Unlocking the potentials of Blue Biotechnology for sustaining ecological balance of Bangladesh

Mohammad Nazir Hossain*

Abstract

Blue biotechnology- commonly known as marine biotechnology is considered as one of the most promising sectors in Bangladesh for sustainable development. As the movement of eco-efficient innovation gaining its popularity day by day therefore an advancement in blue biotechnology can contribute to develop a better environmental status by improvising the utilization of resources more efficiently. However, the development of eco-efficient innovations in marine biotechnology and its economic growth needs to accommodate three major network, namely political, economic, and scientific. These three triads are considered as the networking backbone of blue biotechnologies. Fine tuning and interaction of these three separate systems can contribute to the creation of a green sphere. The concept of this ecological sphere or green sphere in blue biotechnology eventually leads to invention of eco-friendly products. After the historical settlement of maritime dispute over India and Myanmar, the total maritime area Bangladesh approximates 207000 square kilometers which has enormous potential for the development of eco-efficient products by blue biotechnology. Though marine biotechnology has a wide-ranging scope but the degree of ecological modernization of sector greatly varies depending on need. At present, Bangladesh is solely depended on land-based food products. While the number of populations is rising exponentially, our land area is losing greenery everyday due to excessive use of land area for farming and creating habitat. Apart from this, our current industries and technologies are not up to the mark to meet the demand of such massive needs. Therefore, time has come to adopt new strategies to maintain ecological balance and save the habitats from further extinction. This article focuses on the necessity of blue biotechnology for supporting the growing needs and thus maintaining the ecological balance for a green Bangladesh.

Key words: Blue biotechnology, Eco-efficient innovation, Ecological

* Correspondence : Associate Professor, Department of Genetic Engineering and Biotechnology
Bangabandhu Sheikh Mujibur Rahman Maritime University
Email: nazir.geb@bsmrmu.edu.bd

1. Introduction

The whole world is facing extraordinary environmental crisis because of ever growing human population and their activities and Bangladesh is no exception. Bangladesh is one of the world's least developed nations but has the highest population density in the world (1265/sq. km) [World meter 2020]. Being located in the tropical region, Bangladesh enjoys having the vast riches of mother nature. Lands here are very fertile and the whole country is covered with luxuriant greenery. People here mostly depend on agriculture and it is still one of the dominant sectors in economy. Since agriculture is the economy's dominant sector, land is of the highest importance as a resource. The country's total cultivable land is not more than 0.782 acres ha and just 0.0526 ha is per capita land. In addition, in Bangladesh, 1% of its arable land or 82900 ha of crop land is lost every year and 221 ha of arable land every day [Islam et al. 2011]. As the land area is limited, rapid population rise brings extra pressure on land which is already considered a highly demanded natural resource. The land use pattern of a country represents its socio-economic requirements. Though changes in land use concern issues in the sense of a country's socio-economic changes, the trend of changes in Bangladesh is to meet the complex social demand that generates pressure on the natural environment. As a consequence, in the natural environment, there are many dissonant [Department of forest 2020]. Therefore, every year the country is losing its greenery exponentially, putting the country at high risk of natural disaster. Moreover, people here in Bangladesh not only depends on land for food but also on natural resources for their primary health care. Modern healthcare facilities in Bangladesh are very limited and, on an average, only about 20–25% of the people have access to them. The remaining 75–80% of the rural population in Bangladesh still receives healthcare services from the indigenous traditional medical practitioners who prepare these medications from rich natural resources [Ghani et.al.2016. However, the population burst has already endangered these natural resources. Despite the sincere measurements of Bangladesh government to control the high birthrate, the population still continues to expand by 2 million people per year because of the large current population base. [World Bank 2020]. By 2030 the population of Bangladesh will be around 190 million and at that time extra 25% food grains will have to be produced from much smaller land area than currently available. Besides the ongoing unsustainable use of natural resources, the current trends of production and consumption are drastically increasing the pressure on the environment through different ways of pollution and ecosystem degradation [Bhuiyan et el. 2003]. This is really alarming for a small country like Bangladesh. Therefore, Bangladesh has to adopt new strategies to meet the future demands. This article describes the enormous possibilities of blue biotechnology to provide the growing needs of future generations that will further help in maintaining the ecological balance and greenery of Bangladesh

2. Blue Biotechnology

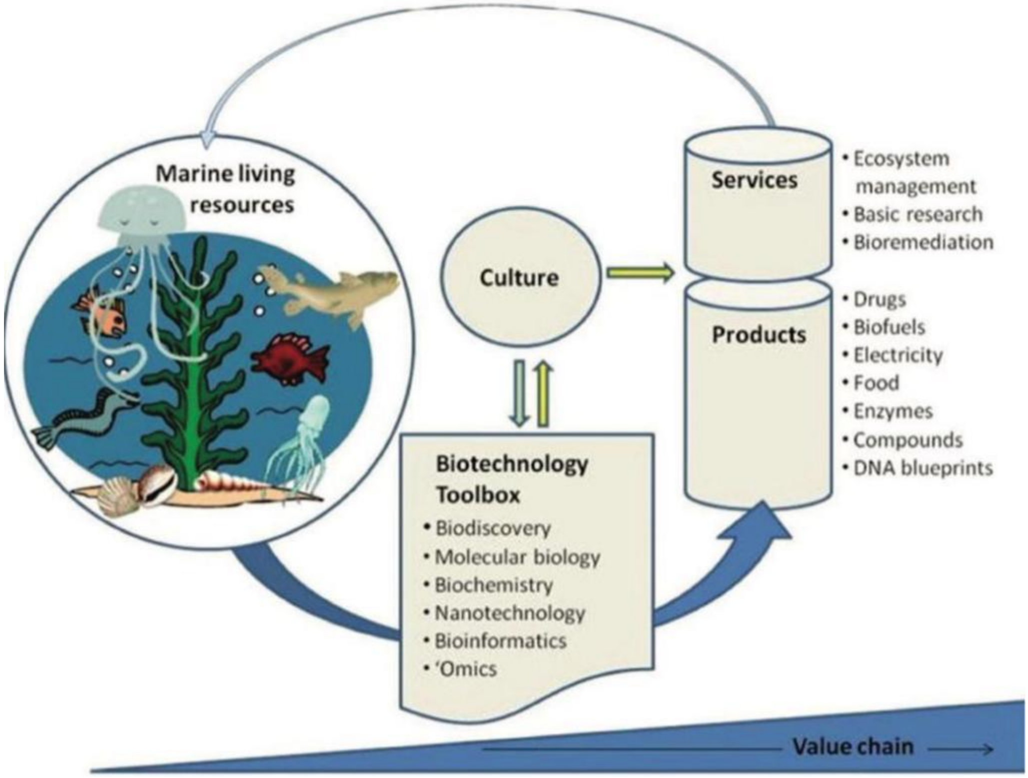

Figure 1: Marine biotechnology (Source OCED, 2013)

Blue biotechnology or marine biotechnology can be defined as the use of marine resources and marine organisms to develop products and services biotechnological gain. Marine biotechnology also includes the application of biotechnology developed using any resource (marine, terrestrial, freshwater or a combination) to the marine environment, and human activities therein [ECORYS, 2014]. It is a category of products and/or tools relating to marine bio-resources, as either the source or target of their application that provides goods and services for innovative industries and/or society as a whole (Fig. 1).

The blue biotechnology sector is unique among the biotechnology sectors in terms of definition. Where other biotechnology sectors portray on the basis of the processes they entail or the market they serve, i.e. red biotechnology (medical, health and pharmaceutical), green biotechnology (agricultural), yellow biotechnology (environmental) and white biotechnology (industrial), blue biotechnology is the only biotechnology sub-sector which is defined by its source material, such as marine resources [Kafarski, 2012]. Therefore, blue biotechnology includes the processes starting from sampling to discovery and bioprospecting, to research and development

(R&D) and initial product development. Hence blue biotechnology has enormous potential to make positive contribution to other varieties of biotechnological and industrial sectors. Therefore, blue biotechnology cannot be described as simply as it appears although it is generally considered the use of marine bioresources as the source of biotechnological applications (Fig. 2).

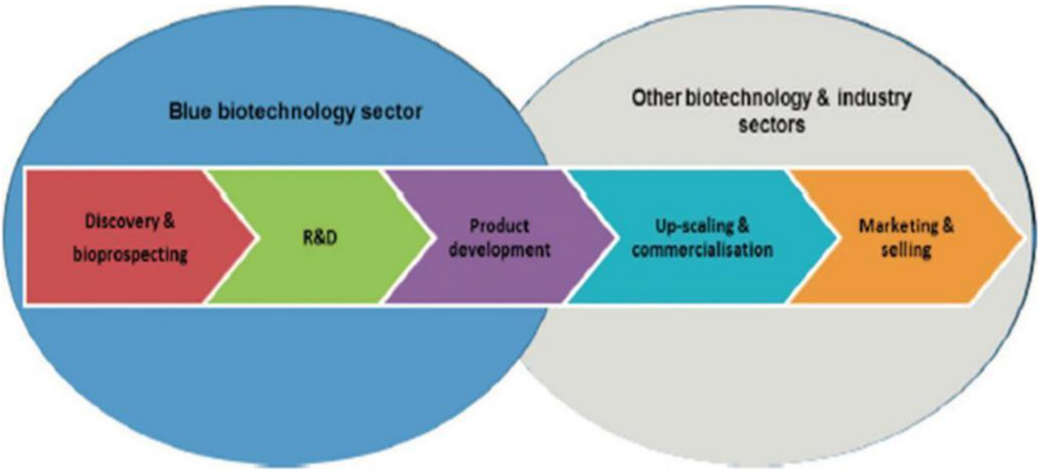

Figure 2: Visual representation of the blue biotechnology sector in Europe. *Source*: ECORYS, 2014.

Blue biotechnology might help to decrease the dependency on natural resources on land that may lead to a change better environment in the future. It may also help to improve sustainability by exploitation of marine natural resources in a proper scientific way [Tramper et al., 2003]. Blue biotechnology offers the necessity of using unexplored species for the development of sustainable product i.e., Microalgae cultivation and refinement. Blue biotechnology possibilities are not limited to the various algae organisms rather it covers the study and uses cover all different aquatic organism taxa. Thus, expanding the possibilities of mitigating present environmental dissonant. [Luiten et al., 2003].

Table 1: Applications of Blue Biotechnology

Sub-sector	Potential Product Areas	Specific Product Areas
Health	Pharmaceuticals	Anti-cancer drugs, anti-viral drugs, novel antibiotics; wound healing; anti-inflammatory; immunomodulatory agents
	Biomaterials	Bio adhesives, wound dressings, dental biomaterials; alternative disinfectants (being more environmentally friendly and avoiding resistance development); medical polymers; dental biomaterials; coating for artificial bones that enhance biocompatibility; medical devices.
	Other	Tissues regeneration, 3D tissue culture
Cosmetics	Functional ingredients	UV-filter, after sun; viscosity control agents; surfactants; preservatives; liposomes, carrier systems for active ingredients; regulation of sebum;
	Raw materials	Micro and Macro-algae extracts; colourants, pigments; fragrances; hair-styling raw materials
Food	Functional foods	Prebiotics; omega 3 supplements;
	Nutraceuticals	Useful as antioxidants, anti-inflammatory; fat loss; reducing cholesterol; anti-HIV properties, antibiotic and mitogenic properties anti-tumor; iodine deficiency, goiter and myxoedema; anti-influenza; treatment of gastric ulcers;
	Food products and ingredients of marine origin	A stabilizer, suspending agents, bodying agents, makes a good jelly, prevents separation and cracking, suspending agent, foaming agent.
Energy	Food packaging and conservation	Films and coatings with antimicrobial effects
	Renewable energy processes (micro and macroalgae)	Microalgae; produce polysaccharides (sugars) and triacylglycerides (fats) that can be used for producing bioethanol and biodiesel. Macroalgae; large scale cultivation of macroalgae (seaweed) for the production of biofuel
	Microbial Enhanced Oil Recovery (MEOR)	Enhanced oil recovery and productive life oil reservoirs.
	Industrial additives	Anti-blur additives for textile printing, binding agent in welding rods, drilling fluid

Sub-sector	Potential Product Areas	Specific Product Areas
Aquaculture	Seed	Surrogate broodstock technologies; transgenic approaches; developing culture species; selective breeding of existing cultured species for novel and disease resistant hybrids.
	Feed	Fish oils produced from algae; pigments in fish feed
	Disease Treatment	Diagnosis; treatment of disease; disease-resistant strains.
	Aquaculture systems	Treatment of re-circulated water.

Marine environ-mental health	Bioremediation	Biosurfactants (BS), bioemulsifiers (BE) induce emulsification, foaming, detergency, wetting dispersion, solubilization of hydrophobic compounds and enhancing microbial growth enhancement; marine exopolysaccharides (EPs) induce emulsification.
	De-pollution	Removal of Toxic elements including metals (lead, cadmium, zinc and metal ions); removal of dyes.
	Bio-sensing	Biomarkers and biosensors for soil sediment and water testing; to identify specific chemical compounds or particular physio-chemical conditions, presence of algal blooms, human health hazards.
	Antifouling	Reduce drag and fuel use for boat-going vessels without any negative environmental impacts.
	Bio-adhesives	Underwater industrial adhesives.
Other	Bio-refineries (separation of functional biomass components)	Biodiesel; feedstock for the chemistry industry; essential fatty acids, proteins and carbohydrates for food, feed for animals (replacement of feed with fishmeal) and production of proteins and chemical building blocks;

Source: ECORYS, 2014.

3. Global scenario of Blue biotechnology

Biofuels and marine bioactive compounds are top priorities in Africa whereas Central and South America focus on wide biodiscovery, bioenergy, bioremediation and biofouling.

North America is keen to discover biodiversity and other aspects of marine biotechnology, including molecular aquaculture in Canada (salmon) and the U.S. Atlantic Coast (shellfish). The Department of Energy and Department of Defense of north America is investing for algal biofuels.

Although India focuses on biofuels but its more interested to biodiscovery for human pharmaceuticals, food, feed and cosmetics. Korea is way ahead of other Asian countries as they have a dedicated institute in Ocean Science and Technology.

In Israel sponge biotechnology predominates. But they are also involved in marine bioactives and biofuel research. Turkey is involved in bioactives and in algal culture for bioenergy and biorefineries. The region is likely to have new possibilities for algal biotechnology and molecular aquaculture.

South-East Asia and the Indian Ocean Islands, are much focused on exploitation of natural biodiversity for novel bioactives. Vietnam and Thailand have become pioneer in molecular aquaculture, especially for crustacea (shrimps, prawns).

The biotechnology research roadmap of the New Zealand Ministry of Research, Science Technology in Australia-Pacific identifies molecular aquaculture and marine bioactives as two of New Zealand 's research strengths [Global news 2020].

4. Destruction of greenery in Bangladesh

Bangladesh is facing a number of environmental issues like deforestation, land erosion and degradation, excessive air pollution, water pollution and ultimately losing biodiversity. Several factors playing key in such environmental anomalies. Poverty is playing a major role in deforestation. Bangladesh is losing its natural forests at a rate of 2.1% to 3.3% every year. Agricultural land expansion, commercial logging, fuel wood collection is causing this exponential deforestation. The birth rate of Bangladesh is around 2%. At this rate the population of Bangladesh will reach around 190 million by 2030.To provide this huge population, large area of natural forest has been converted into farmland to grow crops [Independent Dec 2019].

Bangladesh has a rich history of using ethno-medicinal plants in primary health care system. In fact, at present over 70% of the rural people receive their primary health care from medicinal plants. Traditional medicine system like Ayurvedic, Unani and herbal are solely dependent on the medicinal plants as Bangladesh is rich in floral and faunal diversities. However, the alarming increase in population density is threatening this rich biodiversity and adequate measures should be taken immediately to conserve the ethno-medicinal plant resources [Ghani et a. 2016].

5. Potential of blue biotechnology in Bangladesh

Bangladesh has a land *area* of 148,460 square kilometers whereas sea area of Bangladesh is about 207000 square kilometers. Though sea area is larger than the land area, but this huge area is still remaining unexplored. With the burden of 7 new faces every minute, Bangladesh must explore these areas to meet the demand of the future and to sustain greenery in the land [Molly Moore 2020]. Blue biotechnology has huge potential to provide food, medication and others to the mass people if it is properly used.

5.1 In food and nutrient sector:

The people of Bangladesh consume large quantities of rice after Laos. On an average 438gm of rice is consumed per day/person. Whereas in Japan 119gm of rice is being consumed by per inhabitant/day. In addition, most of the people of Bangladesh are still depending in freshwater fish and consumption is about 19.71 gm per person every day. However, in Japan fish consumption is about 85 gm [FAO report 2019] and these are mostly marine fishes. This data shows that Bangladeshi people are still way behind consuming marine fishes which still is considered as gold mine. Marine Biotechnology can help fish industries through aquaculture technique. Aquaculture can help to grow fishes much faster with tastier muscle. In order to improve the aquaculture process, biotechnological research is mainly focus on species diversification, optimum food and feeding, health and disease resistance. It is also concerned about impact on environment. Development of transgenic fish is underway using recombinant technology, with the intention of introduction of properties such as fast growth, resistant to pathogens, temperature and salinity tolerance etc. Moreover, new feed stock and vaccine for aquaculture have been invented by biotechnological approaches to enhance production. Many probiotics have been developed for improving fish health. This may in turn may ensure food security in Bangladesh [Heppell et al. 1998].

For billions of years, seaweeds have been present in marine environments producing oxygen and consume CO2 required for chlorophyll to carry out photosynthesis. The oxygen produced by seaweeds is necessary for aquatic organisms to live. Seaweeds have high adoptability in extreme environmental conditions and as the same time they are proved to be a rich source of nutrients, promising bioactive compounds and cosmetics agents. Seaweeds are often classified by their color (Green, Blue, brown and red) and wide varieties of seaweeds are consumed for human and animals [Mc Hough and Zarmoni 2011].

Seaweed is served in approximately 21% of Japanese meals [Yoshinaga et al 2001] with 20-38% of the Japanese male and female population aged 40-79 years consuming seaweed more than five times per week, 29-35% three to four times per week, 25-35% one to two times per week, 6-13% one to two times per month, and 1-2% rarely consuming seaweed [Iso H et. al. 2005]. China is catching up Japan in terms of cultivation and export. China's of seaweed production is around 8 billion US dollars.

Seaweeds are considered unique because of their richness in proteins, minerals, fibers, vitamins and functional compounds [Cardoso SM et al. 2015]. In addition, many bioactive compounds like antibiotics, antifouling, anti-inflammatory, antimitotic, anti-hereditary, antibacterial and anticancer have been isolated from varies seaweeds [Salvador and Selvin et al. 2007, 2004]. Seaweeds are also used a major source of iodine as for many years [Andersen S et al 2019]. One of the structural components of seaweeds are polysaccharides. These polysaccharides have the ability to form colloidal solutions when dispersed in water and exhibit various biological activities. For this property they are used in pharmaceuticals, nutraceuticals and in cosmetic industry [Pereira L and Fernando 2018]. Many biocidal compounds have been identified from different species of sea weeds that are used to kill parasitic vectors in their larval stage or after complete metaphosphoric in adults. These biocidal compounds have shown better efficacy than synthetic products but way cheaper than their synthetic counterpart. [Selvin J 2004]. Many of the seaweeds are used as fertilizer in agricultural industry and they can be used a renewable and ecological source.

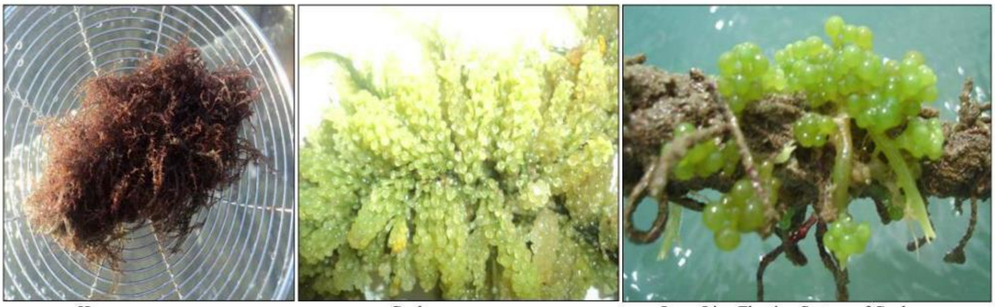

Figure 3: Some identified seaweeds from St. Martin Island and Coxs bazar (Courtesy Source Shafiuddin et.al 2019)

In the coastal area of Bangladesh 193 seaweed varieties have been identified. Out of 193 varieties, 14 varieties turned out to be commercially important. Although seaweeds have been consumed and considered as a source of earning foreign currency in many Asian countries, the scenario of seaweeds exploitation and utilization is quite opposite in Bangladesh. Other than some tribal people the utilization of seaweeds are almost nil in rest of the country. [Majumder, 2010, Sarkar, 2016]. Recently government and some private organizations have taken some initiatives to utilize seaweeds [DoF, 2014, COAST Trust, 2013].

Table 2: Different Commercially important Seaweeds of Bangladesh (Source Shafiuddin et.al 2019)

Sl No	Genus	Species	Type
1	Caulerpa	Caulerparacemosa	Green Seaweed
2	Enteromorpha	Enteromorphasp	Green Seaweed
3	Gelidiella	Gelidiellatenuissima	Red Seaweed
4	Gelidium	Gelidiumpusillum	Red Seaweed
5	Halymenia	Halymeniadiscoidea	Red Seaweed
6	Hypnea	Hypneapannosa	Red Seaweed
7	Hydroclathrus	Hydroclathrusclathratus	Brown Seaweed

8	Sargassum	Sargassumsp	Brown Seaweed
9	Enteromorpha	Enteromorphaintestinalis Enteromorphamoniligera	Green seaweed
10	Padina	Padinatetrastromatica	Brown Seaweed
11	Catenella	Catenellaspp	Red Seaweed
12	Porphyra	Porphyraspp	Red Seaweed
13	Gelidium	Gelidiumamansii	Red Seaweed
14	Codium	Codium fragile	Green Seaweed

5.2 In Medicine sector:

More than 70% of the village people in Bangladesh is still dependent on traditional medicine that uses medicinal plants from forest to produce valuable medicine. Scientists are in quest for potentially active molecules from tropical forest. However, land resources are depleting very fast, therefore new area needs to be explored. History of using extracts of marine organisms as medicine dates back 2000 years ago. Doctors started prescribing cod liver oil as supplement in early 19th and 20th century. But systematic expedition of sea for drugs started in the middle of 20th century. Scientist started exploring organisms that make deadly toxins to protect themselves in search for potential drug candidate. 'Holothurin' a toxin isolated form Bahamian sea cucumber *Actynopyga agassizi* in early 1950s showed some antitumor activity5. This was the beginning of searching candidate bioactive compounds form marine sources. Till now around 10,000 new potential compounds have been isolated from marine organisms and the number is increasing every year 6. Many of the isolated compounds have been formulated and commercially available in markets, though some in still in preclinical or clinical stage. For example, antibiotic cephalosporin from marine fungus, cytostatic cytarabine from sponge, anthelmintic insecticide kanic acid from red alga, analgesic zincototide from mollusk, etc. are already available in drug store. Antiviral agent Ara-A and anti-tumour compound Ara-C isolated from the 8 sponge are are now in clinical use Ara-C is currently sold by the Pharmacia & Upjohn Company under the brand name Cytosar-UR. In addition to these compounds, there are many other candidate compounds like blood-clotting compound from cone snail, anti- inflammatory ointment from sea sponge, anticancer substance and disinfectants from shark, gene therapy vehicle and adhesive from shellfish's chitosan are under development. Likewise, enzyme inhibitors such as PKC isolated from *Bugula neritina* showed potent anticancer activity.

It is said that ocean biodiversity is more sophisticated than land. There are millions of bacteria living in ocean environment and have the potential to become rich source of novel bioactive compounds. Hence efforts are underway to search antibiotics from this source. Prof. Jensen and Prof. Fenical of 'Scripps Institute of Oceanography, USA, recently reviewed the status of numerous potential dryps, isolated from marine microorganisms. Many promising alkaloids like Sorbicilactone-A have been isolated from marine fungi. The value of living fossils like the horse-shoe crab, should not be overlooked in the area of marine biotechnology. Due to their simple cellular structures, many marine invertebrates have provided a rich source of new insight and serve as candidate non-mammalian models for study. These invertebrates can be used in the study of tumor development. In addition, several models have shed light on the mechanism of nerve cells in marine invertebrates, with clear implications for human and other mammalian studies. Sea urchins provided new information to the scientists on fertilization; a fundamental biological process. Thus, marine model systems may also provide fresh insight into fundamental biological concepts that will help further advances in medicine and industry.

5.3 In Controlling Environment

Everyday thousands hazardous materials are disposed to the land and sea creating environment crisis. Scientists have discovered that some marine microorganism having novel biodegradation pathways for breaking down number of organic pollutants. One such bacteria is *Pseudomonas chlororaphis* that produces pyoverdin, capable of degradation organic compounds in sea water. Marine cyanobacteria have been reported to have crude oil degrading capability and may contribute in environment bioremediation [Raghukumar C 2001, Karna R R1999].

Environmental waste management at a cheaper cost is necessary to healthy world. Several marine microorganisms have been reported to produce eco-friendly chemicals, such as biopolymers and biosurfactants that may be used in environmental waste management and treatment [Karna 1999, Cohen Y, 2002].

Biosensors are commonly used to measure biologically important environmental parameters, such as inorganic and organic nutrients, marine organisms' harmful materials, and 24 contaminants. The development of sophisticated biosensors and diagnostic devices for medicine, aquaculture and environmental biomonitoring is underway using marine microorganisms. Already several bioluminescent proteins from marine organisms are currently being used as reporter gene.

6. Conclusion and Recommendation

Bangladesh is famous for its greenery and rich biodiversity. However, excessive population is putting this small country into resource depletion. Every year new faces are adding to the demography and to provide food for the newcomers, new farms lands are created by destroying natural forest. Traditionally, rice is the staple food for

Bangladeshi people and Bangladesh is the seconds largest rice consumers in the whole world. Such heavy dependency on rice is creating pressure on ecological balance of the country. Countries like Japan shifted from rice to more suitable sea food in last 40 years. But our country is still heavily dependent on rice as their primary food. Hence, we are creating environmental crisis and losing greenery every year.

The concept is blue biotechnology is rather new in Bangladesh. However, depletion of land resources forced scientists to think the enormous possibilities of blue biotechnology. As described in this review, the rich diversity of marine biota and their unique physiological adaptations to the harsh marine environment has opened up new exciting prospect for the exploration of life-saving drugs, novel industrial products and processes, and devices that can monitor environment monitor.

Bangladesh has 580km of coastline and has maritime zone around 200000 sq.km. The seacoast of Bangladesh is one of the unreached areas of the world and no systemic scientific expedition has been carried out so far. Therefore, country lacks very fundamental information and statistics regarding our rich marine resources. Without proper information and statistics, it would be impossible to figure out the true potential of blue biotechnology in Bangladesh. As a result, the potential of blue biotechnology remains largely unexplored. Developed countries in Asia, Europe and America already have recognized the importance of establishing interdisciplinary research centers focusing on Blue biotechnology. Bangladesh should take similar strategies to explore biotechnological potential of untapped marine biodiversity.

7. Reference:

https://www.worldometers.info/world-population/bangladesh-population/

Islam M.R. and Hassan M.Z.2011.Land use changing pattern and challenges for Agricultural land: a study on Rajshahi district. J. Life Earth Sci., Vol. 6: 69-74, 2011

Forest Department, Ministry of Environment and Forest, Government of Bangladesh, Bangladesh Forest Department Homepage, 2010, URL: http://www.bforest.gov.bd

Ghani A: Present state-of-the art of traditional medicine practice in Bangladesh; Available at: https://books.google.com.bd/books?id= 5gi1lf4a3QgC&printsec=frontcover&dq=isbn:1439896321&hl=en&sa=X&ved= 0ahUKEwiUp8TFqKPZAhWKvo8KHdJRBdcQ6AEIJTAA#v=onepage&q&f=fals e [Accessed 20 Feb 2016].

https://data.worldbank.org/indicator/SP.DYN.CBRT.IN?locations=BD

Bhuiyan M. 2003. Has urbanization caused agricultural land loss? The Daily Star, November 1 2003.

Food taxes and their impact on competitiveness in the agri-food sector Final report Client: DG Enterprise and Industry Rotterdam, 12 July 2014

Organisation for Economic Co-operation and Development 2013

Paweł KAFARSKI – Rainbow code of biotechnology CHEMIK 2012, 66, 8, 811-816
Johannes Tramper , Chris Battershill, Willem Brandenburg, Grant Burgess, Russell

Hill, Esther Luiten, Werner Müller, Ronald Osinga, Gregory Rorrer, Mario Tredici, Maria Uriz, Phillip Wright, René Wijffels What to do in marine biotechnology? Biomol Eng. 2003 Jul;20(4-6):467-71.

Esther E M Luiten , Ida Akkerman, Albert Koulman, Pauline Kamermans, Hans Reith, Maria J Barbosa, Detmer Sipkema, René H Wijffels Realizing the promises of marine biotechnology Biomol Eng 2003 Jul;20(4-6):429-39

http://www.theindependentbd.com/post/229385

Population density of Bangladesh https://www.statista.com/aboutus/our-research-commitment 2020

http://www.fao.org/fishery/facp/JPN/en 2019

Selina S. Heppell Application of Life-History Theory and Population Model Analysis to Turtle Conservation Copeia Vol. 1998, No. 2 (May 1, 1998), pp. 367-375

McHough DJ. 2002. Prospects for seaweed production in developing countries. FAO Fisheries Circular No. 968. Rome, FAO, pp 28.

Zamroni A, Yamao M. 2011. Coastal resource management: fishermen’s perceptions of seaweed farming in Indonesia. International Journal of Nutrition

Yoshinaga J, Morita M, Yukawa M, Shiraishi K, Kawamura H: Certified reference material for analytical quality assurance of minor and trace elements in food and related matrixes based on a typical Japanese diet: interlaboratory study. *J AOAC Int* 2001, 84: 1202–1208.

Iso H, Date C, Noda H, Yoshimura T, Tamakoshi A, JACC Study Group: 2005 Frequency of food intake and estimated nutrient intake among men and women: the JACC Study. *J Epidemiol*, 15: S24-S42. 10.2188/jea.15.S24

Cardoso SM, Pereira OR, Seca AM, Pinto DC, Silva AM. 2015. Seaweeds as preventive agents for cardiovascular diseases: From nutrients to functional foods. Mar Drugs 13(11): 6838-6865. https:// doi.org/10.3390/md13116838

Salvador N, Garreta AG, Lavelli L, Ribera MA. 2007. Antimicrobial activity of Iberian macroalgae. Scientia Marina 71(1): 101113.https://doi.org/10.3989/scimar.2007.71n1101

Selvin J, Huxley AJ, Lipton AP. 2004. Immunomodulatory potential of marine secondary metabolites against bacterial diseases of shrimp. Aquaculture 230(1-4):241-248.

Andersen S, Noahsen P, Rex KF, Florian-Sørensen HC, Mulvad G. 2019. Iodine in edible seaweed, its absorption, dietary use, and relation to iodine nutrition in arctic people. J Med Food 22(4): 421-426.

Pereira L. 2018. Seaweeds as source of bioactive substances and skin care therapy cosmeceuticals, algotheraphy, and thalassotherapy. Cosmetics 5(4): 68.

Fernando IPS, Kim KN, Kim D, Jeon YJ. 2018. Algal polysaccharides: potential bioactive substances for cosmeceutical applications. Crit Rev Biotechnol

Selvin J, Lipton AP. 2004. Biopotentials of Ulva fasciata and Hypnea musciformis collected from the peninsular coast of India. Journal of Marine Science and Technology 12(1): 1-6

Abdullah Al Mamun Siddiqui, Md. Abul Kashem, Md. Atiqul Islam Mondal and Md. Shafiuddin. 2019, Commercially important seaweed cultivation and its potentials for the coastal areas of Cox's Bazar, Bangladesh International Journal of Fisheries and Aquatic Studies; 7(5): 463-470

Majumder S. Development of value added products from seaweed available in the Bay of Bengal, Bangladesh coast. MS thesis. Department of Fisheries Technology. Bangladesh Agricultural University, Mymensingh, Bangladesh, 2010.

Sarkar MSI, Kamal M, Hasan MM, Hossain MI. 2016, Present status of naturally occurring seaweed flora and their utilization in Bangladesh. Res. Agric. Livest. Fish.; 3(1):203-216.

DoF. National Fish Week Compendium (In Bengali). Department of Fisheries, Ministry of Fisheries and Livestock, Bangladesh, 2014, 144.

Raghukumar C, Vipparty V, David J J & Chandramohan D, 2001, Degradation of crude oil by marine cyanobacteria, Appl Microbiol Biotechnol, 57 433-436.

Karna R R, Uma L, Subramanian G & Mohan P M, 1999 Biosorption of toxic metal ions by alkali extracted biomass of a marine cyanobacterium, Phormidium valderianum BDU 30501, World J Microbiol Biotechnol, 15 729-732

Cohen Y, 2002, Bioremediation of oil by marine microbial mats, Int Microbiol, 5 189-193.