were observed. Although the pressure in the magma reservoir decreased continuously during the eruption, the discharge rate remained constant. This contradicts the basic physical model, and the cause of discharge rate variation remains unclear. However, this variation can originated from processes that occur during magma ascent through the subsurface.

Typically, magma ascends from a reservoir that exists at a depth of several kilometers through a volcanic conduit, which is a pathway to the surface. During this ascent, several physicochemical processes can significantly change the physical properties of the magma. For example, within a magma chamber, the magma injection from deeper sources can change the pressure in the magma reservoir. Meanwhile, processes such as gas exsolution due to depressurization, outgassing from the magma, and mineral crystallization may occur within the conduit, which can change the magma density and viscosity. These processes and/or their coupling can change the physical properties of the magma, potentially contributing to complex variations in the magma discharge rate.

Therefore, understanding the mechanism of the variation in the magma discharge rate requires a detailed examination of the changes that occur in the magma as it ascends. One way to investigate these dynamics is to analyze volcanic products. The textures within the products often preserve the bubbles and crystals formed by the physicochemical processes, and the size, number, and shape of the bubbles and crystals are controlled by the dynamics of magma ascent (Fig. 1). Furthermore, chemical composition of the crystals reflects the temperature and pressure

conditions under which they form. By conducting detailed analyses of the bubbles and crystal textures within the products, it is possible to reconstruct magma ascent processes.

In this research, I aim to clarify how the magma ascent process evolved over the course of the six eruptions during the 1977 eruption of Usu Volcano by analyzing the volcanic products. Through this, I aim to reveal the factors that contribute to the variations in the magma discharge rate.

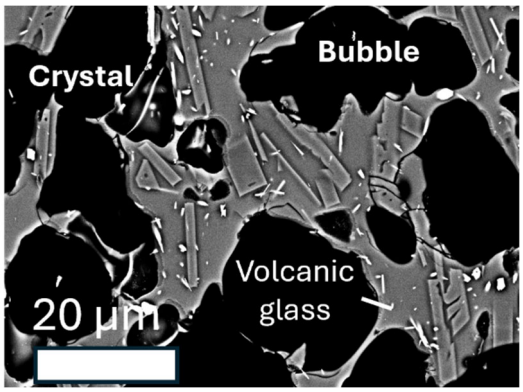

Figure 1. Backscattered electron image of bubble and crystal texture.

Achieving a more “disaster resilient society” by clarifying the strength of transmission towers

Department of Civil and Environmental Engineering Yuto Yamano

Introduction of my research topic: Numerical analysis of transmission tower

Transmission towers play an important role in electric power supply. However, some collapse accidents owing to natural disasters have been reported in these towers. In Japan, many transmission towers were constructed during the period of rapid economic growth after World War II (from approximately 1955 to 1973). Lifetime expectancy was assumed to be approximately 50 years. However, many of them still play a role in electric power supply.

What is the current situation? In my opinion, we face a future risk of severe supply disruptions as a result of the degradation of transmission towers. Some collapses of transmission towers have even been reported.

Some examples of tower collapse are presented below. In September 2019, the transmission towers collapsed owing to Typhoon No.15 in Chiba Prefecture. This collapse caused severe supply disruption. In December 2022, snow accretion on the power lines caused the collapse of a transmission tower in Hokkaido.

Figure1: Example of damage in Niigata Chuetsu Offshore Earthquake

Furthermore, damage caused by ground deformation has been reported. Figure 1 shows a tower damaged by ground deformation caused by the 2007 Niigata Chuetsu Offshore Earthquake. The breakdown of power supply system caused by the collapse of a tower affects not only civic lives but also various industrial activities.

To avoid the breakdown of power supply facilities, many researchers have studied the collapse of transmission towers using computer simulations: simulations under very strong winds caused by typhoons [1]; the simulation assuming the ground deformation [2]; and simulations of more efficient methods of building transmission towers [3].

However, few studies have been conducted on the effect of repairs on damaged transmission towers. In current engineering practices, the judgment on repair or reconstruction is determined according to the state and degree of damage. Repair by member replacement is usually based on qualitative damage assessment (e.g., large, medium, or small). The usefulness of this assessment is dependent on the skill and experience of the inspector. Furthermore, the efficiency of damage assessment and repair methods partly remains unclear.

In view of the above-mentioned background, studies on damage assessment and repair methods are expected to be in high demand for effective management of transmission towers. In our research team, we assumed certain types of seasonal loads due to natural disasters and ground

deformation. Subsequently, we analyzed the damage simulations under these seasonal loads using a computer. Through the above simulations, we obtained data on the progress of member damage and the degradation of tower strength.

Furthermore, after the damage simulations, we attempted to analyze the repair simulation of the damaged tower. This study provides fundamental knowledge to enable the reasonable selection of a repair method for complete strength recovery.

Potential impact of my research on the sustainability of society

In this research, I hope to clarify the recovery effect quantitatively. This will aid the effective management of existing transmission towers. To ensure a sustainable society, existing facilities should remain in service for as long possible. By establishing an effective repair method, I can contribute to the realization of a sustainable society.

Moreover, this research may contribute to countermeasures against disasters that are more serious than in the past because of climate change. Climate change is one of the most significant problems facing modern society worldwide. There are many opinions about climate change, but almost all people think that we have to do our best to reduce the effects of climate change.

In this study, I attempt to clarify the strength of transmission towers during serious disasters. By clarifying the strength of an existing transmission tower and forecasting disaster risks using the latest observation devices, we can reduce the breakdown risk of power supply system.

I show some examples. If we can forecast serious disasters and predict the risk of transmission tower collapse, we can judge the use of the other power lines and avoid breakdowns. Moreover, if a transmission tower collapses, we have to determine what repairs or reconstruction must be performed. However, recovery is prioritized after a disaster. To recover the electric power supply quickly, resources must be invested in repairing transmission towers. If a transmission tower is severely damaged, attempts to repair may be wasted. In these cases, reconstruction may be judged to be necessary.

The results of this study are expected to contribute to this judgment. I feel sure that we can restore transmission towers after serious disasters without severe breakdown of electric power supply and thereby enhance the resilience of society in the face of natural disasters. Resilience refers to the ability to recover from damaged state caused by external factors. The disaster-resilient society is essential for sustainability.

References

[1] Tian L, Pan H, Ma R, Zhang L, Liu Z. Full-scale test and numerical failure analysis of a latticed steel tubular transmission tower. Eng Struct 2020;208:109919.

[2] Shu Q, Yuan G, Huang Z, Ye S. The behavior of power transmission tower subjected to horizontal support's movements. Eng Struct 2016;123:166--180.

[3] Sun L, Trovatob M, Stojadinović B. In-situ retrofit strategy for transmission tower structure members using light weight steel casings. Eng Struct 2020;206:110171.

Nitrogen removal from swine manure using a two-stage PNA process

CHA JUNHO

Environmental issues are a major global problem, and this research has focused on one aspect of this problem. It is wastewater. In particular, I focused on nitrogen removal from wastewater. If a large amount of nitrogen is present in water, it can lead to problems such as bad color, foul odors, diseases, pests, and even eutrophication, which can change water to green or red and destroy aquatic ecosystems. To prevent this type of pollution, I am currently conducting research on nitrogen treatment. In particular, I am researching pig farm wastewater (swine manure) that contains high nitrogen concentrations. While domestic wastewater contains approximately 20–100 mg/L of nitrogen, livestock wastewater can contain 100–7,000 mg/L, with swine manure containing the highest levels. Therefore, I am studying swine manure because it contains the highest levels of nitrogen among livestock waste types.

In wastewater, nitrogen exists in the form of NH_4^+ (ammonium), which must be converted into N_2 (nitrogen gas) through nitrification and denitrification to release it into the air. Conventional nitrogen removal processes in wastewater treatment plants utilize anaerobic, anoxic, and oxic reactions. The anaerobic process removed phosphorus, whereas nitrogen removal occurred in the anoxic and oxic zones. In the anoxic zone, NO_3^- was converted to N_2, and in the oxic zone, NH_4^+ was converted to NO_3^-. The oxic effluent is recycled back to the anoxic zone to complete the nitrification and denitrification processes. The oxic zone occurs after the anoxic zone. Then, one can ask why they are classified as anoxic or oxic. This is because they work together to remove both phosphorus and nitrogen simultaneously. However, this method also has several disadvantages. This process requires a continuous air supply, generates a large amount of sludge, and requires large amounts of organic matter for denitrification.

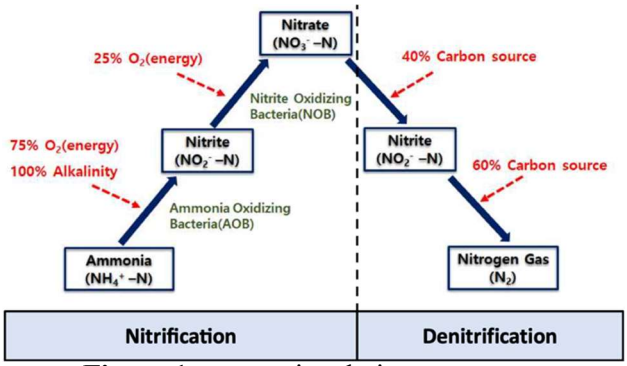

Figure 1. conventional nitrogen process

To overcome these issues, I studied the Partial Nitrification and Anammox (PNA) processes. It

utilizes AOB (ammonium-oxidizing) and anammox (anaerobic ammonium-oxidizing) bacteria. The PNA process combines partial nitrification and anammox processes. Partial nitrification uses only the step in which NH_4^+ is converted to NO in whole nitrification (NH_4^+ -> NO_2^- -> NO_3^-). And in the anammox process, NH_4^+ and NO_2^- are converted to N_2. This process saves 60% of the air supply with no need for organic matter for denitrification, produces less sludge, and simplifies the overall process. There are two types of PNA processes: single-stage and two-stage. I consider a two-stage process. Anammox bacteria are highly sensitive to environmental changes and influent concentrations. A two-stage process is easier to operate, more stable, and more effective at reducing nitrogen concentrations than the single-stage process. Therefore, I am using this process to study the removal of nitrogen from swine manure.

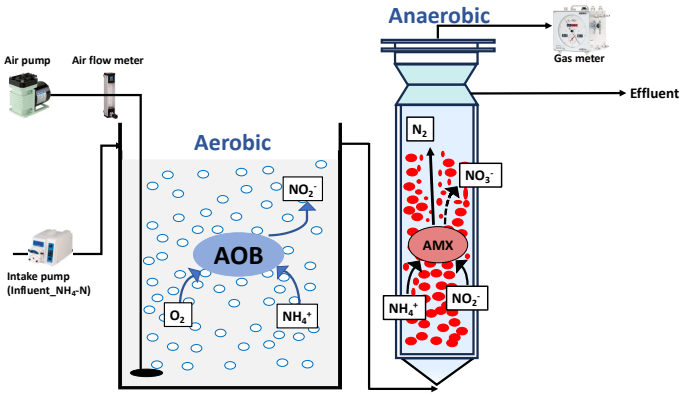

Figure 2. Two-stage PNA process

The results of this study suggested an effective treatment process for removing high nitrogen concentrations from swine manure. This approach simplifies the nitrogen removal process, saves space in treatment facilities, and reduces costs. It also requires almost 60% less air, which saves energy and reduces CO_2 emissions by a factor of approximately four to five compared to conventional processes. This has a positive impact on carbon-related environmental issues. I plan to continue my research on the stabilization and optimization of the PNA process for broader applications.

Studying tells me about the new world

Haruka Momma

A famous philosopher, Arthur Schopenhauer, said, “Every man takes the limits of his own field of vision for the limits of the world.” I am studying social science, whose object is “humans.” They, may be difficult to understand because they do not follow any immutable laws, and they change dynamically. In addition, as we experience in our daily lives, we wonder if we will ever truly understand each other because of differences in values. However, continuing to seek to understand “humans” broadens our perspective. It helps us to overcome out limitations and allows us to understand the modern world. In this essay, I introduce my studies and the attractiveness of the social science.

What is “Behavioral Science”?

I am majoring in behavioral science in the Department of Arts and Letters. Behavioral science is the study of social phenomena and human behavior using statistics, computer simulations and mathematical models. In addition, it is a field of study comprising sociology, psychology, and economics. Behavioral science researchers mainly study cooperative behavior, social inequality, and information transmission on networks. Recently, in addition to these studies, opinion formation in the political matters has been studied through machine-learning and natural-leaning processes using big data.

What the mathematical measure works in the field of sociology

Sociology is studied using several methods, such as field-work, interviewing people, experiments, and document studies. The use of mathematical methods in sociology is relatively new. There are some criticisms of the use of mathematical modeling in sociology, such as, “Humans do not behave like model subjects” and “Models do not express the differences between people.” However, the mathematical model reveals insights that language alone cannot convey. This unveils the underlying context of human action.

The attractiveness of “social dilemma”

I study what is called the “social dilemma,” which is related to cooperative behavior and explains many social phenomena and problems. Social dilemmas are dilemmas between personal and group rationality. An example is separating non-burnable garbage from other garbage. Separating garbage is important to avoid greenhouse. However, separating non-burnable garbage from other garbage is bothersome, is it not? Therefore, for each of us individually, it is easier not to separate garbage, but each of us not doing so will accelerate the global warming problems at the global level. That is, if we choose to disregard cooperation, we will gain more benefit individually, whereas if we choose

cooperation, we will lose individually. What makes the social dilemma difficult is that they are caused by humans' rationality. This implies that it is not caused by humans being unrealistic.

However, humans often male "irrational" cooperating choices. Have you ever seen someone offer their seat to another person, whom he or she would not meet again on the train? Have you ever seen someone arbitrating a quarrel even though they might get hurt?

Fortunately, I have been helped by the "irrational" kindness of my friends. Perhaps you have experienced this, too. Through my research, I want to reveal why people behave "irrationally", while also showing that invisible factors such as altruism toward others or the discomfort we feel when we see others who are worse off than ourselves—play a vital role in society. I am studying how people perceive their utility through altruism and equality using a mathematical model, and based on this, I clarify the mechanisms behind cooperative behavior. Figure 1 shows an example of a mathematical representation of utility.

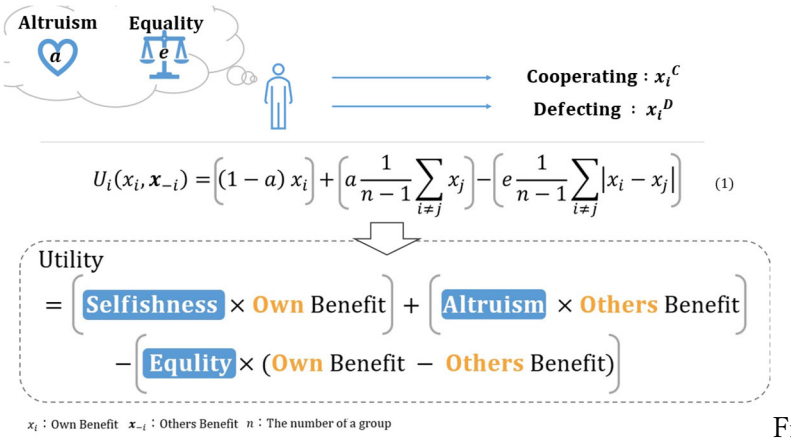

Figure 1 Mathematical model

(1) Muto, Masayoshi, 2006, "A Theory of Social Motives on Altruism and Egalitarianism," *Sociological Theory and Methods,* 21(1): 63-76.

To study humans

What makes sociology, or the field of studies related to humanity, difficult is that humans and society change constantly and have little regularity. In addition, the subjects include ourselves, that is, researchers. Social problems, such as poverty, inequality, psychiatric disorders, and discrimination, which are sometimes caused by disasters or epidemics, are triggered by emotions, something invisible, and what is in humans. The political situation and money order change dynamically with invisible things of humans.

Behavioral science is a study that weaves what society, which I think of as a creature, looks like and where society goes.

Magnetohydrodynamics in Accretion Disk

Daichi Kashizaki(Dept. Geophys. , Grad. Sch. Sci, M1)

In September 2019, almost 100 years after Einstein formulated the theory of general relativity, we succeeded in directly photographing a black hole shadow through observations using the Event Horizon Telescope (EHT). It is thought that extremely dynamic physical phenomena occur around black holes, such as jets, in which gas is ejected at speeds close to the speed of light, and phenomena in which gas emits strong light as it falls toward the black hole.

These dynamic phenomena are thought to be driven by a disc-shaped structure called an accretion disk. Accretion disk is a disk-shaped structure that is mainly composed of plasma. In 2023, the EHT group succeeded in directly photographing an accretion disk [1]. Accretion disks are formed around celestial bodies other than black holes, such as protostars and neutrons. Therefore, accretion disks are universally used.

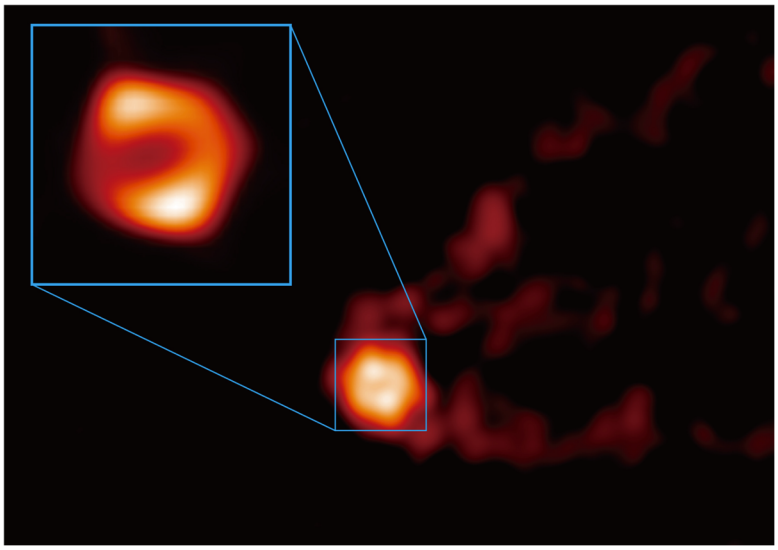

Figure 1 Radio image of the center of M87. The ring-shaped structure in the center is an accretion disk surrounding a supermassive black hole.

However, the physical mechanisms of accretion disks, such as gas accretion and coronal heating (e.g., the sun), remain unknown. I would like to use a magnetohydrodynamic approach to investigate accretion disks to clarify these unsolved problems.

First, there is the problem of gas accretion. The accretion disk is composed of a substance called plasma, which consists of protons and electrons. This plasma is often referred to as a gas. In an accretion disk, it is thought that this gas falls (accretes) toward the central celestial body, such as a black hole, and shines brightly as the gravitational energy of the gas is converted into thermal and light energy. The physical mechanism that explains this gas accretion is referred to as magneto rotational instability (MRI), a magnetohydrodynamical instability proposed by Balbus & Hawley in 1991 [2]. Analytical studies and numerical simulations incorporating MRI are currently being actively conducted; however, researchers have yet to reach a consensus, and the phenomenon is not yet fully understood.

Second, there is the problem of coronal heating. It is thought that, similar to the solar corona, accretion disks also have a region called the corona, which is hot and has a low density. Gierlinski et al. suggested the existence of an accretion disk corona in 1999 [3]. By observing a black hole called Cyg X-1, they discovered that Cyg X-1 emits low-energy X-rays (1 ~ 10 keV) and high-energy X-rays (100 ~ 1000 keV). At that time, the emission of low-energy X-rays could be explained within the framework of the existing theory, but the emission of high-energy X-rays could not. It is believed that there may be a high-temperature, low-density corona region in the accretion disk, similar to the solar corona. Currently, the existence of a corona is widely accepted, but there are still many unknown aspects of the physical processes involved, such as the heating mechanism. I am conducting analytical research on this issue, considering that the Parker instability, which is a magnetohydrodynamic instability, may be a major contributor.

References

[1] NAOJ, “Astronomers Image for the First Time a Black Hole’s Accretion Flow Together With a Powerful Jet,” EHT-Japan, 2023.04.27.
https://www.nao.ac.jp/en/news/science/2023/20230427-gmva.html

[2] S. A. Balbus and J. F. Hawley, “A Powerful Local Shear Instability in Weakly Magnetized Disk. I. Linear Analysis,” The Astronomical Journal, 1991, vol. 376, pp.214 – 222.

[3] M. Gierlinski, A. A. Zdziarski, J. Poutanen, P. S. Coppi, K. Ebisawa, and W. N. Johnson, “Radiation Mechanisms and Geometry of Cygnus X-1 in the Soft State,” Monthly Notices of the Royal Astronomical Society, 1999, Vol. 309, pp.496 - 512.

The relationship between solar activity and the space environment around the Earth—Space Weather forecast

Naoto Kinno

The Sun not only provides light and heat, which are essential for our daily life on Earth, but also emits **plasma**, composed of charged particles such as electrons and protons. The space environment surrounding Earth is constantly exposed to **ultraviolet light** radiation and **high-energy particles** originating from the solar surface. The intensity and quantity of these emissions fluctuate with changes in solar activity and can have a significant impact on communication satellites, technological systems, and human health in space. For example, **extreme ultraviolet radiation** can interfere with satellite communication by affecting atmospheric heating and ionization. This phenomenon alters **the attitude and orbit of satellites**. In addition, a large number of **high-energy particles** released by the sun can cause **degradation** of satellite solar panels, reducing their power output and, in extreme cases, leading to satellite **malfunctions or destruction**. These particles also pose risks to **human health**, particularly to astronauts, because they can damage DNA and other biological structures. These physical phenomena, which depend on solar activity, are collectively referred to as "**space weather.**" Space weather describes the variations in the interconnected state of the space environment influenced by both **solar and terrestrial atmospheric changes**. These fluctuations can affect the performance and reliability of space- and ground-based technological systems, potentially posing direct and indirect threats to human wellbeing. For modern civilization to continue advancing and humanity to expand its presence in space, it is crucial to **understand and predict space weather events accurately**. By doing so, we can reduce the damage done to our technological infrastructure and human lives by the hazardous effects of space weather.

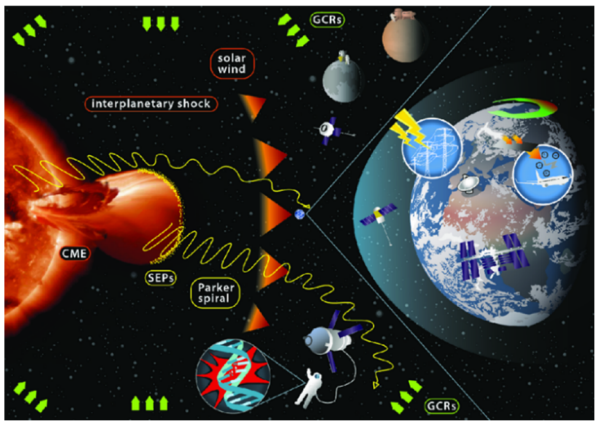

Fig. 1: Space weather phenomena and their impact on society. (Guo et al. (2023))

Our research focuses on the **physical mechanisms** underlying large-scale plasma eruptions using radio emissions. Occasionally, significant amounts of plasma are ejected from the solar surface via **Coronal Mass Ejections (CMEs)**, which are triggered by active solar conditions. CMEs generate **shock waves** that accelerate plasma particles to extremely high energies. One example is the **type II Solar Radio Burst (SRB II)**, which is produced when shock waves from CMEs propagate through interplanetary space, driven by various elementary plasma processes. CMEs propagate at speeds of thousands of kilometers per second, typically taking approximately **two or three days** to reach Earth. In contrast, SRB II, which is a form of radio emission, propagates at the speed of light, taking only approximately **eight minutes** to be detected after the CME eruption. By analyzing the properties of SRB II, we can **predict when the associated CMEs reach Earth**.

However, directly observing plasma parameters near the sun is challenging because of extreme temperatures on the solar surface. It is difficult to measure the plasma density, coronal magnetic field structure, and precise dynamics of CMEs, as they propagate close to the sun. Similarly, **the mechanisms** by which **particles are accelerated** and **SRBs propagate** through the solar corona, where both the plasma density and the magnetic field structure change dramatically, **remain unsolved**. Therefore, we focus on observing the SRB II events. There is a clear relationship between the frequency of radio emissions and the distance from the sun. By analyzing the **frequency-time variation** of SRB II, we can **track its propagation** and **obtain valuable insights** into how CMEs propagate through interplanetary space.

Therefore, the **accurate prediction** of the speed of CMEs and their distances from the sun using the frequency-time variation of SRBs, which propagate at the speed of light, is **crucial** for mitigating space weather disasters. This also offers an opportunity to further our understanding of the **physical mechanisms** in the solar corona.

Reference

Guo, J., Wang, B., Whitman, K., Plainaki, C., Zhao, L., Bain, H., Cohen, C., Dalla, S., Dumbovic, M., Janvier, M., Jun, I., Luhmann, J., Malandraki, O., Mays, M., Rankin, J., Wang, L., and Zheng, Y.. Particle Radiation Environment in the Heliosphere: Status, Limitations and Recommendations. Advances in Space Research (2023), in press. doi: https://doi.org/10.1016/j.asr.2024.03.070

Plasma parameters at Europa's orbit estimated from the Hisaki observation

Natsuko Matsushita

Jupiter's four largest moons are called the Galilean satellites: Io, Europa, Ganymede, and Callisto. My research area is the first two satellites surrounded by Jupiter's enormous magnetic field, where the planet's rotation and particles from the satellites play an important role in forming the magnetospheric environment, as shown in the left figure.

Io, orbiting 5.9 R_J (where R_J = 71,492 km is the Jovian radius) from Jupiter, has active volcanoes. Sulfur oxide gas from these volcanoes is ionized and heavy ions (S^+, S^{2+}, S^{3+}, O^+, and O^{2+}) become a significant source of magnetospheric plasma. As Jupiter rotates for approximately 10 hours, the ions are distributed in a doughnut shape because the charged particles moving along the magnetic field lines also corotate at the same angular velocity around the planet. The region is called the Io plasma torus. The torus plasma gradually diffuses outward, and icy satellites outside the orbit of Io are embedded in the Io-originated plasmas.

Europa is located at 9.4 R_J, and the potential for a large underground liquid ocean and the possibility of life has become an interesting topic for space missions. Europa is entirely covered with icy shells and has a tenuous atmosphere composed mainly of molecular oxygen. It is thought that when the magnetospheric charged particles around the moon sputter molecules such as H_2O, O_2, and H_2 from the icy surface, O_2 remains in the atmosphere, where H_2O freezes at the surface and H_2 readily escapes Europa's gravity. Some molecules are assumed to dissipate and form a neutral cloud (H_2, H, O, O_2) near Europa, while others are believed to be ionized by ultraviolet light or electron impact. In other words, Europa is another plasma source.

To improve the understanding of the production and loss of Europa's atmosphere, a more accurate interaction between the magnetosphere and the satellite is required. However, observations at Europa's orbit are still limited, whereas the plasma conditions at Io's orbit have been understood by combining observations and models. This study used JAXA's Hisaki data observed in May 2015 to estimate the plasma parameters at Europa's orbit.

Hisaki is a space telescope specializing in observing planets from the Earth's orbit. An ultraviolet spectrograph aboard Hisaki measured sulfur and oxygen ion emission lines in the extreme ultraviolet wavelength range (55 - 145 nm). The torus emission intensity peaks around Io's orbit and decays with increasing radial distance from the planet, as shown in the right figure. At Europa's orbit, the brightness was so weak that contamination from the terrestrial radiation belt and emissions from the Earth's upper atmosphere (geocorona) were carefully removed, and

the spectrograph data were integrated for one week (over 1,080 min).

The emission intensity is a product of the ion density and natural transition probability along the line of sight. Torus ions are excited by electron impact: thus, the ion density of a certain energy level depends on the density and temperature of the electrons. We used the atomic database to find the best-fit plasma parameters of the observed spectrum by minimizing the chi-square, which method is known as plasma diagnosis.

The sulfur and oxygen ion emission lines were successfully identified at Europa's orbit. Their brightness was approximately 2 to 6 % of that at Io's orbit. The signal-to-noise ratio (S/N) > 2 was satisfied for the S^{+}, S^{2+}, and S^{3+} emission lines at 65-80 nm, for the O^{+} and O^{2+} lines at 83.4 nm, and for the S^{3+} lines at 106 - 108 nm. In the wavelength range longer than hydrogen Ly-α (121.6 nm), S/N decreased because the intensity of the torus emission was comparable to that of the scattered geocoronal emission. Emission lines with S/N < 2 were excluded from plasma diagnosis.

From plasma diagnosis, we found that the electron density was 310 ± 200 cm^{-3}, the core electron temperature was 4.6 ± 3.7 eV, and the fraction of hot electrons (several hundred eV) was 25 ± 27% at Europa's orbit. Our results indicated a greater electron density than in-situ data measured by the Galileo orbiter, 63 - 190 cm^{-3}, and a lower core electron temperature than that reported by Bagenal et al. (2015), 10 - 30 eV. These discrepancies with the findings of previous studies can be attributed to the weak emission intensity at Europa's orbit. Therefore, we are attempting to extend the integration time to improve S/N, considering the effects of Io's volcanic activity on Europa's atmosphere.

After establishing the analytical methods, we plan to illustrate the radial distribution of ions and electrons between the two satellites and evaluate the impact of Io's volcanic activity on Europa's atmosphere.

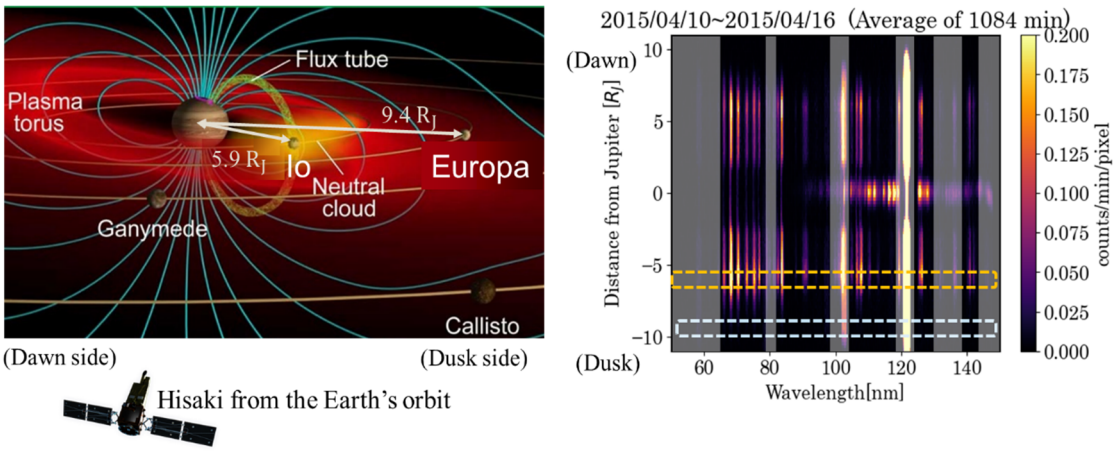

Fig. Jupiter and Io plasma torus observed by the Hisaki satellite

(Left) Schematic of the plasma environment between Io and Europa (Bagenal et al., 2020). Io is located at 5.9 R_J and Europa is located at 9.4 R_J.

(Right) Ultraviolet spectral image of the Io plasma torus observed by Hisaki. The areas encompassed by yellow and blue dotted lines are Io's and Europa's orbits, respectively. The wavelength painted gray indicates geocoronal emission lines and is not used for the analysis.

Thermal Analysis of the U_3O_8-Fe_2O_3 System in Air

Toshiki Iwahara

The 2011 off the Pacific coast of Tohoku and the accompanying tsunami caused a loss of coolant accident at the Fukushima Daiichi Nuclear Power Plant (1F). In this accident, the high-temperature fuel rods melted while reacting with the fuel cladding tubes and internal structures of the reactor. Fuel debris is then deposited at the bottom of the reactor pressure vessel (RPV) and primary containment vessel (RCV). In this accident, it was believed that U-Zr-O and U-Zr-Fe-O debris were generated because the UO_2 in the nuclear fuel and zircaloy, the zirconium alloy, in the fuel rod cladding tubes first came into contact. However, in the analysis of samples related to the investigation of the inside of the containment vessel, fine particles of the U-Fe-O and U-Fe-Cr-O systems that did not contain Zr were found. It is believed that these were generated by the reaction of the fuel with the iron alloys used in the control rod cladding tubes, the core support structure, and the pressure vessel. Previous research has shown that the U-Fe-O system is a eutectic system. In the eutectic reaction, the melting point of a mixture is lower than that of the pure substances. This decrease in melting point has a significant effect on the progression of the accident and the phase of fuel debris. However, research on the U-Fe-O system is limited, and the reported eutectic temperatures between U_3O_8 and Fe_2O_3 are different in the literatures by Evans and White (1964) and by Riley (1968). Evans and White (1964) performed the thermogravimetric analysis (TGA) in the heating process; however, phase analysis and thermal analysis of the cooling process related to the formation of fuel debris were not performed in this study. Other research by Riley (1968) did not describe the analytical method. Furthermore, an analysis of the phases formed during the cooling process was performed by Petrov et al. (2009), who showed that $FeUO_4$, which does not exist in these phase diagrams, may have formed.

Information on the reaction temperature and phases of the U-Fe-O system is still limited. Understanding the phases of nuclear fuel debris and their states is important for the retrieval, analysis, storage, and disposal of nuclear fuel debris. It is also important to obtain information on reaction temperatures to improve future accident progression analyses. However, no studies have been conducted on the reaction temperature during the cooling process. Therefore, the purpose of this study was to clarify the reactions that occur during the cooling process.

The starting materials were triuranium octoxide (U_3O_8) and ferric oxide (α-Fe_2O_3). The starting mixtures were prepared by weighing them using an electronic balance and mixing them in an agate mortar. To determine the reaction temperature during the cooling process, the mixed samples were studied by thermogravimetry-differential thermal analysis (TG-DTA). The

thermogravimetric analysis measures the weight change of a sample due to oxidation and reduction when the temperature changes. Then, the released or absorbed heat due to the exothermic or endothermic reactions of the sample was also measured by differential thermal analysis.

The TG-DTA results for each process and composition are shown in Fig.1. The black line represents the phase diagram proposed by Evans and White (1964) using TGA during the heating process. The eutectic melting temperatures between U_3O_8 and Fe_2O_3 during the heating process were almost the same as that reported in the literature. During the cooling process, it became clear that the eutectic melting temperature decreased in the Fe-rich region. Because eutectic solidification in the Fe-rich region was accompanied by a weight increase, the oxidation state of U in the eutectic liquid phase of Fe-rich samples is considered to be less than +5.33 that of U_3O_8 and to be +5.33 by its solidification. This seems to affect the decrease in the eutectic temperature in the Fe-rich region.

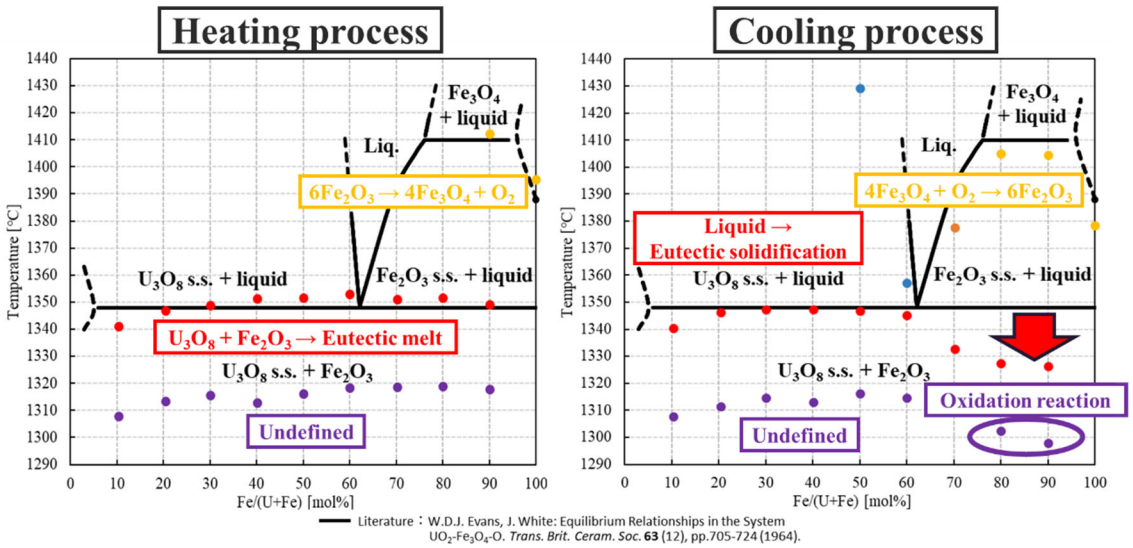

Fig.1 Comparison between results reported in the literature (for the heating process) and TG-DTA results

This study revealed that the solidification temperature of Fe-rich samples decreased. Furthermore, thermal analysis suggested the existence of a reaction that was not present in the previous phase diagram.

The impact of climate change on cyanotoxins in drinking water sources

Shoya Tanaka

Climate change poses a significant threat to global water security, particularly through its impact on cyanobacterial blooms and the associated cyanotoxin production in drinking water sources. This study explored the complex relationship between climate change and cyanotoxin dynamics by focusing on microcystin (MC), cylindrospermopsin (CYN), anatoxin-a (ATX-a), and nodularin (NOD).

Cyanobacterial blooms have become more frequent and intense in recent years, and this trend is expected to continue as global temperatures increase. These blooms produce various toxins that pose a significant risk to the drinking water. MC, primarily produced by *Microcystis* and *Dolichospermum* spp., are potent hepatotoxins. CYN, mainly produced by *Cuspidothrix* and *Raphidiopsis*, is a cytotoxin that affects multiple organs. ATX-a, produced by genera such as *Dolichospermum* and *Phormidium*, is a potent neurotoxin. NOD, primarily produced by *Nodularia spumigena*, is a hepatotoxin with structure which is similar to that of MC.

The production of these cyanotoxins is influenced by environmental factors that are directly affected by climate change, including temperature, light intensity, and nutrient concentrations. However, the specific effects can vary depending on the toxin and the species that produces it.

Temperature, which is a primary factor affected by climate change, has various effects on cyanotoxin production. For MC, some studies have reported increased production at higher temperatures, whereas others have reported a decrease. CYN production generally decreased at higher temperatures, although the relationship was not always linear. ATX-a production appears optimal at moderate temperatures (around 20°C), decreasing at both higher and lower temperatures. NOD production has been reported to decrease at higher temperatures in some studies; however, this relationship can be complex and influenced by other factors, such as salinity.

Light intensity, which can be affected by climate change through changes in cloud cover and water column stratification, plays a crucial role. In MC, moderate light intensities often promote toxin production, with inhibition observed at very high or low light levels. CYN production increased with light intensity up to a certain point, after which it decreased. ATX-A production was inhibited under low light conditions. However, the effects of light on NOD production require further investigation. Nutrient dynamics, particularly nitrogen and phosphorus concentrations, are affected by climate change through changes in precipitation patterns and runoff. The relationship between nutrients and cyanotoxin production is complex and often species-specific. Some studies have reported increased production of MC under nitrogen-limited conditions, whereas others have found the opposite. CYN production increased under both nitrogen- and phosphorus-rich

conditions. In some species, ATX-a production is increased under nitrogen-limited conditions. Although some studies have reported increased NOD production under phosphorus-limited conditions, it appears to be less affected by nutrient concentration. Although our understanding of the environmental factors that influence cyanotoxin production has improved, the physiological roles of these toxins in cyanobacterial cells remain unclear. Recent research suggests that MCs may play a role in protecting cells against oxidative stress, which is particularly relevant in the context of climate change because factors such as higher temperatures and increased light intensity can increase oxidative stress in cells. The complex and often conflicting evidence regarding environmental influences on cyanotoxin production highlights the challenges in predicting the effects of climate change on cyanotoxin dynamics in drinking water sources. Climate change is likely to alter multiple environmental factors simultaneously, and the combined effects may be difficult to predict based on the current understanding of the effects of individual factors. Climate change may alter the composition of cyanobacterial communities in water bodies. Some species may benefit from warmer temperatures or altered nutrient dynamics, potentially leading to shifts in the type and amount of cyanotoxins produced. For example, *Raphidiopsis raciborskii*, a CYN-producing species, expands its geographical range with increasing temperature.

These changes have significant implications for drinking water safety. Water treatment facilities may face new challenges in dealing with the increased frequencies and intensities of cyanobacterial blooms, as well as potential shifts in cyanotoxin types. Existing treatment processes may require reevaluation and potential upgrades to ensure the effective removal of a wider range of cyanotoxins. To address these challenges, several key research areas need prioritization:(1) Comprehensive studies on the physiological roles of cyanotoxins, particularly CYN, ATX-a, and NOD. (2) Long-term studies examining the effects of multiple environmental factors on cyanotoxin production. (3) Improved models for predicting cyanobacterial blooms and cyanotoxin production under various climate change scenarios. (4) Research on innovative water treatment technologies capable of dealing with a wide range of cyanotoxins.

In conclusion, the impacts of climate change on cyanotoxins in drinking water sources are complex and require interdisciplinary research and collaboration. By improving our understanding of cyanotoxin dynamics under changing environmental conditions, effective strategies can be developed to ensure drinking water safety under climate change. This challenge underscores the intricate connections among climate change, ecosystem dynamics, and human health, highlighting the need for holistic approaches to environmental management and public health protection in the coming decades.