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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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

Table 1. Papers/AERD researchers and patents/BERD researchers for 12 G20 countries for which data are available in the G20 report[2]

Country	AERD researchers	Papers	Papers/AERD researchers	BERD researchers	Patents	Patents/BERD researchers
Argentina	64,300	98,448	1.53	19,647	766	0.04
China	464,002	2,741,465	5.91	1,605,648	1,306,019	0.81
France	134,671	818,118	6.07	249,172	70,939	0.28
Germany	179,871	1,172,143	6.52	406,159	176,235	0.43
Italy	71,592	713,369	9.96	114,324	31,346	0.27
Japan	197,145	899,903	4.56	733,575	460,660	0.63
Mexico	29,518	143,215	4.85	12,704	2,522	0.20
Russia	143,402	366,639	2.56	216,391	27,782	0.13
South Africa	29,516	130,175	4.41	22,361	2,178	0.10
South Korea	99,742	582,754	5.84	383,054	226,568	0.59
Turkey	90,330	300,883	3.33	120,439	11,144	0.09
United Kingdom	165,835	1,274,025	7.68	345,145	53,746	0.16

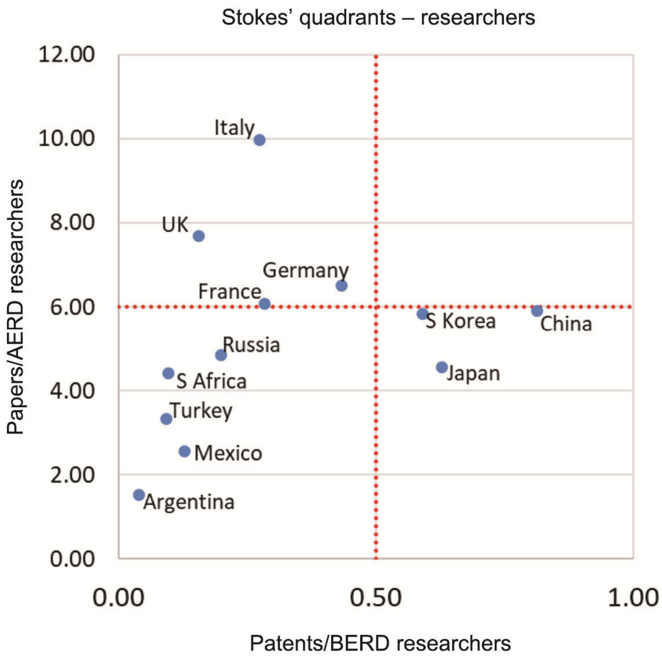

Figure 1. Stokes' quadrant depiction of papers/AERD researchers and patents/BERD researchers for 12 G20 countries for which data are available in the G20 report[2].

Korea, Turkey, United Kingdom and USA.

Wherever possible, the scorecard gives the number of researchers in that population, the number of papers published in a ten-year window (2009–2018), the number of patent applications in 2017 in the WIPO database, the gross expenditure on R&D (GERD), and the business expenditure on R&D (BERD). From this it is possible to speculate that the difference between GERD and BERD is the spending on basic research (academic expenditure on R&D; AERD). We shall further speculate that the cost of a full-time equivalent researcher (FTER) is the same in the AERD and BERD sectors, and so we shall apportion the number of researchers to the academic and business sector in the same ratio. In the same way, we shall link AERD spending to the publication of papers and BERD spending to patent applications. This allows a deconstruction of the scorecard so that a representation using Stokes' quadrants can be made using a researcher's criterion and a spending criterion.

Table 1 shows the indicators, viz. papers/AERD researchers and patents/BERD researchers for 12 G20 countries for which data are available in the G20 report[2]. Figure 1 is the corresponding Stokes' quadrant depiction of papers/AERD researchers and patents/BERD researchers for these countries. Table 2 shows papers/AERD spending and patents/BERD spending for 15 G20 countries for which data are available in the same report. Figure 2 depicts the Stokes' quadrant position of these countries using the same indicators. We can see from the figure that China, Japan and South Korea are making a determined bid to stay in the pure applied research quadrant and perhaps move up

Table 2. Papers/AERD spending and patents/BERD spending for 15 G20 countries for which data are available in the G20 report[2]

Country	AERD (PPP US$ billions)	Papers	Papers/ AERD	BERD (PPP US$ billions)	Patents	Patents/ BERD
Argentina	3.6	98,448	27,347	1.1	766	684.7
Australia	9.9	624,023	63,033	11.3	11,656	1031.4
Canada	13.1	736,856	56,249	14.1	23,914	1700.9
China	111.2	2,741,465	24,653	384.8	1,306,019	3393.8
France	22.7	818,118	36,040	42	70,939	1688.8
Germany	40.3	1,172,143	29,085	91	176,235	1936.2
Italy	12.9	713,369	55,300	20.6	31,346	1521.3
Japan	36.2	899,903	24,859	134.7	460,660	3420.9
Mexico	7.9	143,215	18,128	3.4	2,522	733
Russia	16.7	366,639	21,954	25.2	27,782	1103.3
South Africa	3.3	130,175	39,447	2.5	2,178	876.4
South Korea	18.8	582,754	30,998	72.2	226,568	3136.2
Turkey	9.3	300,883	32,353	12.4	11,144	901.7
United Kingdom	16	1,274,025	79,627	33.3	53,746	1611.8
United States of America	146.1	4,427,597	30,305	397.1	524,835	1321.8

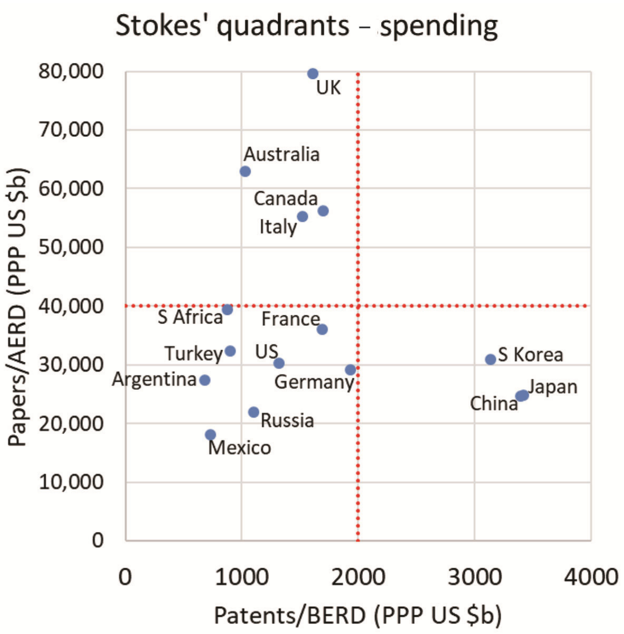

Figure 2. Stokes' quadrant depiction of papers/AERD spending and patents/BERD spending for 15 G20 countries for which data are available in the G20 report[2].

to Pasteur's quadrant. The United Kingdom, Australia, Italy and Canada and to a lesser extent Germany and France are demonstrably more oriented to the pure basic research quadrant. Argentina, Russia, Mexico, Turkey and South Africa have the United States as an unexpected companion in the first quadrant – the efficiencies are low in ultilizing both spending and manpower. Pastuer's quadrant is a seemingly elusive goal for all 19 countries in the G20.

It is to be noted that India, Indonesia, Brazil and Saudi Arabia are absent in these two tables as crucial data are missing in the G20 report[2].

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2. Adams, J., Rogers, G. and Szomszor, M., The annual G20 scorecard – research performance 2019, Institute for Scientific Information 2019; https://clarivate.com/g/the-annual-g20-scorecard-research-performance-2019/

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