Summary

Cyanobacteria and green algae are mostly aquatic and photosynthetic organisms distributed in fresh as well as in saline water. Because cyanobacteria are Gram negative bacteria, they are quite small and usually unicellular. Though, there are some strains grow in colonies which are large enough to see like green algae. They have the distinction of being the oldest known fossils, more than 3.5 billion years old. In fact, they are one of the largest and most important groups of bacteria on Earth. They have no nucleus, DNA without histone protein and Chl a encloses in the photosynthetic membranes. In fact, blue-green algae are more similar to bacteria and their biochemical and structural characteristics. They are oxygen evolving prokaryotes, and play significant role in global carbon cycle for sequestration of CO$_2$ during photosynthesis. Thus, they enhanced the accumulation of primary products such as lipid rich biomass that considered as biofuel agents. Microalgae being fast growing accumulate more lipid and carbohydrates in their biomass, and they reach high densities by absorbing solar energy. The production of large quantities of carbohydrates and lipid rich biomass is highly important for the microalgal biofuels. The ever increasing demand of fuels lead to increase in their prices, instability of fuels, ultimately increase the level of greenhouse gases in the environment. All these factors are responsible for increasing our interest towards the sustainable approach of microalgae consortia behavior for CO$_2$ sequestration and mitigation.

For more production of aqueous-phase as well as organic compound rich biomass researchers apply genetic engineering, chemical mutagenesis and bioprocess fermentation. Chemical mutants are considered as safer than genetically manipulated strains. The main aim of this study is to develop microalgae strains that have potential to grow rapidly producing lipid and carbohydrates rich biomass by employing chemical mutagenesis. So we can use them for production of more sustainable rich biomass for human welfare to combat the society demand.

Carbon dioxide (CO$_2$) is one of the most important contributors for the increase of the greenhouse effect. CO$_2$ concentrations are increasing in the last decades. A promising technology is the biological capture of CO$_2$ using microalgae. These microorganisms can fix CO$_2$ using solar energy with efficiency ten times greater than terrestrial plants.
Moreover, the capture process using microalgae has the following advantages: (i) being an environmental sustainable method; (ii) Using directly the solar energy; And (iii) coproducing high added value materials based on biomass, such as human food, animal feed mainly for aquaculture, cosmetics, medical drugs, fertilizers, biomolecules for specific applications and biofuels.

The exploitation of algae has been further extended to the treatment of sewage waste, energy generation and also as photosynthetic gas exchangers during space travel. The species could be isolated/ selected/ mutated or even be genetically engineered for bioremediation of organic/ inorganic pollutants or effluents effectively.

The CO$_2$ conversion into biomass is high only under conditions where the CO$_2$ mass loading rate is low. At a high CO$_2$ mass loading rate, the formation of volatile organic compounds is the main CO$_2$ biotransformation route. So, there is need of rapid growth of microalgae and more production of biomass but conventional methods are ineffective. There is genetic manipulation applied by EMS mutagen to mutate microalgae for more production of sustainable biomass.

CO$_2$ fixation by photoautotrophic algal cultures has the potential to diminish the release of CO$_2$ into the atmosphere, helping alleviate the trend toward global warming. To realize workable biological CO$_2$ fixation systems, selection of optimal microalgae species is vital. The selection of optimal microalgae species depends on specific strategies employed for CO$_2$ sequestration. In this process, the criteria used for selecting microalgae species for CO$_2$ sequestration systems will be discussed, as well as the characteristics of some species, which have been tested for use in CO$_2$ mitigation.

Consortium is a group of organisms which lives within a defined area / environment. Different organism of a consortium participate either in agonistic or antagonistic manner with each other, so consortium may be designed for the production of a desired compound within a fermentation medium, for plant growth promotion or for Biomass yields etc.
The present study will be conducted for development of an algal/cyanobacterial consortium having good CO$_2$ sequestration capability. Such consortium can be utilized for maximum CO$_2$ mitigation from the environment, production of biomass for desired purpose.

The developed algal consortium will be grown in fresh water, heavy metal contaminated water and their CO$_2$ sequestration ability will be elucidated first in \textit{in vitro}; then after \textit{in vivo}.

The present research thesis demonstrates that the potential of consortia of cyanobacteria and green algae support for sustainable higher production than individual monoculture for CO$_2$ sequestration. These can be efficiently utilize for sustainable bioenergy/biofuel production using the combined use of synthetic biology, potential progressive heavy metal toxicity, bioprocess engineering, Fluorescence response and fermentation technology. This thesis demonstrates that how the community production technology can be combined to dominate over the monoculture learned from nature. Multiple fixation of CO$_2$ is one significant factor, which is used to mitigate CO$_2$ sequestration, control global warming issue and operating costs. To achieve the required improvements in both investment and operating costs, a step change was targeted to significantly influence productivity and/or costs.

In this thesis there are total 7 chapters; in first chapter different member of different order of cyanobacteria and green algae monoculture as well as their consortia has been evaluated towards their aggregate abundance/ Standing sock or total biomass production for CO$_2$ sequestration and mitigation. In second chapter, the ecological biomass stability of developed consortium through CO$_2$ sequestration has been evaluated. In third chapter to evaluate potentiality against heavy metal toxicity, chromium induced altered structure and services in monoculture as well as in their consortia desired. In fourth chapter progressive adsorption of hexavalent chromium evaluated through removal and uptake feedstock in microalgae consortia. Furthermore, Ethyl methane sulphonate (EMS) mutants of 3 cyanobacteria and 2 green algae and consortia of both wild type as well as mutated microalgae have been generated, some of them are better for aqueous-phase co-productivity and some carbohydrate enriched biomass feedstocks in fifth
chapter. Whilst in sixth chapter a novel bacterium enzymatic activity of bicarbonate anhydrase was isolated and characterized through photochemical and non-photochemical analysis of carbon concentration mechanism (CCM) for CO₂ sequestration.

In seventh last chapter, photosynthetic designer microalgae consortium production enhancement was statistical software by central composite design (CCD) to Response surface methodology (RSM) on interaction of two independent variable (pH, %CO₂ concentration) through CO₂ sequestration technologies were combined to produce the reducing sugars.

Fig.1 Graphical diagram showed (1) Pulse Amplitude modulation chlorophyll fluorescence analysis (2) Factorial design through Response Surface Methodology Software via Central Composite design (CCD) (3) Development of enhanced productivity consortia by optimal resource capture (4) Elemental characterization for responsible factor through Laser Induced breakdown spectroscopy (LIBS)

Isolation, purification and characterization of algal strain to developing consortia for CO₂ sequestration. Characterization of carbohydrate productivity by different algal/cyobacterial strains using different biochemical methods like Anthrone test, Nelson-Somogyi, DNS test or any other suitable method as possible. Heavy metal toxicity test to apply wastewater treatment potentiality of microalgae consortia. Chemical mutagenesis using EMS/NTG/EtBr or any other, isolation of mutants and their characterization for CO₂ mitigation. Study of photochemical, nonphotochemical quenching, fv/fm ratio, and
quantum yields. The photochemical quenching (PQ) and non-photochemical quenching (NPQ) would not be studied by adding the DCMU / paraquat in fermentation broth, the \( \frac{f_v}{f_m} \) ratio of different algal strains will be used for determination of maximum quantum yields. Bioprocess engineering for consortium development, media optimization using statistical methods like response surface methodology and Plackett Burman designing. Fermentation broth will be optimized for developed algal consortium using the Plackett Burman designing / Central Composite Design /Response Surface Methodology.