Current Science Reports

Paleoclimate in Kashmir Valley

From sediments of Wular Lake

Wular Lake, a large freshwater body in the northern Kashmir Valley, is considered a remnant of the past mega-Karewa Lake. The Jhelum, the main river flowing through Kashmir, drains into the Wular, carrying enormous amounts of water and sediments. The sediment can provide insights into past climates.

Image: Imran Rasool Dar

In January 2017, a team from IISER Bhopal, and other universities and institutes in India, took out a two-metre-long bed-sediment core from a five-metre water depth on the north western side of Wular Lake. The core was sectioned into two halves and sub-sampled at two centimetre intervals.

The core had three distinguishable layers: brown clayey silt on top till about 46 centimetres, light grey clay silt till a depth of 162 centimetres and dark grey slit to a depth of about 2 metres.

The researchers used Accelerator Mass Spectrometry to establish the chronology of the sediment deposits by carbon dating. The two-metre core samples showed a continuous sediment supply from about 4200 years ago. The linear sedimentation rate in different core sections seemed to have varied by about 13% from an average value of 48.6 cm per thousand years.

The team combusted the samples at 1020°C and used an elemental analyser to measure total organic carbon and nitrogen. The organic matter properties seemed to reflect dramatic hydroclimatic changes in the past 4200 years.

Concentrations of elements such as aluminium, manganese, iron, barium and so on also supported hydroclimatic changes deduced from sedimentation rates, grain-size distributions and organic matter.

The dataset suggests that the valley hydroclimate changed from a warm-wet phase (4200–3400 years ago) to relatively drier conditions (3400–1700 years ago) and later, extreme drought-like condition (1700–600 years ago) before the wet Little Ice Age (600 years ago) to modern times.

To understand the forcing mechanisms that led to such variations in the climate of the Kashmir valley, the researchers tried to correlate them with various factors such as solar insolation, solar activity, western disturbance, monsoon variability, etc.

The intertropical convergence zone, where the trade winds of the Northern and Southern Hemispheres come together, seemed to have regulated a hydroclimate turnover from an earlier Indian summer monsoon dominated to later western disturbance dominated seasonal precipitations contributing to observed wetter periods in the valley.

The extreme drought period was perhaps connected to the lowest moisture content in western disturbances and high-frequency El Niño-Southern Oscillation. Meltwater supply from permafrost ice seemed to be significant during higher solar activity events around 2500 years ago and in the deglaciation phase of the Little Ice Age.

The conclusions about the climatic variations deduced from the sediments of Wular Lake may be applicable to the north-western parts of the Himalayas, say the researchers.

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Groundwater Quality

In Bemetara district

Bemetara district in Chhattisgarh is known for huge amounts of limestone deposits. Though the deposits make the region richer, they also create a severe problem of hardness and salinity in groundwater.

Scientists from the National Institute of Hydrology, Roorkee collaborated with researchers from the Gurukul Kangri University, Haridwar and the Central Ground Water Board, Raipur to evaluate groundwater quality in the district.

They collected 116 groundwater samples from 51 different locations in the district, before and after the monsoon seasons and they analysed the water quality index as well as several physico-chemical parameters such as pH, electrical conductivity, total dissolved solids, alkalinity, total hardness, sodium, potassium, calcium, magnesium, bicarbonates, chlorides, sulphates and nitrates.

All parameters analysed were under the acceptable limits of the Bureau of Indian Standards except for total dissolved solids, total hardness, calcium, magnesium, sulphates and nitrates.

The team found that groundwater quality changes from region to region along with the depth of the water table. Generally, deeper aquifers have high concentrations of different water quality parameters.

The water quality of the south-western part of the Bemetara district was found to be more unsuitable for drinking than water from the north-eastern part.

The groundwater samples from the Nawagarh and Bemetara blocks had high concentrations of sulphate ions. The researchers say that this may be due to the dissolution of gypsum minerals in the Maniyari shale formation of the region.

The presence of magnesium, calcium, chlorine and fluorine in the groundwater samples could be due to other rock–water interactions and human activities.

The state government of Chhattisgarh can now design a sustainable groundwater management plan for the Bemetara district.

Such district-wise studies on groundwater quality are slowly creating a database useful for policymakers at the national level.

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Predicting Soil Erosion

Using a hydrological model

Rainfall erodes soils, especially on hill slopes. Intense rainfall magnifies the severity of soil erosion. To counter this, watershed-based land-use management techniques, such as agroforestry, silviculture and livestock rearing, have been formulated. Can these techniques

help prevent soil erosion in the event of changes in rainfall patterns?

Burhan U. Choudhury and a team from the ICAR-RC for North East Hill Region employed process-based hydrological simulation to predict the resilience of micro-watershed models to soil erosion. They predicted runoff and soil loss in Integrated Farming System-based micro-watersheds using the Water Erosion Prediction Project model.

The team examined six micro-watershed designs in experimental plots at the ICAR Research Complex: forestry, abandoned shifting cultivation, livestock with fodder crops, agroforestry, agri-horti-silvi-pastoral and horticulture. Using data on observed rainfall, measured soil parameters, runoff and soil loss for 24 consecutive years in the Water Erosion Prediction Project model, they predicted soil erosion based on different Coupled Model Inter-comparison Project phase 5 climate change scenarios for each micro-watershed.

Prior to performing the simulation, the Water Erosion Prediction Project model was calibrated, satisfactorily validated, and evaluated for sensitivity analysis. The team adopted climate change scenarios on the basis of an assessment report from the Inter-Governmental Panel on Climate Change.

The scenarios revealed an erratic change in annual rainfall over the projected periods of the 2020s, 2050s and 2080s. The model predicted increasing soil erosion with increasing intensity of rainfall, regardless of land-use type.

However, the team noted that the simulated soil loss was lowest in forests and highest in shifting cultivation. Horticulture, followed by agroforestry and agri-horti-silvi-pastoral, was found to be the most effective at minimising soil loss. The model predicts that sustainable integrated farming techniques may help reduce surface runoff and soil erosion by up to 40%.

To combat soil erosion, the researchers recommend promoting horticulture and agroforestry on steep slopes instead of traditional farming techniques. Farmers can also adopt bio-mulching and other vegetative covers as highly effective adaption strategies to reduce soil loss.

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Diabetic Retinopathy

A marker to detect vision loss

Diabetic retinopathy is a leading cause of blindness and vision impairment among people with diabetes mellitus. Globally, 25% of people with diabetic retinopathy end up losing their vision.

The progression to blindness could be prevented with the universal retinal screening of the population with diabetes mellitus. But regular retinal screening is not possible due to a lack of resources in middle and low-income countries.

Hence, Sobha Sivaprasad, ophthalmologist-cum-researcher, and her team explored a cost-effective alternative to diagnose sight-threatening diabetic retinopathy. They evaluated the potential of previously identified blood biomarkers as indicators of sight-threatening diabetic retinopathy.

The researchers inducted around 500 participants, aged 40 years and above, from India and the UK. For comparison, the researchers divided the participants into distinct groups: one group had diabetes mellitus with no signs of retinopathy, another group had mild retinopathy and the third group had severe retinopathy affecting sight. The team also included a group with no diabetes mellitus as control.

They collected self-reported data regarding baseline variables from all the groups. Blood samples were taken to analyse thirteen biomarkers using the enzyme-linked immunosorbent assay, ELISA.

Among the participants in India, the team found higher levels of four biomarkers in people with sight-threatening diabetic retinopathy. But in the UK, only two of the thirteen biomarkers were at higher levels. The common factor was cystatin C, a biomarker for kidney and cardiovascular malfunction – the other complications of diabetes.

Thus, the results of this multicentric cohort study show that cystatin C is a more reliable biomarker to detect sight-threatening diabetic retinopathy across different races.

Though retinal screening is the established diagnostic tool to detect the condition, lack of availability and accessibility to the facilities highlight the importance of cystatin C as biomarker to identify patients with sight-threatening diabetic retinopathy.

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Pesticides in Fresh Vegetables

Assessing health risk

In the hilly areas of Himachal Pradesh, vegetable cultivation provides livelihoods. To get a better yield, farmers there use a lot of pesticides.

Atul Kumar and a team from the Himachal Pradesh Agricultural University recently analysed the amounts of pesticide residues on fresh vegetables cultivated in the region.

Image: Fredericknoronha via Wikimedia

They collected 300 samples of 21 species of vegetables from various agricultural farms in Himachal Pradesh. In the lab, using gas chromatography, they checked for 19 commonly used pesticides – organochlorines, organophosphates, synthetic pyrethroids, herbicides and fungicides.

They detected 17 pesticides. Hexaconazole, a fungicide, was the most frequently detected, followed by aldrin, an insecticide, and alachlor, a herbicide.

More than a third of the samples contained pesticide residues. The highest residues were in cauliflower, cucumber, beans, tomato, okra and green chillies. Tomato and beans were contaminated with a greater number of pesticides, followed by cucumber and okra.

One-sixth of the samples exceeded the maximum permissible limits. Endosulfan, a banned pesticide, was detected beyond maximum residue limits in garlic, peas and onion.

To assess the health risk due to the intake of the pesticide residues in vegetables, the researchers used the vegetable intake per person in the study area provided by the National Sample Survey Office, and calculated the daily

intake of the pesticide residues based on their research and compared it with the acceptable limits of daily intake. They found that children, the elderly and those who consume a greater amount of vegetables were more prone to health risks.

Farmers need to adopt good agricultural practices and adhere to food safety laws. Food safety regulations need to be enforced to protect the environment and human health.

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Repurposing Antiviral Drugs

For Omicron variants

Omicron variants dominate the current COVID-19 cases. Drug development to manage this variant may take years. But identifying and repurposing currently available drugs to treat the variants is quicker.

To do this, Somdutt Mujwar from the Maharishi Markandeshwar University, Ambala collaborated with scientists from Turkey and Poland.

From a protein data bank, they acquired the structure of the COVID-19 spike protein that initiates the infection. To get the mutant spike protein structure, the team introduced the spike protein of the omicron variant, which has several mutations, into the original COVID-19 spike protein structure using PDB Viewer, a tool that can analyse several proteins at the same time. And thus they created a model of the mutant spike protein of omicron variants.

The researchers then downloaded about 3000 approved antiviral drug molecules from ZINC, a drug database. To identify possible viral entry inhibitors, they screened the mutant spike protein of the omicron variant against the approved drug molecules. Using molecular dynamic simulations, they shortlisted six molecules, based on side effects and efficacy. The researchers then evaluated their use and side effects based on current literature.

'We identified four antiviral drugs that could be repurposed for the omicron variant: adapalene, dihydrotachysterol, levocabastine and bexarotene,' says Somdutt Mujwar. After clinical trial evaluations, these drugs may be considered for emergency use in critical conditions.

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Facility Location Allocation Model

For maternal healthcare

In India, an average of 120 women die per day due to pregnancy-related complications. And mortality cases are greater in rural areas due to a lack of facilities.

To find an optimal location of healthcare facilities for mothers-to-be, researchers from IIT-BHU developed a model. Their location-allocation model took into account the hierarchy in Indian health facilities: sub centre, primary healthcare centre and community health centre.

Sub centres cater to the needs of mothers-to-be for routine check-ups and diagnostic examinations. Primary health centres can do that and also manage caesarean deliveries. Community health centres have additional facilities and can cater to neonatal care also.

The location of maternal health care facilities should be within a radius of 5 to 7 kilometres for the mothers-to-be. The fixed and operating costs of the three types of health facilities are also predetermined.

The researchers applied their model to Chandrauli district, Uttar Pradesh. The team used three sequential steps: construction, improvement and refinement.

In the construction stage, the community health centre location is allocated first and then the primary health centre and lastly the sub centre. In the improvement stage, the community health centre's location is determined from the existing primary health centre and sub centre. The refinement stage allocates all facilities simultaneously. This three-step method decreased computational requirements drastically.

To validate the model, the researchers generated test instances based on coverage distance for mothers-to-be and cost of the community health centre, primary health centre and sub centre establishment. They conclude that the requirement for community health centres is greater than that of the primary health centre and sub centre.

'The lack of female doctors aggravates the problem. Most mothers-to-be do not like consulting male doctors,' says Ankit Chouksey, IIT-BHU.

'There is a significant gap between what exists and what is required for maternal health care facilities. But augmenting existing facilities can also be done based on the model,' explains Anil Kumar Agrawal, his colleague.

In India, the maternal mortality rate is greater than that of other countries. This can change if proper health care facilities are provided to mothers-to-be during pregnancy and childbirth.

Choosing the right location to establish maternal health care facilities, especially in rural districts, is the first step in this direction. The Ministry of Health and Family Welfare can use this model to rationalise their decisions and to reduce political interference in location-allocation.

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Region Specific Cell Growth

Using audible sound

Hundreds of biological and chemical processes depend on reactions where the output of one process initiates a second reaction, creating a domino-like cascade. In such reactions, we often find chemical gradients of small molecules and even compartmentalisation.

Rahul Dev Mukhopadhyay from the Ramananda College, West Bengal, and researchers from the Institute of Basic Sciences, Republic of Korea thought of a new way of producing such compartmentalised chemical domains using audible sound.

When sound impinges on a liquid vertically, circular domains of the liquid where the maximum vibration occurs, have greater mixing with the oxygen in air. The team visualised this using the reaction of glucose oxidase and horseradish peroxidase cascade when glucose is supplied.

They used a dye to mark out domains with higher mixing. The oxygen-rich domains created by sound had an intense bluish cyan hue while oxygen-deficient domains were pale cyan. The distance between the concentric rings thus formed could be changed by changing the pitch of the sound applied.

Encouraged by the results, the researchers tried another reaction. They made gold particles of about 4 nanometres. An aqueous solution containing these nanoparticles, along with glucose

oxidase, glucose and gold chloride was poured into a Petri dish. Within ten minutes, the solution turned red. The gold particles acted as seeds or nuclei for the growth of bigger gold particles of about 11 nanometres.

But, if sound is applied, concentric rings of intense red develop in a shorter time. The sound vibrations accelerated the growth of gold particles in circular domains.

The idea of using sound to create chemical domains and, thus, stimulate selective growth in specific spatial regions would be useful for tissue engineering and regenerative medicine.

To test this possibility, the researchers used gold nanoparticles functionalized with carboxylic acid which normally aggregate in acidic pH, exhibiting vivid colour changes from red to blue. With glucose and glucose oxidase, the researchers applied 40 Hertz sound. Within three minutes, they could see blue and red concentric rings corresponding to aggregated and isolated nanoparticles, which were then arrested within a hydrogel matrix.

They added factors to improve cell adhesion and proliferation into the hydrogel and grew HeLa cells. After a day, they could observe the growth of HeLa cells in the same concentric ring pattern, which matched well with the location of the nanoparticle aggregates.

'Not only HeLa cells. We could even grow human umbilical vein endothelial cells in a region selective manner,' says Rahul Dev Mukhopadhyay.

So, here we have a technique to control region-specific reaction kinetics of enzyme cascades and other complex chemical network systems in a solution. The applications of using audible sound in biomedical research may be innumerable.

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Eggshell as Bio-cement

Microbial calcium carbonate

To stabilise sand for construction purposes, cement is used. More than three and a half billion tonnes of cement are used around the world each year. This is a costly method. Moreover, cement production is responsible for 6% of man-made greenhouse gases.

There is an environment friendly and less costly alternative for stabilising sand: bio-cementation. Microbes degrade urea to carbonate ions. If there is a source of calcium, calcium carbonate crystals are deposited to interlink the grains of sand. Engineers use calcium chloride as a source of calcium. But this is costly and, environmentally, not so safe.

Ponnusamy Kulanthaivel, Kongu Engineering College, Tamil Nadu and civil engineering researchers from Chennai and Mandsaur recently tried using waste eggshells, a source of calcium, to replace calcium chloride.

Cleaned and powdered eggshells were dissolved using vinegar and were used to compare the results using calcium chloride.

The team used local clean sand to fill unplasticized polyvinyl chloride tubes. They injected bacterial cultures of *Sporosarcina pasteurii* and *Lysinibacillus fusiformis* into the sand column. Then, they supplied urea and either the eggshell solution or calcium chloride.

The researchers found optimum mixing values to make better samples by measuring Young's modulus and calcium carbonate content.

The unconfined compressive strength of sand using the eggshell solution was more than a hundred kilopascals than that of sand with calcium chloride. The sand treatment with *S. pasteurii* was better than the one using *L. fusiformis.*

The permeability of untreated sand was about 500 times more than that of the sand treated with *S. pasteurii* and eggshell solution.

'The bacteria move freely in the inner voids of the sand. And the calcite formed interconnects sand particles and fills gaps. This increases strength and reduces permeability,' explains Subburaj Selvakumar, Vel Tech Rangarajan Dr Sagunthala R&D Institute of Science and Technology, Tamil Nadu.

'Using eggshell, instead of calcium chloride, reduces the cost of the treatment to almost half,' explains Balu Soundara, Saveetha Institute of Medical and Technical Sciences, Tamil Nadu. 'The only limitation is the time taken,' says Ponnusamy Kulanthaivel.

'The treatment has to be repeated. From the third cycle onwards, we see changes. And, by the tenth cycle of treatment with the bacteria and eggshell solution, the sand stabilises,' adds Arunava Das, Mandsaur University, Madhya Pradesh.

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