

Current Science Reports

Microbial Ecological Balancing Role in ammonia and sulphur cycling

Krossfjorden, on the northwest coast of Norway, is a deep 30 kilometre-long water body with steep walls of rock on either side – a fjord formed by Arctic glaciers. The Arctic region has microbial communities such as bacteria and archaea that survive and thrive at extremely low temperatures. But currents and tides often bring the warm waters of the Atlantic to the fjord, changing salinity, nutrition and temperature.



Image: Svein-Magne via Wikimedia Commons

For Avinash Sharma and team from NCCS, Pune, who have been exploring the microbiota of diverse and extreme ecosystems, Krossfjorden posed a challenge. How do the microbial communities there network to adapt to such variations in extremes? What role do these microbial communities in the Arctic play in biogeochemical cycling?

During the summer of 2017, the researchers collected sediment samples from different depths at Krossfjorden. Back at their laboratory in Pune, they extracted DNA from the samples using a soil DNA extraction kit.

To identify the taxonomic diversity, the team targeted the V3–V4 region of 16S rRNA genes of archaea and bacteria from the samples, using high throughput DNA sequencing. The V3–V4 region shows maximum sequence diversity and provides more precise and accurate estimates of taxonomic positions.

'We found that bacterial diversity increases with depth, whereas archaeal diversity is higher in middle

depth sediments,' says Swapnil Kajale, NCCS, Pune.

The *Thaumarchaeota* group formed about four-fifths of the total archaeal community. *Thaumarchaeota* is known to oxidise ammonia in marine sediments. *Crenarchaeota*, involved in nitrification, made up about 10 per cent. *Euryarchaeota*, known to remove methane, a greenhouse gas, constituted about 5%. *Woesearchaeota* and other marine groups, seen along hydrothermal vents, were also present.

Ammonia oxidising archaea are dominant in deep water sediments while archaea that remove methane dominate in shallow waters. Sediments from medium depths revealed a wider diversity of archaea involved in biogeochemical cycling.

The gene involved in chemotaxis and archaeellum was abundant in the fjord environment. This suggests that the archaea can move and migrate to favourable conditions.

These groups play a major role in biogeochemical cycling in the Arctic marine ecosystem and are known for their ability to produce useful molecules. However, most of them are still unculturable.

Among bacteria, the researchers observed a predominance of *Proteobacteria* phylum – about fifty-three per cent of the total bacterial community. The other dominant bacterial communities belong to various phyla, such as *Bacteroidetes*, *Fusobacteria*, *Actinobacteria*, *Planctomycetes*, *Firmicutes*, *Verrucomicrobia*, *Chloroflexi* and *Lentisphaerae*. These bacterial groups are used in many industrial applications.

'We found that some of these bacterial communities are capable of oxidising sulphur,' says Kunal Jani, NCCS, Pune.

The abundance of sulphur oxidising bacteria such as *Sulfurimonas* and *Sulfurovum*, suggests that these organisms may modulate the sulphur cycle in deeper parts of the fjord.

The researchers also found *Psychrilyobacter*, *Psychromonas* and

Marinifilum bacterial communities that form acetate compounds. The presence of bacteria from the family *Desulfobacteraceae* and *Desulfobulbaceae* suggest that the acetate so formed is used up by sulphate reduction.

'Archaeal communities across all depths of the fjord engage in ammonia cycling whereas bacterial communities show divergence in gene abundance for ammonia and sulphur cycling,' says Avinash Sharma, NCCS, Pune.

Archaeal and bacterial communities seem to support each other in biogeochemical cycling in the Arctic fjord. The archaeal methanogens interact with the sulphate reducing bacteria.

In recent decades, the Arctic is exposed to increasing temperatures. The melting of glaciers and sea ice increases freshwater and sediment flows in Arctic fjords. This can affect the ecosystem and the biogeochemical cycles. The report can help create a baseline to monitor the microbial diversity and to devise strategies for mitigation.

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Landslides along NH-10 Rainfall and lithology

Darjeeling, in the Himalayan ranges, is famous for its tea plantations. But the area is plagued by landslides due to loose soil and high slopes. Though the landslides are shallow and limited to small regions, they create massive traffic congestion and, often, casualties, especially along NH-10, an important corridor in the Darjeeling-Sikkim Himalayas. Early prediction of location and time of landslides can save lives and reduce losses.

Prodop Mandal and Shraban Sarkar from the Cooch Behar Panchanan Barma University decided to investigate. Continuous rainfall, beyond a certain cut-off point, leads to landslides. The cut-off point varies for different regions of the Himalayas. So identifying this critical limit along NH-10 was the first challenge for the duo.

They took rainfall data for 2011–18 from the four rain gauge stations in the region. For each station, they took into consideration peak rainfall in a day and continuous rainfall for a few days as a rainfall event with a corresponding landslide event. They also created a database of 681 landslides from various sources such as government departments, newspapers and reports.

Using Google Earth images, the team tried to locate the landslides from scars. They identified NH-10 on Google Earth and, using field surveys and GPS, located 174 landslides along the highway. Then the task was to connect the data about the landslides to the rainfall data from the nearest rain gauge station.

To understand the relationship between landslide occurrence, rainfall intensity and duration, they used an intensity-duration-based model. Out of the 288 landslide triggering rainfall events, 267 were used for calibrating the model and the remaining were used for validation.

Most landslides occur due to heavy rain of short duration, mostly in June. The researchers found that the threshold value of rainfall triggering landslides along NH-10 is 20.10 millimetres per day. However, if the rain continues for more than a day, landslides can happen even when the intensity is low. Less than 9 millimetres per day for a week is adequate.

NH-10 runs along various geological features – the Teesta river, the Siwalik, the Gondwana supergroup, slate and chlorite sericite schist. The underlying lithology influences landslides. So the duo used the model for each of these geological features separately.

Though the Gondana supergroup and Siwalik regions get heavier rainfall, the number of landslides was greater in the slate regions. Though the chlorite sericite schist region was more resistant to short duration high intensity rain than other regions, longer duration rain of lower intensity can also lead to landslides in this region. In fact, as the number of antecedent days of rain increases, the probability of landslides increases rapidly.

While testing, the team found that the model was less certain about the landslides in the Gondwana supergroup area. This is probably due to the low number of data points from the area, say the researchers. In the Teesta valley, where more data points were available for training, the model performed much better.

‘High resolution rainfall data from automated weather stations and accurate landslide records can minimize false alarms and fine-tune estimations,’ says Shraban Sarkar, Cooch Behar Panchanan Barma University.

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COVID-19 Cleans Ganga Lockdown lowers pollution

The Ganga is considered a holy river. It is believed that a sip of water from the Ganga will lead to salvation. However, the water is so polluted that it is not even fit for bathing, let alone for drinking. Thousands of crores of rupees were spent in the last two decades and yet the Ganga remained a paradox of purity and pollution.



Image: Subham Jena

However, the COVID-19 pandemic has been a boon for the Ganga, say researchers from the Babasaheb Bhimrao Ambedkar University, Lucknow, after examining the water quality before and during the lockdown.

Divya Dubey, Venkatesh Dutta, and Saroj Kumar collected water quality monitoring data from the Central Pollution Control Board and from several state pollution control boards to examine real-time data on the quality of water from the Ganga from 2017 to 2019. Rainfall data was taken from the India Meteorological

Department, New Delhi and basin storage data from the Central Water Commission. The data showed that the river water was not suitable even for bathing, except in the upper stretch till Haridwar.

But during lockdown, there was improvement in water quality. This, they say, is due to the reduction in the discharge of industrial pollutants and solid waste into the Ganga. A noticeable improvement was observed along the entire river's stretch, especially upstream of Kanpur. Since most factories and commercial establishments were closed due to the lockdown, the Ganga had become comparatively cleaner.

However, the researchers found no significant improvement in the river's organic load, as there was no change in domestic discharge after lockdown. There was only a marginal reduction in chemical oxygen demand values due to continued wastewater discharge from municipal sources.

The dissolved oxygen concentration was low in the initial phase of the lockdown, but, in the later phases, it improved to such an extent that it was considered safe for bathing at all locations.

A comparative assessment of the biological oxygen demand of the Ganga during the pre-lockdown average and the lockdown average of March to May of 2019 and 2020 showed reduced amounts of biomass in the water due to lockdown – except at two stations, Rajwari and Khagra.

At most locations, there was a declining trend in nitrates due to reduced agricultural run-off, reduced faecal coliform and total coliform concentrations due to lower domestic discharge. Water quality improvement was most significant around industrial clusters and urban areas due to limited industrial activities during lockdown.

‘This improvement is perhaps short-lived. The water's quality may decline once normal industrial activities are resumed,’ says Venkatesh Dutta, Babasaheb Bhimrao Ambedkar University.

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Treating Infections and Cancer Using bacteria from seaweed

Kajal Chakraborty and team from the Central Marine Fisheries Research Institute, Ernakulam have been exploring marine organisms for possible therapeutic molecules. Recently, they collaborated with the Cochin University of Science and Technology, to examine the bacteria associated with *Hypnea valentiae*, a red seaweed, and discovered two bacteria with potential to provide new anticancer and antibacterial compounds.

The researchers collected the seaweed from the intertidal zones of the Bay of Bengal. Bacteria residing on this seaweed were isolated and cultured in basal-salt agar medium with all the necessary nutrients. Then the researchers extracted the bacterial metabolites, secreted in agar medium using ethyl acetate. The extracts were used for exploring their therapeutic properties.

They found that nearly 53 bacteria live in association with seaweed for their food. All these heterotrophic bacteria secrete compounds with anti-infective properties. They were effective against vancomycin-resistant *Enterococcus*, methicillin-resistant *Staphylococcus*, and many others.

Among those, the secretions from two bacteria had the most significant inhibition of pathogens: *Shewanella algae*, a rod-shaped, brown pigmented, gram-negative bacterium, and *Bacillus amyloliquefaciens*, long filamentous chains of gram-positive bacteria.

The researchers also conducted anticancer assays of organic extracts of *Shewanella algae* and *Bacillus amyloliquefaciens*. The extracts showed prospective anti-proliferative activity against liver and breast carcinoma cell lines.

'Analysing the secreted secondary metabolites and immunotoxins from these two strains may help develop new microbial and anti-cancer drugs,' says Vinaya Kizhakkekalam, CMFRI.

But will the drugs produced be safe?

The researchers investigated the cytotoxic effect of the bacterial extracts on normal mouse fibroblast

cells. There was no significant inhibition of growth of the normal fibroblasts even when greater than the prescribed threshold concentrations of bacterial extracts were used.

'Seaweed-associated heterotrophic bacteria may help develop new anti-infective and anti-cancer drugs,' says Kajal Chakraborty, CMFRI.

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Oral Antifungals Re-evaluating efficacy

A team of scientists from the Banaras Hindu University was concerned: there was a rising impression among dermatologists that the effectiveness of oral antifungal drugs on skin infections has been reducing dramatically in recent years. So they decided to test the validity of such impressions, often formed by one or two cases.

They decided to do a randomised pragmatic trial with fluconazole, griseofulvin, itraconazole and terbinafine – four antifungals from different classes used for treating chronic and chronic relapsing *Tinea corporis*, *Tinea cruris* and *Tinea faciei* infections.

They excluded the patients with pregnancy, lactation and history of allergy to drugs, etc. and managed to get 200 patients with the selection criteria. The team randomly allocated them into four groups using Research Randomiser – a free resource to generate random numbers or to assign participants to experimental conditions.

Each group of patients was treated for eight weeks with standard doses of the four antifungals. The team recorded body surface area affected, treatment given, microscopy results, investigations at baseline and subsequent follow-ups, and follow-up data.

They found that terbinafine, once considered very effective for fungal infections, is less effective. Fluconazole was found to be superior to griseofulvin. And itraconazole was superior to fluconazole, griseofulvin and terbinafine.

Even though these drugs are commonly used oral antifungals, the general impression of dermatologists

about the reduction in effectiveness of these drugs was corroborated.

This type of clinical trials is helpful to a medical practitioner to select the most effective drugs for the current situation and specific region in the context of changing responses of the pathogens against our treatment regimens.

The clinical management of fungal diseases is being compromised by the emergence of drug resistance. Evolution of drug resistance is common among bacteria and is a well-studied phenomenon. The development of new generations of antibiotics has however, kept bacterial epidemics at bay. But fungi are more complex organisms. So, active research on mechanisms responsible for antifungal drug resistance, and development of new antifungal drugs to overcome drug resistance need to be taken up.

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Diagnosing Depression Using smartphone app

Depression, a mood disorder, makes people very sad. They lose interest in life. The disorder affects daily activities and social interactions. As per the WHO, about 300 million people are affected worldwide. Depression is the second leading cause of years lost to disability. Early diagnosis might help mitigate the consequences – an increasing sense of being a failure that can even lead to suicide.

Saurabh Singh Thakur and his supervisor, Ram Babu Roy, from IIT Kharagpur, thought of using smartphone data to predict depression. Smartphone use has increased among young people and they carry their mobile phones with them most of the time. Data on physical activity can be gathered from accelerometers, mobility data can be recorded using GPS and sociability can, to some extent, be measured by the number of phone calls and duration.

To reduce the drainage of mobile phone batteries during data gathering, instead of a continuous stream of data, the researchers opted for discrete data: One minute of monitoring where the data is collected every 2–3

seconds, pause for three minutes, then another minute of monitoring and data recording.

The duo collected such data of 48 students and, after removing those with incomplete data, they used the data of 45 students collected over 10 weeks. From this data, the researchers extracted and normalised features related to three categories: mobility, physical activity and sociability.

They also used standard psychological survey instruments to extract and measure levels of stress, depression, sleep quality, feeling of loneliness and feeling of well being in the student sample.

A descriptive analysis helped the researchers understand the data features and their relationship with mental health variables. People with depression tend to restrict themselves to a few locations. Total distance moved is also much lower than normal.

The students undergoing stress walked much less than others. Their call durations were also lower. Mobility, sociability, and physical activity were found to be statistically significant factors to identify those with mental health issues.

A correlation analysis between the factors measured through psychological survey instruments showed relationships between stress and sleep quality, between stress and depression, between depression and loneliness, etc. The subjective feeling of well being had a negative correlation with the scores from other measures.

Thus, confirming that they were on the right path, the duo created a binary logistic regression model to predict depression, based on the predictor variables. The model had an accuracy of more than 70%. But the researchers were not satisfied.

They took the model as a baseline and tried to improve on the results by using five different supervised machine learning techniques. After comparing and contrasting the results from the five machine learning models, they created an ensemble model that was 83% accurate in predicting stress and 74% in predicting depression.

Since most depressed patients do not have the enthusiasm to access mental healthcare, remote monitoring and outreach can be made possible with such mobile-based applications. Such an app can help doctors, teachers and family members take appropriate measures to prevent depression and suicides in educational institutes.

However, clinical evidence on smartphone-app based diagnosis remains scant. Moreover, consumers need to be aware of the issues related to prediction accuracy, data security and privacy before choosing the applications that are bound to come into the market.

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Zinc Oxide Photodetectors For UV wavelengths

Optical sensors that operate only in the ultraviolet region of the electromagnetic spectrum have various applications – spectroscopy, space communications, detecting hazards in the environment... But these sensors are costly, difficult to fabricate and have poor performance.

Researchers from IIT Indore and IIIT Kancheepuram have now developed a photodetector which can detect photons from the ultraviolet regions of the electromagnetic spectrum. They used zinc oxide, as it has good photodetection properties in the UV region. The team engineered the photodetection properties of the zinc

oxide nanomaterial into a visible-blind UV photodetector.

The team used glass slides as base for the sensor. They took a solution of zinc acetate, and ethanolamine to integrate zinc particles while maintaining stability, and spin-coated the solution over the glass.

After annealing the coating, the glass sample was soaked in a solution of potassium permanganate and sodium citrate and kept for hydrothermal growth. Potassium permanganate reduces oxygen vacancies, reducing defect states in the photodetectors. Sodium citrate increased the surface area of the semiconductor by growing nanoplates around nanorods. Thus, these chemicals improved the surface area and electron transport efficiency of the photodetector. Morphological analysis confirmed the formation of zinc oxide nanorods with fewer defects, improving electron-hole pair transport.

The versatility of photodetectors depends on three factors: their operating speed, their sensitivity to lower levels of light, and the range of the spectrum. The photo sensor designed by the team progressed in all three aspects – it can operate for the given range of light, with a higher response rate and sensitivity.

The research team hopes that this low-cost, easily fabricated, highly sensitive photodetector can be integrated to perform multispectral analysis in space, providing visual and chemical information.

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