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## Abstract Volume
## 4th International Conference on "SUSTAINABLE UTILIZATION OF NATURAL RESOURCES" (SUN-R 25)

Feb 19-20, 2025
RAK Auditorium, NCE in Geology, UoP

National Centre of Excellence in Geology
University of Peshawar
Khyber Pakhtunkhwa, Pakistan

## Message from Secretary

*The International Conference on Sustainable Utilization of Natural Resources (SUN-R 2025) is a timely initiative, considering the depletion of natural resources globally. Pakistan, in particular, has immense potential for sustainable development, given its rich resources, including minerals, water, and renewable energy sources like solar, wind, and hydropower.*

*The conference's objective to promote sustainable utilization of natural resources aligns with the government's efforts to encourage investments in mineral development, processing, and growth of markets with sustainable products. This collaborative approach involving the state, businesses, academia, and local authorities has already shown rapid growth in Pakistan's utilization of natural resources.*

*Pakistan's natural resources, including coal, gas, and minerals like copper, gold, and iron, are crucial for its economic development. However, it's essential to strike a balance between utilizing theses resources and ensuring sustainable development. The conference provides a platform for experts to share knowledge, best practices, and innovative solutions to address these challenges.*

*The National Centre of Excellence in Geology (NCEG) at the University of Peshawar has been at the forefront of promoting sustainable development and a positive image of Pakistan through research and academic activities. This conference is another step in that direction, and I'm confident it will contribute significantly to Pakistan's reputation as a leader in sustainable natural resources management.*

**Ministry of Federal Education and Professional Training, Islamabad**

## Vote of Thanks

*The International Conference on Sustainable Utilization of Natural Resources (SUN-R 2025) provided an excellent opportunity for geoscientists to exchange and share their research and innovative work related to minerals, water, and renewable energy sources such as solar, wind, and hydropower.*

*We are highly obliged to sponsors from both government and non-government organizations (e.g., Central South University, NDMA, NCGSA and Directorate of Soil Conservation) which have made this event successful. I would like to extend my gratitude to the SUN-R 2025 team for providing all the necessary facilities for these sponsored sessions.*

*In response to our call for abstracts for SUN-R 2025, I would like to thank the graduate students and professionals from academia and industry who submitted over 50 abstracts on various themes within earth sciences. I am also grateful to the peer reviewers for their valuable contributions. I appreciate the dedicated efforts of the committee members who were instrumental in organizing SUN-R 2025.*

*Finally, I would like to express my heartfelt thanks to the Chief Guest, Guest of Honor, foreign and national keynote speakers, session chairs and co-chairs, as well as all participants for accepting the invitation to attend SUN-R 2025 and for sharing their insights in the field of earth sciences.*

*Prof. Dr. Liaqat Ali*
*Conference Convener,*
*SUN-R 2025*

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# BOOK OF ABSTRACT

## 4th International Conference
## "Sustainable Utilization of Natural Resources (SUN-R 2025)"

***February 19-20, 2025***

**National Centre of Excellence in Geology, University of Peshawar**

**Organized by**

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**BOOK OF ABSTRACTS**

***4th International Conference Sustainable Utilization of Natural Resources (SUN-R 2025) February 19-20, 2025***

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# PREFACE

Since its establishment in 1974, the National Centre of Excellence in Geology (NCEG) has been at the forefront of higher education and research in geosciences within Pakistan. In addition to its core mission of academic excellence, NCEG has been instrumental in fostering intellectual exchange and scholarly discourse through organization of conferences, seminars, and workshops centered around various facets of geosciences. Notably, one of NCEG flagship events is the Sustainable Utilization of Natural Resources (SUN-R) conference, a gathering that has become synonymous with excellence in the field. The inaugural SUN-R conference took place in 2013, marking the beginning of a series of successful editions held in subsequent years: 2016, 2023, and 2025.

The SUN-R conference series has emerged as a cornerstone event in the realm of geosciences, serving as a dynamic platform for scientific dialogue, collaboration, and progress. Over the years, the conference has earned widespread acclaim both domestically and internationally, drawing the participation of esteemed scientists, researchers, and practitioners hailing from diverse backgrounds. With each successive iteration, the SUN-R conference continues to evolve, enriching the global discourse on geosciences and contributing significantly to the advancement of knowledge in this vital field.

The SUN-R 2025 features multidisciplinary thematic sessions covering crucial topics such as Mineral Exploration and Mining, Agriculture, Environment and Water, Climate Change and Sustainable Resource Management, Geotechnical Engineering and Natural Hazards, Investment Opportunity in Industrial Sector, Circular Economy and Policy Guidelines. By facilitating discussions and presentations on cutting-edge research, SUN-R 2025 stimulates new research directions and collaborations, ultimately contributing to the advancement of earth sciences. The conference also provides an opportunity for the corporate sector to showcase their products/services and connect with 500+ researchers, stakeholders, and policymakers from all over the country and abroad. They can network with attendees and access to ALL educational sessions.

In response to the call for abstract for SUN-R 2025, we have received over 50 abstracts from academics, graduate students, and professionals from academia and industry on various themes of earth sciences. All submitted abstracts have undergone review by at least two referees.

# ABSTRACTS

# Structures (folds and faults), petroleum and mineral resources of Rajanpur District (South Punjab, Pakistan)

M. Sadiq Malkani[1*], Nasir Somro[2]
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Rajanpur District (west to east) represents Rakhni-Chacha-Baikar-Janthali synclinorium (core Kahan Group), Moranj anticline (exposed core Pab sandstone), Phailawagh syncline (core Shaheed Ghat shale), Kup anticline (core Dungan Limestone), Kalchas-Loop syncline and Sham anticline (core Shaheed Ghat shale), Dera Bugti syncline (core Kahan and Vihowa groups), Fort Munro-Maarri-Giandari anticline (core Mughalkot marl and mudstone) generally trending NE-SW and N-S with low to moderate dips. Kingri-Rakhni-Chacha and Dragal-Phailawagh are major left lateral faults. Water with possibly petroleum spring observed at Mat Khetran area along K-Pg boundary. First possible petroleum reservoir level is Cenozoic strata like Pirkoh, Habib Rahi, Drug and Dungan limestones and Rakhi Gaj sandstones being permeable due to primary and secondary porosity. Drazinda, Domanda, Baska, Shaheed Ghat and Rakhi Gaj shales can act as source and trap/cap rocks due to being impervious. Second petroleum reservoir level is Late Cretaceous Mughalkot, Fort Munro, Pab and Vitakri formations (Fort Munro Group). Mughalkot Formation shows porcellaneous marl/mudstone lithology except southern and western extremity where sandstone and shale appear and may act as both source and reservoir rocks. Third petroleum level is Early Cretaceous Parh Group consisting of Sembar (shale), Mekhtar (sandstone, commonly called lower Goru sandstone) Goru (shale and marl) and Parh (mainly limestones) formations. The Sembar and Goru shales act as source rock, while Mekhtar sandstone (Lower Goru), Goru marl and Parh limestone act as reservoir rocks. Cap rock for Mekhtar sandstone and Goru marl (lower unit) is Goru shale. The Cap rock for Goru marl (upper unit) and Parh limestone is Mughalkot shale. Fourth petroleum level is Triassic to Jurassic aged Sulaiman Group consisting of Wulgai (=Spingwar shale, marl and limestones), Loralai (thin to thick bedded limestones), Chiltan (mainly thick bedded to massive limestone) and Dilband (ferruginous brown and black weathered marl and siltstone and brown shale) formations. Wulgai shale act as source rock while Wulgai marl/limestone and Loralai and Chiltan limestones act as reservoir rocks. The Cap rock for this level is Sembar shales.

Rajanpur District host huge gypsum deposits, huge cement resource/raw rocks such as limestones, clays/shale and gypsum), coal and carbonaceous shale from Thol and Khaan areas. Decorstone and marble from Dungan limestone and Rakhi Gaj fossiliferous sandstone at Kaha Harrand section. Millstone and abrasives from Pab sandstone, ochre showings, celestite showings in Drug and Baska formations. Resistant (to erosion and weathering) and high density (heavy) minerals such as magnetite, gold, ilmenite, sheelite, garnet, sillimanite, rutile, zircon, REEs bearing monazite and xenotime, and others in placers. Gemstones and jewelry resources such as attractive detritial (pebbles and cobbles) and fragmentary chalcedonic silica (jasper, flint, chert) and others hosted in placer deposits of Oligocene to Recent. Construction materials from Pab sandstones, Dungan limestones, Rakhi Gaj sandstone, Drug,

Habib Rahi and Pirkoh limestones. Gravels from conglomerate of Sakhi Sarwar and Vihowa Groups and from alluvial terraces and fan deposits. Sand from Indus River and its east west flowing tributaries. Possible agrominerals like phosphatic nodules/shales, and different clays like fuller earth, bentonite and fireclays. Vast deposits of different clays are found in Koh Sulaiman Range of Rajanpur District. A footprint of Maastrichtian titanosaurian sauropod, Sauropaonia (*Dgkhansauroperus maarri*) dinosaur is found from Maarri peak area, however the western vicinity yielded famous titanosaurian sauropods, small and medium to large theropods, mesoeucrocodiles, pterosaur, bird and snake from latest Maastrichtian Vitakri Formation. The excavation and development of these geological resources, construction of water dams and installation of cement and gypsum industry share a lot for the development and economic growth of area and ultimately South Punjab and Pakistan. The eastern part of Rajanpur District producing diverse agricultural commodities, while the western part (along north south trending belt) host barren lands. While further westward the Koh Sulaiman Range hosts many mountain peaks and also host many rud/nalas. Most of its water is being wasted as flood. The vast western plain areas of Rajanpur District can be used for agriculture if necessary arrangements for water resources and small, medium and large sized dam's construction may apply. Most of the water resources of the area wasted as flood, if these water resources are stored and can be used properly to cultivate the vast barren land, Pakistan economy will be promoted significantly.

**Keywords:** Folds and faults; Petroleum and mineral potential; Rajanpur District; South Punjab; Economic growth, Pakistan**.**

# Ophiolites of Pakistan: their mineral resources

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In general, ophiolitic mélange or ophiolitic complex consists of igneous rocks (ultrabasic, basic to acidic) with sedimentary and metasediments deposited on sea floor spreading and later this material was obducted by tectonic and geodynamic movement. It is generally believed that Ophiolites obducted show sutures or boundaries of tectonic plates. In Pakistan, the ophiolites are obducted in Karakoram suture, Northern Indus suture, Western Indus suture, Raskoh gap (arc-trench gap) and Washuk gap (arc-trench gap). The Karakoram suture is found between the Hindukush-Karakoram belt of Asian (Eurasian/Laurasian) continental plate (in the north) and Kohistan-Ladakh block of Tethys sea plate (in the south). Kohistan Ladakh block was part of Tethys sea plate and being weak subducted under the Hindukush-Karakoram block during Late Cretaceous by the northward movements and primary collision of Indo-Pakistan subcontinental plate and consequently the ophiolites were preserved along Karakoram suture line and magmatism in Hindukush-Karakoram block resulted. The preserved ophiolitic melanges are at Mirkani locality (found between Mirkani and Lowari pass), Drosh locality (found in Shishi stream of Chitral area), Sor-Laspur locality (found southwest of Shandoor pass), Yasin Valley, Chatorkhand locality (found in Ishkuman region), Chalt locality (found in Hunza region), Hispar locality, Panmah area, Shigor region, Hushe and Machelu localities. These ophiolitic melanges obducted during the late Cretaceous when the Kohistan-Ladakh block of Tethys Sea was sandwiched by tectonic collision of Indo-Pakistan subcontinental plate with Asian continental plate. The Northern Indus suture is located between the Kohistan-Ladakh block (in the north) and Khyber-Hazara-Neelam basin (Uppermost Indus/North most Indus basin; in the south). Just after the development of Karakoram suture, then the sandwiched block of Tethys subducted under the Kohistan-Ladakh block during the Late Cretaceous (by continuous compression and northward movement of Indo-Pakistan plate which created northward movement of Sandwiched Tethys block) and which resulted the magmatism in Kohistan-Ladakh block and also preservation of Ophiolitic melanges of northern Indus Suture. These ophiolites and igneous complexes are represented as Mohmand, Dargai (Malakand), Shangla, Besham (Jijal), Chilas, Sapat, Burzil (east of Astore; pass between Deosai and Taobat Neelam) and Dras (east of Burzil, SW of Kargil) ophiolitic complexes. Western Indus suture is located between the Indus Basin (in the east) which is part of Gondwanan fragment and Balochistan Basin (in the west) which is part of Tethys Sea. This suture is represented by Bela, Muslimbagh, Zhob and Waziristan ophiolitic complexes and obducted by the transpression of Indo-Pakistan subcontinental and Balochistan basin a part of Tethys during the northward movement of Indo-Pakistan plate. In Balochistan basin there are two ophiolitic complexes namely Raskoh and Washuk ophiolites. The Raskoh ophiolite is resulted during the subduction of Arabian Sea plate (northward movement during Paleocene-Eocene) under Chagai block of Tethys Sea. These subducted materials created the Chagai arc (Balochistan magmatic arc). This is the first arc trench gap. Later on arc trench gap was shifted southward at southern base of Washuk-Palantak-Zurati (Siahan Range, northern Makran Range)

and resulted Washuk ophiolite. This ophiolite is resulted by northward movement of Arabian Sea plate during Eocene-Oligocene. These ophiolitic complexes are potential sources of significant chromite, magnesite, asbestos, copper, manganese, construction materials and gemstones. Ophiolites of Pakistan and its mineral resources act as milestone for the development of Provinces and Pakistan.

**Keywords:** Ophiolites, Tethys; Arabian sea plate; Indian Plate; Asian Plate

# Ionosphere lithosphere interaction analysis for earthquake precursor analysis

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The geographic location of Pakistan has surrounded by multiple seismically active region; these seismic regions are the result of ongoing tectonic collision. The seismic prospective of these zones has potential of producing destructive higher magnitude earthquake. The society resilience to such geologic hazard is poor to such calamity caused by underdevelopment. The enormous destructive potential of an earthquake could be softened in its damaging effect if perceived through some precursor technical analysis prior to its occurrences. it is always the desire of each seismologist to identify some technically analyzable precursor to an earthquake occurrence. This study was conducted for an ionosphere atmospheric anomalies detection prior to the earthquake main event through the Total Electron Content (TEC) anomaly detection. The disruption caused by seismically active zones has been extensively documented both before and after earthquakes. This analysis offers crucial insights into the fundamental mechanisms of the lithosphere-ionosphere interaction. The detection of short- and long-term seismic anomalies before the occurrence of the main shock has been reported from ionosphere and atmospheric indices including Global positioning system TEC data and other remote sensing data. The tectonic forces are responsible for the generation of earthquakes inside the earth during the earth preparation period. These tectonic stresses create high level pressure which ultimately create a rupture, at the time of these tectonic stress drop, the total electron content in the atmosphere shows an anomaly/disturbance. In this study we tried to notice the anomalies to predict or forecast the earthquake before the main event occurrence. This study analyzes earthquake precursor data from Honshu, Japan, to gain a better understanding of anomalies observed five days after and fifteen days before two significant seismic events: a 7.3 magnitude earthquake and a 7.1 magnitude earthquake. The results identify specific precursory signals that can enhance our ability to forecast and broaden our knowledge of seismic activity, and to be adopted in higher rated seismic active region like Pakistan.

**Keywords:** Ionosphere; atmosphere; earthquake; precursor; Japan; seismic activity

# Geochemical and Petrographic Investigation of Copper Mineralization in the Kohistan Island Arc: Insights into Subduction Zone Magmatism and Ore Genesis

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Copper mineralization in the Kohistan Island Arc (KIA), located in Upper Dir, Pakistan, which is positioned in northwest Himalayas. Field observations, petrographic analysis, and geochemical data helped in understanding copper mineralization and the effects with subduction-induced magmatic events through $SiO_2$ vs. FeOt/MgO plot. Petrographic analyzes gave evidence of porphyritic texture with phenocrysts of quartz and plagioclase encased into iron oxide (e.g., limonite and hematite) and secondary copper minerals such as malachite and azurite. These features indicate the hydrothermal activity at the later stages of volcanic systems related to subduction. XRF and atomic absorption spectroscopy determined a mafic composition based on $SiO_2$ ranging from 42.01 to 46.53%; $Al_2O_3$ from 15.82 to 20.02%; and CuO from 10.89 to 14.92%. Other noteworthy constituents are: $Fe_2O_3$ 4.98–7.28%, $K_2O$ (~3.5%), $Na_2O$ (~2.5%), and 5.23%–5.13% loss on ignition, signifying the involvement of volatiles in mineralization. The ternary ($10P_2O_5$-$TiO_2$ - 10MnO) diagrams suggested also a geochemical association with alkali basalts from oceanic islands. Total Alkali-Silica (TAS) diagrams identified most samples in the tephrite-basanite category, with a small percentage in the trachy-basalt field, showing a wide range of subduction-related magmatic processes. The latter, particularly the triangular ($10Mn–TiO_2–10P_2O_5$) and the R1–R2 plots provide evidence for an oceanic island-arc like source consistent with a late-orogenic magmatic phase. Samples plotted in the $SiO_2$ vs. FeOt/MgO diagram demonstrated a tholeiitic trend consistent with the character of mantle-derived mafic magmas generated in a subduction-zone environment. These discoveries give a perspective on the tectonic and magmatic relations resulting in copper mineralization in island arc systems, and present a template for future exploration in such settings.

**Keywords**: Petrography; Upper Dir; mafic magmas; geochemistry

# Metallogenic Prospects of the Central Chagai Arc: A Review

Inayat Ullah[1*], Naseer Uddin[1], Shams Uddin Lehria[2], Shah Wali[1], Muhammad Ishaq Kakar[1]

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Numerous types of ore deposits have been identified in the Chagai Metallogenic Belt (CMB) in western Pakistan, including porphyry Cu-Au-Mo, epithermal Cu-Au, skarn-related Cu-Fe-Zn-Pb, and polymetallic VHMS-type deposits. The metallogenic/magmatic belt is divided into three major segments: Western, Central, and Eastern Chagai. The geological and geochemical characteristics and the isotopic ages of these deposits indicate a sequence of structural-magmatic processes. The Central Chagai arc is composed of granites, granodiorites, and diorites, making it a potential target for metallogenic prospecting. The eastern and western parts of the CMB host several types of metallic minerals, while the central part remains unexplored. These deposits formed in response to Neo-Tethys oceanic plate subduction beneath the Eurasian plate and present an Andean-type arc at the southern boundary of the Afghan block. Granitoids in the Central Chagai arc, covering over 1000 km², potentially created ideal conditions for metallogeny and mineralization.

**Keywords**: Chagai; metallogenic belt; porphyry; isotopic; neo-tethys; Balochistan

# Depositional environments and diagenesis of Jurrasic Isha Formation, Isha section, north Waziristan, Pakistan

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This study focuses on the petrographic examination of the Jurassic Isha Formation at the Isha section, located within the axial belt of North Waziristan, Khyber Pakhtunkhwa, Pakistan. The investigation aims to interpret its microfacies distribution, depositional conditions, and diagenetic alterations. Field observations indicate that the formation predominantly consists of dark grey limestone, interspersed with dolomite of a similar hue. Occasional brownish limestone beds are also noted. The formation is characterized by an extensive network of calcite veins, fractures, stylolites, and a distinctive stockwork geometry in calcite veining, along with butcher-chop weathering patterns.

A petrographic analysis of twenty-four thin sections led to the identification of seven distinct microfacies (MF1–MF7): Dolomudstone (MF1), Mudstone (MF2), Bioclastic Mudstone (MF3), Bioclastic Peloidal Wackestone (MF4), Peloidal Packstone (MF5), Ooidal Grainstone (MF6), and Bioclastic Ooidal Grainstone (MF7). These facies reflect diverse depositional settings. The petrographic study also revealed multiple diagenetic modifications, including micritization, neomorphism, compaction, fracturing, and cementation. Additional diagenetic features such as dissolution, dolomitization, and pyritization were also identified. Various types of cement—equant or blocky calcite, drusy calcite, and isopachous cement—were observed. Physical compaction and dissolution are evident in some facies, with features like closely packed grains and saw-tooth stylolites. The presence of dolomitization and pyritization suggests deep burial diagenesis.

Calcite veins observed in the samples suggest late-stage diagenetic processes such as telodiagenesis. Based on microfacies classification, MF2, MF3, MF4, and MF5 indicate a lagoonal environment, while MF6 and MF7 suggest deposition in carbonate shoal settings of the inner ramp. MF1 is linked directly to the inner ramp environment. The findings suggest that the Jurassic Isha Formation was deposited in an inner ramp setting comprising lagoons, shoals, and tidal flats, subsequently influenced by multiple diagenetic processes.

**Keywords**: Isha Formation; microfacies; diagenetic features; inner ramp; carbonate shoal.

# Petrochemical studies of the rocks of the Ushiri Valley, Upper Dir, North Pakistan

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The study area, as a part of the Ushiri Valley, is located in the western part of the Kohistan Island Arc, which is comprised of three distinct rock types such as (i) amphibolites, (ii) granodiorites, and (iii) granites. The amphibolites are exposed in the northern part while granodiorites and granites occupy the southern part of the study area. These rocks display intrusive contacts and exhibit local shearing and faulting in certain places. The amphibolites are usually massive but have a banded appearance at places. In areas of extensive faulting and shearing, these are intruded by quartzo-feldspathic and quartz veins. The medium to coarse-grained granodiorites and granites occur as small intrusions within these amphibolites. The amphibolites mainly contain hornblende and plagioclase with a lesser amount of alkali feldspar and quartz, while muscovite, biotite, epidote, chlorite and opaque minerals occur as accessories. The granodiorites are dominantly composed of plagioclase, alkali feldspar and quartz with a lesser amount of sericite, epidote, chlorite, and augite. The granites consist mainly of quartz and alkali-feldspar with a lesser amount of plagioclase. Epidote, biotite, muscovite and opaque minerals are present as accessories. The chemical characteristics of the studied amphibolites are indicative of igneous protolith and are considered as part of the Kamila amphibolites, while that of granodiorites and granites suggest that these are co-magmatic and can be related to the stage-II pluton of the Kohistan batholith. The detailed geochemical analysis of major and trace elements of these amphibolites, granodiorites, and granites and their plotting on the tectonic discrimination diagrams, suggest that these are calc-alkaline in nature related to the arc magmatism within the subduction-related environment.

**Keywords**: Petrography; Geochemistry; Major and trace elements; Calc-alkaline; Arc magmatism.

# Petrography, Geochemistry, and Industrial Uses of Nepheline Syenite from Koga, Buner, North Pakistan

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Nepheline syenite is a feldspathic rock extensively used in the manufacturing of glass, ceramics, paints, cement, aluminum, potassium, and sodium carbonate. The present study aimed to investigate Nepheline Syenite of the Ambela igneous complex in terms of its petrography, geochemistry, and industrial uses. Based on the petrographic study, the nepheline syenites consist of three-grain sizes: coarse, medium, and fine-grained. The coarse and medium-grained varieties are the most common and exhibit the hypidiomorphic porphyritic texture. The fine-grained varieties range from saccharoidal to hypidiomorphic. The rock consists of three important minerals: Microcline (20.00% to 69.46%), Albite (2.00% to 41.78%), and Nepheline (5.00% to 39.67%). The accessory minerals are sodalite, cancrinite, aegirine, arfvedsonite, biotite, muscovite, calcite, apatite, zircon, sphene, ilmenite, garnet, hematite, magnetite, pyrite, and epidote. Microcline shows a significant negative correlation with albite, aegirine, and calcite, while ilmenite shows a positive correlation with calcite. Nepheline shows a positive correlation with apatite, while albite shows a negative correlation with ilmenite and a positive correlation with hematite. Similarly, sodalite shows a positive correlation with ilmenite. Aegirine shows a positive correlation with calcite, while sphene shows a positive correlation with pyrite. Magnetite and pyrite show positive correlations with epidote. The average geochemical concentration of major oxides is $SiO_2$ = 58.23%, $Al_2O_3$ = 20.35%, Na = 7.79%, $K_2O$ = 0.06%, $Fe_2O_3$ = 2.97%, $Na_2O$ + $K_2O$ = 13.85%, $Na_2O$: $K_2O$ = 1.29. The $SiO_2$ concentration shows a significant negative correlation with MgO, Ca, and LK/I, while the concentration of Na2O shows a significant negative correlation with $Al_2O_3$. Experiments on glassmaking with nepheline syenite demonstrated that contaminants, notably iron, had a major influence on the colour of the glass produced. Magnetic separation was used to reduce iron concentration, which revealed that the sample with the most iron removed produced colorless glass. Ceramics studies show that nepheline syenite can be used from 25% to 40% in the ceramic body, thereby replacing feldspars. Due to its compact nature and attractive look, it can be used in the construction of buildings and for decorative and ornamental purposes. Nepheline syenite can also be used to manufacture alumina and alkalis.

**Keywords**: Nepheline Syenite; Industrial Uses; Koga; Buner; North Pakistan.

# Integrating Geochemical Data and Machine Learning: A Case Study from the Mohmand District, Pakistan

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This study investigates the geochemical properties of rocks and minerals from the Mohmand District, Pakistan, focusing on the prediction of copper (Cu) concentrations. Geochemical data were obtained through atomic absorption spectroscopy, ensuring precise measurements of trace and major elements. The geochemical dataset, was used to develop predictive models employing Random Forest (RF) and Support Vector Machines (SVM). The RF model outperformed SVM, achieving a coefficient of determination ($R^2$) of 0.81 and a root mean square error (RMSE) of 17.42. These results indicate a moderate level of predictive accuracy for Cu concentration. Significant variables influencing the prediction included $Cr_2O_3$ and other trace elements, highlighting the complex interplay of oxides and elemental compositions in Cu geochemistry. The inclusion of such variables demonstrated their critical role in enhancing model performance. While the RF model provided robust predictions within the constraints of the dataset. This research establishes a solid baseline for using machine learning models in geochemical exploration. The findings underscore the potential of RF as a reliable tool for geochemical prediction, particularly in regions like Pakistan, where mineral exploration remains underdeveloped. Future work will focus on integrating additional geochemical features and larger, more representative datasets to enhance the precision of predictions and contribute to the broader field of geoscience research.

# Remote Sensing-Based Identification and Mapping of Mineralized Zones in the Waziristan Ophiolite Complex, Pakistan

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The Waziristan Ophiolite Complex in northwest Pakistan is being studied for mineralized zones using spectral analysis, X-ray diffraction (XRD), and remote sensing. This geologically complex region has important deposits of iron (Fe) and copper (Cu) as well as mafic-ultramafic rocks. Advanced methods were used to map and explore accurately. The ASTER sensor's multispectral data was used to identify important lithologies and mineralized regions. To bring emphasis on geological characteristics, a variety of image processing techniques were used, including Decorrelation Stretch (DCS), Band Ratios (BR), and False Color Composites (FCC). FCC combinations like (4, 6, 8) and (3, 2, 1), along with DCS (1, 3, 8), proved effective in distinguishing altered zones from the surrounding rock formations. Band Ratios, including (5/4 + 1/2, 2/1) and (6/4, 4/7, 5/6), were employed to further differentiate copper and iron-bearing alteration zones, improving the identification of mineralized areas. Lithological units and related alteration minerals could be identified more precisely because to the integration of Thermal Infrared (TIR), Short-Wave Infrared (SWIR), and Visible and Near Infrared (VNIR) data. XRD analysis confirmed the presence of copper and iron-bearing minerals, validating the spectral findings. The mineral makeup of one of the examined samples showed that 72% of the minerals were goethite, 13% were quartz, 9% were brochantite, and 6% contained arsenic. These findings indicated oxidation and weathering processes, corroborating the alteration zones observed in the remote sensing data. This integrated approach improved the precision of mineral mapping in the Waziristan Ophiolite Complex. The results not only validated the spectral data but also provided a framework for future exploration and potential mining activities in the region, contributing to economic development by guiding targeted exploration efforts.

**Keywords**: Ophiolites; ultra-mafic; Waziristan; Spectral; remote sensing

# Prospecting and exploration for the geochemical distribution of lithium and beryllium in Pakistan

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Metals like lithium and beryllium, the strategic resources, are crucial for use in information technology and the manufacturing of novel materials. Pakistan is located where the Eurasian, Indian, and Arabian tectonic plates collide, providing perfect conditions for lithium and beryllium mineralization; however, the entire Pakistan's lithium and beryllium resource potential is still limited because of a lack of geological research. A low-density geochemical survey (1:1 million scale) is a useful technique for quickly defining the prospecting areas and studying the distribution of lithium- and beryllium-bearing mineral prospects. A low-density geochemical survey with a ratio of 1:1 million has been employed to examine the geochemical background of lithium and beryllium in Pakistan. The geochemical survey revealed lithium concentrations in aqueous sediments of bedrock outcrops nationwide ranging from 1.56 to 118.2 µg/g, with an average of 20.06 µg/g, and the concentrations of beryllium ranging from 0.07 to 7.16 µg/g, with an average of 1.22 µg/g. The prospective areas are chosen based on the delineation of 18 lithium and 12 beryllium geochemical anomaly sites using 92% cumulative frequency data. Whereas saline brine-type lithium ore deposits are found in the eastern parts of the Chagai magmatic belt, the pegmatite-type lithium ore deposits are found in the Himalayan fold belt and the Karakoram region. It is suggested that the most promising area for additional research into lithium and beryllium mineral deposits is the Karakoram terrain.

**Keywords**: Prospecting and exploration; Geochemical distribution; Lithium and beryllium; Karakoram; Pakistan

# Impacts of COVID-19 Pandemic on Water Quality of Meriç–Ergene River Basin, Türkiye

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Freshwater resource plays pivotal role in the economic development of a region. The objective of present research was to investigate the impact of the COVID-19 lockdown on surface water quality of the Meriç–Ergene River Basin. This was achieved by examining the levels of physicochemical parameters in water collected from 25 designated sampling site of the studied basin. Significant ecotoxicological indicators, including the Heavy Metal Pollution Index (HPI), Heavy Metal Evaluation Index (HEI), Total Hazard Index (THI), and Total Carcinogenic Risk (TCR), were evaluated for the examined data. The findings revealed that organic pollution and salinity variables did not exhibit significant variation of pre-lockdown and lockdown periods. These were attributed to the regular discharge of domestic and agricultural wastewater. However, the levels of inorganic pollutants such as heavy metalloids showed a considerable decrease during the lockdown. Correspondingly, the HPI and HEI revealed that water quality was significant improved for the investigated locations. Additionally, THI values for children and adults decreased by 67% and 69%, and the TCR values for As and Cr lowered by 60% and 94%, respectively. This decrease was attributed to limited operation of most industrial activities and subsequent effluents within the watershed during lockdown period. The COVID-19 pandemic underscored that the sustainable utilization of water and other natural resources are within human control, and effective management strategies could mitigate ecosystem degradation.

**Keywords**: COVID-19; Heavy metalloids; Total Hazard Index; Total Carcinogenic Risk

# Evaluation of groundwater for irrigation water quality indices and their spatial distribution, Khyber District, North Western, Pakistan

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The present study evaluates groundwater suitability used for irrigation purposes in four tehsils (Mullagori, Jamrud, Bara, and Landikotal) of District Khyber, North Western Pakistan. The study aimed to investigate groundwater quality for agriculture purposes through various irrigation water quality indices (IWQI) and understand its hydro-geochemistry with the help of chemometric techniques as well as the assessment of spatial distribution of IWQI through GIS zonation in each of the four Tehsils. 61 samples taken from different groundwater resources were investigated and analyzed with different physicochemical parameters. The studied groundwater was evaluated for irrigation using permeability index (PI), Kelly's ratio (KR), percent sodium (%Na), magnesium hazard, sodium adsorption ratio (SAR), residual sodium carbonate (RSC), residual sodium bicarbonate (RSBC), and potential salinity. The ternary plot ascertained that 78.8% of samples are in the doubtful quality class while 3.2% are in good quality. Implementing GIS zonation-based indices, agriculturally suitable zones were assessed using IWQ and hydro-geochemical variables. IWQI results concluded that infiltration and permeability are prevalent issues found in the study area. Fertilizers are highly recommended when irrigating crops and conducting other agricultural activities.

**Keywords**: Kyber; groundwater; irrigation; hydro-geochemical; spatial distribution

# Drinking and Irrigation Water Quality Assessment and its Effects on Public Health of the Kandia River Basin, Upper Kohistan District, Northern Pakistan

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Water is a necessary source for the sustainability of life. Pure water is inevitable for a healthy lifestyle and is a fundamental human right. The current study shows the surface water quality of four different valleys: Barthoot, Gabrial, Kandia, and Kangal Valley, in the Kandia River basin in the district of Upper Kohistan, Upper Indus Basin, Pakistan, for drinking and irrigation purposes. Samples were taken from these four valleys upstream (n=41) at considerable distances and analyzed for physicochemical parameters (n=18) including pH, EC, TDS, TS, TSS, Turbidity, ORP, T, $NO_3$, Cl, and F, TH, and TA, $SO_4$, Na, K, Ca, and Mg. Most of the results are within the WHO permissible threshold for drinking purposes excluding turbidity which is higher in Kandia Valley and falls within the WHO range in other valleys similarly, TSS is slightly higher in Gabrial Valley all other sixteen parameters are in the range which shows the suitability of water is good for drinking. The water quality index (WQI) was characterized and calculated as Good to poor. The quality of water was assessed for irrigation as a sodium hazard which includes sodium adsorption ratio (SAR) and sodium percentage (Na%). SAR values and the Riverside diagram show that the water is 94% deemed fit for irrigation except few sampling sites. The Piper and Gibbs diagrams show that the water is sodium chloride (Na-Cl) type which indicates that the water is initially influenced by atmospheric precipitation. The Doneen diagram was used for the total concentration and permeability index which shows that the maximum samples (36-41) fall within the high permeability range (80-100%) which is class-1 showing that the water is good and suitable for irrigation purposes. The statistical analysis shows that the geogenic activities primarily atmospheric precipitation and secondly rock weathering regulate the chemistry of the Kandia River Basin water.

**Keywords**: Drinking Water Quality; Irrigation Water Quality; Kandia River Basin; Upper Kohistan

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# Heavy metal contamination and ecotoxicological hazards in the agricultural soil, Pakistan

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The significance of soil being vital environmental resource cannot be exaggerated, since it offers a variety of ecosystem amenities and sustains agricultural practices. However, contamination of soil can negatively impact agricultural services, productivity, and public health. The presence of heavy metals (HMs) in soil poses a significant risk to human health and living organisms because of their toxicity, ability to bio-accumulate, and persistence in the environment. This research focuses on HMs contamination in agricultural soils of Pakistan, examining on distribution patterns, ecological risk, and the potential implications for human health. The contamination factor, geo-accumulation index (Igeo), and integrated indices, including the spatial distribution of the ecological risk index were calculated based on HMs concentrations. Likewise, the Igeo valves were noted in the following way: Sindh > Baluchistan > Punjab > Khyber Pakhtunkhwa > Gilgit-Baltistan > Islamabad. Similarly, the province of Punjab, Khyber Pakhtunkhwa, and Islamabad territory exhibited higher mean ecological risk levels (160 < ERI < 320), primarily because of cadmium (Cd). The non-carcinogenic risk, measured by hazard quotient, was shown to be elevated for children of Punjab (1.59) owing to arsenic (As) ingestion, while a diminished risk was noted for adults in Punjab from inhaling zinc (Zn) (2.5E−08). Additionally, soil exposure to (As) (1.61) had a higher health index (HI) than the other HMs. Furthermore, the determined cancerous risk remained within the permissible limits (10–4–10–6). This research emphasizes that continuous monitoring of HMs pollutants in soil is necessary, particularly in the provinces of Sindh, Baluchistan, and Gilgit-Baltistan.

**Keywords**: Contamination; Ecological risk; Health risks; Heavy metals (HMs); Pakistan; Soil

***Acknowledgements**: Financial support from the Higher Education Commission, Pakistan is highly acknowledged for project # 20-17208/NRPU/R&D/HEC/2021

# Spatiotemporal Evolution of Water Bodies in the Tarbela Dam Region: Drought Impact and Propagation Mechanisms Using Google Earth Engine

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This study examines the spatiotemporal dynamics of water bodies in the Tarbela Dam region, leveraging transition mapping and pixel-level analysis to identify key hydrological changes and their potential drivers. Using remote sensing data, water bodies were classified into nine distinct transition classes, including permanent, seasonal, and ephemeral categories, as well as their respective transformations. Results reveal significant losses of permanent water bodies, the emergence of new seasonal and permanent features, and transitions from seasonal to stable regimes, indicating both hydrological variability and human-induced changes. Quantitative pixel-based analysis further corroborates these findings, showing high recurrence and stability in permanent water bodies, alongside marked reductions in occurrence and seasonality in areas categorized as "lost permanent" or "lost seasonal". The observed changes are attributed to a combination of climate change, sedimentation, and anthropogenic factors such as upstream water management and land-use changes. For instance, the emergence of new seasonal water bodies may reflect extreme rainfall events linked to climatic variability, while the stabilization of seasonal bodies into permanent water features could result from reservoir operations and increased groundwater inflows. These transitions have profound implications for regional water availability, biodiversity, and ecosystem services, highlighting the need for sustainable water resource management. This research underscores the importance of integrated watershed management strategies to address the loss of critical water resources and mitigate the impacts of climate change. Policymakers must prioritize interventions such as afforestation, optimized irrigation practices, and rainwater harvesting to safeguard water bodies and ensure sustainable development in the Indus River basin. Future research should focus on combining remote sensing data with hydrological and socio-economic models to further unravel the complex drivers of water body changes and enhance regional water resilience. By providing a detailed assessment of water body dynamics in a key hydrological region, this study contributes valuable insights into the challenges and opportunities for water management under changing climatic and anthropogenic conditions.

**Keywords**: Water body dynamics; Spatiotemporal analysis; Hydrological transitions; Google Earth Engine; Climate change impacts

# Assessing heavy metal pollution and ecological risks in aquatic ecosystems of northern Pakistan: a multiscale perspective

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Sediments are key components in aquatic ecosystem, serving as natural reservoirs and sources for heavy metals, with contaminants accumulating from both dissolved and particulate sources. When exposed to aerobic conditions, sediments undergo chemical transformations, thereby altering metal solubility. Therefore, to understand pollutant behavior and potential environmental risks, it is necessary to examine the extent and origin of heavy metal accumulation. This research examines the spatial distribution, sources, and ecological implications of heavy metals contamination in freshwater sediments across diverse geological settings of northern Pakistan, including the Hunza River, Indus River, Dor River, and Naltar Lakes. Using advanced techniques such as atomic absorption spectrometry (AAS), sediment samples were analyzed to quantify pollution levels, identify contamination sources, and evaluate the ecological and human health impacts of heavy metals and potentially toxic elements (PTEs). The findings reveal that heavy metal concentrations, particularly iron (Fe), cadmium (Cd), chromium (Cr), and nickel (Ni), are influenced by both natural geological processes, such as bedrock weathering and erosion, and localized anthropogenic activities, including agricultural runoff and wastewater discharge. Contamination indices such as contamination factors (CF), pollution load indices (PLI), and ecological risk indices (ERI) indicate moderate to high pollution, with downstream areas showing higher contamination levels. Health risk assessments of sediment contamination identify arsenic and cobalt as significant contributors to potential hazards. Statistical analyses highlight the predominant role of geogenic sources in sediment contamination, while localized human activities further consolidate heavy metal accumulation. This research provides essential insights into sediment contamination dynamics, contributing to a broader understanding of heavy metal transport and deposition in riverine ecosystems. The findings support the development of sustainable sediment management practices to mitigate environmental risks in the region. It also provides essential insights for sustainable ecosystem management and policymaking to protect aquatic habitat and public health, aligning with the United Nations Sustainable Development Goals (SDGs).

**Keywords**: Spatial Distribution; Sediment; Atomic Absorption Spectrometry; Potential Hazards; Sustainable Development Goals.

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# Lead Contamination in Drinking Water: Vulnerability and Risk Assessment in Southern Khyber Pakhtunkhwa

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Exposure to lead (Pb) through drinking water has adverse health impacts that are particularly severe in children. The main objective of this study was to determine lead contamination levels in drinking water in the southern parts of Khyber Pakhtunkhwa and to conduct vulnerability analysis and risk assessment of the exposed population. Lead concentration in drinking water samples using the atomic absorption spectrophotometric technique (AA) ranges between 0.02 mg/l and 1.572 mg/l. Data analysis shows that the lead concentration level in 44 samples is more or less within the permissible limit of WHO (0.05 mg/l), 2002.While 99 drinking water samples out of 145 had a higher value of Pb than the permissible exposure level of 0.05 mg/l set by the WHO in 2002, The hot spot areas include district Kohat, Hangu, D.I. Khan, Bannu, and district Karak. The range of 0.581 mg/l to 1.572 mg/l. The overall interpretation indicates the lead concentration level is many folds higher in 99 samples collected from the above-mentioned locations as compared with the permissible exposure limits (0.05 mg/l) set by the WHO for drinking water. On the basis of observed data in the study area, different types of care strategies were suggested to control the effects of Pb in the vulnerable sites of the study area to protect humans and the environment from exposure to lead toxicity.

**Keywords**: vulnerable; Risk; prediction; hotspot area; Karak; Bannu; Hangu

# Introducing *iwaqr*: an open-source integrated framework for irrigation water quality assessments and visualizations in R

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This abstract describes the structure, functionality, utility, and validation of the *iwaqr* package (version 1.8.4), developed at NCE in Geology. The *iwaqr* package provides an integrated framework for researchers, agronomists, and environmental scientists. This package streamlines the estimation of key irrigation water quality indices, including Sodium Adsorption Ratio (SAR), Sodium Calcium Adsorption Ratio (SCAR), Magnesium Hazard (MAR), Permeability Index (PI), Kelly's Ratio (KR), Potential Salinity (PS), Residual Sodium Carbonate (RSC), and Residual Sodium Bicarbonate (RSBC). These indices serve as crucial metrics for evaluating water suitability in agricultural contexts, aiding in sustainable irrigation management and soil conservation. Beyond numerical assessments, *iwaqr* also offers visualization capabilities, generating widely recognized irrigation water quality classification diagrams such as the US Soil Salinity Diagram (USSL), Wilcox Diagram, Riverside Diagram, and Doneen's Diagrams for varying permeability levels (Low, Medium, High). Built upon the *ggplot2*, *ggthemes*, and *ggrepel* libraries, the package enables the creation of high-quality, publication-ready visualizations with minimal user intervention. Functions such as *plot_USSL*, *plot_Wilcox*, *plot_Riverside*, and *plot_Doneen* allow users to generate these diagrams seamlessly by specifying essential parameters. Designed for flexibility and ease of use, *iwaqr* includes features such as automatic unit conversion from mg/L to meq/L, simplifying data pre-processing. Its *irrigationALL* function facilitates the simultaneous computation of multiple indices, storing results in a structured data frame for further analysis. This abstract presents the functionality and validation of the package and compares its utility with other well-known open-source and commercial software. The open-source package is available on CRAN and Github repositories. Future developments would include additional irrigation water quality metrics, visualizations, bug fixing, and the estimation of a composite index.

**Keywords**: Environmental informatics; R; *iwaqr*; irrigation waters; visualization; software

# Assessment of marble waste water, and its impact on river Kabul, Khairabad Khyber Pakhtunkhwa

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The study evaluated the marble effluent from twenty marble industries, and the water from River Kabul as this effluent is commonly discharged into it, in the Khairabad Nowshera KP region. Seven (07) physical parameters, pH, TDS, EC, TSS, temperature, salts and turbidity, were analyzed in the effluent samples from all industries. The results showed that all physical parameters were within the safe limits except for salts and turbidity, they exceeded the safe limit given by Pak EPA. Three out of six marble industries having treated effluent (settling tanks) had salt levels exceeding the safe limit of 200 mg/L. The highest salt levels were found in industry three. Ten out of fourteen industries with no treatment method also had their salt levels surpassing the safe level (200mg/L). Highest levels were found in industry 1, 4 and 17. The turbidity in all five samples of the river Kabul were also above the safe limit with highest found in AMP (On mixing point) samples. All other parameters were within the permissible limit in river Kabul samples. Turbidity in industries with treated effluent also surpassed the safe limit with the highest levels found in industry 15 and 16. Industries with no treatment had their turbidity levels exceeding the safe levels with highest found in industry 1 and 8. Nine chemical parameters alkalinity, total hardness, $Mg^{+2}$, $Ca^{+2}$, nitrates, sulphates, chlorides, sodium and NaCl, were also analyzed in wastewater and river Kabul samples. The results of chemical analysis showed that Mg+2 surpassed the safe limit by Pak EPA (100 mg/L) in all effluent samples except for industry 10 and 14 with highest found in industry 11, 13, and 17. The results of river Kabul also showed that $Mg^{+2}$ surpassed the safe limits of 100 mg/L in all samples with highest number in BMP and AMP samples. All other chemical parameters were within safe limits. 18 elements were also analyzed in effluent samples and samples from river Kabul. The levels of Zn, Cd, Cr, Co, Mn, Pb, and Al were below the detection limit (BDL). The result of other parameters, Sr, Si, Li, Pd, Cu and Ba were all within the safe range given by Pak EPA and NEQs in all samples. Industry 3 had Hg levels surpassing the safe limit of 0.07mg/L. The study emphasizes the pollution of surface water, particularly the Kabul River, from marble effluent causing ecological disruptions, reduced aesthetics, water pollution, and crop failures due to limited awareness and treatment infrastructure. Improved wastewater management, regulatory supervision, and community knowledge are needed to reduce these consequences.

**Keywords**: Wastewater; Heavy metals; physicochemical; marble industries; Khyber Pakhtunkhwa

# Mapping rainwater harvesting sites in Panjkora River Basin, Khyber Pakhtunkhwa, Pakistan

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For improved water resources management, conservation of water, and the resolving/coping water-related challenges, rainwater harvesting (RWH) practices are of vital importance. For increasing agricultural productivity and water availability, selecting the suitable site with appropriate design for RWH is essential, particularly when water resources are more vulnerable to the impacts of climate change. State of the art integrated methods must be employed to for better water sustainability, especially under mountains environment. For this purpose, the Panjkora river basin was selected using Multi Influencing Factor (MIF) as spatial data model technique. The said model was incorporated in the Geographic Information System (GIS) using both customary and remotely sensed datasets. According MIF results, the study area has 80.22 $km^2$, 1681.99 $km^2$, 3116.10 $km^2$, 844.86 $km^2$, and 35.10 $km^2$ as less suitable, moderately suitable, suitable, high suitable and very high suitable for RWH interventions, accordingly.

To verify the accuracy and suitability of the model, the results were evaluated using ROC-AUC tests where MIF exhibited a score of 0.724, which is considered an encouraging and acceptable accuracy. On the basis of the results, the applied technique is recommended to be extended to various hydro-meteorological and physiographic regions in north of Pakistan.

**Keywords**: GIS; MIF; RWH; accuracy assessment; ROC-AUC.

# Assessing Sediment Yield and Reservoir Sustainability in the Indus Basin: A 30-Year Hydrological Modeling Approach for Tarbela Dam Management

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Over the past thirty years, sedimentation in Pakistan's Tarbela Reservoir—a critical hub for irrigation and hydropower—has significantly reduced its active storage capacity, driven primarily by sediment influx from the Upper Indus Basin (UIB). This research evaluates sedimentation dynamics (1994–2023) through an integrated approach combining satellite-derived data (USGS STRM, ERA5-Land Climate Reanalysis, FAO Soil Maps, and Global Land Cover datasets) with field measurements from the Surface Water Hydrology Project and Tarbela Dam archives. A spatially distributed model of the 102,028 km² UIB watershed was developed using ArcSWAT, incorporating 26 subbasins and 64 hydrological response units (HRUs) to address heterogeneity. Sensitivity analysis, calibration, and validation were conducted via SWAT-CUP with the SUFI-2 algorithm, employing 22 parameters. The model demonstrated strong performance, yielding calibration metrics ($R^2 = 0.89$, NSE = 0.84) and validation results ($R^2 = 0.81$, NSE = 0.68). Simulations revealed that 78% of precipitation at Besham Qila contributes to streamflow, dominated by surface runoff (61%). Peak rainfall, sediment flux, and discharge coincided in July. Annual surface runoff averaged 505.35 mm, with upland sediment yields ranging between 2,086.09 and 5,772.90 Mg/ha. Substantial in-channel sediment deposition (-2,082.52 Mg/ha) exacerbates flood vulnerability. Decadal analysis indicated a decline in sediment yields from 5.9–385.3 to 2.7–370.6 tons/ha. To mitigate sedimentation impacts on reservoir capacity and energy production, the study proposes targeted interventions such as afforestation, terraced agriculture, check dam installation, and sustainable land management. Long-term monitoring collaboration is emphasized to preserve hydraulic infrastructure efficiency and resilience.

**Keywords**: SWAT; SWAT-Cup; Sedimentation; Tarbela Dam; Upper Indus Basin; storage capacity

# Tarbela Reservoir's Sediment Deposition and Delta Progression: Obstacles and Solutions for Long-Term Sustainability

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A key component of Pakistan's water management system, the Tarbela Reservoir is essential for flood control, hydroelectric power production, and agriculture. However, sedimentation is a severe issue that affects the reservoir's storage capacity and operating efficiency. This research looks at the patterns of the accumulation of sediment and erosion in the Tarbela Reservoir during the last 30 years, with an emphasis on the migration of the underwater delta and the consequences for reservoir management. The research uses elevation data from range lines throughout the reservoir's upper, middle, and lower portions to identify unique patterns of sediment buildup, notably in the middle and lower regions, whereas the higher area shows a mix of deposition and erosion. Predictive modeling predicts the underwater delta's progress toward the Main Embankment Dam (M.E.D), with a decrease in distance from 3.78 miles in 2023 to 0.58 miles by 2043, if present sedimentation rates continue. The results underscore the vital need of appropriate sediment management measures in reducing the negative impacts on storage capacity and hydropower efficiency. This study gives vital insights into sedimentation patterns, laying the groundwork for future reservoir management and sustainable operation in the face of persistent sediment issues.

**Keywords**: Erosion; Deposition; Sedimentation; Tarbela Dam; Main Embankment Dam (M.E.D); Underwater Delta

# Taxus wallichiana (Himalayan yew) is more tolerant to climate stresses at altitudinal gradient in the moist temperate forest of Himalayan, Pakistan

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Taxus wallichiana (TW) is endangered species of moist temperate forest of Himalayas. The antioxidant system of this species is very important which enable the plant to survive under extreme climatic conditions. Climate change poses significant effect on the antioxidant defense system of the TW. Therefore, it was important to assess the effect of climate change on TW antioxidant system. The results of this study revealed the contention that DPPH and SOD, POD were greater of the TW. These antioxidants are important for survival of TW under climate change.

**Keywords**: Taxus wallichiana; ROS; antioxidant potential; moist temperate forest; DPPH

# Green Rooftops using Hydroponics and Fresh Water

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Rapid urbanization and population growth have intensified challenges related to food security, water conservation, and urban climate management. Conventional agriculture's reliance on extensive water and land resources exacerbates these issues. This research addresses these challenges through rooftop hydroponic systems, which offer sustainable solutions by reducing water usage, optimizing space, and lowering carbon footprints. Conducted on the rooftop of the Urban Engineering Department at NED University of Engineering and Technology, Karachi, Pakistan, this study investigates the performance of hydroponic systems—Nutrient Film Technique (NFT) and Dutch Bucket System (DBS)—and compares their efficiency with conventional agricultural methods. The methodology involved setting up NFT and DBS hydroponic systems under controlled greenhouse conditions. Water recirculation techniques were employed to conserve resources, while parameters such as temperature, humidity, pH, and Total Dissolved Solids (TDS) were monitored daily. Crops like strawberries, lettuce, and soybean were grown using nutrient-rich solutions, and their growth performance was compared to plants cultivated through conventional soil-based methods.

Results demonstrated that hydroponic systems significantly reduced water consumption, with up to 33% less water usage compared to conventional methods, while maintaining optimal TDS and pH levels. Space utilization in hydroponic systems was notably efficient, accommodating 60 strawberry plants in just 30 square feet compared to 48 square feet required for conventional setups. Although conventional systems yielded higher plant output in some cases, hydroponics provided better control over environmental factors, enabling year-round production and improved crop quality. The study concludes that rooftop hydroponics is a viable solution for urban agriculture, addressing food security and sustainability concerns. By reducing water usage, optimizing spatial efficiency, and mitigating urban heat island effects, hydroponics presents an innovative approach to sustainable food production. Further research is recommended to enhance crop yield, improve cost efficiency, and adapt these systems to diverse climatic conditions for broader urban applications.

**Keywords**: Climate adaptation; Urban farming; Hydroponics; Water conservation; Urban sustainability.

# District Charsadda Groundwater evaluation through chemical, geophysical and geological integration

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Located at the confluence of the Kabul, Swat and Jandi rivers, Charsadda District has excellent potential for groundwater storage and continuous supply due to continuous recharge from these rivers. The area is characterized by a deep layer of gravel and sediments, which serve as an energy source for underground water storage. About 80% of the district Charsadda area is covered by recent alluvium, including rivers, streams, floodplains and lakebeds, dating back to the Pleistocene. The remaining 20% is covered by other rocks, and the ridge slopes towards the northeast at an angle of 45 to 50 degrees. The soil properties of Charsadda facilitate the infiltration of water from these rivers, which recharges the groundwater aquifer. The Landover of the Charsadda is excellently tuned for all agricultural activity and yield sufficient wheat, Maize, many fruits etc., for local needs, due to this extensive cultivation activity the fertilizer and pesticide used for crops finally reach to the groundwater aquifer., and possess a permanent threat for health issues upon exposure/utilization. The thickness of the sediments cover through Peshawar valley is around 300 meter, due to the mountains barrier which surround the valley from all direction, hence no horizontal permeable connection on surface and within subsurface for horizontal flow except the Khairabad fault which provides a pathway to horizontally drain the aquifer of Peshawar valley. The ground water also flows within subsurface generally (not always) follows the surface flows direction. This flow of the groundwater within first few tens of meter maintain the serenity of the aquifer for longer periods by removing all these received contaminations.

The new central campus of Bacha Khan University, which is currently under construction from 2021, is located in an area where the water table reaches 2-3 meters below the ground. The purpose of this research is to study quantitative and qualitative estimates of groundwater, to determine the quality and hence the feasibility of designing an optimal water treatment system for local land conditions. The Groundwater analysis, includes testing for chemicals and rare earth metals, to provides insight into actual groundwater quality and allows filtration protocols to purify water by customized filtering to meet drinking standards. The main objective is to provide clean water to the university population, including students and staff, and to study the feasibility of establishing a mineral water company to sell ground water. This project not only addresses the water needs of the university community, but also the resource generation potential for universities that are currently facing them.

**Keywords**: Groundwater; Charsadda; infiltration; storage; drinking standards

# Ecology of Antarctic soil fungi and climate change

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Antarctica hosts a biodiversity higher than previously expected, primarily confined to areas where the melting of snow during the austral summer provides sufficient liquid water for metabolic activity. The main substrates for microbial life in Antarctica are rocks and soils. Rich and well-differentiated microbial communities have been recorded and described in these substrates, even under the extreme conditions of the innermost regions of Continental Antarctica and the cold deserts of the McMurdo region.

Poly-extremophilic microorganisms have been isolated from these sites, capable of surviving in extremely low temperatures, limited water and nutrient availability, high solar and UV radiation, and dehydrating, intense winds. Remarkably, some of these microorganisms have demonstrated the ability to withstand environmental conditions vastly different from those encountered in their natural habitats, such as extremely high temperatures, exposure to ionizing radiation, and growth on various perchlorates. Additionally, they exhibit unexpected metabolic competencies.

Could climate change lead to the disappearance of these species? This is a question for which, based on current studies, there is no definitive answer. However, there is a significant risk that these poly-extremophilic strains may face competition from less extremophilic species as environmental conditions change.

**Keywords**: Antarctica; microbial life; climate change; biodiversity

# Soil Carbon and Nitrogen Stocks under contrasting Land-Use Systems of a Western Himalayan Valley

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Land use system influence soil organic carbon (SOC) and nitrogen (N) which are indispensable for soil health and food security. Different types of land use have different capacity to recycle SOC and TN which is necessary to understand for sustainable ecosystem productivity. In this context, surface (0-15 cm) and sub-surface (15-30 cm) soil was sampled from five different land use types (e.g., cropland, paddy, apple orchard, grassland and forest) of Leepa valley, District Hattian Bala, Azad Jammu and Kashmir (AJK) to assess SOC and TN stocks and associated soil properties. The results showed that, irrespective of soil depth, both SOC and N varied significantly ($p < 0.05$) across the land-use systems, and was highest in soils under forest and lowest in paddy soils. On the other hand, SOC and N contents declined significant ($p < 0.05$) with increasing soil depth being highest in surface soils. The mean total SOC and N stocks ranged from 22.12 to 42.36 Mg $ha^{-1}$ and 2.04 to 3.68 Mg $ha^{-1}$ in surface soils and 18.06 to 40.89 Mg $ha^{-1}$ and 1.95 to 3.54 Mg $ha^{-1}$ in sub-surface soils being highest under forest land use, respectively. The majority of the SOC and N were associated with macro-aggregates (Ma) in the 0-15 cm layer, with micro-aggregates (Mi) in the 15-30 cm layer, while the silt + clay fraction contained the least SOC and N across all land uses and soil depths. In terms of soil properties, bulk density (ρb), pH and electrical conductivity (EC) were directly proportional to soil depth. The soil pH, EC, and ρb were higher in sub-surface soil than surface soils. The results of the present study showed land use impact on SOC, TN and associated soil properties. The findings of the study could be used to restore SOC and TN for sustainable livelihood security in the valley.

**Keywords**: Land use system; Soil organic carbon; Total nitrogen; Soil properties; Azad Kashmir

# Reconstruction of climate using dendrochronology

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Forest tree species respond to climate change, and dendro-climatological investigations of such species provide valuable insights into climate variations. These investigations are instrumental in reconstructing historical climate data and facilitating the development of effective mitigation and adaptation strategies. This study focuses on utilizing the climate-sensitive tree rings of Himalayan fir (Abies pindrow Royle ex D. Don) to reconstruct monthly temperatures during the growing season (pre-monsoon) in the climate-vulnerable western Himalayan region of Pakistan. We constructed a tree ring width chronology spanning 1773 to 2020 CE. The findings indicate that Abies pindrow exhibited negative growth responses (r = -0.46) and (r = -0.50) to the May minimum temperature (May Tmin) and May-June average temperature (Tav MJ) for the Murree Meteorological Station, respectively. Similarly, negative responses were observed (-0.34, -0.522, -0.60, and -0.64) for the calculated May minimum temperature (May Tmin), May average temperature (Tav-May), May maximum temperature (May Tmax), and mean May-June maximum temperature (Mean MJ Tmax) of the Kakul Meteorological Station, respectively. Only Mean MJ Tmax (Kakul MET Station) was found to be having valuable reconstruction potential and reconstruction of the same was under taken with an explained variance of around 40%. The reconstruction spanned from 1855 (with an expressed population signal > 0.85) through 2020, revealing 16 recorded cold and 16 recorded warm years. The reconstructed temperatures aligned with some commonly reported hot and cold years in regional studies. Additionally, short frequency cycles (2.43–3.57 years) attributed to El Niño Southern Oscillations and a geographical correlation with precipitation and potential evaporation were observed. Reconstructed temperature anomalies coincided with major global volcanic eruptions, highlighting the broader impacts of climate change on trees in the western Himalayas. This study serves as a valuable resource for researchers exploring regional climate change dynamics, providing comprehensive insights into the intricate relationships between climate variations and tree growth in the western Himalayas.

**Keywords**: Dendrochronology; climate change; reconstruction; Himalayan; variations

# Geochemical characterization of water and sediments in the high-altitude lacustrine ecosystem

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The primary resources of water in the country are high altitude lacustrine ecosystem that store and control the flow for downstream ecological, industrial, household, and agricultural uses. Consequently, the heavy metals (HMs) are deposited in ecosystems, and stagnant lakes put water supplies at risk. The current study investigated the quantities of HMs such as Zn, Pb, Mn, Fe, Co, Cr, Cd, Ni in five high-altitude lakes (HAL) water and sediments in District Mansehra, Pakistan. The concentrations of HM in sediments were used to determine pollution variables such as ecological risk assessment (ERA), sediment pollution index (SPI), risk index (RI), contamination factor (Cf) and pollution load index (PLI) and for the water quality different physicochemical parameters were used to find heavy metals evaluation index (HEI) and chronic risks. Fe had the highest concentration of 1411 mg/kg in lake sediment, while Cd had the lowest at 1.06 mg/kg. The findings showed that, with the exception of Cd, the majority of HM concentrations in HAL sediments fell under the sediment quality standards (SQGs) level. Siri Lake's sediments had greater levels of HM pollution as well as greater RI, ERA, PLI and Cf values as compared to the other lakes. With the exception of moderate levels of Pb and significant levels of Cd in the exposed aquatic habitat, most HMs in HAL sediments exhibited minimal contamination. The water analyses found that children who drank Siri Lake (SL) water had higher cadmium (Cd) hazard quotient (HQ) values of 0.36 ± 0.05 and the values obtained from heavy metal ingestion for Hazard Index (HI) were found to be below the 1.0 threshold. The analysis revealed that 96% of the sediment samples posed minimal to moderate risks to the lake environment and the water parameters studied were within the WHO drinking guidelines. The geogenic sources of pollution were found to be significantly contributing to the sediments for HM contamination, according to statistical and geographic assessments

**Keywords**: Risk Assessment; District Mansehra; High altitude lakes; Pollution

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# Heavy metalloids Concentration in Poultry Feed, Edible Muscles, and Litter in Peshawar Valley, Khyber Pakhtunkhwa, Pakistan

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The poultry industry is a vital source of dietary protein worldwide. The contamination of heavy metalloids (HMs) in poultry feed, edible muscles, and litter raises significant health and environmental concerns. This study evaluates the concentrations of HMs including Pb, Mn, As, Cr, Fe, Ni, Zn, Cu, and Cd in poultry products from selected districts including; Nowshera, Charsadda, Khyber and Peshawar in Khyber Pakhtunkhwa, Pakistan. Using a cross-sectional research design and a multi-stage sampling approach, samples were collected from markets and slaughterhouses and analyzed via inductively coupled plasma mass spectrometry (ICP-MS). The results revealed that Cd and As concentrations exceeded WHO permissible limits, with Cd reaching 0.624 mg/L (WHO limit: 0.5 mg/L) and As recorded at 0.456 mg/L. Pb was detected in nearly all samples, with a maximum concentration of 0.500 mg/L, though within acceptable limits. Statistical analysis using ANOVA and Pearson's correlation confirmed significant bioaccumulation of metals from feed to edible tissues, with strong correlations for Pb ($r = 0.79$, $p < 0.01$), Cd ($r = 0.64$, $p < 0.05$), and As ($r = 0.83$, $p < 0.001$). Hazard Quotient (HQ) analysis indicated that Cd (HQ = 1.25) and As (HQ = 2.53) pose severe health risks, necessitating urgent regulatory interventions. These findings underscore the importance of stringent monitoring and policy enforcement to mitigate HMs contamination in poultry production, ensuring food safety and environmental sustainability.

**Keywords**: HMs Concentration; Poultry Feed; Edible Muscles; Peshawar Valley

***Acknowledgements**: Financial support from the Higher Education Commission, Pakistan is highly acknowledged, project # 20-17208/NRPU/R&D/HEC/2021.

# Micropetrographic Analysis and Rock Durability Assessment of Granitoids from North Pakistan

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Weathering and durability are essential factors that determine the suitability of rocks for engineering and construction applications. These properties influence the long-term performance and stability of rocks under diverse environmental conditions and load scenarios. Given the complexity of rock behavior, relying on a single test is insufficient to comprehensively evaluate their suitability. Instead, a combination of physical, mechanical, and chemical tests and indices is commonly employed to ensure a thorough and reliable assessment. Among these, the evaluation of weathering and durability properties, alongside rock strength, is critically important. This study focuses on the application of the micropetrographic index and various rock durability indicators, including both dynamic and static properties, to evaluate the weathering state and durability of granitoids. The indices are developed through an integrated methodology involving petrographic analysis and a series of physico-mechanical tests. Additionally, the slake durability index (SDI) is employed, as it exhibits strong correlations with both static and dynamic durability indicators, providing valuable insights into the strength and durability of the rocks.

This research examines eight granitoid types from Northern Pakistan, specifically Kesu Granodiorite, Warai Granodiorite, Ambela Granite, Garam Chashma Granite, Kumrat Granodiorite, Warsak Syenite, Malakand Granite, and Utla Granite. The micropetrographic index, derived from a detailed petrographic examination, is systematically correlated with physical and mechanical properties to establish reliable durability indicators. This study highlights the utility of these indices in classifying granitoids into distinct weathering and durability categories. Furthermore, the study explores the estimation of durability indices by combining the slake durability index with the micropetrographic index for improved reliability. Comprehensive testing of the granitoids reveals that integrating these indices provides a dependable framework for evaluating rock performance and categorizing weathering states. The findings enhance the understanding of the engineering properties of granitoids, offering a practical approach for their optimal utilization in construction and geotechnical projects.

**Keywords**: Micropetrographic index; Rock durability indicators; Weathering; Durability

# Multidisciplinary characterization of landslides using UAV photogrammetry and geophysical methods: A case study of an active landslide with early warning applications

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Northern Pakistan is vulnerable to frequent and severe landslide hazards, substantially threatening lives, infrastructure, and the environment due to its distinctive tectonic activity and climatic conditions. Effective landslide hazard management necessitates a comprehensive understanding of both surface and subsurface characteristics of potential landslide zones. This study adopts an integrated methodological framework, combining Unmanned Aerial Vehicle (UAV)-based photogrammetry, with geophysical techniques such as Electrical Resistivity Tomography (ERT) and the Microtremor Survey Method (MSM). This multidisciplinary approach facilitated a detailed characterization of the recently initiated Dolai landslide in the Muzaffarabad district, which obstructed the main Kohala-Muzaffarabad highway and threatened the blockage of the Jhelum River downstream. UAV-based photogrammetry offers high-resolution spatial and temporal datasets, enabling precise surface characterization. In parallel, ERT and MSM provide critical insights into subsurface conditions, including soil stratification, pore water pressure, and shear stress. The integration of these methods significantly enhances the accuracy of landslide hazard assessments and the efficacy of early warning systems. The findings from this investigation are pivotal for local authorities and stakeholders, informing the implementation of targeted mitigation measures, refining risk assessment strategies, and ultimately safeguarding vulnerable communities and critical infrastructure from the persistent threat of landslides in this geologically dynamic region.

**Keywords**: Landslide characterization; subsurface; UAV-based Photogrammetry; ERT; MSM

# Debris flow modelling of Uchar Stream through Geophysical and Remote sensing technique

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The Uchar Nullah, or Uchar stream, represents a tributary of the Indus River, akin to numerous other watercourses that contribute to the Indus River's flow, characterized by a considerable topographic gradient. The region spanning from Besham to the northernmost reaches of the country has been structurally influenced by historical tectonic activities, resulting in a surface configuration such that each stream exhibits a higher risk of transporting debris to the River Indus. Currently, two major dams are under construction in the Dasu hydel power project (HPP) and Diamer Basha dam areas. The existence of these substantial reservoirs necessitates a comprehensive assessment of debris modeling for each stream to accurately quantify its capacity for its debris transport to the River Indus. The Uchar Nullah conjoins the Indus River at an elevation of approximately 800 meters above mean sea level (MAMSL), originating at an altitude of around 4500 meters MAMSL, covering a total length of 17 km. The Uchar stream is characterized by a steep gradient towards the Indus, and its surrounding mountain ranges exhibit pronounced slopes towards the stream's center. Loose debris accumulations are evident along the banks and various depositional centers at different elevations. The primary dam of the Dasu Hydro Power Project (HPP), which is currently under construction, is situated 1.5 kilometers downstream from the confluence point of Uchar and the Indus River. In July 2022, severe monsoonal rains triggered flash floods that transported one million cubic meters of debris into the Indus River. This event not only destroyed the bridge at Karakorum Highway (KKH) but also completely demolished the contractor camp of the HPP, leading to a temporary cessation of construction activities due to the adverse effects of the transported debris. A collaborative investigation, conducted by a Joint Investigation Team from WAPDA and Bacha Khan University, aimed to model the debris transport characteristics of the Uchar Nullah, considering both its geophysical and geological aspects. This study endeavors to integrate all assessments conducted on the Uchar Nullah, including remote-sensing evaluations, to model the volume and transport characteristics of its debris. The topography of the entire Uchar catchment is modeled through a Digital Elevation Model (DEM), and the accretion and erosion rates of the Nullah are evaluated through temporal assessments of debris area. Recommendations and suggestions are provided to mitigate the debris transport characteristics and enhance the resilience of the Hydro Power Project (HPP).

**Keywords**: Debris flow; Uchar Nullah; DEM; WAPDA; catchment; Indus River

# Deep Learning Applications in Exploration Geophysics: A Review

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In exploration geophysics, deep learning (DL) has become a game-changing technique, providing innovative solutions to challenging problems in resource estimation, subsurface imaging, and the interpretation of geophysical data. Recent developments in DL methods for processing, inverting, and interpreting seismic data are highlighted in this study, along with how they are integrated into geophysical processes. The use of generative adversarial networks (GANs) for the creation of synthetic data, recurrent neural networks (RNNs) for temporal analysis in geophysical time series, and convolutional neural networks (CNNs) for the extraction of seismic features are important advancements. DL has greatly improved resolution, accuracy, and computational efficiency in geophysical activities by utilizing big datasets and high-performance computers. Nevertheless, issues including interpretability, the lack of labeled data, and the requirement for domain-specific modifications still exist. By increasing exploration efficiency and lowering environmental impact, DL can help ensure the sustainable use of natural resources and open the door for creative geophysical solutions, as this paper highlights.

**Keywords**: Deep Learning; Geophysics; CNN; GAN; Exploration Geophysics

# SPT-Based Bearing Capacity Analysis of Shallow Foundations Using Terzaghi and Meyerhof Methods

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In geotechnical engineering, accurate assessment of bearing capacity is crucial for ensuring the structural stability and safety of shallow foundations. The Standard Penetration Test (SPT) is widely used to determine soil parameters for this purpose. This study compares bearing capacity calculated using Terzaghi's and Meyerhof's methods, based on SPT-N values collected from 58 boreholes in the Top City area of Wah Cantt, Pakistan. The SPT data was collected at every 5ft intervals to a depth of 25ft from each borehole. The upper soil strata primarily consisted of very stiff to hard Silty Clay (CL-ML group) with traces of grass roots and concretions. The ultimate bearing capacity was determined using both Terzaghi's bearing capacity equation and Meyerhof's modification, considering various factors such as depth, width, cohesion, and unit weight of soil. The results indicate that Meyerhof's method yielded higher bearing capacity values than Terzaghi's method. Meyerhof's calculations ranged from 5.0 to 6.8 tsf, while Terzaghi's method produced values between 4.0 and 5.5 tsf. The 20-25% higher values obtained through Meyerhof's method can be attributed to its incorporation of embedment depth, shape factors, and adjustments for various footing types (isolated and strip footings). The findings demonstrate that both methods are viable for estimating ultimate bearing capacity from SPT-N values. However, since no groundwater table was encountered during drilling, Meyerhof's method provided more realistic bearing capacity values, particularly for dry soil conditions and heterogeneous subsurface profiles like silty clay. This study emphasizes the importance of selecting appropriate methodologies based on site-specific conditions to prevent over- or under-estimation of bearing capacity. Further validation through in-situ testing and numerical modeling is recommended to enhance the accuracy of these estimations and ensure foundation design safety.

**Keywords**: Geotechnical; Shallow Foundations; Bearing Capacity; SPT-N Values; Terzaghi Method; Meyerhof Method.

# Assessing multi-hazard vulnerability and risk applying a random forest algorithm and statistical approaches, a case study of Hunza

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The Northern Pakistan is a disaster-prone area that has experienced frequent and devastating natural hazards, including landslides, debris flows, floods, and glacial lake outburst floods (GLOFs). The region's unique geology, rugged terrain, and changing climate make it highly susceptible to these hazards, which have resulted in significant loss of life, and infrastructure. Despite the high risk, there is a lack of comprehensive risk assessments that integrate multiple hazards, vulnerability, exposure, and capacity to inform disaster risk reduction and management efforts. This study addresses this gap by presenting a comprehensive risk assessment of District Hunza, which integrates multi-hazard susceptibility, multi-dimensional vulnerability, integrated exposure, and capacity index maps. A machine learning model was used to develop the multi-hazard susceptibility map by integrating landslide, debris flow, seismic, GLOF, and flash flood susceptibility maps. Meanwhile, the weights for the multi-dimensional vulnerability, integrated exposure, and capacity index maps were calculated using statistical approaches, which considered various socio-economic, infrastructural, and environmental indicators. The statistical approaches allowed for the objective-subjective assignment of weights to each indicator, ensuring that the resulting maps accurately reflected the complex interactions between these components. The final risk map categorizes the district into eight zones of varying risk levels, covering a total area of 22.19km², falling under the Extremely High-Risk zone. The findings of this study provide a critical framework for disaster risk reduction and management, enabling policymakers and stakeholders to prioritize resource allocation and mitigation efforts in the most vulnerable areas, and ultimately reducing the risk of disasters and promoting sustainable development in the region.

**Keywords**: Disaster Risk reduction; Climatic hazards; Multi-hazard susceptibility; Machine Learning; RF

# Comparative Study on Flash Flood Vulnerability Assessment in the Historical Makkah Region, Saudi Arabia

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Flash flooding poses a significant threat in arid and semiarid regions, leading to property damage and population displacement. This research employs the analytic hierarchy process (AHP) and correlation methods to assess flood vulnerability in the Makkah Region, Saudi Arabia, by integrating digital elevation models (DEMs) and Landsat 8 Operational Land Imager (OLI) data within a geographic information system (GIS). Thematic layers, encompassing topographic, geomorphic, climatic, and hydrological factors, are analysed through AHP, yielding a Flash Flood Hazard Zone (FFHZ) map. This study identified five risk zones, with higher vulnerability in the southern region and moderate to low risk levels in the northern and central regions. This research integrates diverse data sources and assigns weights via AHP to generate hazard maps based on attributes such as rainfall, distance to rivers, elevation, and slope. Comparative analysis with correlation methods enhances flood hazard detection and management strategies. The findings offer valuable insights for urban planning, disaster management, and informed decision-making, serving as a resource for policymakers, research institutions, and farmers to enhance risk assessment accuracy and develop resilient strategies for agriculture and livelihoods.

**Keywords**: Flash flooding; Hazard mapping; AHP; GIS; DEMs; Landsat 8 OLI; Makkah

# Defining a 3D Seismic Source Characterization model for PSHA studies: A case study of Himalayan Thrust system, Pakistan

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Planar fault models have been developing in Middle East and Pakistan region under the scope of Earthquake Model for Middle East (EMME) project. These models require information on the geometric, kinematic and seismicity parameters of the major seismogenic faults. The active compressional nature, complex fault patterns, dipping geometeries, and insufficient data in NW Pakistan pose a serious problem in constraining various parameters that are essential for such models. This study aims at characterizing the seismic source parameters of Himalayan Thrust system of Pakistan for future utilization in fault based probabilistic seismic hazard assessment (PSHA) studies. The approach is primarily based on three datasets: geologic, geodetic and seismic data. Surface traces of active faults are compiled from the published literature and segmentation models are defined using first order geological complexities. Seismogenic depth and geometry i.e., dip angles are constrained from instrumental seismicity and focal mechanism solution catalogues. One of the major concern in this area is to analyze the methodological procedures for assigning and distributing the activity rates. Activity rates are assigned to the fault systems by two different approaches using geodetic and seismic data. Later on, contemporary Empirical relationships are utilized to assign the maximum magnitude (Mmax) values to active sources. Moreover, moment balancing technique is applied to select appropriate earthquake frequency models for the region. By integrating all the data, we define a 3D fault model for the major faults in the thrust system that can be directly adopted for regional scale PSHA studies.

**Keywords**: 3D fault models; fault-based PSHA; Himalayan thrust system; NW Pakistan

# Comprehensive assessment of debris in the Karakoram Mountain ranges of northern Pakistan using geospatial tools and field data

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Debris flows are among mountainous regions' most destructive natural hazards, causing frequent and significant physical, environmental, and economic damage. The spatial and temporal dynamics and magnitude of debris flow are influenced by climate, geology, topography, hydrology, interconnected sediment sources, and human activity. Northern Pakistan is particularly susceptible to debris flows due to its active tectonic, steep terrain, fragile landscape, and climate. The frequency of these events has increased in recent years due to climate change, posing a major challenge to the sustainable development of the vulnerable mountain communities. Therefore, it is crucial to identify potential debris flow hazard zones and assess their impacts on downstream infrastructure and communities to support evidence-based risk mitigation and adaptation strategies. This research presents a systematic approach for debris flow hazard assessment at the catchment scale, integrating the evaluation of downstream infrastructure, environmental, and social vulnerabilities in District Ghizer. The methodology employs open-source remote sensing datasets, extensive field observations, and statistical modeling techniques to enhance hazard characterization and risk assessment. Digital Elevation Model (DEM) and satellite images-derived morphometric parameters, hydrological settings, and land cover were analyzed using a multi-criteria decision support system to evaluate the susceptibility of catchments to debris flow. The hazard assessment results concluded the prone catchments to debris flows. The study evaluates the potential impacts of debris flow on the elements at risk situated on the respective alluvial fans, including buildings, roads, population, forest, and agricultural land. In this study, the vulnerability of elements exposed to debris flows has been evaluated by analyzing their type, quantity, spatial distribution, economic significance, and structural fragility. The delineated catchments and evaluated risks in the study are vital for local communities and organizations in formulating mitigation strategies for adapting to evolving risk to debris flows driven by climate change.

**Keywords**: Debris flow; Catchment; Hazard; vulnerability; risk; north Pakistan; Remote sensing

# Site-Specific Seismic Ground Response Analysis for Sustainable Construction in Islamabad

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Understanding how soil behaves during earthquakes is important for designing safe and sustainable buildings, especially in earthquake-prone areas like Islamabad. In this study, we investigated the dynamic properties of soils in Islamabad by collecting undisturbed samples from 30 locations and testing them in the laboratory using cyclic triaxial and resonant column tests. From these tests, we developed site-specific shear modulus and damping ratio curves, which helped improve the accuracy of seismic ground response analysis (GRA). The study evaluated the ground response to different earthquake motions and analyzed the results in terms of surface acceleration time history, shear stress to vertical effective stress ratio over time, acceleration response spectrum, Fourier amplitude ratio as a function of frequency, and other key parameters. These findings provide better estimates of ground motion and will be useful for engineers and planners in designing earthquake-resistant infrastructure. The results are especially important for local authorities and disaster management organizations working to reduce earthquake damage in Pakistan.

**Keywords**: Dynamic soil properties; Shear modulus; Damping ratio; Earthquake-resistant design; Nonlinear site response

# Landslide risk management in Khyber Pakhtunkhwa, a policy brief

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Khyber Pakhtunkhwa (KP), Pakistan, is highly susceptible to landslides due to its rugged terrain, seismic activity, and climate change-induced shifts in rainfall patterns. Landslides pose significant threats to human life, infrastructure, and the natural environment. The growing frequency of landslides in KP is driven by poorly planned infrastructure development, deforestation, and unsustainable land-use practices. These activities exacerbate slope instability, especially in mountainous regions. Climate change has further intensified the risk by altering precipitation patterns and accelerating glacier melting. The proposed multi-pronged approach for sustainable landslide risk management in KP, advocates for a comprehensive landslide hazard zonation and risk assessment framework, integrating spatial analysis, real-time monitoring, and community-based disaster risk reduction. Developing a tailored policy for KP requires integrating scientific tools such as GIS-based landslide susceptibility mapping and rainfall threshold models for early warning systems. Effective land-use planning is essential, focusing on slope stabilization, reforestation, and regulation of construction activities in hazard-prone areas. Sustainable practices like nature-based solutions, including watershed management and afforestation, can significantly reduce soil erosion and enhance slope stability. The policy guidelines highlight the importance of capacity building, stakeholder collaboration, and community engagement in disaster preparedness. By adopting innovative solutions and strengthening institutional frameworks, KP can mitigate landslide risks while promoting the sustainable use of natural resources, thereby protecting vulnerable communities and preserving the region's environmental integrity.

**Keywords**: Landslide; risk management; KP; policy guidelines; sustainable

# CubeSats: Revolutionizing Space Exploration and Education

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This talk will provide an in-depth exploration of CubeSats, the innovative miniature satellites that are reshaping the landscape of space exploration and education. The core systems and components of CubeSats will be discussed, including their design, development, and deployment processes. Participants will gain a comprehensive understanding of the technical challenges and solutions associated with CubeSat missions. Additionally, the seminar will highlight the pivotal role of CubeSats in STEM education, demonstrating how they offer students practical, hands-on experience with cutting-edge space technology."

**Keywords**: CubeSats; STEM; satellites; landscape; education; exploration

# A success story of the application of an indigenous, low-cost, and sustainable floating treatment wetlands technology in Pakistan

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In Pakistan, due to very high capital and operational costs of conventional technologies, > 99% wastewater is discharged in water bodies untreated. This wastewater contaminates the water, soil and food. The use this contaminated water and food causes a significant number of diseases and deaths. To address this issue of high cost of wastewater treatment, a very low-cost floating treatment wetlands (FTWs) technology has been developed using locally designed and developed floating mat and available indigenous plants and microbes. FTWs is a low cost, sustainable, and environment friendly technology for wastewater treatment and reuse. Moreover, it is an innovative roots filter technology in Pakistan for the cost-effective treatment of wastewater without relying on energy or chemicals. It requires ~100 times lower capital investment than conventional technologies, without any operational cost. Until now 500,000 sq.ft FTWs have been applied at more than 100 sites in Pakistan and it improves the quality of about 500 billion cubic meter wastewater annually, and sequesters 300 tons of carbon per year. It removes (up to 90%) both organic and inorganic pollutants from the wastewater, and treated water is being safely discharge in the environment or reuse in agriculture and horticulture.

**Keywords**: wetland; microbes; Pakistan; treated

# Sugar Industry Wastewater Treatment with The Combined Wetlands-Anaerobic-Filtration Pilot-scale Bioreactor

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Sugar industry wastewater dispose-off untreated discharge into the environment and causes water contamination. Conventional wastewater treatment methods are often expensive and resource-intensive, making them impractical in developing countries like Pakistan. Sustainable and low-cost wastewater treatment technologies are required to improve water quality while ensuring affordability and environmental sustainability. Different nature-based technologies, such as floating treatment wetlands (FTWs), constructed wetlands (CWs), anaerobic digester (AD) and sand filtration (SF) are being used to treat sewage and industrial wastewater. The purpose of this study was to combine FTWs, CWs, AD, and SF to develop a bioreactor for the effective treatment of wastewater from sugar industry. The tailor-made bioreactor efficiently removed chemical oxygen demand (COD), biochemical oxygen demand (BOD), total dissolved solids (TDS), nitrogen, phosphorus, chlorides, sulfates, lead, and cadmium to 84.7%, 84.1%, 71.6%, 79.5%, 74.6%, 99.9%, 41.5%, 53.3%, and 44.1%, respectively, from wastewater with a hydraulic retention time of 7 days. There was a complete removal of bacterial pathogens, E. coli and fecal coliforms, from wastewater. The kinetics model and correlation coefficient ($R^2$) data demonstrated that the removal process is more influenced by chemisorption and microbial activities and contributed to the overall carbon neutrality objective by the sequestering atmospheric carbon into the plant biomass efficiently. It is a nature-based, low cost and sustainable approach to treat the sugar industry wastewater for its safe discharge in the environment.

**Keywords**: Removal; contamination; BOD; TDS; model

# Application of Nature-Based, Low-Cost and Sustainable Floating Treatment Wetland Technology for the Remediation of Detergent Contaminated Wastewater

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Washing liquid is the most toxic contaminants in the effluents released from household and industry to the river. The effluents add linear alkylbenzene sulfonate (LAS), an anionic surfactant that has harmful effects on li terrestrial and marine or aquatic lives. Numerous, time consuming and costly techniques are screened for the removal of detergents, may not be applicated in developing countries Pakistan. Pakistan. Floating treatment wetlands (FTWs) is nature-based technology and becoming more popular due to its low capital and operation cost, effective, sustainable, and environmentally -friendly nature. FTWs mesocosms were vegetated with Brachiaria mutica (Para grass), and augmented with LAS-degrading bacteria. It was observed in this study that the nearly all LAS were degraded from the washing liquid contaminated water. FTWs, minimized the COD and BOD to nearly 90%. This is concluded from this study that FTWs with bacteria had a significant effect on the degradation of LAS, COD and BOD with TOC of the water with washing liquid.

**Keywords**: Floating wet lands; bacterial; contaminated water; COD; BOD

# Application of Nature-Based Technologies in a Textile Industry to Treat and Reuse the Wastewater

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Textile industry wastewater is highly polluted, and its untreated discharge into the environment causes water contamination. Conventional wastewater treatment methods are often expensive and resource-intensive, making them impractical for widespread implementation. To address this, sustainable and low-cost wastewater treatment technologies offer a viable solution to improve water quality while ensuring affordability and environmental sustainability. Different nature-based technologies, such as anaerobic digestor (AD), floating treatment wetlands (FTWs), constructed wetlands (CWs) and sand filtration (SF) are being used to treat sewage and industrial wastewater. The purpose of this study was to combine AD, FTWs, CWs, and SF to develop a bioreactor in a textile industry for the treatment of wastewater. Treated wastewater meet National wastewater discharge standards, and is being used in horticulture and/safe discharge is the environment. This is the first example in the Pakistan to apply Nature-Based Technologies in an industry to treat and reuse the wastewater. The technology removing (more than 90%) both organic and inorganic pollutants from the wastewater. Now the treated water is also non-toxic. The water is being reuse in horticulture, and /or safely discharge in the environment.

**Keywords**: Pakistan; safely; environment; organic; inorganic; water

# Geotechnical comparison between Limestone and Dolostone from the Upper Indus Basin, Pakistan

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The geotechnical comparison between limestone and dolostone samples collected from the geological formations in the Upper Indus Basin, Pakistan is presented. The limestones from Sakesar and Samana Suk Formation, while dolostones from the Jutana and Kingriali Formation were examined. The physical and mechanical properties of the samples were evaluated using porosity, water absorption, specific gravity, ultrasonic pulse velocity, Schmidt hammer test, unconfined compressive strength (UCS), and point load test.

Petrographic analysis shows that the Sakesar Limestone sample contains skeletal grains, including larger benthic foraminifera such as Assilina, Alveolina, Nummulites, and Lockhartia, embedded in the micrite matrix and classified as a bioclastic wackestone. In contrast, the limestone from the Samana Suk Formation comprises non-skeletal grains, including ooids in sparite matrix and is classified as an ooidal grainstone. The dolostone from the Jutana Formation consists of fine- to medium-grained rhombic and angular dolomite crystals, whereas the dolostone from the Kingriali Formation is composed of dolomite with significant secondary porosity caused by diagenetic alterations.

The findings reveal that the dolostone from the Jutana Formation exhibits the highest strength among all samples, attributed to its primary dolomitic nature, angular crystal morphology, and minimal porosity. Conversely, the dolostone from the Kingriali Formation demonstrates the lowest strength due to significant secondary porosity. The limestone samples exhibit intermediate strength, with the bioclastic wackestone of the Sakesar Limestone outperforming the ooidal grainstone of the Samana Suk Formation. This difference is attributed to the micrite matrix in the bioclastic wackestone, which provides higher strength due to its fine-grained and cohesive nature, whereas the sparite matrix in the ooidal grainstone, being coarse-grained with loose intergranular contacts, reduces its overall strength.

These findings emphasize the role of mineralogical composition, grain size, and porosity in determining the mechanical behavior of carbonate rocks, with important implications for geotechnical applications in the construction industry.

**Keywords**: Geotechnical properties; Limestone; Dolostone; Upper Indus Basin; Petrographic analysis