Exploring Bacterial Pigments from the Arctic: Potential for Biotechnological and Environmental Applications

Sediment samples used in the present study were collected from the Arctic region, an environment characterized by persistently low temperatures, high levels of ultraviolet radiation, limited nutrient availability, and extreme seasonal variability. These harsh conditions support unique microbial communities with specialized adaptive mechanisms. The samples comprised environmental Arctic sediments, bacterial isolates derived from these sediments, and pigment extracts obtained from cultured bacterial strains.

The biological material investigated in this study consisted of psychrophilic and psychrotolerant bacterial isolates capable of pigment production, adapted to survive under Arctic stress conditions. Four pigment-producing bacterial isolates were selected for detailed analysis: SN-95 producing a green pigment (Gram-positive cocci), SN-104 producing an orange pigment (Gram-positive cocci), AN-57 producing a creamy white pigment (Gram-positive cocci), and FN-38 producing a red pigment (Gram-negative rod).

The objectives of data collection included the extraction of pigments from Arctic bacterial isolates, preliminary physicochemical characterization of the pigments, evaluation of in-vitro bioactivities such as antioxidant, cytotoxic, and UV-protective properties, molecular identification of pigment-producing bacteria using 16S rRNA analysis, and identification of bioactive pigment constituents using advanced analytical techniques. Pigments were extracted using methanol from seven-day-old bacterial cultures, followed by drying and reconstitution of the extracts in methanol for further analysis.

Characterization and bioactivity assessment involved UV–Visible wavelength scanning, qualitative UV protection assays using the cling film method, antioxidant activity evaluation using the DPPH assay with IC_{50} determination, and cytotoxicity assessment through the MTT assay using the NCI-H460 lung cancer cell line, with comparison to the standard drug doxorubicin. Preliminary bacterial identification was carried out using Gram staining, and molecular analysis included genomic DNA isolation and 16S rRNA PCR amplification for species-level identification.

The key observations indicated measurable antioxidant activity for selected pigment extracts, with IC_{50} values of 564.02 µg/mL for SN-95 and 565.09 µg/mL for SN-104. All pigment extracts exhibited qualitative UV-blocking potential. Cytotoxicity assessments were successfully conducted against the NCI-H460 lung cancer cell line. Molecular analysis confirmed successful 16S rRNA PCR amplification, while sequencing and taxonomic confirmation are currently in progress.

The data generated from this study include spectral data from UV–Visible absorbance profiles, bioassay data such as IC_{50} values and cell viability percentages, microscopic observations from Gram staining, molecular biology data including PCR profiles, and image data documenting pigment characteristics and UV protection assays. The findings highlight the potential applications of Arctic bacterial pigments as photoprotective agents in cosmetic formulations, antioxidant and anticancer lead compounds, and natural colorants for pharmaceutical and nutraceutical use. Additionally, these pigments represent promising candidates for nanoemulsion-based stabilization and commercialization.

Overall, the study enhances understanding of Arctic microbial functional diversity and supports bioprospecting and bioresource utilization from polar regions. The outcomes contribute to sustainable Arctic biotechnology research and align closely with Indian Arctic research priorities under the National Centre for Polar and Ocean Research (NCPOR). Pigment extraction and preliminary bioactivity evaluations have been completed, molecular identification is ongoing, and advanced structural characterization and stabilization studies are planned.