Detection of toxigenic cyanobacteria in freshwater bodies of North East India

North East (NE) India, represented by seven sister states of Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland and Tripura, is a biodiversity hotspot and is ecologically represented by the Eastern Himalayan biome. This region is rich in diversity of a number of endemic flora and fauna. Noted level of biodiversity is present in the rivers and lakes of this region, and the valuable ecosystem provides livelihoods to millions of people. These water bodies harbour many species of microalgae, including cyanobacteria, some of which are beneficial while some others are harmful as they are known to produce cyanotoxins, which are injurious to humans and animals. Though this biodiversity-rich region comes under Indo-Burma hotspots (except Assam), its algal diversity record is minimal and there are no substantial data available on the assessment of toxicity of the cyanobacterial population of the region.

Harmful algal bloom (HAB) is a global problem as it produces and releases deadly toxins into the aquatic environment[1]. Toxins like microcystin and nodularin are carcinogenic[2,3], whereas anatoxin is neurotoxic[4] and cause a serious threat to human health. These blooms are mainly caused due to anthropogenic activities such as extensive use of pesticides, agricultural run-off and detergent from water-treatment plants[5]. Climate change has accelerated the incidence of HABs round the globe[5].

An exploratory research conducted by the Defence Research Laboratory (DRDO), Tezpur, revealed the presence of few toxic cyanobacteria in some water bodies of NE India. Molecular tools like PCR and qPCR assay were used for the detection of toxigenic cyanobacterial species. The toxin biosynthesis gene complex which encodes for the toxins was targeted for molecular detection. Microsystin synthetase gene complex (mcy), nodularin synthesis gene complex (nda) and anatoxin-a synthetase gene cluster (ana) respectively of *Microcystis*, *Nodularia* and *Anabaena* were targeted for PCR amplification, whereas HPLC was used for detection of the respective toxins. Three toxigenic species, viz. *Microcystis aeruginosa* (microcystin producer, 18 isolates), *Nodularia* (nodularin producer, one isolate) and *Anabaena* (anatoxin producer, five isolates) have been detected by post-PCR sequence analysis. Among 44 water bodies evaluated, 24 were contaminated by these cyanobacteria. It is notable to infer that 90% of these toxigenic cyanobacteria were detected in the water bodies where anthropogenic activities were high. Modern molecular and analytical methods offer a new dimension in the detection and identification of toxin producers as well as their respective toxins. However, accurate information on the full spectrum of effects and the amount of toxin leading to their toxicity is generally unavailable for many toxins. Therefore, the present study was designed to generate a database of toxigenic freshwater cyanobacteria in NE India and thereby to develop assays for detection of toxigenic cyanobacteria. Such studies will help medical researchers in the accurate detection of causal agents other than medically established infectious agents such as *Cholera* for any suspicious casualty caused by consumption of toxic water from natural sources. They will also help in monitoring the water quality in aquaculture as well as in the detection of cyanotoxins during episodes of unnatural deaths of fishes and other aquatic animals.

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JADAB RAJKONWAR
AJITABH BORA*
SANJAI K. DWIVEDI

Defence Research Laboratory,
Defence Research and Development Organization,
Post Bag No. 2,
Tezpur 784 001, India
**e-mail: ajitabh@drl.drdo.in*

Basic and applied research in selected G20 countries – a depiction using Stokes' quadrants

Research associated with science, technology and innovation has two main goals – increase the sum of human knowledge and diminish the sum of human misery. It can be pursued in various ways falling between two extremes – seeking a fundamental understanding (pure basic research), or solving immediate or pressing problems (pure applied research). A two-dimensional representation with applied research on the horizontal axis and basic research on the vertical axis leads to four quadrants[1]. The fourth quadrant, known as Pasteur's Quadrant[1], is an ideal situation where the search for fundamental understanding also has immediate utility for society.

G20 is a group of 19 leading economies, spread regionally around the globe, with the European Union (EU) as an additional member, that represents more than 80% of the GDP and two-thirds of the global population, employing 87% of the world's researchers and publishing 70% of global research papers. Recently, Adams *et al.*[2] examined the research performance of the G20 countries and included a scorecard and executive summary for each of the 19 member nations: Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South