VARIOUS carbon dioxide mitigation procedures towards abatement of global warming are being currently studied, researched and globally carried out. These include chemical reaction based approaches and carbon dioxide removal techniques like storage of carbon dioxide under the ocean bed, underground storage, etc. But these methods have involved major challenges, like high space requirements and chances of leakage over time.

Another carbon dioxide mitigating method is through biological means where carbon dioxide is biologically converted to organic matter. This is promising because biological carbon dioxide fixation leads to generation of biomass energy through photosynthesis process.

Microalgae are a group of fast-growing microorganisms that have the ability to fix carbon dioxide from different sources such as atmosphere, industrial exhaust gases like flue gas and flaring gas.

Microalgae are a group of fast-growing microorganisms that have the ability to fix carbon dioxide with an efficiency of 10 to 50 times more than that of terrestrial plants. Microalgae can fix carbon dioxide from different sources – from atmosphere, industrial exhaust gases like flue gas, flaring gas and fix carbon dioxide in the form of soluble carbonates (mainly NaHCO₃ and Na₂CO₃).
Algal production, close to coal power stations that emit large amounts of carbon dioxide to the atmosphere or close to sewage treatment plants, might be able to solve the major problems related to climate change as well as air and soil pollution in the North East (NE) region. Microalgae cultivation can lower the pollution impact by consuming a major fraction of industrial exhaust gases. The algal mobile van concept would be a solution for carbon dioxide mitigation in NE region in the future, where vehicles carrying 5000-10,000 liter of algal cultures could be sent to various flue gas emitting sites, thereby cells can be fed with flue gases for their growth and biomass generation.

Another way to mitigate rising carbon dioxide is to set up algal ponds near industrial sites where they can be directly fed with flue gases. Algae can also be used to recycle automobile exhaust gases by consuming a major fraction of the carbon dioxide gas. Future research needs to be oriented towards connecting algal culture tanks to automobile exhaust systems, indicating a vehicle self-mitigation system because the biomass obtained from algae fed with exhaust gases can be transformed again into biofuel.

In the North East, particularly in Assam, the number of vehicles is increasing at an exponential rate creating enormous pollution. Therefore, the algal self-mitigation concept could be a solution for this anomaly in the future and could also be replicated in other parts of the country as well.

If our public transport system is integrated with biomass production facility, it could solve many problems regarding high emission levels and alternative fuel generation problem. The Indian Railways holds great promise in algal biomass generation. The algal reactor or culture tanks can be mounted on the rooftop of train coaches and they can be fed with the same engine exhaust gases. In this way large amount of biomass could be generated and simultaneously processed for biodiesel production.

To check the sustainability of the process, a few train coaches loaded with algae culture can be tested, while harvesting and collection of biomass facility may be installed in some specific stations, from which biomass could again be sent to the nearest research institute or organization for further processing. The Indian Railways being one of the single largest bulk consumer of diesel in the country, has decided to promote the use of biodiesel for powering its huge network of over 4000 diesel trains in its endeavour to adopt green technologies.

A number of companies and researchers have already indicated the potential of algae as a source for renewable aviation fuels, also known as biojet fuel. Biojet fuels have the advantage of offering lower-emission option for fueling commercial and military aircraft. A number of companies are still working on developing biojet fuel from algae, such as Sapphire Energy, Heliae, Phycal, Cellana, Solazyme, General Atomics, etc.

In January 2009, Continental Airlines first tested the flight of a commercial jet in the US with algae-based fuel, marking the beginning of a new era in sustainable jet fuels. In the year 2010, the EADS biofuel project in Berlin showcased the world’s first flight of an aircraft powered by pure biofuel made from algae. A Diamond Aircraft DA42 powered by two Austro Engine AE300 engines took part in this demonstration and test flights at Diamond’s home base in Wiener Neustadt, Austria. This opens up the possibility of carbon-neutral flights.

In June 2011, the US Navy successfully demonstrated a 50-50 blend of traditional and algae-based jet fuel, produced by Solazyme, in a MH-60S Seahawk helicopter. This event marked the first time in history that a military aircraft had flown on algae-based jet fuel. In July 2011, ASTM International, the world’s standards body, announced the approval of airlines to fly passenger
jets using B50 blends indicating the potentialities of renewable aviation biofuels.

In November, 2011, United Flight 1403 flew from Houston to Chicago, on a 40 percent blend of Solazyme’s algal jet fuel, becoming the first U.S. commercial flight powered in part by algae-based biofuel. It was fueled with 60% traditional petroleum-based jet fuel and 40% aviation biofuel made from algal oil (Algae Biomass Organization, U.S. Department of Energy and Los Angeles Times).

Many countries have already started installing algae reactors on building rooftops, building walls, etc. A 15-unit apartment building in Hamburg Germany, called Bio Intelligent Quotient (BIQ) House, has a total of 129 algae culturing tanks, which are affixed to the building via an automated external scaffolding structure that turns the tanks towards the sun all the time.

S.H. Al-Iwayzy and T. Yusaf in the year 2013 reported the use of microalgae as an alternative fuel for tractor diesel engine. They used B20 blend (80% petroleum oil mixed with 20% biodiesel) to examine the performance and emission of a 25.8 kW agriculture tractor engine and found satisfactory results.

Similarly, S.S. Kulkarni of the Department of Biological and Agricultural Engineering, University of Arkansas and his team in the year 2011 reported that B20 biodiesel should be used and recommended as the optimal biodiesel blend for use in irrigation power units. They used a John Deere (Moline, I.II.) PowerTech 4.5 L model, 4045HF280 engine for fuel testing. It was a direct injection, four-cylinder, turbocharged, and after-cooled engine is rated at 67-kW 2400 rpm. These results indicate the promising future use of biodiesel in agriculture and farming engines.

Japanese companies are too moving forward to develop algae biofuels to control greenhouse gas emissions. Two companies, Isuzu Motors and Bioventure, announced that they would promote bus services using oil extracted from Euglenophyceae. This will be the first attempt in Japan that would be a continuous use of the green algae-based biofuel. The two companies are aiming to develop a fuel fully made from Euglenophyceae by 2018.

Assam in the North East holds great promise towards developing a cleaner environment by producing biomass derived fuels. In the outskirts of a city like Guwahati where there are a number of brick industries continuously emitting significant volume of flue gases, a portion of it can be mitigated by establishing algal cultivation systems like open ponds that hold a vast scope for algal biofuel recovery.

A combination of carbon dioxide mitigation, biofuel production, and wastewater treatment may thus provide a very promising future ahead for current algal carbon dioxide mitigation strategies. It is reported that an annual average rate of some algae-based oil production is equivalent to 1014 GJ/ha and with Chlorella species it is predicted to be 3,200 GJ/ha per year, which is very promising as a number of Chlorella sp. are easily available in Assam and reported already.
There are many other potent microalgae strains like *Scenedesmus* sp., *Selenastrum* sp., and *Chlorella* sp. that have already been identified, cultured and accession numbers obtained from NCBI database by submitting Ribosomal RNA sequences. It is possible to manipulate and modulate the fatty acid and lipid content by optimizing nutrients, growing environment and introducing stress conditions in the algae cultures.

The microalga *Chlorococcum littorale* showed significant tolerance to high carbon dioxide concentration up to 40% as reported by Iwasaki in 1998. Many *Scenedesmus* sp. and *Chlorella* sp. have already been reported that can tolerate high levels of bicarbonate salt (45-75 ppm) and high carbon dioxide gas concentration with significant flow rate.

However, till date there is no scientifically designed algal pond (production) system near brick industries and other flue gas emitting industries in the North Eastern region, particularly in Assam. The rich and diverse algal bioresource in this region is yet to be explored in terms of its biotechnological applications.

In the North Eastern region, selection of a microalga with good growth rates, biomass productivity, carbon dioxide gas tolerance and high oil accumulation are some of the major requirements for sustainable biomitigation and biofuel technology development. Efficiency of algae strains can be further improved by selection, adaptation, biochemical and genetic engineering approaches (Singh et al. 2012).

Algal strain selection could also be based on its ease in mass culture, requiring minimal nutrient inputs while producing desirable output such as lipids, nutraceuticals, pharmaceuticals, etc. Impressive results were delivered by many microalgal strains found in Assam more particularly *Scenedesmus* sp. which are able to accumulate large amounts of oil (20-37%) having biofuel properties.

Other microalgae strains reported from Assam also have oil content of 20-50% dry cell weight, which is very promising. Fransisco in the year 2010 reported microalgae oil had the best biodiesel properties, conforming to US standard (ASTM 6751) and European standard (EN 14214) indicating a promising future for North Eastern algal research.

The *Scenedesmus* sp. isolated in Assam may have calorific value more than 40 KJ/gm, when B20 blend is prepared (20% biodiesel, 80% petroleum diesel), which is higher than many other strains reported till now. Although there are many media to grow microalgae, recent research indicates implementation of locally available cheap media beneficial for algal growth.

The locally reported species from Assam hold great promise for mass culture in huge quantities producing large amounts of bio fuel. A few species like *Scenedesmus dimorphus*, *Scenedesmus quadriguada*, *Selenastrum gracile*, *Chlorella homospheara*, etc. are found to be very promising in terms of their growth behavior under high carbon dioxide environment and better fuel recovery.

There are a number of microalgae and blue green algae species reported to be isolated and screened for their potential applications and uses in Assam. Search for potent microalgal strains suitable for abatement of rising harmful greenhouse gases particularly converting carbon dioxide gas into usable biomass, as well as sustainable biofuel production through biomass generation is the primary agenda of this region.

Dr. Rajiv Chandra Dev Goswami (former INSPIRE Fellow) (rajvgoswami23@gmail.com) and Prof. M.C. Kaila (mckailag@gmail.com) are with the Department of Biotechnology, Guwahati University, Guwahati-781014, Assam.