"ECOPHYSIOLOGICAL STUDIES ON FRESH WATER ALGAL SAMPLES FROM THE VENA RIVER IN HINGANGHAT AREA DIST. WARDHA (M.S.)"

Thesis submitted to the Sant Gadge Baba Amaravati University, Amaravati for the award of Degree of Doctor of Philosophy in the faculty of Science (Botany).

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Certificate

This is to certify that the thesis entitled **"ECOPHYSIOLOGICAL STUDIES ON FRESH WATER ALGAL SAMPLES FROM THE VENA RIVER IN HINGANGHAT AREA DIST. WARDHA (M.S.)"** submitted for the award of degree ***DOCTOR OF PHILOSOPHY IN BOTANY*** in the faculty of science to Sant Gadge Baba Amravati University, Amravati embodies the bonafide research work carried out by **MR. BALAJI M. RAJURKAR** under my guidance and supervision. No part of the thesis has been submitted for any other degree. All the assistance and help availed of during the course of this investigation and source of literature have been duly acknowledged.

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Declaration

I hereby declare that the work presented in this thesis entitled, **"ECOPHYSIOLOGICAL STUDIES ON FRESH WATER ALGAL SAMPLES FROM THE VENA RIVER IN HINGANGHAT AREA DIST. WARDHA (M.S.)"** has not been submitted earlier for the award of Degree or Diploma to any other university.

The present work is completely original and has been carried out at Molecular Biology, Biotechnology and Plant Breeding Laboratory, Post-Graduate Department of Botany, Govt. Vidarbha Institute of Science and Humanities, Amravati.

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Place: Amravati
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Mr. Balaji M. Rajurkar

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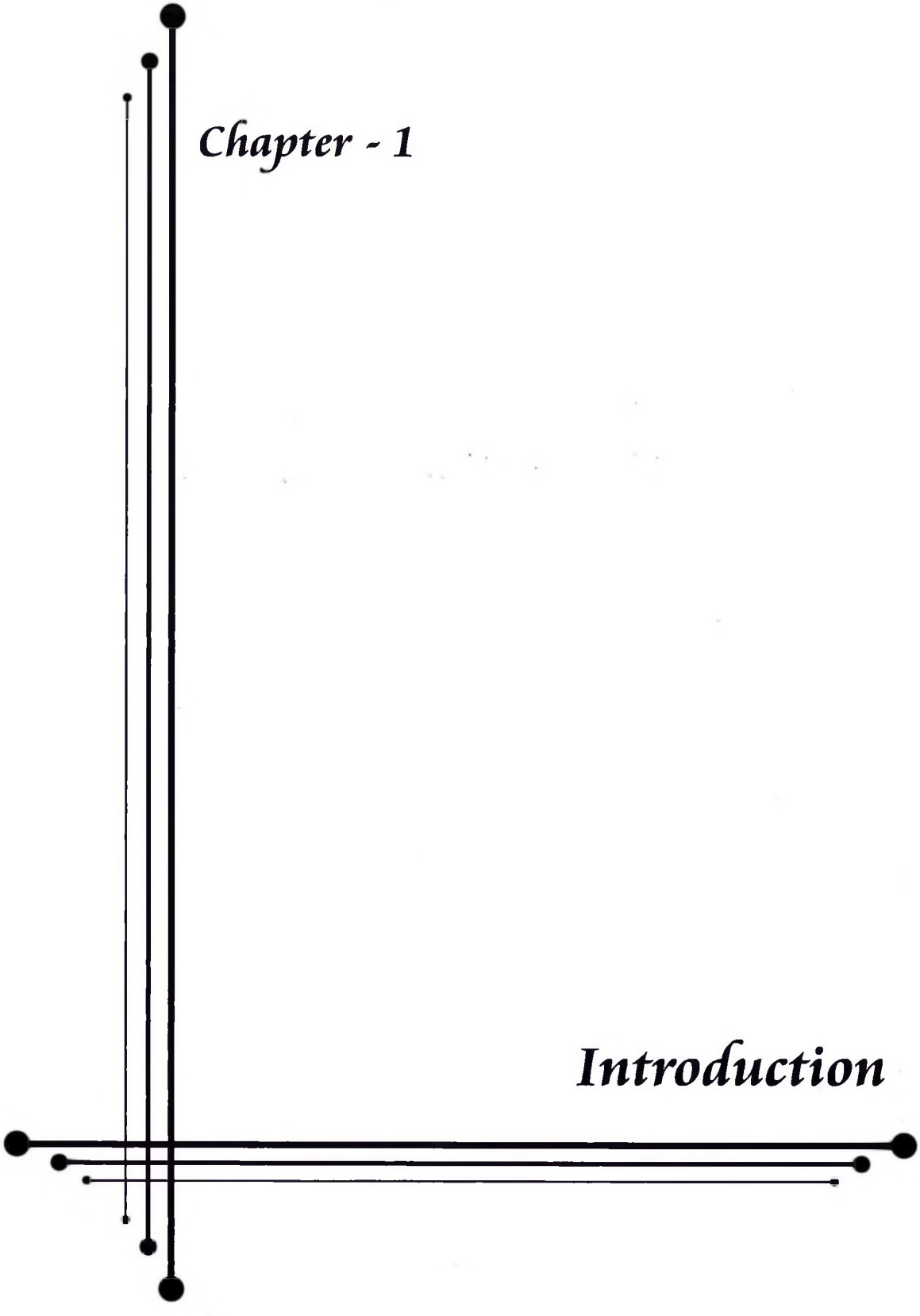
List of Abbreviations.

%	Percentage
&	And
µg	Microgram
µmho/ m	Micro mho per meter
^0C	Degree celsius
AD	Anno Domini
ATS	Algal Tuft Scrubber
$AgNO_3$	Silver nitrate
Al	Aluminium
BBM	Bold's Basal Medium
Ca	Calcium
$CaCO_3$	Calcium carbonate
Cd	Cadmium
CH_4	Methane
Chl. or chl.	Chlorophyll
Cl^-	Chloride ion
Cl_2	Chlorine
ClO^-	Hypochlorite
ClO_3	Chlorate
cm	Centimeter
Co	Cobalt
CO_2	Carbon dioxide
CO_3	Carbon trioxide
Conc.	Concentration
Cr	Chromium
Cs	Cesium
Cu	Copper
D.W.	Distilled water
DPX	Di-N-Butyle Phthalate in Xylene
eg.	Example
EDTA	Ethylene Diamine Tetraacetic Acid
FAA	Formalin Acetic Acid
Fe	Iron
Fig.	Figure
g/l	Gram per liter
gm	Gram
H^+	Hydrogen ion
H_2O_2	Hydrogen peroxide
H_2SO_4	Sulphuric acid
H_3PO_4	Orthophosphoric acid

HCl	Hydrochloric acid
$HClO_4$	Perchloric acid
HCO_3	Bicarbonate
Hg	Mercury
HNO_3	Nitric acid
hr.	Hour
hrs.	Hours
ICMR	Indian Council of Medical Research
K	Potassium
$K_2Cr_2O_7$	Potassium Dichromate
KCl	Potassium Chloride
Kg	Kilogram
Kg/capita/day	Kilogram per capita per day
M	Molarity
MIPS	Microscopic Image Processing System
Mg	Magnesium
mg	Milligram
mg /l	Milligram per liter
mg/g or mg/gm	Milligram per gram
mg/kg	Milligram per kilogram
mm	Millimeter
Mn	Manganese
Mo	Molybdenum
N	Normality
Na	Sodium
NaCl	Sodium Chloride
NaOH	Sodium Hydroxide
NEERI	National Environmental Engineering Research Institute
Ni	Nickel
no.	Number
NPK	Nitrogen, Phosphorus, Potassium
OH^-	Hydroxide ion
P	Phosphate
Pb	Lead
pH	Negative logarithm to the base 10 of hydrogen ion concentration
ppm	Parts Per Million
S	Sulphur
Sq. Km	Square kilometer
t	Tons
U	Uranium
UK	United Kingdom
US	United States
USA	The United State of America
USEPA	United States Environmental Protection Agency
UV	Ultra violet

var.	Variety
Vol.	Volume
WHO	World Health Organization
WQI	Water Quality Index
Zn	Zinc



Chapter - 1

Introduction

Chapter 1

INTRODUCTION

Contents:

1.1 General Introduction:

Algae, the large and diverse group of simple, typically autotrophic organisms, ranging from unicellular to multicellular forms such as the giant kelp (large brown alga), that may grow up to 50 meters in length. Most are photosynthetic and "simple", because they lack many of the distinct cell organelles and cell types found in land plants. The largest and most complex marine forms are called seaweeds.

There is no clear consensus regarding definition of algae. One of the definition of algae is that "algae have chlorophyll-a as their primary photosynthetic pigment and lack a sterile covering of cells around their reproductive cells". Other authors exclude all prokaryotes and thus do not consider cyanobacteria (blue-green algae) as algae.

Algae constitute a polyphyletic group since they do not include a common ancestor, and although their plastids seem to have a single origin, from cyanobacteria, they were acquired in different ways. Green algae are examples of algae that have primary chloroplasts derived from endosymbiotic cyanobacteria. Diatoms are examples of algae with secondary chloroplasts derived from an endosymbiotic red alga.

Algae exhibit a wide range of reproductive strategies, from simple, asexual cell division to complex forms of sexual reproduction. Algae lack the various structures that characterize land plants, such as the phyllids (leaf-like structures)

of bryophytes, rhizoids in nonvascular plants, and the roots, leaves, and ther organs that are found in tracheophytes (vascular plants). Most are phototrophic, although some groups contain members that are mixotrophic, deriving energy both from photosynthesis and uptake of organic carbon either by osmotrophy, myzotrophy, or phagotrophy. Some unicellular species such as the green algae *Prototheca* W. Kruger, and *Helicosporidium* D. Keilin have become parasitic heterotrophs, relying entirely on external energy sources and have limited or no photosynthetic apparatus.

Algae have photosynthetic machinery ultimately derived from cyanobacteria that produce oxygen as a by-product of photosynthesis, unlike other photosynthetic bacteria such as purple and green sulfur bacteria. Fossilized filamentous algae from the Vindhya basin have been dated back to 1.6 to 1.7 billion years ago.

The singular alga is the Latin word for particular seaweed and retains that meaning in English. The etymology is obscure. Although some speculate that it is related to Latin algere, "be cold", there is no known reason to associate seaweed with temperature. A more likely source is alliga, "binding and entwining."

The Ancient Greek word for seaweed was fukos or phykos, which could mean either the seaweed (probably red algae) or a red dye derived from it. The Latinization, *Fucus* Linnaeus, meant primarily the cosmetic rouge. The etymology is uncertain, but a strong candidate has described that the word is related to the Biblical "paint" (if not that word itself), a cosmetic eye-shadow used by the ancient Egyptians and other inhabitants of the Eastern Mediterranean. It could be any colour black, red, green or blue.

Accordingly the modern study of marine and fresh water algae is called either phycology or algology, depending on whether the Greek or Latin root or word is

used. The name *Fucus* Linnaeus appears in a number of taxa. Most algae except cyanobacteria contain chloroplasts. Chloroplasts contain circular DNA and are similar in structure to cyanobacteria, presumably representing reduced cyanobacterial endosymbionts. The exact nature of the chloroplasts is different among separate lineages of algae, reflecting different endosymbiotic events.

Algae are the important part in the food web and provide shelter to other organisms. Thus, they are the major part in aquatic ecosystem. Algae grow in different habitat and in different location but it is generally cosmopolitan in distribution and grows almost everywhere in the World. They play a crucial role in the aquatic ecosystem to absorb nutrients, toxic material, heavy metals and convert it into simplest form. There is no easy definition of an alga. Algae are generally single celled to multi-cellular microscopic organism, and it is thought to be simple aquatic plants, which do not have roots, stems, or leaves and have primitive methods of reproduction. They fix the carbon dioxide from air and release valuable oxygen for the living organism. However, some algae display primitive animal features such as motility, while blue green algae differ markedly from plants and all other algae, in that they have a cellular structure and function that is more common to bacteria called cyanobacteria in the plant kingdom.

Algae live in a wide range of aquatic environments and are a natural component of the most aquatic ecosystems. They occures in the lentic (standing water) as well as lotic water (running water), many of them terrestrial which lives in soil and snow or in association with other organisms likes plants *Cycas* and *Anthoceros*, especially fungi (as lichens) and animals. Aquatic algae are found in both fresh and marine water, their range from large size (kelp) to those visible only under a microscope.

Some algae have an economic importance because they are the source of carotene, glycerol, and alginates and can be converted into a food source for aquaculture. They vary considerably in size, shape, and growth form. They can be single celled, either colonial or as filamentous cells. They prefer the habitat like free floating in the water column (Planktonic). This comprises the microscopic unicellular, colonial and filamentous forms known as "Phytoplankton", growing as films on rocks at the bottom (benthic). These may be single celled or small, colonial and filamentous species growing out into the water column but attached to a substrate at one point. These comprise the larger filamentous algae and macro algae (e.g. seaweeds).

The main groups of algae found in freshwater are green algae, diatoms, desmids, euglenoids, cyanophycean members like *Gloeocapsa* Kutzing, *Microcystis* Kutzing and Lemmermann, *Nostoc* Vaucher *ex* Bornet and Flahault, *Anabaena* Bory de Saint-Vincent ex Bornet and Flahault, *Spirulina* Turpin ex Gomont, *Rivularia* C. Agardh *ex* Bornet and Flahault, *Gloeotrichia* J. Agardh ex Bornet and Flahault, *Lingbya* C. Agardh *ex* Gomont, *Oscillatoria* Vaucher *ex* Gomont, *Scytonema* C. Agardh ex Bornet and Flahault, *Stigonema* C. Agardh ex Bornet and Flahault etc. Chlorophycean members like *Chlamydomonas* Ehrenberg, *Pandorina* Bory de Saint-Vincent, *Eudorina* Ehrenberg, *Pleodorina* Shaw, *Volvox* Linnaeus, *Chlorella* Beyerinck, *Pediastrum* Meyen, *Hydrodictyon* Roth, *Ulothrix* Kutzing, *Enteromorpha* Link, *Zygnema* C. Agardh, *Spirogyra* Link, *Mougeotia* C. Agardh, *Closterium* Nitzsch ex Ralfs, *Cosmarium* Corda ex Ralfs, etc. and Bacillariophycean members present like *Pinnularia* Ehrenberg, *Navicula* Bory de Saint-Vincent, and *Amphiplura* Kutzing etc.

Algae have been intimately connected directly or indirectly with human beings as a source of food, fodder and manure. Other countries of the world are actively engaged in exploring ways to exploit algae as a potent source of food to combat the

problem of rapidly growing world population and also as a possible source in space flight. Antibiotics like chlorellin are extracted from *Chlorella* Beyerinck. Chlorellin is a crystalline substance which decomposed by heating to 120^0C, from its chemical composition it would seem to be a mixture of fatty acids. Chlorellin is active against *Staphylococcus aureus* Rosenbach, a common organism that causes infections of wound and particularly useful in the purifying of sewage effluent. The presence of specific nutrients, heavy metals, toxic effluents, on that grow specific kind of algae. Hormones of the Auxins (IAA) have been found in the filtrate from the culture of *Chlorella* Beyerinck. The quotient hypothesis and some new or little known phytoplankton organisms.

In Hinganghat area, Vena river is a fresh water body. The water of river is mainly used for agriculture and in some extent for drinking purposes of wild animals and human beings. The study of the algal flora of this river is of great importance. An algal biodiversity can be known to the people and may be the heritage of future generation. Hence, it is a need of hour to know each and every thing of this plant world. For this cause, we have undertaken this investigation for our research study.

The Table 1.1 indicates the composition of the three major groups of algae. Many of those algal group and some members that are no longer photosynthetic. Some retain plastids, but not chloroplasts, while, others have lost plastids entirely. Phylogeny is based on plastid not nucleo-cytoplasmic genealogy.

Table 1.1 Composition of three major groups of Algae.

Super group affiliation	Members	Endosymbiont	Summary
Primoplantae/ Archaeplastida	• Chlorophyta • Rhodophyta • Glaucophyta	Cyanobacteria	These algae have primary chloroplast, i.e. the chloroplasts are surrounded by two membranes and probably developed through a single endosymbiotic event. The chloroplasts of red algae have chlorophylls a and c and phycobilins, while those of green algae have chloroplasts with chlorophyll a and b. Higher plants are pigmented similarly to green algae and probably developed from them, and thus, Chlorophyta is a sister taxon to the plants; sometimes they are grouped as Viridiplantae.

Excavata and Rhizaria	• Chlorarachniophytes • Euglenids	Green algae	These groups have green chloroplasts containing chlorophylls a and b. Their chloroplasts are surrounded by four and three membranes, respectively, and were probably retained from ingested green algae. **Chlorarachniophytes**, which belong to the phylum Cercozoa, contain a small nucleomorph, which is a relict of the algae's nucleus. **Euglenids**, which belongs to the phylum Euglenozoa, live primarily in freshwater and have chloroplasts with only three membranes. It has been suggested that the endosymbiotic green algae were acquired through myzocytosis rather than phagocytosis.
Chromista and Alveolata	• Heterokonts • Haptophyta • Cryptomonads • Dinoflagellates	Red algae	These groups have chloroplasts containing chlorophylls a and c, and phycobilins. The shape varies from plant to plant. They may be of discoid, plate-like, reticulate, cup-shaped, spiral or ribbon shaped. They have one or more pyrenoids to preserve protein and starch. The latter chlorophyll type is not known for existence in any

			prokaryotes or primary chloroplasts, but genetic similarities with red algae suggest a relationship there. In the first three of these groups (**Chromista**), the chloroplast has four membranes, retaining a nucleomorph in Cryptomonads, and they likely share a common pigmented ancestor, although other evidence casts doubt on whether the Heterokonts, Haptophyta, and Cryptomonads are in fact more closely related to each other than to other groups. The typical **Dinoflagellate** chloroplast has three membranes, but there is considerable diversity in chloroplasts within the group, and it appears there were a number of endosymbiotic events. The Apicomplexa, a group of closely related parasites, also have plastids called apicoplasts. Apicoplasts are not photosynthetic but appear to have a common origin with Dinoflagellate chloroplasts.

Harvey, W. H. (1811-1866) was the first to divide algae into four divisions based on their pigmentation. This is the first use of a biochemical criterion in plant systematics. Harvey's four divisions were red algae (Rhodophyta), brown algae (Heteromontophyta), green algae (Chlorophyta) and Diatomaceae.

The first plants on earth probably evolved from shallow fresh water algae much like *Chara* Linnaeus almost 500 million years ago. These probably had an isomorphic alternation of generations and were probably filamentous. Fossils of isolated land plant spores suggest that land plants may have come into existence around 475 million years ago.

A range of algal morphologies were exhibited, and convergences of features in unrelated groups were common. The only groups to exhibit three-dimensional multicellular thalli were the reds and browns, and some chlorophytes. Apical growth were constrained to subsets of these groups: the florideophyte reds, various browns, and the charophytes. The form of charophytes were quite different from those of reds and browns, because they have distinct nodes, separated by internode on stem and whorls of branches reminiscent of the horsetails occur at the nodes. Conceptacles were another polyphyletic trait; they appear in the coralline algae and the Hildenbrandiales as well as the browns.

Most of the simpler algae are unicellular flagellates or amoeboids, but colonial and non-motile forms have developed independently among several of the groups. Some of the more common organizational levels, more than one of which may occur in the life cycle of a species, are

- Colonial: small, regular groups of motile cells.
- Capsoid: individual non-motile cells embedded in mucilage.

- Coccoid: individual non-motile cells with cell walls.
- Palmelloid: non-motile cells embedded in mucilage.
- Filamentous: a string of non-motile cells connected together, sometimes branching.
- Parenchymatous: cells forming a thallus with partial differentiation of tissues.

In three lines even higher levels of organization have been reached, with full tissue differentiation. These are the brown algae, some of which may reach 50 m in length (kelps), the red algae, and the green algae. The most complex forms are found among the green algae (Charales and Charophyta), in a lineage that eventually led to the higher land plants. The point where these non-algal plants begin and algae stop is usually taken to be the presence of reproductive organs with protective cell layers, a characteristic not found in the other alga groups.

Many algae, particularly members of the Characeae, have served as model experimental organisms to understand the mechanisms of the water permeability of membranes, osmoregulation, turgor regulation, salt tolerance, cytoplasmic streaming, and the generation of action potentials. Phytohormones are found not only in higher plants, but in algae too.

Some species of algae form symbiotic relationships with other organisms. In these symbioses, the algae supply photosynthatates (organic substances) to the host organism and in return plant provides protection to the algal cells. The host organism derives some or all of its energy requirements from the algae.

Lichens are defined by the International Association for Lichenology to be "an association of a fungus and a photosynthetic symbiont resulting in a stable vegetative body having a specific structure". The fungi, or mycobionts, are from the Ascomycota with a few from the Basidiomycota. They are not found alone in nature

but when they began to associate is not known. One mycobiont associates with the same phycobiont species, rarely two, from the green algae, except that alternatively the mycobiont may associate with the same species of cyanobacteria (hence "photobiont" is the more accurate term).

A photobiont may be associated with many specific mycobionts or live independently; accordingly, lichens are named and classified as fungal species. The association is termed a morphogenesis because the lichen has a form and capabilities not possessed by the symbiont species alone (they can be experimentally isolated). It is possible that the photobiont triggers otherwise latent genes in the mycobiont. Coral reefs are accumulated from the calcareous exoskeletons of marine invertebrates of the order Scleractinia (stony corals).

As animals, they metabolize sugar and oxygen to obtain energy for their cell-building processes, including secretion of the exoskeleton, with water and carbon dioxide as byproducts. As the reef is the result of a favorable equilibrium between construction by the corals and destruction by marine erosion, the rate at which metabolism can proceed determines the growth or deterioration of the reef.

Dinoflagellates (algal protists) are often endosymbionts in the cells of marine invertebrates, where they accelerate host-cell metabolism by generating immediately available sugar and oxygen through photosynthesis using incident light and the carbon dioxide produced by the host. Stony corals that are reef-building corals (hermatypic corals) require endosymbiotic algae from the genus *Symbiodinium* Freudenthal to be in a healthy condition. The loss of *Symbiodinium* Freudenthal from the host is known as coral bleaching, a condition which leads to the deterioration of a reef.

Green algae live close to the surface of some sponges, for example, breadcrumb sponge (*Halichondria panicea* Pallas). The alga is thus protected from predators; the sponge is provided with oxygen and sugars which can account for 50 to 80% of sponge growth in some species.

Rhodophyta, Chlorophyta and Heterokontophyta, the three main algal phyla, have life-cycles which show tremendous variation with considerable complexity. In general, there is an asexual phase where the seaweed's cells are diploid and a sexual phase where the cells are haploid where fusion of the male and female gametes takes place. Asexual reproduction is advantageous in that it permits efficient population increase, but less variation is possible. Sexual reproduction allows more variation, but is more costly. Often there is no strict alternation between the sporophyte and also because there is often an asexual phase, which could include the fragmentation of the thallus.

The Algal collection of the US National Herbarium (located in the National Museum of Natural History) consists of approximately 3,20,500 dried specimens, which, although not exhaustive (no exhaustive collection exists), gives an idea of the order of magnitude of the number of algal species (that number remains unknown). Estimates vary widely. For example, according to one standard textbook, in the British Isles the UK Biodiversity Steering Group Report estimated that there are 20,000 algal species in the UK. Another checklist reports only about 5000 species. Regarding the difference of about 15,000 species, the text concludes: "It will require many detailed field surveys before it is possible to provide a reliable estimate of the total number of species."

Regional and group estimates have identified 5000–5500 species of red algae worldwide, some 1300 in Australian Seas, 400 seaweed species for the western coastline of South Africa, and 212 species from the coast of KwaZulu-Natal. Some of these are

duplicates as the range extends across both coasts, and the total recorded is probably about 500 species. Most of these are listed in List of seaweeds of South Africa. These exclude phytoplankton and crustose corallines. 669 marine species from California (US), 642 in the check-list of Britain and Ireland and so on, but lacking any scientific basis or reliable sources, these numbers have no more credibility than the British ones mentioned above. Most estimates also omit microscopic algae, such as phytoplankton. The most recent estimate suggests a total number of 72,500 algal species worldwide.

The topic of distribution of algal species has been fairly well studied since the founding of phytogeography in the mid nineteenth century AD. Algae spread mainly by the dispersal of spores analogously to the dispersal of Plantae by seeds and spores. Spores are everywhere in all parts of the Earth in the waters fresh and marine in the atmosphere, free-floating and in precipitation or mixed with dust, the humus and in other organisms, such as humans. Whether a spore is to grow into an organism depends on the combination of the species and the environmental conditions of where the spore lands.

The spores of fresh-water algae are dispersed mainly by running water and wind, as well as by living carriers. The bodies of water into which they are transported are chemically selective. Marine spores are spread by currents. Ocean water is temperature selective, resulting in phytogeographic zones, regions and provinces.

To some degree the distribution of algae is subject to floristic discontinuities caused by geographical features, such as Antarctica, long distances of ocean or general land masses. It is therefore, possible to identify species occurring by locality, such as "Pacific Algae" or "North Sea Algae". When they occur out of their localities, it is usually possible to hypothesize a transport mechanism, such as the hulls of ships. For

example, *Ulva reticulata* Forsskal and *Ulva fasciata* Deliele travelled from the mainland to Hawaii in this manner.

Mapping is possible for select species only: "there are many valid examples of confined distribution patterns." For example, *Clathromorphum* Foslie is an arctic genus. On the other hand, scientists regarded overall data as insufficient due to the "difficulties of undertaking such studies."

Algae are prominent in bodies of water, common in terrestrial environments and are found in unusual environments, such as on snow and on ice. Seaweeds grow mostly in shallow marine waters, under 100 metres (330 ft); however some have been recorded to a depth of 360 meters (1,180 ft).

The various sorts of algae play significant roles in aquatic ecology. Microscopic forms that live suspended in the water column (phytoplankton) provide the food base for most marine food chains. In very high densities (algal blooms), these algae may discolour the water and outcompete, poison, or asphyxiate other life forms.

Algae are variously sensitive to different factors, which has made them useful as biological indicators in the Ballantine Scale and its modification. In Classical Chinese, the word is used both for "algae" and (in the modest tradition of the imperial scholars) for "literary talent". The third island in Kunming Lake beside the Summer Palace in Beijing is known as the Zaojian Tang Dao which thus simultaneously means "Island of the Algae-Viewing Hall" and "Island of the Hall for Reflecting on Literary Talent".

Agar, a gelatinous substance derived from red algae, has a number of commercial uses. It is a good medium on which to grow bacteria and fungi as most microorganisms cannot digest agar. Between 1,00,000 and 1,70,000 wet tons

of *Macrocystis* C. Agardh are harvested annually in New Mexico for alginate extraction and abalone feed.

To be competitive and independent from fluctuating support from (local) policy on the long run, bio fuels should equal or beat the cost level of fossil fuels. Here, algae based fuels hold great promise, directly related to the potential to produce more biomass per unit area in a year than any other form of biomass. The break-even point for algae-based biofuels is estimated to occur by 2025.

For centuries, seaweed has been used as a fertilizer; George Owen of Henllys writing in the sixteenth century refers to drift weed in South Wales being used as fertilizers. This kind of ore they often gather and lay on great heapes, where it heteth and rotteth, and will have a strong and loathsome smell; when being so rotten they cast on the land, as they do their muck, and thereof springeth good corn, especially barley. After spring-tides or great rigs of the sea, they fetch it in sacks on horse backs, and carry the same three, four, or five miles, and cast it on the lands, which do the very much better the ground for corn and grass.

Today, algae are used by humans in many ways; for example, as fertilizers, soil conditioners and livestock feed. Aquatic and microscopic species are cultured in clear tanks or ponds and are either harvested or used to treat effluents pumped through the ponds. Algaculture on a large scale is an important type of aquaculture in some places. Maerl is commonly used as a soil conditioner.

Naturally growing seaweeds are an important source of food, especially in Asia. They provide many vitamins including: A, B_1, B_2, B_6, niacin and C, and are rich in iodine, potassium, iron, magnesium and calcium. In addition, commercially cultivated microalgae, including both algae and cyanobacteria are marketed as nutritional

supplements, such as *Spirulina* Turpin ex Gomont, *Chlorella* Beyerinck and the Vitamin-C supplement, *Dunaliella* Teodoresco high in beta-carotene.

Algae are national foods of many nations. China consumes more than 70 species, including *Nostoc flagelliforme* Born. *et* Flah, a cyanobacterium commonly known as *fat choy*, considered a vegetable. The Japan had over 20 species; Ireland consumes dulse; Chile, Cochayuyo. Laver is used to make "laver bread" in Wales, where it is known as *bara lawr.* In Korea, gim; in Japan, nori and aonori. It is also used along the west coast of North America from California to British Columbia, in Hawaii and by the Maori of New Zealand. Sea lettuce and badderlocks are a salad ingredient in Scotland, Ireland, Greenland and Iceland.

The oils from some algae have high levels of unsaturated fatty acids. For example, *Parietochloris incisa* (H.Reisigl) S.Watanabe is very high in arachidonic acid, where it reaches up to 47% of the triglyceride pool. Some varieties of algae favoured by vegetarianism and veganism contain the long-chain, essential omega-3 fatty acids, Docosahexaenoic acid (DHA) and Eicosapentaenoic acid (EPA). Fish oil contains the omega-3 fatty acids, but the original source is algae (microalgae in particular), which are eaten by marine life such as copepods and are passed up the food chain. Algae has emerged in recent years as a popular source of omega-3 fatty acids for vegetarians who cannot get long-chain EPA and DHA from other vegetarian sources such as flaxseed oil, which only contains the short-chain Alpha-Linolenic acid (ALA).

Sewage can be treated with algae, reducing the usage of large amounts of toxic chemicals that would otherwise be needed. Algae can be used to capture fertilizers in water runoff from farms. When subsequently harvested, the enriched algae itself can be

used as fertilizer. Aquariums and ponds can be filtered using algae, which absorb nutrients from the water in a device called an algae scrubber, also known as an "ATS)".

Agricultural Research Service scientists found that 60-90% of nitrogen runoff and 70-100% of phosphorus runoff can be captured from manure effluents using a horizontal algae scrubber also called an algal turf scrubber (ATS). Scientists developed the ATS, which are shallow and formed on 100-foot raceways of nylon netting and can be studied for three years for its efficacy. They found that algae can readily be used to reduce the nutrient runoff from agricultural fields and increase the quality of water flowing into rivers, streams, and oceans. The enriched algae itself also can be used as a fertilizer. Researchers collected and dried the nutrient-rich algae from the ATS and studied its potential as an organic fertilizer. They found that cucumber and corn seedlings grew just as well using ATS organic fertilizer as they did with commercial fertilizers. Algae scrubbers, using bubbling upflow or vertical waterfall versions, are now also being used to filter aquariums and ponds.

The algae *Stichococcus bacillaris* Nageli, has been seen to colonize silcone resins used at archaeological sites; biodeterriorating the synthetic substance. The natural pigments produced by algae can be used as an alternative to chemical dyes and colouring agents. Carrageenan, from the red alga *Chondrus crispus* Stackhouse, is used as a stabilizer in milk products.

Algae are major producer of organic compound. It has an important position in aquatic food chain, since algae indicate the levels of position in water bodies as bioindicator and it also helps to determine the quality and conservation of water (Palmer, 1980) but not much attention has been paid with reference to their occurrence and distribution in different lotic and lentic water bodies.

India is a land of many rivers. Vena is one of the prominent river of Vidarbha, Maharashtra. It is supposed to be the life line of the Wardha district, but due to expanding needs of growing population, river Vena is facing many adversities or changes. The river Vena has received little attention from botanists, ecologists and specially phycologist as such and moreover, the scientific approach was not holistic. Even in dealing with the floristic pattern, habitats of various algal groups were overlooked.

Algae play an important role to purify the water by photosynthesis. In other words it helps in the process of rejuvenation of rivers (Sharma, 2005). However, industrialization has also posed threat to water quality by effluent discharge and sewage disposed in rivers. This has led to eutrophication of rivers and change in ecosystem of rivers. In the present study, exploration of Algal flora from different sites of Vena river in Hinganghat, Wardha, was studied and the biodiversity was measured.

Hinganghat in Wardha district do not have local bodies. Sewage is discharge into Vena River without any treatment. Similarly, the sewage of effluents of several cotton mills is discharged into Vena river without any treatment.

The main objectives of the present investigation is to gather the information reported by researcher in past. The occurrence of large number of algae in different parts of Maharashtra has been reported by various authors and this scientific knowledge is the result of many years of investigation. Algae occurs in sufficient quantities to render its commercial applications, it has been investigated by Marathe, (1969) and Jawale and Chaudhari, (2010).

Heavy metals i.e. macro and micro elements influence the algal growth. Fresh water unicellular and multicellular algae found in almost all aquatic habitats. A few of

them grow on rocks or on banks of river or in water bodies of Vena River. Some are found near the trees which are present Vena river side and they grow on bark of trees.

Water and life have an inseparable relationship and are considered as two sides of a coin. As such water quality plays an important role in the growth of aquatic animals and their distributions, abundance and fluctuations in optimum level of water quality may lead to abrupt changes in the aquatic life.

Vena river in Hinganghat is perennial river of this area. The lotic ecosystem of Vena river is polluted with several cotton mills like Gima Text, Daga Mills, Pee Vee Textile mills, Suguna Oil Industries, Sugar factory etc.

Most of algae found in Vena river are rather free floating or attached in tufts or mats to the substratum, but a few may be epiphytic in natural habitats. Algae obtain all the nutrient minerals or vitamins they require from the water in which they live, but they need proper supply of raw materials or nutrients for their successful growth in the culture medium. Nutrients are essential for the growth. The macro nutrients are used generally as building materials, whereas the micro nutrients are commonly metal constituents of enzymes which enter into biological reactions. (McElory and Nason, 1954). Environmental factors such as temperature, Oxygen and osmotic concentration, play important role in the cultivation of phytoplanktons. The most important elements needed by algae are carbon, oxygen, nitrogen, hydrogen, sulphur, phosphorous, potassium, calcium, magnesium and iron.

Water is one of most important requirement of all living beings for performing essential life functions. But with the rapid growth of industries in the country, pollution in natural water by industrial wastes has increased tremendously. Contamination of environment with heavy metals threatens the existence of terrestrial and aquatic

organism. Pollution by heavy metals can be a much more serious problem than pollution by organic substances, because they cannot be degraded by natural process and persist in sediments from where they are released gradually into water. Many heavy metals are in traces and essential for various metabolic processes because, they act as a cofactors and play important activities of different enzymes (Van Assche and Clijsters, 1990). At higher concentration they became toxic due to creation of physiological stress conditions.

Out of 105 known elements, 83 are metals, most of these metals occur in small or trace amounts in water, of these 68 metals have atomic numbers greater than 23 except rubidium, strontium, cesium, barium and francium. Environmental pollution by heavy metals was instantly recognized with, 'Minimata' disease in Japan in 1963. 500 death occured in 1971-72 due to methyl mercury poisoning and 'Itai-Itai Byo', disease developed in Japan in 1955 due to cadmium. They have the unique property of accumulaton over period of time, along a food chain and very high level can be accumulated in organism from a very low concentration in water and sediments.

Water and life have an inseparable relationship and are considered as two sides of coin. As such water quality plays an important role in the growth of aquatic animals and their distribution and abundance. Fluctuations in optimum level of water quality may be lead to abrupt changes in the aquatic lives.

Many reports are available in India on the water quality assessment of lotic ecosystems (Arora *et al.*,1973; Chandra and Mathur, 1983, 2000; Sawane, 2002, and Dahegaonkar, 2008).

1.2 Physico - Chemical Parameters:

The physico-chemical parameters were studied in the upstream of the river Vena of Hinganghat locality and downstream of Vena river Parameters analysed during the study were water temperature (^{0}C), total dissolved solids (mg/l), dissolved oxygen (mg/l), free CO_2 (mg/l), alkalinity (mg/l), pH, total hardness (mg/l), Nitrate (mg/l) and Phosphate (mg/l). The time taken for study was of two years i.e. June 2011 to May 2013.

Hair forming members of the Chaetophorales were wide spread in nature, and *Stigeoclonium* Kutzing in particular has considerable potential both as monitor and bioassay organism (De Vries *et al.*, 1983). Almost all earlier studies of hair development in Chaetophorales was more extensive during culture at low rather than high concentration of nitrate. Hairs occur in taxonomically diverse algae and among eukaryotes they are especially wide spread in the Chaetophoraceae. Colourless hairs arise at the end of branches or occasionally at the end of main axis, the development of hairs cell involves the loss of chloroplast and cellular contents through the cell which otherwise appear healthy (Gibson and Whitton, 1987).

An experimental study of Eleven strains of *Stigeoclonium tenue* Kuetz and one of *Chaetophora incrassata* Hudson, Hazen reported that, all responded to nitrogen deficiency by forming hairs, but that overall effect was ever more marked under conditions of phosphorus deficiency. In most strains ferrous deficiency also led to marked hair formation, but other element deficiencies led to only very slight hair formation or no hairs at all (Whitton and Harding, 1987). In the Chaetophoraceae such reports have been given for various species of *Draparnaldia,* and *Stigeoclonium* (Uspenskaya, 1930, 1936; Sumalainen, 1933, and Tupa, 1974).

The present studies were of several different approaches and were used to explain why hairs were formed in Chaetophoraceae and what, if a functional significance they have. Hairs occurs in particular types of environment and to what extent the hair formation with some other morphological and physiological features in *Stigeoclonium stagnatile* Hazen, F.S. Collins were recorded in this study.

A more detailed experimental study on strains of the same genera confirmed that hair development was much greater under condition of phosphorus limitation than nitrogen limitation (Gibson and Whitton, 1987). Cultures with hairs formed a response to phosphorus limitation showed marked phosphates activity.

Algae are frequently found in polluted and unpolluted water and due to this behavior they are generally considered as indicators to determine the quality of water because water is essential for life. The main reason for water contamination came from urbanization and industrialization. Contamination is more in rural areas, where the water sources like dam, canal and river are not available and hence the ground water is being continuously explored for agricultural purposes. As per current analysis, it was realized that, the ground water gets polluted drastically because of increased human activities that facilitates the water borne diseases seems to cause lot of health problems.

Therefore, the basic concentration is needed to monitor the quality of water as well as to find out various sources which increases ground water pollution. The present study was basically focused to examine the water quality of various potable water sources specially, ground water at Hinganghat. During experimentation, Physico-chemical parameters of water were tested to ensure good quality of water. But chemical analysis of water provides a good indication of the chemical quality of the aquatic systems, but do not integrate ecological factors such as altered riparian vegetation or

altered flow regime and therefore, do not necessarily reflect the ecological state of the system (Karr *et al.,* 2000).

Water is the basic natural resources required by all living beings and by the modern technological societies in which they live. Water pollution is the natural or induced change in the quality of water which renders it unusable or dangerous as regards food, human and animal health, industry, agriculture microorganisms, and fishing or leisure pursuits. Industrial growth has made polluted soil, air and water.

The wastewater generated by industrial units is discharged into nearby water bodies. This water is consumed by humans for their activities, animals also drink this polluted water and affects their normal activities, causing harmful diseases and sometimes death also occur in the local areas.

In Hinganghat city, various textile industries are located to produce their product. They are engaged in various manufacturing and processing process related to ginning, pressing, making of cloths etc. They are drastically affecting the living biota. The industrial pollution, especially from the textile industries, is creating a high-risk environment due to the nature of pollutants released from these industries. These units discharged volumes of wastewater in water bodies of Vena River. Humans and animals around these units consume the wastewater. This polluted water may responsible for death of cattle and other animals due to toxic content in the effluents. This water also used for irrigation of agricultural fields of the local area.

By considering the above fact, we have to evaluate the physico-chemical properties of such polluted water and determine the Water Quality Index (WQI) of the various sites. They contains some amount of harmful chemicals and heavy metals, such water are also used for irrigation, However, it is also necessary to assess the soil

properties of the agriculture fields.

1.2.1 Temperature :

Temperature is one of the moist important factors in aquatic environment. It influences the rate of biochemical reaction; amount of oxygen dissolved or suspended in the water columns, also influences the growth of algae (Horne, A.J.N. and Goldman, C. R, 1994). Temperature of water in water supply plant is usually low. At the organism level, excessive temperature may be the cause of death, but at lower ranges may influences movement and behavior. The rate of biochemical reactions that use oxygen increases with increasing temperature. According to Rana and Palaria, (1988) high organic contents leads to oxygen depletion. Low oxygen content during monsoon might be due to higher growth of bacteria, which utilized oxygen for their metabolic activities (Pandey *et al.,* 2000). Relatively higher values of DO during winter might be due to increased solubility of oxygen at lower temperature (Sabata and Nayar, 1995).

1.2.2 Hydrogen Ion Concentration:

Hydrogen ion concentration is the master variables in the chemistry of aquatic ecosystem and it strongly influences the kinetics of nutrients uptake and control the chemical species of the ions utilized by algae (Tilman *et al.,* 1982). pH measures the concentration of hydrogen ion in water. The concentration range suitable for the oxidation of most biological life is quite narrow and critical. It also depends upon the relative quantities of calcium carbonates and bicarbonates. The water tends to be more alkaline when it possesses carbonates or it is much less alkaline, when it possesses large quantities carbonates, bicarbonates and calcium.

1.2.3 Dissolved Oxygen:

Dissolved oxygen is required for the respiration of aerobic microorganisms as well as all other aerobic life forms. As the inhabitants of land are concerned about quantity of oxygen present in the air, aquatic organisms are also dependent on oxygen dissolved in water. The oxygen in water can be dissolved from air or is produced by photosynthetic organisms like algae and aquatic plants. Oxygen is poorly soluble gas in water and its solubility depends on temperature of water and its partial pressure. The solubility of oxygen also decreases with increasing salinity of water.

It has been estimated that solubility of dissolved oxygen in fresh water ranges from 14.6 mg/l at $0^{o}C$ to about 7 mg/l at 35°C under 1 atm of pressure. Solubility also decreases with increasing salt concentration of water. Low solubility of water limits its self purification capacity. Addition to oxygen demanding wastes consumes the dissolved oxygen present in water. Some inorganic substances such as hydrogen sulphide, ammonia, and other oxidizable substances also tend to decrease dissolved oxygen. The organisms in water require a particular concentration of dissolved oxygen. Game fish requires at least 5 mg/l, while coarse fish can survive at as low as 2 mg/l. Oxygen also imparts freshness and taste to water.

Measurement of dissolved oxygen is a primary parameter in all pollution studies. It indicates whether processes going on in a system are aerobic or anaerobic. In wastewater treatment plants, it indicates the efficiency and performance. It is essential to measure dissolved oxygen in all ecosystems used for fisheries. Thus, the analysis of dissolved oxygen is a key test for water pollution control.

1.2.4 Free Carbon Dioxide:

Free carbon dioxide dissolved in water is the source of carbon assimilated and

incorporated into the living matter of all the aquatic autotrophs (Hutchinson, 1957). Once fixed by the autotrophs, other organisms at higher tropic level can further utilize it. The free CO_2 is directly proportional to bicarbonates and indirectly to carbonates. Water becomes more acidic between pH 0.0-6.35. In presence of bicarbonates, pH becomes alkaline in between 6.35, and 10.33 in presence of carbonates.

1.2.5 Alkalinity:

Total alkalinity is a measure of the amount of alkaline materials in the water. The alkaline materials act as buffers to changes in the pH. Alkalinity in water is due to the presence of the hydroxides, carbonates, and bicarbonates of elements such as calcium, magnesium, sodium, and potassium. In this, calcium, magnesium, and bicarbonates were most common. The concentration of alkalinity in water is important where chemical treatment is to be used and where ammonia is to be removed by air stripping.

1.2.6 Hardness:

Hardness is commonly understood as property of water, which prevent the lather formation with soap. Water is considered "hard" if its Calcium hardness is over 250 mg/l and its alkalinity is over 150 mg/l. Water is considered "soft", if it's hardness at less than 50 mg/land an alkalinity of less than 30 mg/l. Though, hardness is primarily caused by calcium and magnesium but any alkaline earth metal may contribute to hardness. In water iron, chromium, manganese, carbonates, bicarbonates, sulphates, nitrates and silicates may contribute to hardness. Hardness may be temporary, caused by carbonate and bicarbonates ion, it may be removed just by boiling the water. The permanent hardness caused mainly by chlorides and sulphate of the metals. Hardness below 300 mg/l is considered potable but beyond this limit produced gastrointestinal

irritation (ICMR-1975).

1.2.6.1 Calcium:

Calcium is essential for all organisms and regulates various physiological functions. It is commonly present in all water bodies and is essential for cell wall as well as enzyme activity in photosysnthesis of phytoplanktons. Its small concentration is sufficient for planktonic growth. An alga also requires small quantity of calcium. At higher pH, it precipitates as $CaCO_3$, its concentration depends on the kinds of water pollution.

1.2.6.2 Magnesium:

Magnesium is required by the flora to build chlorophyll (Wetzel, 1975) and in enzymatic transformation especially transphorylations in algae, fungi, and bacteria. The depletion of magnesium acts as a limiting factor for the growth of phytoplankton. Magnesium is generally present in water as mostly calcium bicarbonate in reaction with water.

1.2.7 Sulphate:

Sulphate is an important element and is required in protein synthesis. The sulphate ion occurs naturally in all waters and is also present in sewage and industrial waste. It is released as a result of decomposition of protein. Sulphides are the first products of organic matter decomposition. It produces objectionable odours. Presence of high quality of sulphides is indicative of organic pollution. The depletion of sulphate can inhibit the development of population and reduced production of phytoplankton. In weathering process gypsum (Calcium sulphate) is dissolved and sulphide minerals are partly oxidized giving rise to a soluble form of sulphate that is carried away by water.

Ingestion of water contamination, high concentration of sulphate can have alaxative effect which is enhanced when sulphate is consumed in combination with magnesium. Water containing magnesium sulphate at level about 1000 mg/l act as a purgative in human adults. Sulphate cause scaling in water supplies and problems of odour and corrosion in waste water treatment due to its reduction to H_2S.

1.2.8 Nitrates:

Nitrogen occurs in natural water in elemental state as organic as well as inorganic nitrogenous compounds. Nitrogen is one of the most important parameters in studies of pollution. It is an essential element for all living being. Adequate levels of nitrogen are also required in biological wastewater treatment processes. Nitrogen is considered as an important pollutant and should be removed from wastewater prior to discharge. Its role is causing eutrophication when a wastewater containing organic waste is discharged to a freshwater body. It contains nitrogen bound in the organic forms and released as ammonia after decomposition. Ammonia is usually converted to nitrates. Maximum concentration of ammonia in any water is inductive of water pollution. Concentration above 45 mg/l can cause Methamaglobinemia (blue-baby disease) in children. Natural waters in India (including polluted water) have been founded to have nitrates concentration ranging from traces to 20 mg/l. Nitrogen in water is also known as organic nitrogen.

1.2.9 Phosphorus:

Phosphorus in water may be present in inorganic (H_2PO_4 , HPO_4 , HPO_4^{-2}, PO_4^{-3}) or organic forms. Phosphorus from the rocks cannot be early dissolved to natural water bodies and thus, most of the natural water bodies are deficient in phosphorus content, as it restricts the algal growth. However, various activities of man including disposal of

sewage, household, and industrial waste greatly enhance phosphorus content of freshwaters. Phosphorus containing detergent has been found to be particularly responsible for increased level of phosphorus in natural water bodies all over the world. Sewage may contain phosphorus up to 15 mg/l, while industrial wastes may have a concentration even higher than that. According to USEPA, the phosphorus concentration should not exceed 50 mg/l in any tributary to river or a lake and 25 mg/l within main water resources.

The present object was exploring the ecophysiological study of fresh water algae found in Vena river of Hinganghat region of Wardha district. These algae were interesting ecological group of remarkable diversity. The growth and activity of these algae in response to physical, chemical and biological factors of the environment were studied. Physical factors include temperature, light, pH, and aeration. Availability of suitable substrates, and nutrients was the most important single chemical factor. Though, the occurrence of toxic substances, recalcitrant molecules, and heavy metals in the aquatic environment were affects the life of these algae. Biological factors include a range of complex interactions, which affects or modify the activity of these algae directly or indirectly.

Although the ecophysiological study of fresh water algae deals with exploration of new forms. These studies becames more important when important algal flora was identified which was very abundant in Vena river. This ecophysiological study became the major tool for any research undertaken for genomic study. The ecophysiological study of fresh water algae was important because it's varies with varying nature of climate in India and state of Maharashtra. The studies were explored some more specialized algal flora.

In view of the above, the present study was undertaken to explore the Vena River of Wardha district specially Hinganghat region. This region is adorned with rich aquatic vegetation flourishing under diverse ecological niches and stand as a paradise for algal growth. The Vena River of Wardha district is however almost unexplored and untouched as for as fresh water algae are concerned, therefore the increasingly new forms offer opportunities for workers for their studies. The present work was attempted for collection and identification of various fresh water algae. It initiated the efforts to understand the algal diversity. In considering these problems, the present investigation was undertaken for ecophysiological studies on fresh water algal samples from the Vena river in Hinganghat area.

1.3. Area of study:

Hinganghat is one of the tehsils of Wardha District situated in $20^0 18'$ to $20^0 49'$ N and $78^0 32'$ to $79^0 14'$ E latitude. The town is located on the bank of river Vena, a tributary of the Wardha river which joins the big river Pranhita ahead at a distance place, which ultimately merges into the Godavari river later. In British India, Hinganghat was the centre of India, but after the partition of Hindusthan into India and Pakistan, Nagpur is considered as the center (heart place) of India. At Vena river pump house, there is a historical old stone, on which it was mentioned that Hinganghat is the centre of India.

Major portion of the total annual rainfall is received from the month of June to September of every year. The average rainfall of Hinganghat Tahsil is 1071.70 mm and has a dry tropical weather climate. The climate is hot and dry. Max. temp. in ^{0}C were noted as 47.9 ^{0}C and Min. temp. in ^{0}C were noted as 10.2 ^{0}C. The seasons of a year were divided according climates into three namely cold, hot and monsoon.

Wardha District has a typical seasonal monsoon, where people are engaged in agriculture. Hinganghat city lies in the south east of Wardha District. Its South East border touches Chandrapur District and South west border touches to Yeotmal District. The land scape of the city faces towards the south. There are fast running streams and Vena River borders the north, west and south sides of the city. The city is rich in fauna and flora and water sources.

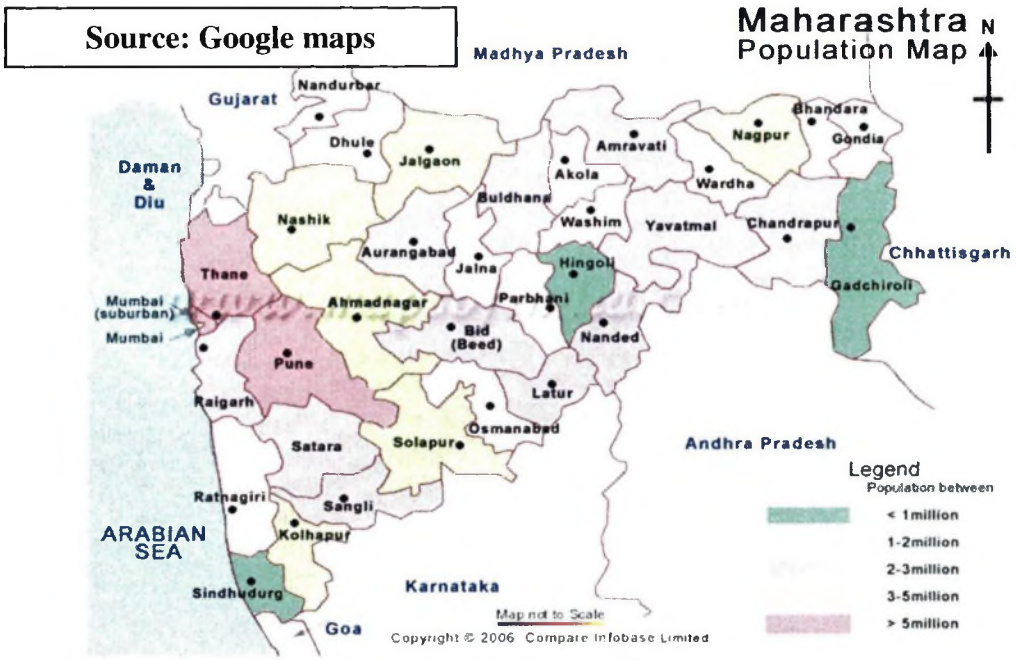


Fig. 1.1 Area of Study: Map of Maharashtra state.

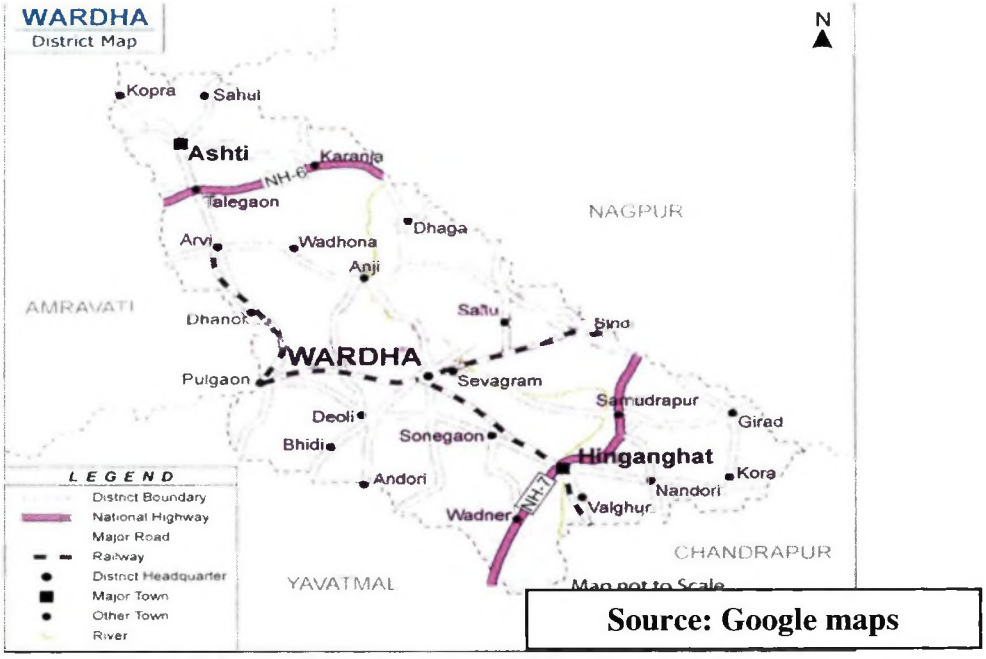
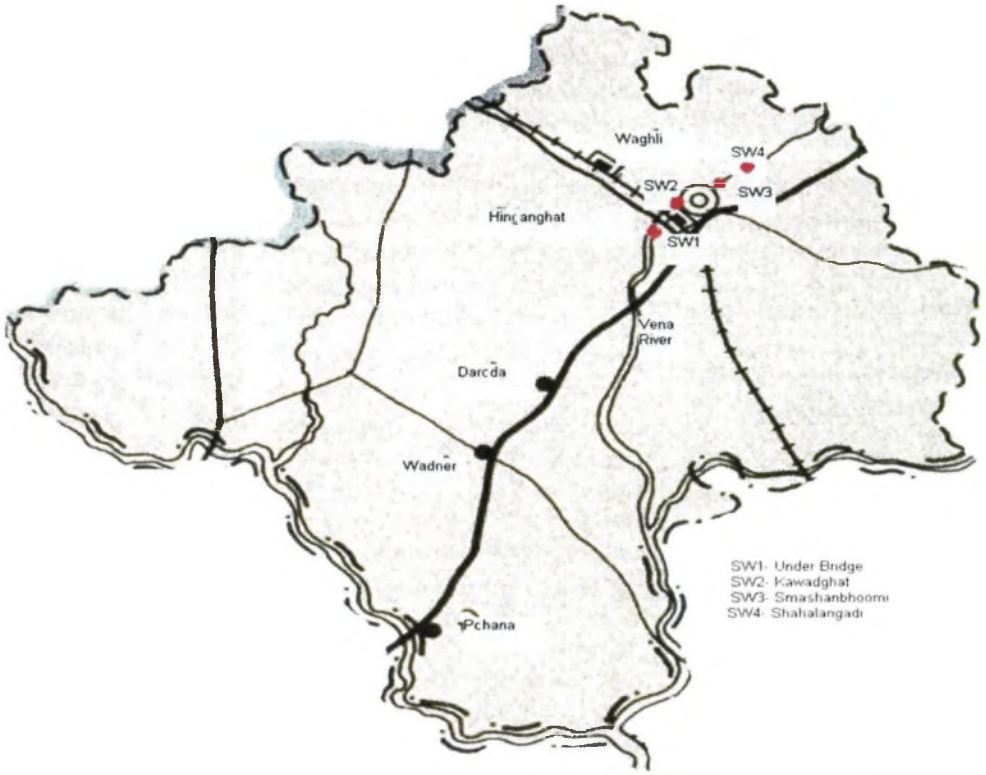


Fig. 1.2 Area of Study: Map of Wardha district.



Source: Google maps

Fig. 1.3 Area of Study: Map of Hinganghat Tahsil showing study area.

Source: Google maps

Fig. 1.4 Area of Study: Map of Hinganghat showing study area.

1.4. Objectives of the Present Investigation:

The main objectives of the present investigation are:

1. To gather information regarding the diversity of freshwater algae in the Vena river of Hinganghat area of Wardha district up to the species level.
2. To evaluate the seasonal and spatial variation of algal flora.
3. To compare the physico-chemical aspects of water in relation to the diversity of algae of the Vena river of Hinganghat area of Wardha district.
4. To analyze the effect of various nutrients on the growth of algae of the area studied.

1.5. Significance of the Present Investigation:

The freshwater biodiversity of Vidarbha region received very little attention from the researchers, planners and policy makers. The freshwater habitats in Vidarbha region are under severe stress due to anthropogenic interventions like deforestation, sand and clay mining, monoculture plantations and intensive agriculture. The freshwater biodiversity of Vidarbha region is not well documented and the rate of possible biodiversity loss is not yet quantified in Vidarbha region. There is no work done either on taxonomic account of algae or on the quantitative account of plankton present in the Vena river in Hinganghat area of Wardha district and hence the present work was undertaken.

The species composition and distribution of algal flora would give more information regarding the species richness of Vidarbha. A perusal of the existing literature reveals that very few limnological investigations related to algal biodiversity had been done in Wardha district. Practically no work has been done on the taxonomy,

species diversity, seasonal and spatial variation of algae in the Vena river in Hinganghat area of Wardha district. The quantitative estimation of phytoplankton and hydrographic parameters of the present study would highlight the present status of algal diversity of Vena river and the probable involvement of phytoplankton to the total organic production in Vena river in Hinganghat area. The present study therefore will undoubtedly furnish valuable information on the algal flora of Vidarbha region.

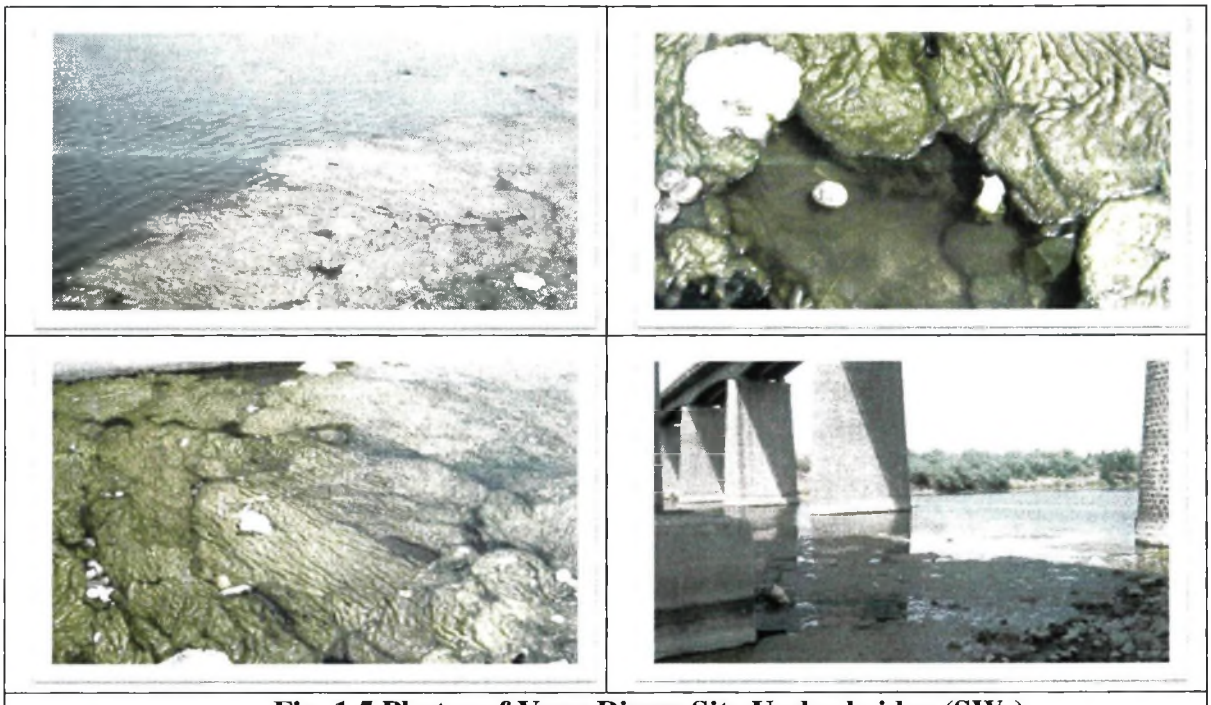


Fig. 1.5 Photos of Vena River: Site Under bridge (SW_1).

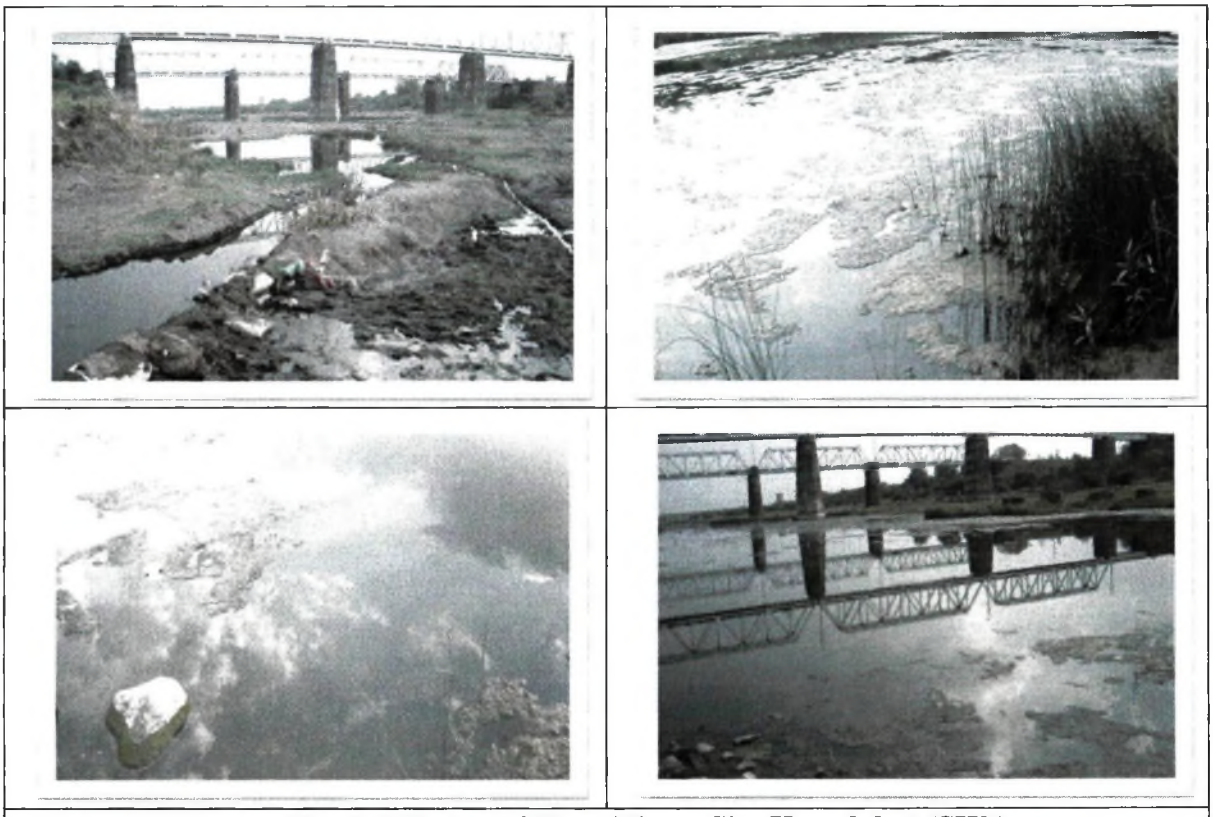


Fig. 1.6 Photos of Vena River: Site Kawalghat (SW_2).

Fig. 1.7 Photos of Vena River: Site Smashanbhumi (SW_3).

Fig. 1.8 Photos of Vena River: Site Shahalangadi (SW_4).

Chapter - 2

Literature Review

REVIEW OF LITERATURE

Contents

The following published literatures have been reviewed for this present study.

2.1. Algological Studies from India:

Ghose, S.L. (1919-32) carried the investigations on the blue green algae, particularly on Zygnemaceae and Oedogoniales of Burma and Punjab. Iyengar, M.O.P. from 1920 onwards published the various papers on algae of south India both fresh water and marine, in collaboration with his students. He also worked on the life history of *Cylindrocapsa geminella* Wolle, and described formation of gametes in a species of *Caulerpa* J.V. Lamouroux. He also described morphology and cytology of *Polysiphonia platycarpa* Borgesen, sexual reproduction in *Dictyosphaerium* Nageli and life history and cytology of *Microdictyon tenuis* J.E. Gray. Along with Subramanyam, he further describes reproduction, division, and auxospore formation of *Cyclotella meneghiniana* Kutzing. His most important contribution is in the discovery of *Fritsella tuberose* Iyengar, a very interesting terrestrial alga. Considering the volume and quality of his work, he can rightly be called the father of algology of India.

Bharadwaja, (1928-36) exercises an effective contribution to our knowledge of the blue green algae of Uttar Pradesh. He worked on *Gleocapsa* Kutzing, nitrogen fixation by *Cylindrospermum stagnale* Bornet & Flahault, *Tolypothrix* Kutzing ex Bornet and Flahault and several other Myxophyceae from United provinces. Singh, R. N. (1938-58), the student of Bharadwaja published series of papers on blue green algae

as well as Zygnemaceae, Oedogoniaceae and Chaetophorales of Uttar Pradesh. He also described the life history of *Frietschiella tuberosa* Iyengar and *Drapalnaldiopsis indica* Bharadwaja. Dwivedi *et al.,* (2005) reported 45 species of 21 genera of fresh water blue green algae from three different agro-climatic zones of Uttar Pradesh. Srivastava *et al.,* (2014) reported 23 fresh water cyanobacterial species belonging to 14 genera from Sai river, Lucknow, Uttar Pradesh (India). Roy *et al.,* (2014) described 16 members of Nostocales of Cyanophyta from Burdwan, West Bengal, India.

Singh, V.P. (1941) described 21 forms of which 12 were blue green algae and 9 belong to Chlorophyceae from Chamba, and Uttar Pradesh. Rao, C.B. (1935-38) published numbers of papers on the Myxophyceae and Zygnemaceae of Uttar Pradesh and Madras. Das *et al.,* (2009) recorded and described 58 species of freshwater algae belonging to Cyanophyta, Chlorophyta, Euglenophyta, and Bacillariophyta from Meghalaya along with their distributional pattern in other regions of India.

Randhawa, (1932-59) published series of papers mostly on Zygnemaceae, Oedogoniales, and Vaucheriaceae from the Punjab, and Uttar Pradesh (India). He recorded 70 species of Zygnemaceae. He discovered another new species from the Western Ghats from Bombay state in 1956.

Narayana Rao, S.R. (1941-49) investigated the fossil algae of India. Subramanyam, (1945) made interesting observations on reproduction on some species of Diatoms from South India.

Allen, (1925-42) described number of species from Uttar Pradesh. Pal, (1932) reported 25 species from Burma. Dixit, (1931-42) reported the many forms from Bombay and suburbs. Sundaralingam, (1959) described 9 species of *Nitella* C. Agardh and 10 species of *Chara* Linnaeus. While Mishra, (1937) recorded 2 species of *Spirogyra* Link in Nees and one of *Sirogonium* Kutzing.

Gonzalves, (1947) and her students carried on useful observations on algal flora of the Bombay State. Mishra, and Saxena, (1996), have been carrying on some interesting work on the culturing of the algae.

Ramnathan, (1939-46) described the life history of *Enteromorpha compressa* (Linnaeus) Nees, as well as sexual reproduction in *Carteria* Diesing and *Dictyosphaerium indicum* Iyengar and Ramanathan.

Work on cytology of algae has been published by Godward, M.B.E. (1969) from London in modern times and from India by Sarma *et al.*, (1967) from Banaras Hindu University.

Algae are not much used in such a manner so to enhance the environment of algal material for sharing the load of increasing population on food, medicinal drugs, and nutritional requirements. The term algae include chlorophyll bearing autotrophic thallophytes bounded by cell wall, made up of pure or mixed carbohydrates (Sharma, 2005).

Fresh water forms occurs abundantly in ponds, lakes, slow flowing streams, water reservoirs and pipelines. According to Matheson, (1952), among the microorganisms, algae is most important due to their ability to grow in large qualities of organic matter in the water. Some algae may also be troublesome, and invariably reduces the length of filter runs and impart notorious taste and odour.

Pearsal, (1932); Rai and Kumar, (1979) reported unattached visible and sometimes extensive accumulation of algae near the surface of water which are designated as blooms, mats or blankets. Many of algae remain attached to rocks, woods, soils, and the surface of trickling filters, and filters beds or coagulation basin walls. These may from continuous carpet due to the growth of algae. When the water becomes

turbulent fragments of algal carpet may be attached and subsequently carried away by the massive growth of algae. It can be troublesome in clogging screens, the production of slime in respect of taste and odour particularly when its anaerobic decomposition occurs.

Mathenson, (1952) reported the algae were grown on the surface of sand filters as a gelatinous slimy film. It may be responsible for gradually reducing the flow of water, through the bed but they may also perform a use for survival by adding oxygen to water. Similar work also reported by Kendlekar and Donugi, (1963) and Nandkar *et al.*, (1983).

Laxminarayan, (1965); Singh and Saxena, (1969) reported the Planktonic algae are likely to be much more significant than the attached benthic algae. Their higher concentration in the lake or reservoir affects the water quality.

Zafer, (1967); Singh, (1968), and Nandkar, (1983) reported all the surfaces of water contain dissolved and suspended material. Some of these serve as a nutrient and support the growth of algae and other aquatic life. The number of which varies with climatic and nutritional factor.

Now a days, World is facing the hazards of water pollution. Some form of algae of common occurrence in such polluted water play a significant role in purifying it to a certain extent due to oxygen given out during photosynthesis. They also utilize the carbon dioxide and other waste organic and inorganic substances by metabolic activities of water and reduce the pollution load. As a result, algae in such polluted water have been receiving considerable attention of ecologists all over the world.

The literature on water pollution indicates that sewage water algae and algae occurring in other polluted environment have not received much attention in India. Some important publications dealing with them were Hammer, (1964); Charian, (1970);

Saha, Sen, Mukherjee and Chakrabortee, (1958); Singh, (1960); Sreenivasan, (1964); Ganpati, (1965); Laxminarayan, (1966); Rana and Kumar, (1974); Arora *et al.*, (1985); Nandkar *et al.*, (1983).

Due to increased population and growing industries pollution load increasing in city, a large number of viable algae in environment are of great significance in phycology. The source of viable algae mostly comes due to pollution in environment and indoor environment with soil and air borne algae (Patil, 1980; Likhitwar and Tarar, 1994, 1994a; and Tarar, 1994).

The algae found in localized surfaces of Vena river from Hinganghat area are transported via atmospheric turbulence. The algae found in air are transported from atmosphere to distant surface (Smith, 1973; Tilak, 1983). The incidence of pollen and fungal spores and metals in air discharged to water bodies in Vena river in Hinganghat and their importance in allergenic disorder is now well recognized. Such reports i.e. Pollen and fungal spores in air have importance of allergenic disorder is recognized by Ramlingam, (1971); and Mittal *et al.*, (1973, 1974, 1979). Some review, and literature available on this aspects were Ramlingam, (1971); Mittal *et al.*, (1973, 1979); Marathe and Reddy, (1980); and Tilak, (1992).

The vast majority of algae are aquatic occurring on the surface of water and moist habitat. The algal flora of temporary water bodies is indirectly influenced by the size of ponds, puddles, ditches and their chemical composition of water.

The algal population of an environment would of course bring out the fact that algae are the prime sources of organic material in an aquatic environment and these could be included in the chain of organism Gonzalves and Joshi. (1946) and Ganpati, (1960).

The algal growth of unusual habitat like bark of trees and building walls was not uniform and it was not restricted to a particular direction but it was found to be a luxuriant. When rain water flows from top to base of particular habitat, the algae formed on the bark of trees or walls of river bank were considered under term aerophytes, (Sujeet Kaur, 1978). These algae grow both in light and shade condition. The sub aerial algae survive in severe condition for long time and resume their growth after the onset of monsoon due to characteristic multilayered sheath and unique feature of protoplasm. Tripathi and Talapasyi, (1980); Pandey, (1982); Banerjee and Kumar, (1992); and Paterson, (1935), showed that the wall surface is well colonized by the algae when they were moisture by percolating water supply from various surfaces.

East India fresh water algae published by Turner, (1892); Boergesen, (1933), laid the basic foundations of the Indian marine algae.

Microbial colonization on hard surface is a common phenomenon in natural aquatic environment which has both ecological and industrial significance (Ford *et al.*, 1989). Submerged surfaces, including surfaces coated with toxic points are readily colonized by bacteria and micro-algae, (Callow, 1986; Cooksey and Cooksey, 1995). These causes problems to ship surfaces cooling systems and other marine-based industries, (Peterson, 1990; Hudson and Burke., 1994; Udayakumar *et al.*, 1998). The formation of a primary biofilm over surfaces favours subsequent colonization by other organisms and facilitates corrosion. Micro-algae are among the major components in the freshwater biofilms, (Callow, 1993).

Micro-algal colonization has been studied in different aquatic environments using various natural and artificial substrata, (Brown, 1976 and Hoogland *et al.*, 1982). A three dimensional microalgal succession was observed in biofilm by earlier workers and it was reported that microalgal succession is analogous to higher plant succession in

terrestrial environment, (Hudon and Bouget, 1981; Hoogland *et al.*, 1982; Korte and Blinn, 1983; Roemer *et al.*, 1984). Among the *Diatoms* succession process has been found to be influenced by water velocity, size immigration, and reproduction rate of the organisms.

Most of the earlier studies on microalgal colonization on artificial substrata on freshwater environments have been focused on *Diatoms*. Studies representing the complete microalgal assemblages are limited. Moreover, the previous succession studies have been carried out in lotic systems, where water movement is likely to influence colonization. In the present, we have studied early events of colonization and succession of the biofilm in an undisturbed lentic freshwater system taking account all the biofilm components such as green algae, *Diatoms,* and Cyanobacteria to find critical changes in microalgal colonization and succession takes place during development of biofilm, (Venketeswarlu, 1968a,b).

Rivers, ponds, and their surrounding constitute excellent habitat for the growth and survival of filamentous green algae, particularly chaetophorales and ulotrichales with branched or unbranched filaments. Chaetophorales were characterized by a complex organization of thallus which is heterotrichous filament consisting of prostrate and erect components. The order may be parasitic epiphytic or endophytic. The prostrate system is typically a flat structure attached to substratum. Prostrate and erect systems of the thallus are readily recognizable in many species of *Stigeoclonium* Kutzing. In other cases erect systems disappears and prostrate system become more or less discoid as in *Protoderma* Kutzing, some species of *Coleochaete* Brebisson, and *Aphanochaete* A. Broun. Members with setae having sheathing base are included under Coleochaetales close to land plants, (Graham, 1993; Graham *et al.*, 2009).

Ulotrichales also chiefly includes fresh water forms. The plant body typically consists of a simple unbranched filament. *Uronema* Lagerheim is known to branch rarely. The wall consists of a simple unbranched filament. The wall consists of two layers, the outer of peptic substance and inner cellulose. Considering the vastness of habitats in the country little work has done on Chaetophorales, and Ulotrichales, (Sarma and Khan, 1980). Besides the earlier reports of foreign workers, Turner, (1892), few notable papers appeared of Indian workers in the first half of the 20th century, (Iyengar, 1939; Iyengar and Kanthamma, 1940a, 1940b, 1941; Mitra, 1945; Randhawa, 1936, 1941, 1948). Two new genera were selected by Iyengar, (1957); Iyengar and Philipiose, (1956); Randhawa, (1959), reported the occurance of two taxa of Ulotrichales from New Delhi. After, the publication of monograph on the order Ulotrichales by Ramanathan, (1964). Several papers published by Indian researchers viz., Kamat, (1975); Kargupta, (1987a); Kargupta and Mishra, (1992); Khan and Barthwal, (1975); Mahato *et al.*, (1992b); Mahato and Mahato, (1991), Prasad *et al.*, (1979); Prasad and Mishra., (1981); Saha, (1985); Tiwari and Pandey, (1972). Krishnamurthy, (2000), and appeared in later years concentrating on order Ulotrichales and have tried to compile the available records from India.

The work on Chlorophycean alga is known through Bharate and Tarar, (1983); Jayaswal, (1993); More and Nandan, (2005); and Nandan, (2006). Algal organisms are the rich source of novel and biologically active primary and secondary metabolite. These metabolites may be potential bioactive compounds of interest in the pharmaceutical industry, (Raina and Hala, 2008). The existence of bioactive compound in algae is to be expected due to co-occurrence of these organisms in aquatic natural communities where an inhibitory interaction occurred between producers and competitors within the same habitat. There metabolites may be synthesized under stress condition and low growth rate, (Keating, 1978).

Various strains of Cyanobacteria are known to produce intracellular and extracellular metabolites with diverse biological activities such as antialgal, antibacterial, antifungal and antiviral activity, (Kalireoglue *et al.*, 2006). Algae indicates the level of pollution in water bodies as a bio-indicator and help to determine water quality and conservation of water, (Palmer, 1980).

The present study deals with exploration of algae at different stations of Hinganghat in Vena river and influence of various physico-chemical factors on different algal groups. The physico-chemical complexes of river water and the distribution of algae have already been described, Venkateswarlu, (1969 a,b) on the reports of River moosi, Hyderabad.

Uptake of heavy metals has important implications in rainwater which is discharged into the water bodies i.e. Vena river. The uptake of heavy metals towards eukaryotic algae has been widely investigated and reviewed by, Say, and Whitton, (1977); Shumate *et al.*, (1978); Sakaguchi *et al.*, (1979); Cain *et al.*, (1980); Rai and Kumar, (1981); Stokes, (1973); Whitton, (1984); Mittal, (1992); Venkataraman, (1992); Rai and Agarwal, (1995); Rai, (1998); Sultan and Fatma, (1999); and Qianbhu *et al.*, (2000). Elements like potassium, calcium, magnesium, iron in the cell as cations play a variety of roles. Potossium is essential to run the activity of number of enzymes including some of those involved in protein synthesis.

Several trace elements such as magnese, zinc, cobalt, molybdenum, and copper are needed to phytoplankton. It is very difficult to demonstrate the requirement of trace element to phytoplanktons because, cells require such small amounts of contaminants in water. Such components often are adequate for growth. Trace elements are normally parts of enzymes and are responsible for growth of algae, but presence in excess has adverse impact on growth of algae.

Many of the methods and basic culture medium concepts that are used today were developed in the late 18th and early 19th century. Algal culture technique had been described by Moore, (1903); Kuster, (1907); Chodat, (1913); Richter, (1913); Pringsheim, (1924); Kufferath, (1928, 29); Bold, (1942); Chu, (1942); Fog, (1965); Venkatraman, (1969); Stein, (1973); and Guillard, (1975).

Ferdinand Cohn, (1850), has succeeded in keeping the unicellular flagellate *Haematococcus* Flotow of Chlorophyceae in his laboratory. This was the first published report of algal cultures.

Famintzin, (1871) in St. Petersberg made the first attempts to culture algae by using a solution of few organic salts. He grew several green algae in which two identified species are *Chlorococcum infusianum* (Scharank) Meneghini and *Protococcus viridis* C. Agardh.

The first report of pure cultures of algae stems from Bejerinck, (1890). He was the first to isolate free living *Chlorella* Beyerinck and *Scenedesmus* Meyen symbiotic green algae, *Zoochlorella* K. Brandt from Hydra and *Cystococcus humicola* Nageli from lichens.

Miquels, worked on diatoms from 1890 to 1898 and was the first to isolate and establish cultures of fresh water and diatoms algae. The Noll, (1892) and Otmanns, (1892) published papers discussing the cultivation of marine algae.

Conventional algal culturing was initiated by Zumstein, (1900). He established bacteria free culture of *Euglena gracilis* Klebs. In United States, Moore, (1903), published an early summery of algal culturing. Kuster, (1907, 1913, and 1921), published papers on algal culturing.

Pringsheim, (1912) published first paper on series of algal culture methods. Warberg, (1919) discovered that fast growing green microalgae like *Chlorella* Beyerinck were ideal experimental material in biochemical and physiological research.

Mainx, (1927, 1929, and 1931) also contributed considerably to the knowledge of pure algal culturing. He introduced centrifugation techniques to isolate algae and also one of the first using phototaxis of motile stages of establishing pure cultures. From the late 1920's on large meshed nets were strung out horizontally between rows of bamboo poles for algal growth. Kathleen M. Drew, (1949) discovered the complete life history of *Porphyra* C. Agardh.

The absolute requirement of elements can be established only by culture. However, many media have been designed for culturing different algae. No single medium can be said as the best one, various guidelines and catalogues suggested the culture collections and condition of algae. Few guidelines were given by Belcher and Swale, E.M. (1992); Starz, R.C. and Zeikus J. A, (1993); Anonymous, (2001); Warren, A., Day, J.G, and Grown, S. (2002) for different groups of algae. The culture media employed for culturing algae can be broadly grouped into many categories.

The media that are added to enrich the natural media are complete synthetic media. While some media, are designed to resemble natural conditions as closely as possible. Rodhe's, (1948), and Chu's, (1942), media designed to natural conditions. Tanda, (1951) used media for diatoms for blue green algae. The media of Witch's, (1948); Scott, (1944); Mayers and Clark, (1951), have been used for culture of *Chlorella* Beyerinck, while most of algae can be successfully cultured on synthetic inorganic medium, few require organic substance for their growth. Rodhe, (1948) observed the growth of algae. Ketchum, B. H. and Redified, A.C. (1949) used several media for growth of *Anacystis nidulans* N.L. Gardner. Allen, (1968); Sorensen *et al.*, (1977); Ohad

et al., (1967); used several media for Chlorophyeae, Chrysophyeae, Cyanophyceae, and Rhodophyceae. Ayala *et al.*, (1982); Richmond, (1979); Krishnamorthy, (1980); and Kruger, (1894), used modified medium. Stainer *et al.*, (1971) and many workers used BG 11 medium.

The basal medium BG 11 preferred over the other media, as it is applicable to both Chlorophyceae, and Cyanophyceae. Attempts were made to study the influence of elements and pollutants on growth of algae in basal medium.

Based on investigation of nutritional requirement of algae and balanced replacement for various essential elements have been made possible in the batch culture of algae such as *Chloroccocum humicolum* (Naeg) Roben H, *Oscillatoria amphibian* C. Agardh ex Gomont, *Selanastrum westii* G. M. Smith *and Coelastrum sphaericum* Nageli.

Cultures grown in laboratory are not only important for knowing the details of external morphology and reproduction in a particular algal group, but also for knowing details of algal life histories, taxonomy, morphology and growth.

The heavy metals i.e. zinc, copper, cadmium are known to adversely affect growth of fresh water algae, (Bartiett *et al.*, 1974; Klass *et al.*, 1974), and Zinc toxicity is known to various fresh water algae, (Whitton, 1980). Morphological changes were noted and also focused to study the influence of nutrients on algal growth *Chloroccocum humicolum* (Naeg) Roben H, *Oscillatoria amphibian* C. Agardh ex Gomont), *Selanastrum westii* G. M. Smith, *and Coelastrum sphaericum* Nageli, were isolated and made auxenic culture in liquid BG 11 (Beneck's) medium, Stainer *et al.*, (1971). The accelerated growth of algae in culture media was the parameter to modify the BG 11 medium.

Study of algal flora is a useful alternative for assessing the ecological quality of aquatic ecosystems, since biological communities integrate the environmental effects of water chemistry, in addition to the physical and geomorphological characteristics of Rivers, and lakes (Stevenson *et al.,* 1999). Phytoplankton encountered in the water body reflects the average ecological conditions, and therefore, they may be used as indicator of water quality, (Bhatt *et al.,* 1999, and Saha *et al.,* 2000). These are very suitable organisms for the determination of the impact of toxic substances on the aquatic environment, because any effect on the lower level of the food chain will also have consequence on the higher level, (Joubert, 1980).

Algae are used for assessing the degree of pollution or as indicator of water pollution of different water bodies, (Trivedy, 1986; Sudhaker *et al.,* 1994; Dwivedi *et al.,* 2002). With the advent of development, there is exponential increase in the demand for water. The main source to fulfill this demand of irrigation, industries, and drinking water is river water. The quality of water is directly linked with human welfare. A comparative study of surface water and ground water sources from villages of different Talukas of Ariyalur area, Tamil Nadu, was investigated by (Rani *et al.*, 2009). Shilpi Bansal, (2006), studied hydrochemical monitoring of pollutants in drinking water of Aligarh and concluded that drinking water quality of Aligarh is deteriorating and water is becoming polluted due to untreated industrial and sewage water discharge, which can be controlled by adopting standard methods for water treatment.

Yadav, Indradev, (2006), analysed the drinking water before and after the flood of east zone of Kosi division and concluded that when the concentration of Nitrates exceed 40 mg/lit, the skin becomes glue due to the decreasing efficiency of haemoglobin to combine with oxygen. It affects the mortality in pigs and calves due to the presence of high concentration in cattle. Koshy, Mathew, (2006) studied water

quality parameters of river in Alappuzha district. The results of present work indicate that there are variations in the physic-chemical parameters in the river water system.

Bilgrami and Dattamunshi, (1985) examined the pH values in river Ganga and its major tributaries mainly Gandak, Barni, and Kosi attributed pH changes due to planktonic and fish activities.

Water resources are said to be polluted when, mans action in adding or causing the addition of matter to the water and altering the physical, chemical, or biological characteristics of water to such an extent that, it's utility for any reasonable purpose or its environmental value is demonstrably depreciated.

The quality of physicochemical and biological characterizations of water is an index to provide a complete and reliable picture of the conditions prevailing for tropic status in the water bodies. Goel, (1997), studied water pollution causes, effects and control in which the authors have presented various types of water pollution and the major sources and control of pollution. Similar studies regarding water pollution was of Trivedy, (2000), in the book, "Pollution and Biomonitoring of Indian Rivers". Similar studies regarding the, "Introduction to water pollution Biology" have been presented by Schmitz, (1995); Tripathi and Pandey, (1995), in which they demonstrated the effect of heavy metal on algae and correlation was shown between nutrient and phytoplanktons. Will Rich and William Hines, (1967), discuss about Water pollution control. Abatement Gower, (1980) written about, "Water quality in catchments Ecosystem", and Khopekar, (2004), describes Environmental Pollution monitoring and control.

Manahan, (1997) studied certain algal forms growing in the special type of polluted water and these species are characteristic features of the particular environment. These forms are the indicator of water pollution. Palmer, (1969) in his

valuable review on algae as biological indicators of pollution found certain algae tolerant to relatively raw sewage or organic waste. Similar studies regarding the use of algae as indicator of river water quality and pollution has been emphasized by Venkateswarlu, (1981), and Kant, (1985).

Kannan and Krishnamurthy, (1985) studied diatoms as indicators of water quality, (Mohanty, 1985) Study algae as indicators of water quality was reviewed. Studies of algae as indicators of water quality by Narkhede and Raghothaman, (2007) were also reviewed. Some diatoms from Hathnur Dam, Tapti River by Kavitha and Balasingh, (2007) were reviewed. The impact of sewage on the phytoplankton communities of parvathy puthanar canal, Thiruvanthpuram by Rajukumar and Rita Kumari, (2004) were reviewed. Rai *et al.*, (1981) studied Phycology and Heavy Metal pollutions were reviewed. Stokes *et al.*, (1973) studied heavy metal tolerance in algae isolated from contaminated lakes near Sadbury was reviewed. Whitton, (1970) describes toxicity of heavy metals to fresh water algae was also reviewed. Govindasamy *et al.*, (2007) studied Impact of Municipal wastes on the river water quality of river Palar, Tamilnadu.

Sheeba and Ramanujan, (2005) worked on Phytoplankton composition and distribution in Ithikkara river, Kerala., in which they stated that, Ithikkara river is rich in algal species quantitatively and qualitatively. They observed that Bacillariophyceae were more abundant than the other groups of Phytoplankton.

Kavitha *et al.*, (2005) in which they gave the information regarding the Genera like *Chroococcus* Nageli, *Anacystis* Meneghini, *Oscillatoria* Vaucher, *Microcystis* Kutzing *ex* Lemmermann, *Oocystis* Nageli *ex* A. Braun) *Spirogyra* Link, *Stigeoclonium* Kutzing, *Navicula* Bory de Saint-Vincent, *Nitzschia* Hassall, *Cyclotella* Kutzing,

Cymbella Agardh, *Synedra* Ehrenberg and *Cocconeis* Ehrenberg were recorded as pollution indicators.

Algae are the predominant organisms in water bodies and contribute to primary productivity of the aquatic ecosystems. The algal diversity and occurrence of specific taxa in a water body varies considerably based on the change in Physico-Chemical characters like pH, BOD, COD, Dissolved Oxygen, and Salinity etc. Based on the Occurrence and Diversity Pattern, algae are used as the indicator species of aquatic environments, (Jena *et al.*, 2005).

Nivedita and Hema, (2010) studied algal biodiversity and Physico-Chemical characteristics of River Kosi in Almora District. Physico-Chemical Parameters and Chlorophyll Concentration fluctuation and Seasonal variations obtained in a Study conducted by Abidi *et al.*, (1983).

Various aspects of algal taxonomy, physiology and ecology with further concentrated on the problems of environment Pollutants and their effect on Plankton biology of algae with reference to uptake and accumulation of metals and detoxification mechanism in algae, heavy metals effects in aquatic food chain, bio-fouling and bio-corrosion by algae and their controls by Anand, (2002) were also reviewed. He also worked on the role of Diatoms in bioaccumulation, Biotransference and Biomagnifications of Heavy Metals.

Cyanobacterial biodiversity of the Tributaries of the river Kaveri by Sankaran, (2006) were studied. Seasonal Variation in Primary Production of Two Freshwater Rock pools of Kollam District, Kerala by Danielkutty and Sobha, (2006) was reviewed. He also studied on Chlorophyll-a exhibited direct relation with the variations in the Phytoplankton Biomass and Productivity.

The species composition of phytoplankton communities differs depending on the local climate, soil, and sewage like environmental factors might be associated with differences among the species include the availability of nutrients and the degree of mixing or stratification by Rajukumar and Ritakumari, (2004) were also reviewed. The results of the study shows existence of differences in species composition and in relative abundance of the various phytoplankton communities of the ecosystems. The fluctuations and the interactions of environmental factors are significant, when analyzing the nature and extent of sewage.

Studies on Algal Diversity in Temple Ponds from North Goa by Tejaswini and Vijaya, (2004) were reviewed. In this *Ankistrodesmus falcatus* (Corda) Ralfs, *Scenedesmus* Meyen, *Closterium* (Kuetzing) Brebisson, and *Pediastrum* Meyen, were the dominant green algae and *Microcystis* Kutzing *ex* Lemmermann, *Merismopodia* Meyen, *Oscillatoria* Vaucher were the common algae. Vishnoi and Srivastava, (2004) studies on Algal flora of polluted water bodies around Jodhpur were also reviewed.

Heavy metals are considered as major environmental pollutants and regarded to be Cytotoxic, Mutagenic, and Carcinogenic. The Heavy Metal pollution of natural environment has been consistently increasing through effluents, sedimentation of rocks and mining activities. High concentrations of all heavy metals are toxic to biological systems and effect of some heavy metal compounds on growth and differentiation in a blue green and green algae by Ahluwalia and Manjit, (1988) were studied. Same worked also done by Rai *et al.*, (1981) in Phycology and Heavy Metal Pollution.

Algae constitute a major Part of the Primary Producers in Aquatic and Terrestrial ecosystems. In spite of high concentration of various toxic metals in the environment, metal tolerance and adaptation to higher concentration have been worked out in many algal species by Stokes *et al.*, (1973) were studied. Sachidananda Murthy

and Yajurvedi, (2004) also worked on monthly variation in water quality parameters of a perennial lake in Mysore City.

Studies on the effect of various industrial effluents on Damodar River Ecosystem by Ghatak and Konar, (1992) were reviewed. In this, the Physico-Chemical and Biological Characteristics of river water was found changing generally and gradually due to drainage of various industrial effluents. The concentrations of dissolved oxygen, phosphate of waste were significantly decreased but carbon dioxide was increased at various sites and resulted in decreases of phytoplankton communities of the river water.

Hydrobiological studies regarding rivers are scarce but its relation with algae are few. Studies on river hydrobiology in Indian regions have been done by many workers for many rivers from time to time. Venkateswarlu, (1969) studied ecology of algal flora of the Moosi river, Hyderabad with special reference to water pollution. He studied the phycochemical characteristics affecting the distribution and periodicity of algae. The change in algal flora in the Cauvery river due to industrial and domestic pollution was studied by Parmasivum and Sreenivasan, (1981).

Effect of industrial effluents on phytoplankton communities of the river Ganga was studied by Bigrami and Siddiqui, (1980). Seasonal variations of Phytoplanktons in the Vishwamitri river Baroda were studied by Nandan and Patel, (1985).

Earlier works were done on Tapi river by Ragothman and Manoj, (1993); Kapila Manoj and Chauhan Manish, (1999); Kapila, Manoj and Himanshu Patel, (1999); Ragothaman, (2007); Ragothaman *et al.*, (2004); Narkhede and Raghothaman, (2007); Ragothaman and Ramaih, (1986); Jaiswal, (1990); Sarin and Swami, (1981); Ragothaman and Reddy, (1982).

Many reports are available in India of Arora *et al.*, (1973); Chandra and Mathur, (1983, 2000); Sawane, (2002); Dahegaonkar, (2008) on the water quality assessment of lotic ecosystems. Saha, L.C. and Choudhary, S.K. (1985) studied the phytoplankton diversity in relation to abiotic factors of a pond at Bhagalpur, India. They occur in the lentic (standing water) as well as lotic water (running water).

Tiwari, A. and Chauhan, S.V.S. (2006), reported the seasonal phytoplanktonic diversity of Kitham lake Agra. Devi, D. (2006), studied the distribution and diversity of algal community growing in the Barambaba Temple pond and many of them terrestrial which is living in soil and snow or in association with other organisms especially fungi (as lichens) and animals.

Some algae have an economic importance because they are a source of carotene, glycerol, and alginates and can be converted into a food source for aquaculture. Algae vary considerably in size, shape, and growth form. They can be single celled either colonial or as filamentous cells, (Johnson, M.E.C, 2006).

Different authors reported the freshwater algae from different regions of India. Anilkumar, S. (2000) reported the "Fresh water Algae of Hassan District, Karnataka state". Bais, V.S., Agarwal, N.C. and Arasta Tazeen, (1995), studied the, "Comparative study on seasonal changes in phytoplankton community in the Sagar lake and Military Engineering lake. Bharathi, S.G. and Hosmani, S.P. (1973), reported the Hydrobiological Studies in ponds and lakes of Dharwar (Vemmekeri Pond). Chaturvedi, U.K. and Iqbal Habib, (1995), reported the algal flora of Srinagar (Garhwal), Uttar Pradesh. Deb, P. (2005) reported the Investigation on the epilithic algae of temporary stream at Dargakona, Cachar district, Assam. Desikachary, T.V. (1969), Cyanophyta, ICAR, New Delhi. Devi, D. (2006), studied the distribution and diversity of algal community growing in Barambaba Temple pond.

Dwivedi, B.K. and Pandey, G.C. (2002), studied the Physico- chemical factors and algal diversity of two ponds in Faizabad. Guruswamy, K. and Ramadas, V. (2000) studied the seasonal variations of Chlorophyll and phytoplankton productivity in manmade pond. Hosmani, S. P., Vasanthakumar, L., and Partha, S. (1999), studied the Ecological significance of biochemical parameters in certain fresh water lakes of Mysore. Jena, M., Ratha, S. K. and Adhikari, S. P. (2006) reported the Diatoms (Baccilariophyceae) from Orissa state and neighbouring regions. Johnson, M.E.C. (2006) reported the Algal flora of Banjara, and Nadimi lakes. Kopoczynska, E. E. (1980), studied the seasonal variations in phytoplankton in the Grand river mouth area of lake Michigan.

Mahadev, J. and Hosmani, S. P. (2002) studied the Langlier's index and relation to phytoplankton in two lakes of Mysore city. Mahadev, J. and Hosamani, S.P. (2005) studied the algae for bio-monitoring of organic pollution in two lakes of Mysore city. Mahadev, J. and Hosamani, S.P. (2010), reported the Statistical Multivariate Analysis of Lakes and Water Quality Parameters in Mysore, Karnataka, India. Munawar, M. (1974) performs the Limnological studies on fresh water ponds of Hyderabad, India. Nazneen, S. (1980) reported the Influence of hydrological factor on seasonal abundance of phytoplankton in Kinjhar Lake, Pakistan. Nygaard, G. (1949), performs the Hydrobiological studies on some Danish pond and lakes.

Pearsall, W.H. (1932), studied the phytoplankton in the English lakes II. Philipose, M.T. (1960), reported the Fresh water phytoplankton of inland fisheries. Prasad, B.N., Mehrotra, R.K. and Singh, Y. (1978), studied the pH tolerance of some blue green algae. Prescott, G.W.A. (1951), reported the Algae of the Western Great lake area. Prescott, G.W. (1954), reported the freshwater algae. Ratha, S.K., Naik, K. and Padhi, S.B. (2003), studied the epiphytic algal diversity associated with different aquatic

macrophytes of fresh water ponds in and around Berhampur University Campus, Orissa, India.

Robert, D.S., Robert, W.H., and Evereff, L.G. (1974), studied the Phytoplankton distribution and water quality indices of Lake Head (Colorodo river). Saha, L.C, and Choudhary, S.K. (1985), reported the phytoplankton diversity in relation to abiotic factors of a pond at Bagalpur, India. Samantaray, S.M., Malik, A.K. and S.B. Padhi. (2002), reported the periodicity of *Oscillatoria* (Vaucher) bloom with relation to certain physico-chemical factors in Chilika lake. Smith, G.W. (1950), reported the freshwater algae of the United State.

Tiwari, Ashesh and Chauhan, S.V.S. (2006 a), reported the seasonal phytoplanktonic diversity of Kitham lake, Agra. Trivedy, R.K. and Goel, P.K. (1986) reported the Chemical and Biological methods for water pollution studies. Vasconcellos, (1994), studied the Toxic cyanobacteria (blue-green, algae) in Portuguese fresh waters. Verma, J, and Mohanty, R.C. (1995), reported the phytoplankton and its correlation with certain physico-chemical parameters of Danmukundpur pond. Zafar, A.R. (1967), studied the ecology of algae in certain fish ponds of Hyderabad, India.

In the past, good deal of work has been carried out in the Cyanophyceae flora from Maharashtra. Desikarchary, (1959); Kamat, (1977); Barhate and Tarar, (1983); Mahajan and Mahajan, (1990); Nandan and Mahajan, (2006) contributed the Cyanophyta from India.

Several studies were carried out regarding the distribution and diversity of fresh water algae throughout India by Gunale and Balakrishnan, (1981); Tiwari *et al.*, (2002); Kavitha *et al.*, (2005); Kavitha and Balasingh, (2007). Rana *et al.*, (2002) showed that, due to seasonal variations and heavy rain the phytoplankton's density was lowered.

Jose John, (2013) represented four hundred ninety four taxa from Idukki district of Kerala.

2.2. Algological Studies from Maharashtra:

In Maharashtra, algal studies were started in 1847 when Griffith described fertilization in *Eudorina elegans* Ehrenberg collected from the pools in Bombay. In 1933, Boergesen, worked on fresh and marine algae of Bombay.

Some of major contribution from Maharashtra were as follows, Dixit, (1936), Gonzalves and Joshi, (1946), Gunale and Balkrishnan, (1981), Pingale, (1981), Sarode and Kamat, (1984), Gode, (1983), Jagdale *et al.*, (1987), Trivedi *et al.*, (1990), Badve *et al.*, (1993), Patil, (1995) and More *et al.*, (2005).

The occurrence and distribution of Chlorococcales in Maharashtra was known through the work of Kamat, (1962, 1963, 1968, 1974, 1976); Ashtekar and Kamat, (1980); Barhate and Tarar, (1983); Nandan, (1993); Patil and Badgujar, (1994); Tarar and Bodke, (1998); Auti and Pingale, (2007); Jawale and Kumawat, (2003); Kumawat and Jawale, (2003a, 2003b, 2004b, 2005); Jawale and Dhande, (2005) and Jawale *et al.*, (2008).

Earlier Kamat, (1968a) reported two hundred and twenty one algal taxa belonging to five classes namely Chlorophyceae, Charophyceae, Euglenophyceae, Chrysophyceae and Cyanophyceae from Maharashtra. From Vidarbh, Maharashtra, Kamat (1975a) reported three hundred and ninety one taxa of Chlorophyceae, ninety six taxa of Euglenophyceae, two taxa of Xanthophyceae, eleven taxa of Dinophyceae and one hundred and thirty six taxa of Cyanophyceae.

The Chlorophyceae with 36 taxa representing 18 genera was listed by Kamat and Freitas, (1976) from Nagpur, Maharashtra. Sarode, P. T. and Kamat, N. D. (1979)

reported the diatoms of Marathawada. Ashtekar and Kamat, (1980a) recorded fifty three taxa of Cyanophyceae belonging to thirteen genera of the order Nostocales from Maharashtra. Ashtekar and Kamat, (1980b) reported forty nine taxa belonging to twenty genera of Chlorococcales from Maharashtra. Freitas, (1980) listed eighty one taxa representing twenty nine genera belonging to seven families of the order Chlorococcales from Maharashtra.

Barhate and Tarar, (1981) reported 41 algal taxa, out of which 1 belonged to *Cyanophyceae*, 8 to *Chlorophyceae*, 32 to *Bacillariophyceae*, of Tapti River, Bhusawal, Maharashtra. Fifty eight taxa of Euglenophyceae belonging to five genera were reported by Ashtekar, (1982) from Maharashtra. The same authors recorded 31 taxa of *Diatomaceae* belonging to 15 genera (1983a) and further enlisted 101 blue-green algal forms, from Khandesh region of Maharashtra (1983b). Sarode, P. T. and Kamat, N. D. (1983), reported the diatoms flora of Marathawada, Maharashtra. Species of *Oscillatoria* and *Lyngbya* were found dominant. Special note on *Phormidium laminosum* Gomont has also been given. The same authors recorded 31 algal taxa of *Chlorophyceae*, 4 belonging to *Volvocales*, 7 to *Chlorococcales*, 3 to *Ulotrichales*, 1 to *Chaetophorales*, 4 to *Oedogoniales* and rest 12 to *Conjugales* from Khandesh, Maharashtra (1985a). They also presented a first report on *Euglenophyceae* of Khandesh region and reported 21 species of this class (1985b). Out of these 10 belonged to genus *Euglena*, 7 to *Phacus* and the rest to *Trachelomonas*. Again they dealt with diatoms of Khandesh and found that a number of species of *Navicula, Cymbella* and *Nitzschia* were dominant (1985c).

Sarode and Kamat, (1978, 1983a, 1983b, 1984) and Barhate and Tarar, (1983a, 1985c) described freshwater diatoms from Maharashtra. Barhate and Tarar, (1983b) reported one hundred and one taxa of Cyanophyceae from Khandesh, Maharashtra.

Sarode, P.T. and N.D. Kamat, (1983), investigated the diatoms flora of Marathwada, Maharashtra. In the present study diatoms were correlated with these references.

Barathan and Sundaralingam, (1984), based on certain morphological evidences and results of experimental work on infertility tests together with known karyological differences, reached to a conclusion that *Chara vandalurensis* Sund. is taxonomically distinct. Chaporkar and Gangawane, (1984) studied the blue-green algal flora of some cultivated soils of Marathwada region and isolated 33 forms of *Cyanophyceae* from various crop field soils, out of which *Microcystis elegans, Nostoc hatei, Anabaena ballygunglii,* and *Tolypothrix fragilis* were reported for the first time from this region.

Barhate and Tarar, (1985a) reported thirty one algal taxa of Chlorophyceae from Maharashtra belonging to Volvocales, Chlorococcales, Ulotrichales, Chaetophorales, Oedogoniales and Conjugales. The same author (1985b) listed twenty one species of Euglenophyceae from Khandesh, Maharashtra and out of these ten belong to *Euglena*, seven to *Phacus* and four to *Trachelomonas*. The Cyanophyceae from the Jalgaon region, Maharashtra was studied by Bhoge and Ragothaman, (1986a) and they listed a total of sixty three taxa.

A contribution to the Vidarbha and Marathwada Cyanophycean Chlorophycean, and Bacillariophycean flora has been investigated by Tarar and Seema Bodkhe, (1998). The same author (1998b), reported the Diatom flora of polluted water bodies of Nagpur. The same author (1998) listed fifty two species of Chlorococcales belonging to fifteen genera from Nagpur, Maharashtra.

Kumawat and Jawale, (2001) described eight taxa of *Spirulina* from Maharashtra. More, (2001) studied the algae from Panzara river of Maharashtra. Nandan and Mahajan, (2006) made significant contribution to the cyanobacterial diversity from Jalgaon and also contributed the role of Blue green algae. in this area. Kumawat, (2006)

reported the biodiversity of diatoms of Jalgaon district Maharashtra and enumerated seventy four diatoms representing both centric and pinnate forms along with their occurrence and succession. Narkhede, (2006a) reported nine taxa of *Nitzschia* and three taxa of *Surirella* from Maharashtra. The same author (2006b) reported fifteen taxa of diatoms belonging to three genera namely *Punnularia* (six taxa), *Amphora* (two taxa) and *Cymbella* (seven taxa) of Suki dam in Maharashtra. Chlorophycean algae of Ahmednagar district, Maharashtra were enumerated by Deshmukh and Pingle, (2006) and a total of one hundred and fifty five taxa belonging to fifty six genera were reported.

Some algal forms of Nostocaceae were reported from Paddy field soils of North Maharashtra by Chaudhari *et al.*, (2007). Nandan and Mahajan, (2007) discovered and described green algae *Chlamydomonas* Ehernberg from Hartala lake of Jalgaon (MS). The systematic account of fifty four taxa of Chlorococcales from Ahmednagar district, Maharashtra was reported by Deshmukh and Gunale, (2007). The phytoplankton diversity of Parola dam, Maharashtra revealed the presence of forty three phytoplankton species belonging to four major groups namely Chlorophyceae, Bacillariophyceae, Cyanophyceae and Euglenophyceae (Jayabhaye *et al.*, 2007).

Dhande and Jawale, (2008) described eleven taxa of diatoms of which eight taxa belong to the genus *Fragillaria* and three to genus *Synedra* from Hartala Lake, Maharashtra. The same author (2008) contributed *Denchorystis raoi* a rare member of Chloroccocales and also described *Oedogonium* Link ex hirn from Jalgaon.

Suryavanshi *et al.*, (2009) reported fifty eight taxa of freshwater diatoms belonging to seventeen genera from Ahmednagar region, Maharashtra. Patil and Chaugule, (2009) reported 79 species of blue green algae from the paddy fields of Maharashtra. Dhande *et al.*, (2009) reported the Genus *Cosmarium* Corda ex Ralfs from Hartala lake of Jalgaon District.

The phycology of fresh water Chlorophyceae, and unicellular Volvocales was given by Jawale., Kumawat and Chaudhary, (2009). The same authors (2009) reported twenty six taxa of freshwater unicellular Volvocales from Jalgaon district, Maharashtra. The same author (2010) reported fifteen taxa of Volvocales from Jalgaon and Dhule districts, Maharashtra.

Kumawat *et al.*, (2010) described some new members of order Chlorococcales. The same author (2010) described eleven species of *Spirulina* and new member of Volvocales i e, *Carteria* Diesing from Maharashtra.

Patil and Deore, (2010a) reported three species of the genus *Dichothrix* belonging to the family Rivulariaceae from Dhule district of north Maharashtra. The same author (2010b) reported blue green algae belonging to family Scytonemataceae of order Nostocales from Maharashtra and they described nine species belonging to four genera. Suryavanshi *et al.*, (2010) reported the diversity of Cyanophyceae members in Maharashtra and they described fifty three taxa of freshwater forms belonging to nineteen genera. Andhale and Papdiwal, (2010) reported twenty two taxa of freshwater Chlorococcalean algae representing six genera from Jayakwadi bird sanctuary of Maharashtra.

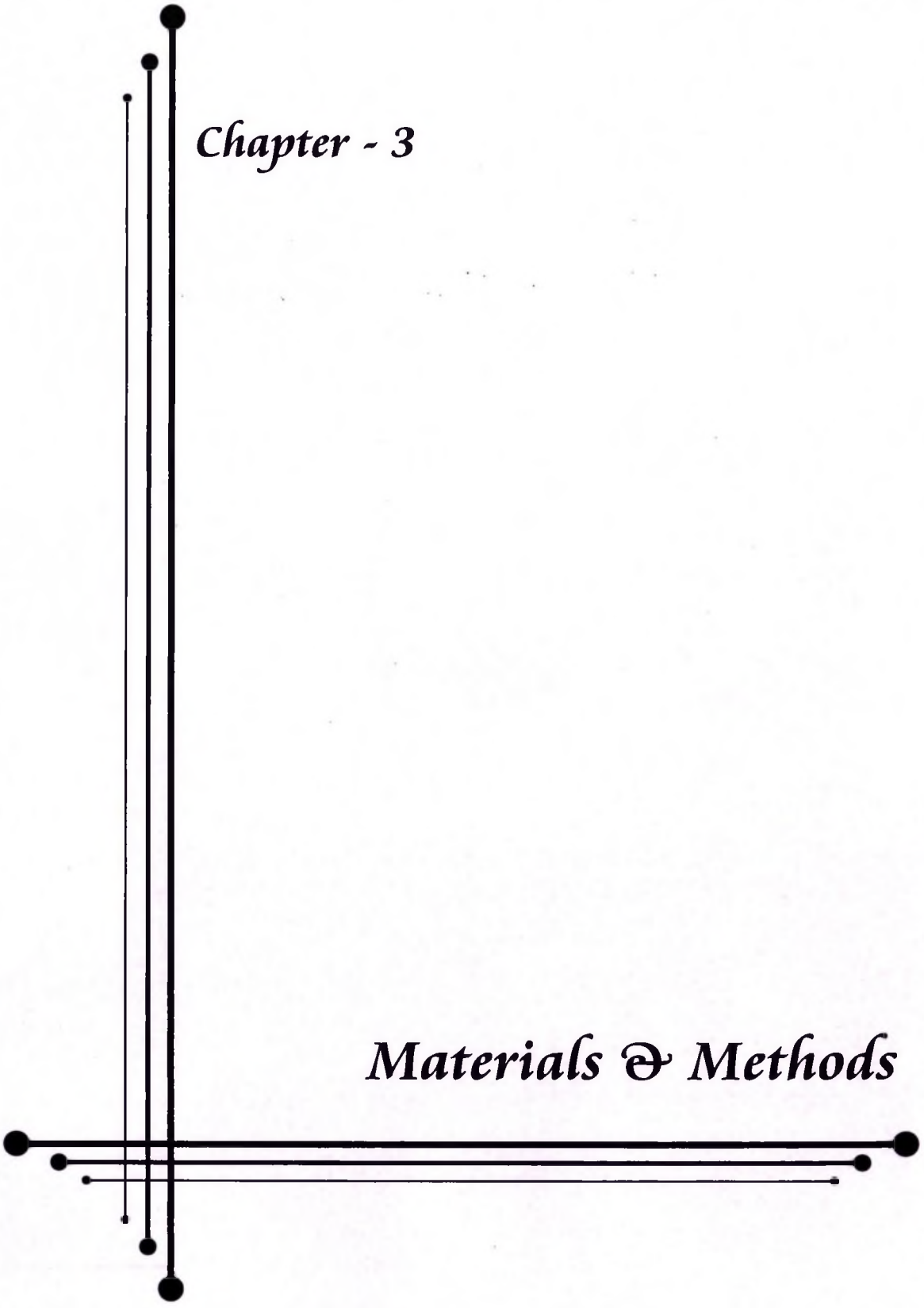
Bhosale *et al.*, (2010a) reported phytoplankton diversity in four lakes of Satara district, Maharashtra and illustrated sixty eight phytoplankton taxa belonging to five classes of algae. The same author (2010c) enumerated and illustrated phytoplankton of the lakes in and around Kolhapur city, Maharashtra and reported one hundred and seventy four taxa of algae belonging to seven classes. The same author (2010d) enumerated and illustrated forty four phytoplankton species belonging to thirty genera from five classes of algae from the water bodies of Maharashtra.

Patil and Mahajan, (2011) made important contribution to fresh water unicultured algae. Mahajan, (2012) reported twenty seven species belonging to the family Nostocaceae from Jalgaon, North Maharashtra. Patil *et al.,* (2012) collected algal flora of Jalgaon district of Maharashtra state in which he reported 539 taxa belonging to 4 classes. Dalal *et al.,* (2013) investigated 53 algal species and physicochemical parameters of Dham river, Pavnar, Maharashtra.

Nandkar *et al.*, (1983) and Singh, (1968) investigated surface of water containing dissolved and suspended materials. Some of these serve as a nutrient and supports the growth of algae and other aquatic life. Kamat, (1976), and Tarar, (1980) also gave the same contribution.

Tayade, (2006) reported the assessment of some metal in ground water and canal water of Nagapur village of Yavatmal district, Maharashtra and concluded that the water contain Calcium, Magnesium, and Iodide elements below the maximum permissible limit, whereas, fluoride was above the maximum permissible limit.

However, the morpho-taxonomic studies of Vidarbha fresh water algal flora have received very little attention. That's why the present study was aimed to explore the algal flora of Vena river in relation to physico-chemical properties. In Hinganghat locality, algae do not occur in sufficient quantities to render its commercial applications. Some interesting aspects of algae of this locality were investigated by Marathe, (1969); Barhate, (1983); Kottawar and Pachpande, (1983); Patil *et al.*, (2011); More, (1997); Jawale and Patil, (2009).



Chapter - 3

Materials & Methods

MATERIALS AND METHODS

Contents:

Vena River is Perennial River of the area. It has different water sources to accommodate in a main stream according to season. In rainy season water of Vena river flows fast. In winter, the water current becomes slow and in summer it has a very slow rate of water current. All the four sites were selected for collections of algal samples at monthly intervals for two years i.e. from June 2011 to May 2013. The algal forms were collected by forceps and brought to laboratory. Some algal forms were stored in laboratory for further investigations and remaining algal forms were employed for culture processes. The algal forms were identified with the help of algal monographs, and recent literature, available books of Desikachary, (1959); Fritch, (1935), flora, research papers, and manuals etc.

Accurate sampling was carried out by correct handling, and presentation of samples to attain reliable results. Immediately after collection, the sample bottles and bags were clearly labeled with water proof ink and relevant details were recorded on the site. Immediately the collected phytoplanktons were fixed as soon as collection was over on the site. There were adverse effects of light and temperature, as light cause rapid decay of organisms. Hence, the collected phytoplankton samples were fixed with acidified formaldehyde solution.

The phytoplankton samples were stored in compressed glass bottles at room temperature, closed by a leak proof cork and were stored in cool, and dark place. The collected and preserved phytoplankton samples were labeled for further analysis. The details about, place of water body, time, serial numbers, preservative, and collection's name were recorded.

For quantitative analysis one drop of sample was taken on clean glass slide and phytoplankton was counted by Lackey's drop count method. In Lackey's drop method, the cover slip was placed over a drop of water in the slide and whole of the coverslip was examined by parallel overlapping strips to count all the organisms in the drop. About 20 such strips were examined in each drop. Number of subsamples taken for observation was dependent on successive sub samples APHA, (1998). The phytoplankton analyzed was assigned to major groups viz., green algae (Chlorophyceae), blue green algae (Cyanophyceae), diatoms (Bacillariophyceae) and Euglenophyceae. The phytoplankton's were identified with the help of classical works of Cupp, (1943); Prescott, (1954); Desikachary, (1959, 1987); and Fritch, (1971).

For the exploration of algal forms, data were collected for two years. The collection procedure is repeated according to season. The whole tenure of study was divided into periods of three months each i.e. June to August (2011), September to November (2011), December (2011) to February (2012), March to May (2012), June to August (2012), September to November (2012), December (2012) to February (2013) and March to May (2013) at four different sites. The time for collection of samples selected was morning hours i.e. 9 am to 10 am. At the time of collection, temperatures, and pH were recorded. These procedures were repeated for two years from the month of June 2011 to July 2013, in monthwise manner and the experimental data were depicted in observation table.

Samples of free floating aquatic algae were collected from Vena river of Hinganghat area from four different stations viz., under bridge (SW_1), Kawalghat (SW_2), Smashanbhumi (SW_3), and Shahalangadi (SW_4), by means of plankton net. The relative proportions of different species represented in a phytoplankton samples were estimated by counting them with the help of haematocytometer. It contains unicellular, colonial, and simple filamentous algae mostly belonging to the Cyanophyceae, Chlorophyceae, and Bacillariophyceae. In addition to phytoplankton, most of the samples contained zooplanktons.

The fresh water phytoplankton collected from Vena river were found in relatively clean and nutrient deficient or oligotrophic water and exhibit a great diversity. Though, the concentration of each species of the algae as a whole is very low.

3.1 Preservation:

To store algae in the laboratory for subsequent morphological studies, they were killed and preserved in 4% commercial formalin. For preserving fresh water algae, 40% formaline were added directly to the sample so as to obtain a final concentration of 4%. For maintaining the algae in their natural (green) colour following preservative was employed. The algae were immersed in it for few days and then transferred to formalin acetic alcohol (FAA) solution.

The preservative as shown in (Table 3.1) is suitable for most of the green algae. If 10 gm of copper acetate is substituted for the cupric chloride and uranium nitrate, the preservative is suitable for blue green algae.

Table : 3.1 Preservative

Composition of Elements	Quantity
50% ethyl alcohol	90 ml
40% formalin	4 ml
Glycerol	3 ml
Glacial acetic acid	3 ml
Cupric chloride ($CuCl_2$)	9.5 gm
Uranium nitrate	1.5 gm

3.2 Preparation of Herbarium sheets:

The specimen was floated in an enamel tray containing fresh water and a piece of moderately thick herbarium sheet inserted in the water from one side below the specimen. Then the algae were allowed to spread and the tray was tilted gently, while the specimen was held or settled on the sheet. The mucilaginous specimens were stuck to the sheet and any excess water on the later is drained off by keeping the sheet on the inclined plane for some time. The sheet is then placed between two dry newspapers or blotting papers. The number of herbarium sheets of different algae has been prepared and all are pressed in herbarium press. After 24 hours the wet newspapers were replaced by fresh, dry sheets and then the specimens were mounted and labeled.

3.3 Permanent micropreparations:

The suitable method applied for permanent preparation of slide for morphological study and identification is as follows.

- Alga was placed on glass slide in a drop of fresh water.
- A drop of 40% formalin were added to fix and drain out excess water.

- A small lump of glycerine jelly was placed on the algae (Glycerine jelly was prepared by dissolving 5 gm of gelatin in 30 ml of water by gentle heat and then added 0.125 gm phenol and 35 ml of glycerol).
- Slides were transfer the slide to an incubator or oven (at 60° C) for a few minutes for the jelly to melt. Spread the algal material appropriately.
- The circular cover glass slip was applied and the slide was kept again in the oven for a short while. Wiped out the excess of jelly from around the coverglass and sealed it with Gold Size and store flat.

3.4 Ecophysiological Study:

The water of Vena River is utilized for various purposes like domestic uses, farming, industrial purposes etc. The effluents from industries and sewage water from villages mostly polluted the river. Hence, in order to know the impacts of pollution due to industrial effluents and waste water, there is an added interest to investigate the physico-chemical parameters of this river along with the investigations of Ecophysiological study of Vena River.

For this investigation work, water samples were collected from different depths, were mixed in equal volumes and preserved in 500 ml stopper bottles and were allowed to stand for at least 24 hours. Thereafter, from the settled phytoplanktons, employing a graduated pipette, an aliquot of samples was taken and one drop (0.05 ml) of the sample was placed on a clean glass slide for qualitative and quantitative analysis. All the chemicals used in the study were of A.R. grades. Double distilled water was employed throughout the study. Standard methods for collection, preservation and analysis were adopted, APHA, (1985).

Sampling Stations: - Water samples from four stations of the Vena River were collected at Hinganghat, Wardha district, of (MS) i.e. Under Bridge (SW_1), Kawalghat (SW_2), Smashanbhoomi (SW_3), and Shalangadi (SW_4). The whole tenure of study was divided into periods of three months each i.e. June to August (2011), September to November (2011), December (2011) to February (2012), March to May (2012), June to August (2012), September to November (2012), December (2012) to February (2013) and March to May (2013). These procedures were repeated for two years from the month of June 2011 to July 2013, in monthwise manner. The time of collection of sample was morning hours i.e. 9 am to 10 am.

3.5 Methods of culturing:

Certain morphological and reproductive stages can best be demonstrated by suitable manipulation of culturing of algae. The algal culture may either be obtained from a culture collection, or raised in the laboratory. Unialgal cultures may, however, be isolated without much difficulty from fresh material collected from nature. A number of culture media has been found suitable. The following culture media are likely to prove useful for the isolation and multiplication of most of the fresh water algae.

3.6 Culure media: Bold's basal medium, (Bold, 1949), Allen's and Arnon's medium, (Arnon, *et al.*, 1974) and BG11 medium were first tried in both solid and liquid forms. The composition of all these media were tabulated in Table 3.2, 3.4 and 3.5.

Table : 3.2 Bold's Basal medium (BBM).

Composition of Elements	Quantity
$NaNO_3$	0.25 g/l
$CaCl_2.2H_2O$	0.25 g/l
$MgSO_47H_2O$	0.75 g/l
$K_2HPO_4H_2O$	0.75 g/l
$KH_2PO_41.5H_2O$	0.175 g/l
NaCl	0.025 g/l
Microelement solution	1 ml/lit.

3.6.1 Microelement solution.

Trace elements solution was prepared in following ways.

Table 3.3 Microelement composition.

Elements	Quantity
a) EDTA KOH	50 gm 31 gm Both the elements were dissolved in 1 liter of double distilled water.
b) $FeSO_4.7H_2O$	4.98 gm was dissolved in 1 liter of acidified double distilled water (Acidified water: 1 ml H_2SO_4 (Conc.) added to 999 ml double distilled water).
c) H_3SO_4	11.42 gm was dissolved in 1 liter of distilled water.
d) $ZnSO_47H_2O$	8.82 gm
e) $MnCl_24H_2O$	0.44 gm
f) MoO_3	0.71gm
g) $CuSO_45H_2O$	1.57gm

$CoNO_36H_2O$ dissolved in 1 liter of doubled distilled water before autoclaving solid medium was prepared by adding 2% (w/v) agar into the hot liquid medium.

Table 3.4 Allen and Arnon's medium (AAM)

Elements	Quantity
NaCl K_2HPO_4 $7H_2O$	0.45 g/l
$MgSO_4 7H_2O$	0.124 g/l
$CaCl_2 2H_2O$	0.015 g/l
Microelement solution	1 ml
$MnCl_2 4H_2O$	1.21 g/l
$HNa_2MoO_4 2H_2O$	1.26 g/l
$H_3BO_3 10H_2O$	2.86 g/l
$CuSO_4 5H_2O$	0.079 g/l
$ZnSO_4 5H_2O$	0.222 g/l
$NaNO_3$	0.239 g/l
$CoCl_2 6H_2O$	0.040 g/l

The pH of the medium was adjusted to 7.5 and solid medium was prepared as with BBM.

Table 3.5 BG 11 medium stock solution

Elements Composition	Quantity
a) Citric acid	6.0 gm dissolve in 1 lit. of doubled distilled water
b) $FeSO_4 7H_2O$	6.0 gm dissolved in 1 lit. of doubled distilled water.
c) Disodium EDTA	1.0 gm dissolve in 1 lit. of doubled distilled water.
d) $CoCl_2 2H_2O$	36.0 gm dissolved in 1 lit. of doubled distilled water.
e) K_2HPO_4	40.0 gm dissolve in 1 lit. doubled distilled water
f) $MgSO_4 7H_2O$	75.0 gm dissolve in 1 lit. doubled distilled water.
g) Na_2CO_3	20.0 gm dissolve in 1 lit. doubled distilled water
h) $NaNO_3$	150.0 gm dissolved in 1 lit. of doubled distilled water.
i)Trace elements solution	
a) H_3BO_3	2.63 g/l
b) $Mncl_2 4H_2O$	1.81 g/l

c) $ZnSO_4 7H_2O$	0.22 g/l.
d) $Na_2MoO_4 7H_2O$	0.3g/l
e) $CuSO_4 5H_2O$	0.07 g/l.
f) $CoNO_2 6H_2O$	0.04 g/l.

Table 3.6 De's (1989) modified Beneck's medium

Elements Composition	**Quantity**
KNO_3	0.2 gm/4 = 0.005 = 5.0 mg
$MgSO_4 7H_2O$	0.2gm 0.005 = 5.0 mg
K_2HPO_4	0.2 gm 0.05 = 5.0 mg
$CaCl_2 2H_2O$	0.1 gm 0.0025 = 2.5mg
$FeCl_2$ (1%)	2 drops
EDTA	Traces

All above quantities dissolved in 1 lit. distilled water (100 ml).

Table 3.7 Chu- 9 medium

Elements Composition	**Quantity**
$Ca(NO_3)_2$	0.02 = 0.04 gm
K_2HPO_4	0.002 gm
$MgSO_4 7H_2O$	0.01gm
K_2SiO_3	0.025 gm
$CaCO_3$	0.01 gm
$FeCl_3$	0.01 gm

Stock solutions prepared and stored in stopper bottles, liquid culture medium when required was prepared by taking 1 ml of each one of the stock solutions, and volume was making with doubled distilled water to make up 1 lit. of medim. pH of medium was adjusted to 7.6. Solid medium was prepared as with BBM.

All above three media were tried in both liquid and solid form. Better algal growth was observed in Bold's Basal Medium (BBM), and BG-11 medium due to

presence of chelating agent EDTA or its sodium salt. Out of these two media BG-11 was prepared for further work due to its easy storage and preparation. Liquid media was opted for this work.

The conical flasks of 100 ml, 250 ml, 500 ml, and 1000 ml capacity, were used as culture vessels. All culture vessels were washed with detergent teepol and rinsed twice with tap water. Then, they were rinsed with chromic acid (made by adding concentrated solution of potassium dichromate to concentrated sulphuric acid). Again they were washed with doubled distilled water, finally washed with very dilute sodium carbonate solution, (0.2 gm dry anhydrous sodium carbonate to 1 lit. distilled water) to compensate for the acid nature of Borosil glass. They were then closed with plugs of non-absorbent cotton.

3.7 Identification:

Unicellular, and filamentous unialgal forms were placed on a clean slide and gently separated by using two dissection needles. A slide was then observed under low power of microscope. Different algal mass separated out with needles and mounted on separate slides. Mounting was done in vitro in glycerine without any stain and remaining algal mass preserved in 4% formalin.

The algal genera were identified visually on the basis of their morphological characters by comparing with referring slides made from total algal forms and by referring to standard literature on algae like Cyanophyta by Desikachary, (1959).

3.8 Microscopy:

All observations were made with binocular research microscope optics. Used objectives vertical, horizontal and reading of mechanical stage was taken, and snaped

the photographs by using MIPS. The present work being generally quantitative, most of the results have been illustrated with the help of standard literature on algae (Desikachary, 1959 and Fritsch, 1935, 1945).

Cultures were grown in laboratory and for cultures, basal medium was used. These cultures demonstrate the algal growth due to the influence of different elements and external appearance and also effect of heavy metals on algal growth.

3.9 Composition of BG 11 Medium:

Table 3.8 BG 11 Medium (Composition)

BG.II Medium	**Elements in inorganic chemicals**	**Salt employed in to test experiment.**
$NaNO_3$	Na, N	$NaNO_3$
K_2HPO_4	K.P	KCl, Na_2HPO_4
$MgSO_4.7H_2O$	Mg	$MgCl_2$, Na_2SO_4
$CaCl_2.2H_2O$	Ca,Cl	NaCl, $CaSO_4$
Citric acid	Citric acid	Citric acid
$FeSO_47H_2O$	Fe	$FeSO_4$
EDTA	EDTA	EDTA
Na_2CO_3	C	Na_2CO_3

3.9.1 Carbon: BG 11 medium contains 2.26 mg of C in the form of Na_2CO_3. Stock solutions of carbon were made by dissolving 0.88 gm of Na_2CO_3 in 100 ml of distilled water. Carbon ranges from 1-19 mg/l was selected for nutrient study.

3.9.2 Nitrate: Basal medium have 247.08 mg/l of N in form of $NaNO_3$. To study the influence of Nitrate elements on growth of algae stock solution were made as 1 ml =10 mg, N as $NaNO_3$ by dissolving 6.35 gm of $NaNO_3$ in 100 ml of distilled

water. The nitrogen ranges were 200-450 mg/l and were selected for nutrient study.

3.9.3 Phosphate: Phosphorous as K_2HPO_4 were 7.112 mg/l in basal medium. A stock solution of PO_4 were made by addition of 0.56 gm of $K_2HPO_43H_2O$ to 100 ml in doubled distilled water. The range of phosphrous was 4.0-28.0 mg/l were selected in the test medium. The levels of K were maintained by adding K as KCl.

3.9.4 Calcium: Medium contains 9.81 mg/l Ca, $CaCl_2$ solution were made by 0.335 gm $CaSO_4$ in 100ml distilled water as to get 1 ml = 1mg Ca. The range of calcium were 4.0 -128.0 mg/l to evaluate its influence on algal growth.

3.9.5 Magnesium: BG 11 medium contains 7.38 mg/l as $MgSO_4$. A stock solution of Mg as made by dissolving 0.38 of $MgCl_2$ in 100 ml doubled distilled water enable to get 1ml = 1 mg. The range was 4.0-128.0 mg/l.

3.9.6 Sodium: The concentration of salt $NaNO_3$ were 405.5 mg/l in BG 11 medium, solution were prepared by dissolving 3.87 gm of $NaNO_3$ in doubled distilled water made 1 ml = 1 mg of Na. The range of Na in the test experiments were 360.0-500.0 mg/l.

3.9.7 Potassium: BG 11 contains potassium 17.95 mg/l in K_2HPO_4. Potassium range were 4.0 -128.0 mg/l were taken to study its influence. The level of phosphorous was made by salt (complementary) 7.11 mg Na_2HPO_4 in 1 liter of medium.

3.9.8 Chloride: The medium have 23.99 mg/l chloride as $CaCl_2$. A stock solution of chloride 1 ml = 1mg were made by dissolving 0.0606 gm of NaCl in 100ml doubled distilled water, chloride range 4.0-128 mg/l was preferred to study its influence on algal growth.

3.9.9 Iron: As $FeSO_4$, were 1.2 mg/l in BG 11 medium, its solution were made by dissolving 0.497 gm of $FeSO_4$ in 100 ml distilled water. The range for test

experiment was 0.2-3.2 mg/l to study the influence of iron on growth of phytoplanktons.

3.9.10 Citric acid: BG 11 medium contains 6 mg/l citric acid and its stock solution was made by dissolving 0.21gm of citric acid in 100 ml of doubled distilled water to have 1 ml = 1 mg solution. The range of citric acid to study its influence on algal growth 3.0-60 mg/l.

3.9.11 EDTA: A stock solution 1 mg/l EDTA were made by dissolving 0.0292 gm of EDTA in 100 ml of doubled distilled water. The range was 0.1-1.0 mg/l in the test experiment.

Table 3.9 Composition of Modified BG-11 medium for *Chlorococcum humicolumn* (Naeg). Rabenh.

Ingredient in inorganic chemicals	Stock solution of BG-11 employed (ml)	Amount of stock solution (g/l)	Essential elment (mg/l)	Optimum amount (mg/l) noted	Max growth (mg/l)	Actual element present in modified	Stock solution employed (ml)	Amount of stock solution in modified BG-11 medium (l-1)
$NaNO_3$	10	150	Na	405	370	370	9.1	136.50
			N	247	300	225.6		
K_2HPO_4	1	40	K	17.95	32	31.1	1.78	71.2
			P	7.1	16	12.65		
$MgSO_4$	1	75	Mg	7.3	32	31.1	4.38	328.5
			S	9.7	32	42.51		
$CaCl_2$	1	36	Ca	13	32	31.1	2.46	68.56
			Cl	23	32	56.60		
Citric Acid	1	6	Citric Acid	6	6	6	1	6
$FeSO_4$	1	6	$FeSO_4$	1.2	1.2	6	1	6

EDTA	1	1	EDTA	1	1	1	1	1
Na_2CO_3	1	20	Na_2CO_3	2.2	2.0	1.69	0.75	15

Table 3.10 Composition of Modified medium for *Oscillatoria amphibia* C.Agardh *ex* Gomont.

Ingredient in inorganic chemicals	Stock solution of BG-11 employed (ml)	Amount of stock solution (g/l)	Essential elment (mg/l)	Optimum amount (mg/l) noted	Max growth (mg/l)	Actual element present in modified	Stock solution employed (ml)	Amount of stock solution in modified BG-11 medium (l-1)
$NaNO_3$	10	150	Na	405	370	370	9.1	136.50
			N	247	300	225.9		
K_2HPO_4	1	40	K	17.95	4	10	0.5	22.5
			P	7.1	4	4		
$MgSO_4$	1	75	Mg	7.3	8	8.1	1	82.16
			S	9.7	8	10.69		
$CaCl_2$	1	36	Ca	13	16	15.99	1.23	44.36
			Cl	23	16	28.31		
Citric Acid	1	6	Citric Acid	6	6	6	1.0	6
$FeSO_4$	1	6	$FeSO_4$	1.2	1.2	6	1.0	6
EDTA	1	1	EDTA	1	1	1	1.0	1.0
Na_2CO_3	1	20	Na_2CO_3	2.2	2.20	20	1.0	20

Table 3.11- Composition of Modified BG-11 medium for *Selenastrum westii* G.M.Smith.

Ingredient in inorganic chemicals	Stock solution of BG-11 employed (ml)	Amount of stock solution (g/l)	Essential element (mg/l)	Optimum amount (mg/l) noted	Max growth (mg/l)	Actual element present in modified	Stock solution employed (ml)	Amount of stock solution in modified BG-11 medium (l-1)
$NaNO_3$	10	150	Na	405	370	370	9.1	136.50
			N	247	300	300		
K_2HPO_4	1	40	K	17.96	32	32	1.78	71.2
			P	7.1	7.1	16		
$MgSO_4$	1	75	Mg	7.3	7.3	7.52	1.21	90.75
			S	9.7	9.7	13.24		
$CaCl_2$	1	35	Ca	13	16	16	1.23	44.28
			Cl	23	32	28.30		
Citric Acid	1	6	Citric Acid	6	6	6	1	6
$FeSO_4$	1	6	$FeSO_4$	1.2	1.2	6	1	6
EDTA	1	1	EDTA	1	1	1	1	1
Na_2CO_3	1	20	Na_2CO_3	2.2	2	1.69	0.7	5

Table 3.12 Composition of Modified BG-11 medium for *Coelastrum sphaericum* Nageli.

Ingredient in inorganic chemicals	Stock solution of BG-11 employed (ml)	Amount of stock solution (g/l)	Essential elment (mg/l)	Optimum amount (mg/l) noted	Max growth (mg/l)	Actual element present in modified	Stock solution employed (ml)	Amount of stock solution in modified BG-11 medium (l-1)
$NaNO_3$	10	150	Na	405	370	370	9.13	136.50
			N	247	300	300		
K_2HPO_4	1	40	K	17.95	16	32	1.78	71.2
			P	7.1	64	16		
$MgSO_4$	1	75	Mg	7.3	32	33	4.50	337.5
			S	9.7	32	43.71		
$CaCl_2$	1	36	Ca	13	32	32	2.46	88.56
			Cl	23	32	56.61		
Citric Acid	1	6	Citric Acid	6	6	6	1	6
$FeSO_4$	1	6	$FeSO_4$	1.2	1.2	6	1	6
EDTA	1	1	EDTA	1	1	1	1	1
Na_2CO_3	1	20	Na_2CO_3	2.2	2.20	20	1	20

Table :3.13 Modified BG-11 medium for *Chlorococcum humicolumn* (Naeg). Rabenh.

Sr.No.	Inorganic chemical formula	Amount employed for preparation (g/l)
1	$NaNO_3$	Use 1ml, 136.50 g/l
2	$K_2HPO_43H_2O$	Use 1 ml, 71.2 g/l
3	$MgSO_47H_2O$	Use 1ml, 328.5 g/l
4	$CaCl_2.2H_2O$	Use 1 ml, 88.56 g/l
5	Citric acid	Use 1 ml, 6.0 g/l
6	$FeSO_47H_2O$	Use 1ml, 6.0 g/l
7	EDTA (Disodium salt)	Use 1ml. 1.0 g/l
8	Na_2CO_3	Use 1 ml, 15.0 g/l

Table : 3.14 Modified BG-11 medium for *Oscillatoria amphibia* C.Agardh *ex* Gomont.

Sr.No.	Inorganic chemical formula	Amount employed for preparation (g/l)
1	$NaNO_3$	Use 1ml, 136.50 g/l
2	$K_2HPO_43H_2O$	Use 1 ml,71.2 g/l
3	$MgSO_47H_2O$	Use 1ml, 328.5 g/l
4	$CaCl_22H_2O$	Use 1 ml, 88.56 g/l
5	Citric acid	Use 1 ml, 6.0 g/l
6	$FeSO_47H_2O$	Use 1ml, 6.0 g/l
7	EDTA (Disodium salt)	Use 1ml, 1.0 g/l
8	Na_2CO_3	Use 1 ml, 20.0 g/l

Table : 3.15 Modified BG-11 medim for *Selenastrum westii* G.M.Smith.

Sr.No.	Inorganic chemical formula	Amount employed for preparation (g/l)
1	$NaNO_3$	Use 1ml, 136.50 g/l
2	$K_2HPO_43H_2O$	Use 1 ml, 71.2 g/l
3	$MgSO_47H_2O$	Use 1ml, 328.5 g/l
4	$CaCl_22H_2O$	Use 1 ml, 88.56 g/l
5	Citric acid	Use 1 ml, 6.0 g/l
6	$FeSO_47H_2O$	Use 1ml, 6.0 g/l
7	EDTA (Disodium salt)	Use 1ml, 1.0 g/l
8	Na_2CO_3	Use 1 ml, 15.0 g/l

Table: 3.16 Modified BG-11 medium for *Coelastrum sphaericum* Nageli.

Sr.No.	Inorganic chemical formula	Amount employed for preparation (g/l)
1	$NaNO_3$	Use 1ml, 136.50 g/l
2	$K_2HPO_4.3H_2O$	Use 1 ml,71.2 g/l
3	$MgSO_47H_2O$	Use 1ml, 328.5 g/l
4	$CaCl_2.2H_2O$	Use 1 ml, 88.56 g/l
5	Citric acid	Use 1 ml, 6.0 g/l
6	$FeSO_47H_2O$	Use 1ml, 6.0 g/l
7	EDTA (Disodium salt)	Use 1ml, 1.0 g/l
8	Na_2CO_3	Use 1 ml,15.0 g/l

3.10 Physicochemical analysis:

Any change in the quality of water has been determined by analysis and ensuring the qualitative and quantative change in the parameters. In this present study we employed the standard methods to analyse different parameters.

The samples were collected between 9 am to 10 am. Water samples were collected from the marginal areas to 1 to 1.5 m depth in dried plastic cans of five liter capacity during morning hours. Four sampling sites were selected (SW_1, SW_2, SW_3, and SW_4) along the stretch of river at a distance of 1 to 1.5 Kms from downstream to upstream. The parameters like water Temperature, pH, and D.O. were analysed at the sampling sites, while remaining parameters were analysed in the laboratory by employing pertinent literature, APHA, (2005).

3.11.1 Sampling programme and Analysis:

For investigation of water quality the following stepwise process were followed.

1) Number of sites - Four

2) Collections of Samples - Monthly

3) Time of sample collection - Between 9 AM to 10 AM

4) On site analysis - Temperature, pH

5) Analysis within 24 hours of sampling - All physico-chemical parameters.

3.11.1.1 Chemicals:

The chemicals employed in the present investigation were of analytical grade (A.R.) and were supplied by E. Merck India, S.D. Fine chemicals, and B.D.H., India.

3.11.1.2 Requirement:

Following instruments were employed during the study period:

3.11.1.2.1 Name of Instruments:

1. BOD incubator.
2. Electronic weighing machine.
3. Jackson turbidity meter.
4. COD Assembly.
5. Hot plate.
6. Hot air oven.
7. Binocular Research Microscope with MIPS.
8. pH meter.
9. Refrigerator.
10. Thermometer (^{0}C).
11. Double Distilled water.
12. Glass fiber filter.
13. Dessicator.
14. Autoclave.

3.11.1.2.2 Glaswares:

All glasswares employed were of corning or make of Borosil India.

3.10.1.3 Sampling Methods:

3.10.1.3 .1 Cleaning and sterilization of Glassware:

All the glasswares were cleaned or washed with teepol detergent and chromic acid and rinsed with distilled water 2-3 times.

a) Sampling Bottles: Sample bottles washed with detergent teepol and chromic acid and rinsed with tap water followed by distilled water.

b) Pipettes: Pipettes of different volume size were washed with cotton plug at upper end; these were then wrapped in butter paper and sterilized in an autoclave at 15lbs/inch^2 pressure at 121^{0}C for 15-25 minutes.

c) Test tubes: Borosil test tubes were washed and then pluged with non absorbent cotton wool, these were arranged in test tube racks and sterilization was done in an autoclave at 15lbs/inch^2 pressure at 121^{0}C for 15-25 minutes.

d) Other Glasswares: Such as conical flask, beakers, measuring cylinders etc. were washed carefully and then sterilized in hot air oven at 160-180^{0}C for 2-3 hours.

3.10.1.3 .2 Collection of samples:

i) For determination of the parameter such as estimation of TDS, alkalinity, pH (hydrogen ion concentration), total hardness, dissolved oxygen, free CO_2, Phosphate and nitrate, water samples were taken from Vena river in marginal areas.

ii) The bottles were filled completely with sample water up to rim and stopper was placed inside water only avoiding any kind of bubble inside it. They were immediately fixed by adding 2 ml each of manganous sulphate ($MnSO_4$) and alkaline potassium iodide at sampling spot, while the sample for BOD was incubated for 5 days in BOD incubator at 20^{0}C. For Dissolved oxygen (DO) /Biochemical Oxygen Demand (BOD), samples were collected in BOD bottles.

3.10.1.3 .3 Reagent preparation:

i) **Potassium Dichromate solution (0.025N):** By Dissolving 12.25 gm of dried A.R. grade $K_2Cr_2O_7$ in doubled distilled water to make one liter of solution, Diluted 10 times to make 0.025N $K_2Cr_2O_7$ solution.

ii) **Ferrous Ammonium Sulphate (0.01N):** By dissolving 39.2 gm of Fe $(NH_4)_2$ $(SO_4)_26H_2O$ in doubled distilled water, adding 20 ml of concentrated H_2SO_4 preparing 1 liter of solution. Diluting it 10 times to make 0.01N Fe $(NH_4)_2$ $(SO_4)_2$ $.6H_2O$ solution.

iii) **Ferroin indicator:** By dissolving 1.485 gm 1, 10 phenonthroline and 0.0695 gm of ferrous sulphate ($FeSO_4.7H_2O$) in distilled water to make 100 ml of solution.

iv) **Sulphuric Acid:** H_2SO_4 (concentrated sulfuric acid).

v) **Mercuric sulphate:** $HgSO_4$ solid.

vi) **Sodium Thiosulphate (0.025N):** By dissolving 24.82 gm of $Na_2S_2O_35H_2O$ in boiled doubled distilled water preparing final volume to one liter. A pellet of NaOH were adding or stabilizer. This is 0.1N stock solution, Diluting 0.1N stock solution 4 times with boiled doubled distilled water preparing 0.025N solution. Keeping it in brown glass stopper.

vi) Alkali Iodide Azide solution:

a) By dissolving 500 gm of NaOH or 700 gm of KOH and 150 gm of KI in doubled distilled water to makes one liter of solution.

b) By dissolving 10 gm of NaN_2 in 40 ml of doubled distilled water mixing both (a) and (b) solution.

vii) Magnesium sulphate solution: By dissolving 100 gm of $MnSO_4 4H_2O$ in 200 ml doubled distilled water.

viii) Starch solution: By dissolving 1gm of starch in 100 ml of warm distilled water and adding a few drops of formaldehyde solution.

ix) Sodium Hydroxide (0.05N): By dissolving 40 gm of NaOH in one liter CO_2 free distilled water for preparing 1N NaOH stock solution. Diluting 50 ml of 1 N NaOH stock solution to 1 liter doubled distilled water standardized the solution using H_2SO_4.

x) Phenolphthalein Indicator: By dissolving 0.5 gm methyl orange in 100 ml of doubled distilled water.

xi) Hydrochloric acid (0.1N): By diluting 12N concentrate HCl (Sp. Gr.1.8) to 12 times (8.34-100 ml) to prepare 1.0N HCL. It was further diluted ten times to make 0.1 N HCl (100-1000 ml).

xii) EDTA solution (0.01ml): By dissolving 3.723 gm of disodium salt of EDTA in doubled distilled water to prepare one liter of solution.

xiii) Buffer solution:

a) By dissolving 16.9 gm of ammonium chloride (NH_4Cl) in 143 ml of concentrated ammonium hydroxide (NH_4OH).

b) By dissolving 1.179 gm of disodium EDTA and 0.78 gm of $MgSO_4 7H_2O$ in 50 ml doubled distill water. Mixing (a) and (b) solution and made final volume to 250 ml using doubled distilled water.

xiv) Eriochrome Black -T indicator: By mixing of 0.5 gm of EBT with 100 gm of NaCl (AR) and grined to get the Eriochrome Black-T indicator.

xv)) Sodium Hydroxide solution (1N): By dissolving 40 gm of NaOH in one liter doubled distilled water.

xvi) Silver Nitrate (0.02N): By dissolving 3.40 gm of dried $AgNO_3$ in doubled distilled water to make one liter of solution and Kept in dark amber bottle.

xvii) Potassium chromate (5%): By dissolving 5 gm of K_2CrO_4 in 100 ml of doubled distilled water to get the Potassium chromate (5 percent) solution.

xviii) Ethyl alcohol 95%.

xix) Lugol's solution: By dissolving 10 gm of KI and 5 gm of iodine crystals in 20 ml of doubled distilled water and then added 50 ml doubled distilled water in which 5 gm anhydrous sodium acetate has been dissolved.

3.10.1.3.4 Analytical method:

Samples were analysed for the following Physico-chemical parameters.

a) Water temperatures.

b) pH.

c) Dissolved oxygen (DO).

d) Free CO_2.

e) Alkalinity.

f) Calcium.

g) Magnesium.

h) Total hardness.

i) Phosphates.

j) Nitrates.

k) Total dissolved solid (TDS).

3.10.1.3.4.1 Methodology:

The collection of water samples and analysis were done with the help of Welch, (1948); Trivedy and Goel, (1984); APHA-AWWA-WPCF, (1998); and Khanna and Bhutiani, (2005) for physico – chemical parameters.

i) **Temperature (^{0}C):** Centigrade calibrated thermometers were used to record the temperature of surface water for measurement of water temperature. Thermometer was dipped into water up to a desirable depth for 5-7 minutes and temperatures were noted down.

ii) **pH:** Measurement of pH is one of the most important and frequently used tests in water chemistry. pH is the hydrogen ion activity or concentration in the given water sample. pH equal to negatively log of hydrogen ion concentration.

$$pH = -\log_{10} (H^+)$$

pH was defined by Sorenson, ($-\log_{10}$) is $-\log_{10}(H^+)$. It is the intensity factor of acidity, pH of water sample were measured by the use of pH meter, but the accurate method is the electrometric method. The sample was analysed with the help of electronic digital pH meter consisting of a reference and indicator electrode.

Procedure: The electrode system was calibrated against standard buffer solution of known pH (pH 4, 7 and 9.2). Doubled distilled water used to rinse the electrode. Now the electrode was dipped in sample water and noted the reading on digital screen.

iii) Dissolved Oxygen:

i) Reagents:

a) **Manganese sulphate solution:** Dissolve 480 gm $MnSO_4.4H_2O$ in boiled and cooled 800 ml distilled water and dilute to 1000 ml.

b) **Alkali-iodide azide reagent**: Dissolve 500 gm NaOH (or 700 gm KOH) and 155 gm NaCl (155 gm KI) in boiled and cooled 800 ml distilled water. Dissolve separately 10 gm NaN_3 (Sodium Azide) in 40 ml distilled water. Mix two solutions and make the volume up to 1 liter by adding boiled and cooled distilled water.

c) **Concentrated sulphuric acid:** One milliliter is equivalent to about 3 ml alkali-azide reagent.

d) **Starch**: Dissolve 2 gm starch and add 0.2 gm Salicylic acid as preservative in 100 ml distilled water.

e) **Standard sodium thiosulphate solution (0.025N):** Dissolve 6.205 gm $Na_2S_2O_3.5H_2O$ in distilled water. Add 1.5 ml 6N NaOH and dilute to 1litre.

ii). Procedure: The sample was fixed in BOD bottle at sampling station, 1ml $MnSO_4$ reagent was added to the sample and followed by 1 ml azide reagent. The stopper was carefully placed to exclude air bubbles. The reagent mixed properly by inverting the bottle several times, and then allows precipitate to settle down. Add 1 ml concentrated sulphuric acid until to find complete dissolution of precipitate. One hundred ml solution of sample was taken out in a conical flask and adds few drops of starch solution. Titrate this with standard. sodium thiosulphate solution till the disappearance of blue colour.

iii) Calculations:

$$\text{Dissolved Oxygen mg/l} = \frac{0.2 \times \text{Vol.of titrant} \times 1000}{\text{Vol. of sample taken}}$$

1ml of 0.025N $Na_2S_2O_3$ = 0.2 mg of O_2

iv) Total alkalinity:

i) Reagents:

a) **Phenolphthalein indicator solution:** Dissolve 0.5 gm of phenolphthalein in indicator bottle containing 50 % of 100 ml ethyl alcohol. Then add 0.02 N NaOH drop wise until a faint pink colour appears.

b) **Standard H_2S0_4 solution (0.02N):** Take 2.8 ml of concentrate H_2SO_4 and dilute up to 1 litre by distilled water i.e. 0.1N solutions. Take 200 ml of 0.1 N solutions and dilute up to 1 liter, with distilled water.

c) **Methyl orange indicator:** Dissolve 0.5 gm methyl orange in 1 liter distilled water.

ii) Procedure: 100 ml of water sample was taken in conical Bask of 250 ml capacity and added few drops of phenolphthalein, it turns pink then titrate with 0.02N H_2SO_4, until to note disappearance of pink colour and recorded the reading for phenolphthalein alkalinity (P). If it remains colourless after addition of phenolphthalein i.e. P = 0.In this add few drops of methyl orange indicator gives yellow colour and titrated against 0.02N H_2SO_4 until a sharp change from yellow to wine red. This is noted as second reading for methyl orange alkalinity.

iii) Calculations:

Total alkalinity was calculated as follows:

$$\text{mg/l as CaCO3} = \frac{\text{A x N x 50,000}}{\text{ml of sample}}$$

Where, A- ml of H_2SO_4 required bringing the pH to 4.5

N- Normality of H_2SO_4, used

v) Free Carbon dioxide (CO_2)

i) Reagents:

1. **Phenolphthalein indicator solution:** Dissolve 0.5 gm of phenolphthalein in an indicator bottle containing 50% of 100 ml ethyl alcohol. Then add 0.02N NaOH drop wise until a faint pink colour appears.
2. **Standard sodium carbonate solution (0.045N):** Dissolve 0.02 gm anahydrous sodium carbonate that has been dried at 140^0C over night in freshly boiled and cooled carbon dioxide free distilled water and dilute to 250 ml store it in rubber stopper pyrex bottle.

ii) **Procedure:** one hundred ml sample was taken in Nesseler tube and added 10 drops of phenolphalaein indicator, if colour of sample turns pink; it indicates absence of carbon dioxide. If the sample remains colourless, then titrate rapidly with standard sodium carbonate solution, stirring gently with a glass rod until a faint pink colour appears permanently.

iii) **Calculation:** Free CO_2 mg/l = $\frac{Volume\ of\ titrant}{Volume\ of\ sample}$ x 1000

vi) Total Hardness (TH): Water hardness was understood by measuring the capacity of water to precipitable soap. Soap is precipitated chiefly by the calcium and magnesium ions present in it.

i) Principle: A small amount of dye such as Eriochrome black T (EBT) were adding to an aqueous solution containing Calcium and Magnesium ions at a pH of 10.0 the solution becomes wine red. If EDTA were added as a titrant the calcium and magnesium will be complexed and solution turn from red to blue, and end point of titration was marked.

ii) Procedure: By taking 100 ml of sample in a conical flask and adding a pinch of EBT indicator and 1 ml of buffer solution the solution turns wine red, It was titrated against EDTA untill wine red colour change to blue.

iii) Calculation: Hardness (mg/l) = ml of EDTA x 1000 /ml of sample.

vii) Calcium Hardness:

i) Reagent:

a) Sodium hydroxide solution (2N): Dissolve 80 gm NaOH in distilled water and dilute to 1000 ml.

b) Murexide indicator: Mix 200 mg of murexide with 100 gm solid NaCl and grind the mixture.

c) Standard EDTA solution (0.01M): Dissolve 3.723 gm disodium salt of EDTA in distilled water and dilute to 1000 ml. standardized it against standard calcium solution. Store this solution in polythene bottle.

ii) Procedure: 50 ml of water sample was taken into porcelain dish and added 1-2 ml NaOH solution to raise a pH 12 and add pinch of murexide indicator to get pink colour. This solution was filtered with standard EDTA (0.01ml) untll pink colour changes to purple, this indicate the end point.

iii) Caculations:

$$\text{Calcium Hardness mg/l} = \frac{\text{Used volume of titrant x A x B}}{\text{volume of sample}}$$

Where A- 0.4008 (Represent that when 1 ml titrant used 0.4008 mg of Ca is present)

B- 1000 ml.

viii) Magnesium Hardness :

i) **Calculation**: Magnesium hardness mg/l as $CaCO_3$=Total Hardness mg/l as $CaCO_3$-Calcium Hardness mg/l as $CaCO_3$..

ix) Phosphorus (Stannous chloride method):

i) Reagent:

a) Phenolphthalein indicator: Dissolve 0.5 gm phenolphthalein in 500 ml 95% ethyl alcohol and 500 ml distilled water. Add few drops 0.02 N NaOH till faint

pink colour appear (pH 8.3).

b) Strong acid solution: Add 300 ml concentrated H_2S0_4 in to about 600 ml distilled water, after cooling add 4 ml concentrated HNO_3 and dilute to 1000 ml.

c) Ammonium molybdate reagent: Dissolve 25 gm $(NH_4)6MoO_{24}.4H_2O$ in about 175 ml distilled water. Add carefully 280 ml concentrated H_2SO_4 to 400 ml distilled water. Cool and add molybdate solution and dilute to 1000 ml.

d) Stannous chloride reagent: Dissolve 2.5 gm fresh $SnCl_22H_2O$ in 100 ml glycerol. Heat on water bath to ensure complete dissolution.

e) Standard phosphate solution: Dissolve 219.5 mg anhydrous KH_2PO_4 in distilled water and dilute to 1000 ml.

1 ml = 50 mg PO_4^{+3}

ii) Procedure: Take 100 ml of sample, a drop of phenolphthalein indicator was added; it was followed by 4 ml molybdate reagent and 0.5 ml stannous chloride reagent. The sample was maintained between 20^0C - 30^0C after 10 minutes colour was measured on spectrophotometer at 690 nm. The sample was compared with calibration curve using distilled water blank. Phosphorus was calculated as follows.

iii) Calculations:

$$PO4\ mg/l = \frac{mg\ of\ PO4 \times 1000}{ml\ of\ sample}$$

x) Nitrate (Ammonical nitrogen):

i) Reagent:

a) Phenol nitroprusside solution: Dissolve 30 gm of phenol in 1000 ml of distilled water and add 2 ml freshly prepared 1.5 % w/v aqueous solution of

sodium nitroprusside.

b) **Alkaline hypochloride solution**: Dissolve 20 gm sodium hydroxide in distilled water and add 5.4 ml, 10% solution of hypochlorite. Make up the volume to 1000 ml with distilled water.

c) **Standard ammonium chloride solution**: Dissolve 3.819 gm NH_4Cl dried at 100^0C in distilled water and dilute to 1000 ml.

ii) Procedure: Take 40 ml sample in 250 ml volumetric flask and add 4 ml each phenol nitroprusside solution and alkaline hypochlorite solution. Make up the volume of content to 250 ml by adding ammonia free distilled water. Keep it in dark place at 25^0C for about 1 hour. Record the absorbance on spectrophotometer at 635 nm. Distilled water used as a blank. Process the standard ammonium solution of different concentration in similar way and record the absorbance for each. Plot the graph of concentration of ammonium ion in mg NH_4^+ against absorbance and prepare a standard curve. Calculate concentration of unknown with the help of curve.

xi) Total Dissolved solids (TDS): Total solids in any sample can be represented by dissolved organic and inorganic matter and may be estimated by evaporating the filtered sample through standard filter and weighing of the left.

Calculation:

$$\text{Total dissolved solids (mg/l) (TDS)} = \frac{A-B}{\text{Volume of sample}}$$

Where A = Final weight of dish with sample.

B = Previous weight of dish without sample (empty).

OBSERVATIONS

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4.1 Physico-chemical characteristics:

Table 4.1 Monthly variation in temp. (^{0}C) at various stations (June 2011 to May 2012).

Sr. No	Month	Temp (^{0}C)			
		SW_1	SW_2	SW_3	SW_4
1.	June	32.2	32.1	32.1	32.0
2.	July	27.9	27.8	27.7	28.0
3.	August	27	27.1	26.9	27.2
4.	September	27.5	27.4	27.6	27.5
5.	October	26.4	26.5	26.3	26.6
6.	November	23.0	23.1	23.2	22.9
7.	December	20.7	20.6	20.8	20.7
8.	January	21.6	21.7	21.5	21.6
9.	February	24.5	24.6	24.5	24.4
10.	March	28.7	28.8	28.6	28.7
11.	April	32.9	33.0	32.8	32.9
12.	May	35.2	35.1	35.1	35.0

(SW_1-Under bridge, SW_2-Kawalghat, SW_3- Smashanbhoomi, SW_4-Shahalangadi)

Table 4.2 Monthly variation in temp. (^{0}C) at various stations (June 2012 to May 2013).

Sr. No.	Month	Temp (^{0}C)			
		SW_1	SW_2	SW_3	SW_4
1.	June	31.9	31.8	31.8	31.9
2.	July	28.1	28.2	28.0	28.2
3.	August	26.9	26.8	26.7	27.0
4.	September	27.3	27.4	27.2	27.3
5.	October	26.9	26.8	27.0	26.8
6.	November	22.8	22.9	22.7	22.8
7.	December	21.1	21.0	21.2	21.3
8.	January	21.8	21.9	21.7	21.9
9.	February	23.9	23.8	24.0	23.9
10.	March	29.0	29.1	29.2	28.9
11.	April	33.1	33.2	33.0	33.2
12.	May	34.8	34.9	34.7	34.8

(SW_1-Under bridge, SW_2-Kawalghat, SW_3- Smashanbhoomi, SW_4-Shahalangadi)

Chapter - 4

Observations

Table 4.3 Monthly variation in pH at various stations.
(June 2011 to May 2012).

Sr. No.	Month	pH			
		SW_1	SW_2	SW_3	SW_4
1.	June	7.31	7.21	7.8	7.44
2.	July	7.8	7.1	8.02	7.64
3.	August	8.7	8.35	8.54	8.53
4.	September	8.2	8.21	8.33	8.24
5.	October	7.35	7.3	7.45	7.36
6.	November	8.64	8.53	8.65	8.6
7.	December	7.68	7.71	8.11	7.83
8.	January	8.57	7.03	7.04	7.54
9.	February	8.2	7.11	7.33	7.54
10.	March	7.79	7.23	7.33	7.45
11.	April	8.21	7.3	7.85	7.78
12.	May	7.46	7.33	6.69	7.16

(SW_1-Under bridge, SW_2-Kawalghat, SW_3- Smashanbhoomi, SW_4-Shahalangadi)

Table 4.4 Monthly variation in pH at various stations.
(June 2012 to May 2013).

Sr. No	Month	pH			
		SW_1	SW_2	SW_3	SW_4
1.	June	6.25	6.1	6.2	6.18
2.	July	9.03	9.09	8.75	8.95
3.	August	8.8	10.8	9.5	9.7
4.	September	7.52	7.46	7.47	7.48
5.	October	8.71	8.61	7.69	8.33
6.	November	8.61	8.65	8.65	8.63
7.	December	8.53	8.1	8.37	8.33
8.	January	6.7	6.75	7.8	7.08
9.	February	6.36	6.23	6.34	6.31
10.	March	7.1	7.15	7.29	7.18
11.	April	8.4	8.26	8.21	8.29
12.	May	8.56	8.5	8.34	8.46

(SW_1-Under bridge, SW_2-Kawalghat, SW_3- Smashanbhoomi, SW_4-Shahalangadi)

Table 4.5 Monthly variation in Dissolved Oxygen (DO) (mg/l) at various stations. (June 2011 to May 2012).

Sr. No.	Month	Dissolved Oxygen (DO)			
		SW_1	SW_2	SW_3	SW_4
1.	June	34.23	19.73	6.84	20.26
2.	July	11.27	10.06	10.47	10.6
3.	August	2.41	2.01	2.41	2.27
4.	September	10.06	2.41	4.83	5.76
5.	October	3.22	16.91	15.3	11.81
6.	November	13.29	11.67	8.86	11.27
7.	December	10.06	8.45	10.06	9.52
8.	January	12.08	12.88	16.1	13.68
9.	February	21.74	35.44	17.72	24.96
10.	March	20.13	34.63	10.47	21.74
11.	April	11.67	8.84	4.02	8.17
12.	May	18.92	30.2	14.09	21.07

(SW_1-Under bridge, SW_2-Kawalghat, SW_3- Smashanbhoomi, SW_4-Shahalangadi)

Table 4.6 Monthly variation in Dissolved Oxygen (DO) (mg/l) at various stations (June 2012 to May 2013).

Sr. No.	Month	Disolved Oxygen (DO)			
		SW_1	SW_2	SW_3	SW_4
1.	June	24.16	24.16	24.16	24.16
2.	July	16.1	16.1	16.1	16.1
3.	August	16.51	18.21	18.92	17.88
4.	September	16.1	14.9	14.49	15.16
5.	October	20.94	22.15	20.94	21.34
6.	November	13.29	13.39	14.9	13.86
7.	December	8.86	6.84	8.056	7.91
8.	January	11.27	10.06	14.06	11.79
9.	February	6.84	6.84	5.63	6.43
10.	March	2.416	2.013	2.013	2.147
11.	April	9.66	9.66	10.06	9.79
12.	May	10.06	11.67	11.27	11

(SW_1-Under bridge, SW_2-Kawalghat, SW_3- Smashanbhoomi, SW_4-Shahalangadi)

Table 4.7 Monthly variation in Free CO_2 (mg/l) at various stations. (June 2011 to May 2012).

Sr. No	Month	Free CO_2			
		SW_1	SW_2	SW_3	SW_4
1.	June	0	0	0	0
2.	July	299	308	369	334
3.	August	506	528	572	535
4.	September	330	180.4	308	272
5.	October	176	132	154	154
6.	November	165	110	143	139
7.	December	341	429	407	392
8.	January	66	55	77	66
9.	February	125.4	44	33	67
10.	March	215.6	169.4	369	169.4
11.	April	22	26.4	418	26.2
12.	May	140.8	66	66	67

(SW_1-Under bridge, SW_2-Kawalghat, SW_3- Smashanbhoomi, SW_4-Shahalangadi)

Table 4.8 Monthly variation in Free CO_2 (mg/l) at various stations. (June 2012 to May 2013).

Sr. No	Month	Free CO_2			
		SW_1	SW_2	SW_3	SW_4
1.	June	0	0	0	0
2.	July	55	13.2	17.6	13.1
3.	August	0	13.2	16.8	13.1
4.	September	66	88	83.6	87
5.	October	8.8	74.8	46.2	73.8
6.	November	94.6	114.4	145.2	115.4
7.	December	88	110	99	109
8.	January	55	66	66	77
9.	February	44	67	67	33
10.	March	169.4	169.4	169.4	369
11.	April	26.4	26.2	26.2	418
12.	May	66	67	67	66

(SW_1-Under bridge, SW_2-Kawalghat, SW_3- Smashanbhoomi, SW_4-Shahalangadi)

Table 4.9 Monthly variation in Calcium (mg/l) at various stations. (June 2011 to May 2012)

Sr. No	Month	Calcium			
		SW_1	SW_2	SW_3	SW_4
1.	June	45.69	41.88	31.26	42.1
2.	July	60.12	56.11	48.09	55.9
3.	August	40.88	47.29	52.1	46.29
4.	September	36.07	36.87	40.08	35.87
5.	October	97.79	80.16	81.76	91.16
6.	November	55.31	56.91	52.1	55.96
7.	December	40	40.88	44	41.02
8.	January	72.14	77.75	81.76	78.75
9.	February	100.02	96.99	96.19	95.99
10.	March	96.19	89.77	60.12	88.77
11.	April	129	140.28	132.2	139.8
12.	May	26.45	20.04	25.65	21

(SW_1-Under bridge, SW_2-Kawalghat, SW_3- Smashanbhoomi, SW_4-Shahalangadi)

Table 4.10 Monthly variation in Calcium (mg/l) at various stations. (June 2012 to May 2013).

Sr. No	Month	Calcium			
		SW_1	SW_2	SW_3	SW_4
1.	June	24.04	24.04	24.04	24.01
2.	July	31.26	32.06	40.08	31.06
3.	August	20.04	19.23	16.03	20.01
4.	September	21.64	20.84	43.28	21.84
5.	October	29.65	35.27	33.66	34.25
6.	November	28.05	52.1	8.81	51.9
7.	December	32.04	36.07	33.66	35.07
8.	January	21.64	32.06	32.06	31.06
9.	February	33.66	4.008	4.008	3.006
10.	March	39.27	31.26	26.45	31.26
11.	April	12.02	12.82	9.619	12.86
12.	May	13.62	12.02	11.22	12.5

(SW_1-Under bridge, SW_2-Kawalghat, SW_3- Smashanbhoomi, SW_4-Shahalangadi)

Table 4.11 Monthly variation in Magnesium (mg/l) at various stations. (June 2011 to May 2012).

Sr. No	Month	Magnesium			
		SW_1	SW_2	SW_3	SW_4
1.	June	36.87	25.65	34.46	25.6
2.	July	18.43	13.62	20.04	13.65
3.	August	31.26	32.86	26.45	31.85
4.	September	52.1	28.05	36.07	28
5.	October	6.41	12.02	16.83	12.27
6.	November	16.83	18.4	34.46	17.45
7.	December	40.08	40.88	44.08	39.81
8.	January	16.03	8.8	8.016	8.9
9.	February	40.08	32.86	40.08	31.81
10.	March	8.817	9.619	14.42	9.569
11.	April	8.817	9.619	13.62	9.619
12.	May	37.71	76.15	82.56	76.15

(SW_1-Under bridge, SW_2-Kawalghat, SW_3- Smashanbhoomi, SW_4-Shahalangadi)

Table 4.12 Monthly variation in Magnesium (mg/l) at various stations. (June 2012 to May 2013).

Sr. No	Month	Magnesium			
		SW_1	SW_2	SW_3	SW_4
1.	June	28.05	32.06	32.06	32.06
2.	July	25.65	25.65	21.64	25.65
3.	August	33.66	43.28	84.16	42.28
4.	September	129.8	131.4	121.68	130.4
5.	October	90.58	92.98	98.59	91.98
6.	November	75.35	48.09	93.78	47.09
7.	December	40.08	40.58	34.46	40.05
8.	January	92.18	90.58	70.54	89.9
9.	February	84.96	107.41	115.4	106.95
10.	March	48.09	59.31	64.12	58.9
11.	April	70.54	77.75	72.14	76.75
12.	May	60.12	63.32	63.32	63.12

(SW_1-Under bridge, SW_2-Kawalghat, SW_3- Smashanbhoomi, SW_4-Shahalangadi)

Table 4.13 Monthly variation in Total Alkalinity (mg/l) at various stations (June 2011 to May 2012).

Sr. No	Month	Total Alkalinity			
		SW_1	SW_2	SW_3	SW_4
1.	June	28.05	32.06	32.06	32.06
2.	July	25.65	25.65	21.64	25.65
3.	August	33.66	43.28	84.16	42.28
4.	September	129.8	131.4	121.68	130.4
5.	October	90.58	92.98	98.59	91.98
6.	November	75.35	48.09	93.78	47.09
7.	December	40.08	40.58	34.46	40.05
8.	January	92.18	90.58	70.54	89.9
9.	February	84.96	107.41	115.4	106.95
10.	March	48.09	59.31	64.12	58.9
11.	April	70.54	77.75	72.14	76.75
12.	May	60.12	63.32	63.32	63.12

(SW_1-Under bridge, SW_2-Kawalghat, SW_3- Smashanbhoomi, SW_4-Shahalangadi)

Table 4.14 Monthly variation in Total Alkalinity (mg/l) at various stations. (June 2012 to May 2013).

Sr. No	Month	Total Alkalinity			
		SW_1	SW_2	SW_3	SW_4
1.	June	26.07	30.08	30.08	30.08
2.	July	23.67	23.67	19.66	23.67
3.	August	31.68	41.30	82.18	40.3
4.	September	128.0	129.6	119.7	128.6
5.	October	88.58	90.98	96.59	90
6.	November	73.37	46.11	91.8	45.11
7.	December	38.1	38.6	32.48	38.07
8.	January	90.18	88.58	68.54	88.1
9.	February	82.98	105.43	113.6	104.97
10.	March	47.1	57.33	62.14	57.1
11.	April	68.56	75.77	70.16	74.77
12.	May	58.14	61.34	61.34	61.14

(SW_1-Under bridge, SW_2-Kawalghat, SW_3- Smashanbhoomi, SW_4-Shahalangadi)

Table 4.15 Monthly variation in Phosphate (mg/l) at various stations. (June 2011 to May 2012).

Sr. No	Month	Phosphate			
		SW_1	SW_2	SW_3	SW_4
1.	June	0.62	0.56	0.94	0.59
2.	July	1.24	1.84	1.2	1.96
3.	August	4.6	6.2	0.56	5.2
4.	September	0.25	2.7	4.85	2.9
5.	October	2.9	3.35	3.1	3.4
6.	November	0.54	0.52	0.33	0.45
7.	December	1.8	1.2	1.5	1.4
8.	January	2.3	1.62	1.95	2
9.	February	1.49	1.49	1.49	1.49
10.	March	1.9	3.8	2.7	2.9
11.	April	2.7	9.8	11.25	9.7
12.	May	0.23	1.37	1.49	0.9

(SW_1-Under bridge, SW_2-Kawalghat, SW_3- Smashanbhoomi, SW_4-Shahalangadi)

Table 4.16 Monthly variation in Phosphate (mg/l) at various stations. (June 2012 to May 2013).

Sr. No	Month	Phosphate			
		SW_1	SW_2	SW_3	SW_4
1.	June	0.59	0.57	0.9	0.6
2.	July	1.2	1.8	1.1	1.98
3.	August	4.7	6.3	0.58	5.1
4.	September	0.5	2.5	4.9	2.8
5.	October	2.9	3.1	3.2	3.3
6.	November	0.52	0.5	0.39	0.46
7.	December	1.7	1.1	1.4	1.5
8.	January	2.3	2	2.05	2
9.	February	1.45	1.45	1.4	1.5
10.	March	1.8	3.7	2.8	3
11.	April	2.6	9.7	11.3	9.8
12.	May	0.25	1.4	1.5	1

(SW_1-Under bridge, SW_2-Kawalghat, SW_3- Smashanbhoomi, SW_4-Shahalangadi)

Table 4.17 Monthly variation in Nitrate (mg/l) at various stations (June 2011 to May 2012).

Sr. No	Month	Nitrate			
		SW_1	SW_2	SW_3	SW_4
1.	June	0.08	0.11	0.18	0.11
2.	July	0.11	0.11	0.22	0.11
3.	August	0.15	0.13	0.34	0.12
4.	September	0.22	0.07	0.09	0.06
5.	October	0.17	0.32	0.28	0.33
6.	November	0.14	0.16	0.11	0.16
7.	December	0.11	0.12	0.28	0.13
8.	January	0.11	0.12	0.15	0.13
9.	February	0.14	0.12	0.18	0.11
10.	March	0.12	0.1	0.14	0.09
11.	April	0.11	0.16	0.14	0.15
12.	May	0.1	0.26	0.13	0.12

(SW_1-Under bridge, SW_2-Kawalghat, SW_3- Smashanbhoomi, SW_4-Shahalangadi)

Table 4.18 Monthly variation in Nitrate (mg/l) at various stations. (June 2012 to May 2013).

Sr. No	Month	Nitrate			
		SW_1	SW_2	SW_3	SW_4
1.	June	0.18	0.19	0.18	0.19
2.	July	0.03	0.055	0.02	0.05
3.	August	0.05	0.07	0.13	0.07
4.	September	0.03	0.11	0.03	0.11
5.	October	0.07	0.07	0.07	0.07
6.	November	0.02	0.05	0.05	0.02
7.	December	0.08	0.06	0.1	0.06
8.	January	0.29	0.5	0.42	0.5
9.	February	0.06	0.09	0.08	0.09
10.	March	0.01	0.02	0.015	0.02
11.	April	0.12	0.07	0.15	0.07
12.	May	0.06	0.15	0.1	0.15

(SW_1-Under bridge, SW_2-Kawalghat, SW_3- Smashanbhoomi, SW_4-Shahalangadi)

Table 4.19 Monthly variation in Total Dissolved Salts (TDS) (ppm) at various stations (June 2011 to May 2012).

Sr. No	Month	Total Dissolved Salts (TDS)			
		SW_1	SW_2	SW_3	SW_4
1.	June	0.919	0.953	0.989	0.953
2.	July	0.468	0.467	0.452	0.466
3.	August	0.691	0.715	0.717	0.714
4.	September	0.537	0.564	0.57	0.563
5.	October	0.698	0.715	0.725	0.714
6.	November	0.181	0.196	0.181	0.197
7.	December	0.603	0.602	0.611	0.601
8.	January	0.697	0.733	0.813	0.732
9.	February	0.832	0.804	0.777	0.801
10.	March	0.849	0.878	0.951	0.876
11.	April	0.881	0.93	0.936	0.925
12.	May	0.698	0.719	0.871	0.72

(SW_1-Under bridge, SW_2-Kawalghat, SW_3- Smashanbhoomi, SW_4-Shahalangadi)

Table 4.20 Monthly variation in Total Dissolved Salts (ppm) (mg/l) at various stations (June 2012 to May 2013).

Sr. No	Month	Total Dissolved Salts (TDS)			
		SW_1	SW_2	SW_3	SW_4
1.	June	0.909	0.935	0.978	0.945
2.	July	0.473	0.457	0.442	0.467
3.	August	0.687	0.701	0.72	0.719
4.	September	0.525	0.56	0.565	0.571
5.	October	0.685	0.72	0.71	0.72
6.	November	0.17	0.18	0.179	0.189
7.	December	0.63	0.61	0.61	0.6
8.	January	0.69	0.723	0.81	0.721
9.	February	0.824	0.801	0.768	0.799
10.	March	0.85	0.88	0.94	0.854
11.	April	0.88	0.94	0.93	0.92
12.	May	0.67	0.72	0.873	0.719

(SW_1-Under bridge, SW_2-Kawalghat, SW_3- Smashanbhoomi, SW_4-Shahalangadi)

Table 4.21 Seasonal value of Physico- Chemical parameters in River Vena during June2011 to May 2013 at site SW_1

Parameter	Monsoon	Winter	Summer	Total
Water Temp. (°C)	29.55 ± 2.65	23.8±3.1	29.55±5 .65	27.63 ± 3.8
pH	7.64 ±1.39	7.70±1.00	7.46 ±1.1	7.6 ±1.16
Dissolved O_2 (mg/l)	18.32 ±15.91	12.08±8.86	12.078±9.66	14.15±11.47
Free CO_2 (mg/l)	253±506	174.9±166.1	118.8± 96.8	182.23±256.3
Total hardness (Ca) (mg/l)	40.08 ± 20.04	59.71±38.07	70.51±58.49	56.76±38.86
Total hardness (Mg) (mg/l)	74.11 ± 55.68	49.29±42.88	46.88±38.06	56.76±45.54
Total Alkalinity (mg/l)	76.73 ±53.06	65.14±27.04	66.03±18.93	69.3±99.03
Phosphate (mg/l)	2.475±2.225	1.71±1.19	1.465±1.235	1.88±1.55
Nitrate (mg/l)	0.125±0.095	0.155±0.135	0.075±0.065	0.118±0.098
TDS (ppm)	0.693 ±0.225	0.434±0.264	0.775±0.105	0.634±0.198

Table 4.22 Seasonal value of Physico- Chemical parameters in River Vena during June2011 to May 2013 at site SW_2

Parameter	Monsoon	Winter	Summer	Total
Water Temp. (°C)	29.45±2.65	23.7± 3.1	29.45±5.65	27.23±3.8
pH	8.45±2.35	7.7±0.95	7.36±1.13	7.83±1.47
Dissolved O_2 (mg/l)	11.075±9.065	14.495±7.65	18.726±16.71	14.76 ±11.14
Free CO_2 (mg/l)	264±528	242±187	97.8±71.6	201.26±262.2
Total hardness (Ca) (mg/l)	37.67±18.44	56.11±24.05	72.14±68.13	55.30±36.87
Total hardness (Mg)(mg/l)	72.51±58.90	50.89±42.09	58.51±48.89	60.63±49.96
Total Alkalinity (mg/l)	77.53±53.86	65.79±27.19	82.37±25.04	75.23±35.36
Phosphate (mg/l)	3.43±2.87	1.925±1.425	5.585±4.215	3.64±2.83
Nitrate (mg/l)	0.122±0.067	0.275±0.225	0.14± 0.12	0.179±0.137
TDS (ppm)	0.705±0.248	0.456±0.276	0.829± 0.110	0.663±0.211

Table 4.23 Seasonal value of Physico- Chemical parameters in River Vena during June2011 to May 2013 at site SW_3

Parameter	Monsoon	Winter	Summer	Total
Water Temp. (°C)	29.4±2.7	23.9±3.1	29.55±5.55	27.61±3.78
pH	7.94±1.76	7.85±0.77	7.385±1.075	7.72±1.20
Dissolved O_2 (mg/l)	13.285±10.87	14.498±6.44	9.86±7.85	12.54±8.38
Free CO_2 (mg/l)	286±572	226.6±180.4	222.1±195.9	244.9±316.1
Total hardness (Ca) (mg/l)	34.06±18.03	45.28±36.37	68.10±64.09	49.14±39.58
Total hardness (Mg)(mg/l)	70.86±50.82	53.30±5.28	64.51± 50.89	62.89±48.99
Total Alkalinity (mg/l)	70.67±51.01	65.53±33.05	88.37±27.03	74.85±37.03
Phosphate (mg/l)	2.73±2.17	1.765±1.435	6.35 ±4.95	3.625±2.851
Nitrate (mg/l)	0.18±0.16	0.235±0.185	0.097±0.082	0.170±0.142
TDS (ppm)	0.715±0.273	0.496±0.317	0.859± 0.091	0.69±0.227

Table 4.24 Seasonal value of Physico- Chemical parameters in River Vena during June2011 to May 2013 at site SW_4

Parameter	Monsoon	Winter	Summer	Total
Water Temp. (°C)	29.5±2.5	23.75±3.05	29.45±5.55	27.56±3.7
pH	7.94±1.76	7.85±0.775	7.385±1.075	7.725±1.20
Dissolved O_2 (mg/l)	13.215±10.94	14.625±6.71	13.55 ±11.4	13.79±9.86
Free CO_2 (mg/l)	267.5±535	229±163	222.1±195.9	239.53±297.96
Total hardness (Ca) (mg/l)	37.95±17.94	61.11±30.05	71.40±68.39	56.82±38.79
Total hardness (Mg)(mg/l)	72.025± 58.37	50.44±41.54	58.25±68.68	60.23±56.19
Total Alkalinity (mg/l)	77.03±53.36	65.02±26.95	82.02±24.92	74.69±35.07
Phosphate (mg/l)	2.89±2.30	1.925±1.475	5.35 ± 4.45	3.38±2.741
Nitrate (mg/l)	0.12±0.07	0.26± 0.24	0.085±0.065	0.155±0.125
TDS (ppm)	0.709±0.243	0.460±0.271	4.129±3.95	1.766±1.488

4.2 Exploration of Algae:

Table 4.25 Spatial variation of the algal genera and number of taxa found in Vena river in Hinganghat Area.

Sr. No.	Algal genera	Number of taxa in stations			
		SW_1	SW_2	SW_3	SW_4
Baccilariophyceae					
1.	*Cymbella*	0	1	1	1
2.	*Dinobryon*	1	0	1	1
3.	*Eunotia*	1	1	1	0
4.	*Fragilaria*	1	0	1	1
5.	*Frustulia*	0	1	1	1
6.	*Gomphonema*	2	2	0	2
7.	*Melosira*	1	1	1	0
8.	*Navicula*	5	3	5	5
9.	*Peridinium*	1	1	0	1
10.	*Phacus*	1	0	1	1
11.	*Pinnularia*	2	1	4	4
12.	*Rhodomonas*	0	1	1	1
13.	*Stauroneis*	2	1	2	0
14.	*Synura*	1	0	1	1
15.	*Tabellaria*	1	1	0	1

Chlorophyceae					
16.	*Closterium*	1	0	0	0
17.	*Triploceras*	0	1	1	1
18.	*Ankistrodesmus*	3	0	2	1
19.	*Chlorella*	1	1	0	1
20.	*Coelastrum*	2	0	1	2
21.	*Dictyosphaerium*	1	1	0	1
22.	*Dimorphococcus*	1	1	0	1
23.	*Eudorina*	1	0	1	0
24.	*Gonatozygon*	0	1	2	1
25.	*Nephrocytium*	0	1	2	2
26.	*Netrium*	1	1	0	1
27.	*Oocystis*	1	0	0	1
28.	*Pandorina*	2	2	1	0
29.	*Pediastrum*	3	0	2	1
30.	*Pleodorina*	1	1	1	0
31.	*Pleurotaenium*	4	1	0	4
32.	*Scenedesmus*	8	7	4	3
33.	*Spirogyra*	1	1	0	1
34.	*Tetraedron*	3	0	3	2
35.	*Tetraspora*	0	1	1	1
36.	*Cosmarium*	6	3	4	3
37.	*Desmidium*	*3*	*2*	*2*	*0*
38.	*Euastrum*	5	3	5	5
39.	*Micrasterias*	4	1	2	4
40.	*Onychonema*	1	0	1	1
41.	*Spondylosium*	1	1	0	1
42.	*Staurastrum*	6	4	4	2
43.	*Xanthidium*	2	2	0	1
44.	*Arthrodesmus*	2	0	2	2
45.	*Hyalotheca*	1	1	0	1
46.	*Spherozosma*	0	1	1	1

Cyanophyceae					
47.	*Anabaena*	1	1	1	0
48.	*Aphanocapsa*	1	0	0	1
49.	*Arthrospira*	1	0	1	1
50.	*Chroococcus*	0	1	1	1
51.	*Gleocapsa*	1	1	1	1
52.	*Lyngbya*	1	0	0	1
53.	*Merismopedia*	0	1	1	1
54.	*Oscillatoria*	2	1	1	0
55.	*Spirulina*	2	2	0	2
56.	*Synechocystis*	*1*	*1*	*1*	*1*
57.	*Synechoccus*	*1*	*0*	*1*	*1*
Euglenophyceae					
58.	*Euglena*	*2*	*2*	*1*	*1*
59.	*Lepocinclis.*	*1*	*1*	*0*	*0*
60.	*Trachelomonas*	5	4	0	2
	Total No. of Taxa	**103**	**68**	**71**	**78**
	Total No. of Genera	**50**	**43**	**41**	**49**

4.3 Phytoplanktons Recorded from Study area:

Table 4.26 Name of the phytoplankton recorded from study area.

Sr. No.	Name of the Phytoplankton	Summer	Monsoon	Winter	
Baccilariophyceae					
1.	*Cymbella cistula* (Hemprich) Grun. var. *woosangisis*Virget.	+	-	+	24
2.	*Dinobryon sertularia* Ehrenberg.	+	+	+	
3.	*Eunotia camelus* Ehr. var. *karveerensis* Gandhi.	+	-	+	
4.	*Fragilaria virescens* Ralfs.	+	-	+	
5.	*Frustulia rhomboides* (Ehr) De Toni var. *saxonica* (Rabenhorst) DeToni.	-	+	-	
6.	*Gomphonema elegans* Grun.	+	-	+	

7.	*Gomphonema vidarbhense* Kamath.	+	+	+	
8.	*Melosira granulata* (Ehr.) Ralfs.	+	+	+	
9.	*Navicula cari* Ehr. *fa. indica* Sarode et Kamat.	+	+	+	
10.	*Navicula cryptocephala* Kuetz.	+	+	+	
11.	*Navicula cuspidata* Kuetz. var.*ambigua* (Ehr.) Cleve.	+	+	+	
12.	*Navicula pupula* Kuetz. var. *capitata* Hustedt.	-	+	-	
13.	*Navicula viridula* Kuetzing.	+	+	+	
14.	*Peridinium cinctum* (Muller) Ehrenberg.	+	-	+	
15.	*Phacus caudatus* var. *tenuis* Swirenko.	+	+	+	
16.	*Pinnularia acrosphaeria* (Breb.)W.Smith.	+	+	+	
17.	*Pinnularia brevicostata* Cleve var. *indica* Gandhi.	+	+	+	
18.	*Pinnularia gibba* Her.	+	-	+	
19.	*Pinnularia major* (Kuetz.) Cleve var. *linearis* Cleve.	+	-	+	
20.	*Rhodomonas baltica* Karst.	+	-	+	
21.	*Stauroneis anceps* var. *gracilis* (Ehr) Cleve.	+	+	+	
22.	*Stauroneis phoenicenteron* (Nitzsch) Ehr. var. *intermidia* Dippel.	-	+	-	
23.	*Synura uvella* Ehrenberg.	+	-	+	
24.	*Tabellaria fenestrata* (Lyngbye) Kuetzing.	+	+	+	
Chlorophyceae					
25.	*Closterium acerosum* var. *angolense* West and West.	+	+	+	73
26.	*Triploceras gracile* Bail var. *undulatum* Scott & Pres.	+	+	+	
27.	*Ankistrodesmus falcatms* (Corda) Ralfs	+	-	+	
28.	*Ankistrodesmus falcatus* (Corda) Ralfs var. *acicularis* (A. Braun) G.S.West	+	+	+	
29.	*Ankistrodesmus spiralis* (Turner) Lemmermann.	+	+	+	
30.	*Chlorella vulgaris* Beyer. (Smith).	+	+	+	

31.	*Coelastrum cambricum* Archer var. *intermidium* (Bohlin) G.S.West.	+	+	+	
32.	*Coelastrum sphaerium* Naeg.	+	-	+	
33.	*Dictyosphaerium ehrenbergianum* Naegeli.	+	+	+	
34.	*Dimorphococcus lunatus* A. Braun.	+	+	+	
35.	*Eudorina elegans* Ehr.	+	+	+	
36.	*Gonatozygon aculeatum* Hast.	+	-	+	
37.	*Gonatozygon monotaenium* De Bary.	+	-	+	
38.	*Nephrocytium agardhianum* Nag.	+	+	+	
39.	*Nephrocytium lunatum* W.West.	-	-	+	
40.	*Netrium digitus* (Ehrbg.) Itzigs. &Rothe.	+	+	+	
41.	*Oocystis elliptica* W. West.	+	+	+	
42.	*Pandorina cylindricum* Iyengar.	+	+	+	
43.	*Pandorina. morum* (Mull.) Bory.	-	+	-	
44.	*Pediastrum tetras* (Ehr.) Ralfs.	-	+	-	
45.	*Pediastrum biradiatum* Meyen non Ralfs var. *longicornutum* Gutwinski.	+	+	+	
46.	*Pediastrum duplex* Meyen var. *coronatum* Raciborski.	+	+	+	
47.	*Pleodorina californica* Shaw.	+	+	+	
48.	*Pleurotaenium baculoides* (Roy & Biss) Playf.	+	-	+	
49.	*Pleurotaenium nodosum* (Bail.)Lund.	+	+	+	
50.	*Pleurotaenium trabecula* (Ehrbg) Nag	+	-	+	
51.	*Pleurotaenium trabecula* (Ehrbg) Nag var. *maximum* (Reinsch) Roll	-	+	-	
52.	*Scenedesmus arcuatus* (Lemmarmann) Lemmarmann	+	+	+	
53.	*Scenedesmus bijugatus* (Turp.) Kuetz	+	+	+	
54.	*Scenedesmus dimorphus* (Turpin) Kuetzing.	+	-	+	
55.	*Scenedesmus perforatus* Lemmermann.	+	+	+	
56.	*Scenedesmus perforatus* (Lemmermann) var. *major* (Turner) Philipose.	+	-	+	
57.	*Scenedesmus quadricauda* (Turpin) Brebisson Var. *bicaudatus* Hansgirg.	+	-	+	

58.	*Scenedesmus quadricauda* (Turpin) Brebisson Var. *longispina* (Chodat) G.M.Smith.	+	-	+	
59.	*Scenedesmus quadricauda* v. qttadrispina (ChM.) G.M. Smith.	+	+	+	
60.	*Spirogyra ternata* Ripart.	-	+	-	
61.	*Tetraedron enorme* (Ralfs) Hansg var. *pentaedricum* Prescott.	+	+	+	
62.	*Tetraedron limneticum* Borge.	+	+	+	
63.	*Tetraedron trigonum* (Naeg) Hansg. fa. *gracile* (Reinsch) De Toni.	+	+	+	
64.	*Tetraspora gelatinosa* (Vauch.) *Desv.*	+	+	+	
65.	*Cosmarium auriculatum* Reinsch.	+	+	+	
66.	*Cosmarium contractum* Kirchner var. *pachydermum* Scott&Prescott.	+	-	+	
67.	*Cosmarium cuneatum* Joshua.	+	+	+	
68.	*Cosmarium quadrifarium* Lund.	+	+	+	
69.	*Cosmarium quadrum* Lund var. *minus* Nordst.	+	+	+	
70.	*Cosmarium geminatum* Lund.var. *ornatum* Behre.	+	-	+	
71.	*Desmidium aptogonum* Breb.	+	-	+	
72.	*Desmidium baileyi* (Ralfs) Nordst. fa. *longiprocessum* Scott & Prescott.	+	+	+	
73.	*Desmidium swartzii* Agardh.	+	+	+	
74.	*Euastrum acanthophorum* Turn.	+	-	+	
75.	*Euastrum ansatum* Ehrbg.	+	-	+	
76.	*Euastrum moebii* (Borge) Scott & Prescott var. *burmense* West & West.	+	-	+	
77.	*Euastrum sinuosum* Lenorm. var. *capitatum* Prescott.	+	+	+	
78.	*Euastrum sinuosum* Lenorm. var. *reductum* West & West.	-	+	-	
79.	*Micrasterias lux* Josh var. *brevibracchiata* Behre fa. *spinosa* Prescott.	+	+	+	
80.	*Micrasterias mahabuleshwarensis* Hobs. var. *surculifera* Lagerh.	+	+	+	

81.	*Micrasterias pinnatifida* (Kuetz.) Ralfs var. *pseudoscitans* Gronbl.	+	+	+	
82.	*Micrasterias radians* Turn.	+	-	+	
83.	*Micrasterias foliacia* Bail var. *quadrinflata* Prescott.	+	-	+	
84.	*Onychonema laeve* Nordst. var. *latum* West & West.	-	+	-	
85.	*Spondylosium planum* (Wolle)West & West.	+	-	+	
86.	*Staurastrum anatinoides* Scott & Prescott var. *javanicum* Scott & Prescott.	+	-	+	
87.	*Staurastrum pinnatum* Turn var. *subpinnatum* (Sehm)West &West fa. *robustum* Krieg.	+	+	+	
88.	*Staurastrum setigerum* Cleve.	+	-	+	
89.	*Staurastrum tohopekaligense* Wolle var. *insigne* West & West.	+	-	+	
90.	*Staurastrum zonatum* Borges var. *majus* Presc.	+	+	+	
91.	*Staurastrum crenulatum* (Nag) Delp.	-	+	-	
92.	*Xanthidium sexmamillatum* West & West var. *pulneyense* Iyengar & Bai.	-	-	+	
93.	*Xanthidium. spinosum* (Josh.) West & West.	+	+	+	
94.	*Arthrodesmus convergens* Ehr.	+	+	+	
95.	*Arthrodesmus curvatus* Turn. var. *latus* Scott and Prescott.	+	-	+	
96.	*Hyalotheca dissiliens* (Smith) Breb. var. *hians* Wolle.	+	+	+	
97.	*Sphaerozosma granulatum* Roy & Biss.	+	+	+	
Cyanophyceae					
98.	*Anabaena sphaerica* var. *attenuata* Bharadwaja.	+	+	+	13
99.	*Arthrospira massartii* Kuffareth.	+	+	+	
100	*Aphanocapsa littoralis* Hansgirg.	+	+	+	
101	*Chroococcus turgidus* (Kuetz.) Nag.	-	+	-	
102	*Gleocapsa atrata* (Corp.) Kuti.	+	+	+	

103	*Lyngbya aestuarii* Liehm. Ex. Gomont.	-	+	-	
104	*Merismopedia glauca* (Ehrenb). Nag.	-	+	-	
105	*Oscillatoria formosa* Dory ex Gomont.	+	-	+	
106	*Oscillatoria princeps* Vaucher ex Gomont.	-	+	-	
107	*Spirulina labyrinthiformis* (Menegh.) Gomont.	+	+	+	
108	*Spirulina princeps* Wet. G.S. West.	+	+	+	
109	*Svnechocvstis aquatilis* Sauv.	+	-	+	
110	*Synechoccus elongates* Nag.	+	+	+	
Euglenophyceae					
111	*Euglena proxima* Dangeard.	+	+	+	
112	*Euglena spirogyra* Ehr.	-	+	-	
113	*Lepocinclis ovum* (Ehr.) Lemm. var. *butschlii* Conr.	+	+	+	
114	*Trachelomonas armata* (Ehr.) Stein. var. *stenii* Lemm.	+	-	+	
115	*Trachelomonas dubia* (Swiremend) Defl.	+	+	+	08
116	*Trachelomonas hispida* (Perty) Stein var. *hispida.*	+	-	+	
117	*Trachelomonas lacustris* Drez. var. *lacustris* Asual.	-	+	-	
118	*Trachelomonas superba* (Swir.) Defl. var. *spinosa* Defl	+	+	+	
	Total number of taxa recorded (season wise)	**400**	**160**	**408**	

Table 4.27 Result of various genera recorded during exploration of site.

Name of the Site	Types of Class	Winter	Summer	Monsoon
SW_1	Chlorophyceae	Maximum	Minimum	Rare
	Cyanophyceae	Maximum	Minimum	Rare
	Bacillariphyceae	Maximum	Minimum	Rare
	Euglenophyceae	Maximum	Minimum	Rare
SW_2	Chlorophyceae	Maximum	Minimum	Rare
	Cynophyceae	Maximum	Minimum	Rare
	Bacillariphyceae	Maximum	Minimum	Rare
	Euglenophyceae	Maximum	Minimum	Rare
SW_3	Chlorophyceae	Maximum	Minimum	Rare
	Cynophyceae	Maximum	Minimum	Rare
	Bacillariphyceae	Maximum	Minimum	Rare
	Euglenophyceae	Maximum	Minimum	Rare
SW_4	Chlorophyceae	Maximum	Minimum	Rare
	Cynophyceae	Maximum	Minimum	Rare
	Bacillariphyceae	Maximum	Minimum	Rare
	Euglenophyceae	Maximum	Minimum	Rare

Table 4.28 Monthwise two years of Exploration (June 2011 to May 2013).

Sr. No.	Name of the Phytoplankton	Summer				Monsoon				Winter				Total
		Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	
Baccilariophyceae														
1.	*Cymbella cistula* (Hemprich) Grun. var. *woosangisis*Virget.	+	+	+	+	-	-	-	-	+	+	+	+	24
2.	*Dinobryon sertularia* Ehrenberg.	+	+	+	+	+	+	+	+	+	+	+	+	
3.	*Eunotia camelus* Ehr. var. *karveerensis* Gandhi.	+	+	+	+	-	-	-	-	+	+	+	+	
4.	*Fragilaria virescens* Ralfs.	+	+	+	+	-	-	-	-	+	+	+	+	
5.	*Frustulia rhomboides* (Ehr) De Toni var. *saxonica* (Rabenhorst) DeToni.	-	-	-	-	+	+	+	+	-	-	-	-	
6.	*Gomphonema elegans* Grun.	+	+	+	+	-	-	-	-	+	+	+	+	
7.	*Gomphonema vidarbhense* Kamath.	+	+	+	+	+	+	+	+	+	+	+	+	
8.	*Melosira granulata* (Ehr.) Ralfs.	+	+	+	+	+	+	+	+	+	+	+	+	
9.	*Navicula cari* Ehr. *fa. indica* Sarode et Kamat.	+	+	+	+	+	+	+	+	+	+	+	+	
10.	*Navicula cryptocephala* Kuetz.	+	+	+	+	+	+	+	+	+	+	+	+	
11.	*Navicula cuspidata* Kuetz. var.*ambigua* (Ehr.) Cleve.	+	+	+	+	+	+	+	+	+	+	+	+	
12.	*Navicula pupula* Kuetz. var. *capitata* Hustedt.	-	-	-	-	+	+	+	+	-	-	-	-	

13.	*Navicula viridula* Kuetzing.	+	+	+	+	+	+	+	+	+	+	+	+	
14.	*Peridinium cinctum* (Muller) Ehrenberg.	+	+	+	+	-	-	-	-	+	+	+	+	
15.	*Phacus caudatus* var. *tenuis* Swirenko.	+	+	+	+	+	+	+	+	+	+	+	+	
16.	*Pinnularia acrosphaeria* (Breb.)W.Smith.	+	+	+	+	+	+	+	+	+	+	+	+	
17.	*Pinnularia brevicostata* Cleve var. *indica* Gandhi.	+	+	+	+	+	+	+	+	+	+	+	+	
18.	*Pinnularia gibba* Her.	+	+	+	+	-	-	-	-	+	+	+	+	
19.	*Pinnularia major* (Kuetz.) Cleve var. *linearis* Cleve.	+	+	+	+	-	-	-	-	+	+	+	+	
20.	*Rhodomonas baltica* Karst.	+	+	+	+	-	-	-	-	+	+	+	+	
21.	*Stauroneis anceps* var. *gracilis* (Ehr) Cleve.	+	+	+	+	+	+	+	+	+	+	+	+	
22.	*Stauroneis phoenicenteron* (Nitzsch) Ehr. var. *intermidia* Dippel.	-	-	-	-	+	+	+	+	-	-	-	-	
23.	*Synura uvella* Ehrenberg.	+	+	+	+	-	-	-	-	+	+	+	+	
24.	*Tabellaria fenestrata* (Lyngbye) Kuetzing.	+	+	+	+	+	+	+	+	+	+	+	+	
Chlorophyceae														
25.	*Closterium acerosum* var. *angolense* West and West.	+	+	+	+	+	+	+	+	+	+	+	+	
26.	*Triploceras gracile* Bail var. *undulatum* Scott & Pres.	+	+	+	+	+	+	+	+	+	+	+	+	
27.	*Ankistrodesmus falcatms* (Corda) Rails.	+	+	+	+	-	-	-	-	+	+	+	+	73
28.	*Ankistrodesmus falcatus* (Corda) Ralfs var. *acicularis* (A. Braun) G.S.West.	+	+	+	+	+	+	+	+	+	+	+	+	

29.	*Ankistrodesmus spiralis* (Turner) Lemmermann.	+	+	+	+	+	+	+	+	+	+	+	+	
30.	*Chlorella vulgaris* Beyer. (Smith).	+	+	+	+	+	+	+	+	+	+	+	+	
31.	*Coelastrum cambricum* Archer var. *intermidium* (Bohlin) G.S.West.	+	+	+	+	+	+	+	+	+	+	+	+	
32.	*Coelastrum spherium* Naeg.	+	+	+	+	-	-	-	-	+	+	+	+	
33.	*Dictyosphaerium ehrenbergianum* Naegeli.	+	+	+	+	+	+	+	+	+	+	+	+	
34.	*Dimorphococcus lunatus* A. Braun.	+	+	+	+	+	+	+	+	+	+	+	+	
35.	*Eudorina elegans* Ehr.	+	+	+	+	+	+	+	+	+	+	+	+	
36.	*Gonatozygon aculeatum* Hast.	+	+	+	+	-	-	-	-	+	+	+	+	
37.	*Gonatozygon monotaenium* De Bary.	+	+	+	+	-	-	-	-	+	+	+	+	
38.	*Nephrocytium agardhianum* Nag.	+	+	+	+	+	+	+	+	+	+	+	+	
39.	*Nephrocytium lunatum* W.West.	-	-	-	-	-	-	-	-	+	+	+	+	
40.	*Netrium digitus* (Ehrbg.) Itzigs. &Rothe.	+	+	+	+	+	+	+	+	+	+	+	+	
41.	*Oocystis elliptica* W. West.	+	+	+	+	+	+	+	+	+	+	+	+	
42.	*Pandorina cylindricum* Iyengar.	+	+	+	+	+	+	+	+	+	+	+	+	
43.	*Pandorina. morum* (Mull.) Bory.	-	-	-	-	+	+	+	+	-	-	-	-	
44.	*Pediastrum tetras* (Ehr.) Ralfs.	-	-	-	-	+	+	+	+	-	-	-	-	
45.	*Pediastrum biradiatum* Meyen non Ralfs var. *longicornutum* Gutwinski.	+	+	+	+	+	+	+	+	+	+	+	+	

46.	*Pediastrum duplex* Meyen var. *coronatum* Raciborski.	+	+	+	+	+	+	+	+	+	+	+	+	
47.	*Pleodorina californica* Shaw.	+	+	+	+	+	+	+	+	+	+	+	+	
48.	*Pleurotaenium baculoides* (Roy & Biss) Playf.	+	+	+	+	-	-	-	-	+	+	+	+	
49.	*Pleurotaenium nodosum* (Bail.)Lund.	+	+	+	+	+	+	+	+	+	+	+	+	
50.	*Pleurotaenium trabecula* (Ehrbg) Nag.	+	+	+	+	-	-	-	-	+	+	+	+	
51.	*Pleurotaenium trabecula* (Ehrbg) Nag var. *maximum* (Reinsch) Roll.	-	-	-	-	+	+	+	+	-	-	-	-	
52.	*Scenedesmus arcuatus* (Lemmarmann) Lemmarmann.	+	+	+	+	+	+	+	+	+	+	+	+	
53.	*Scenedesmus bijugatus* (Turp.) Kuetz.	+	+	+	+	+	+	+	+	+	+	+	+	
54.	*Scenedesmus dimorphus* (Turpin) Kuetzing.	+	+	+	+	-	-	-	-	+	+	+	+	
55.	*Scenedesmus perforatus* Lemmermann.	+	+	+	+	+	+	+	+	+	+	+	+	
56.	*Scenedesmus perforatus* (Lemmermann) var. *major* (Turner) Philipose.	+	+	+	+	-	-	-	-	+	+	+	+	
57.	*Scenedesmus quadricauda* (Turpin) Brebisson Var. *bicaudatus* Hansgirg.	+	+	+	+	-	-	-	-	+	+	+	+	
58.	*Scenedesmus quadricauda* (Turpin) Brebisson Var. *longispina* (Chodat) G.M.Smith.	+	+	+	+	-	-	-	-	+	+	+	+	
59.	*Scenedesmus quadricauda* v. qttadrispina (ChM.) G.M. Smith.	+	+	+	+	+	+	+	+	+	+	+	+	

60.	*Spirogyra ternata* Ripart.	-	-	-	-	+	+	+	+	-	-	-	-	
61.	*Tetraedron enorme* (Ralfs) Hansg var. *pentaedricum* Prescott.	+	+	+	+	+	+	+	+	+	+	+	+	
62.	*Tetraedron limneticum* Borge.	+	+	+	+	+	+	+	+	+	+	+	+	
63.	*Tetraedron trigonum* (Naeg) Hansg. fa. *gracile* (Reinsch) De Toni.	+	+	+	+	+	+	+	+	+	+	+	+	
64.	*Tetraspora gelatinosa* (Vauch.) *Desv.*	+	+	+	+	+	+	+	+	+	+	+	+	
65.	*Cosmarium auriculatum* Reinsch.	+	+	+	+	+	+	+	+	+	+	+	+	
66.	*Cosmarium contractum* Kirchner var. *pachydermum* Scott&Prescott.	+	+	+	+	-	-	-	-	+	+	+	+	
67.	*Cosmarium cuneatum* Joshua.	+	+	+	+	+	+	+	+	+	+	+	+	
68.	*Cosmarium quadrifarium* Lund.	+	+	+	+	+	+	+	+	+	+	+	+	
69.	*Cosmarium quadrum* Lund var. *minus* Nordst.	+	+	+	+	+	+	+	+	+	+	+	+	
70.	*Cosmarium geminatum* Lund.var. *ornatum* Behre.	+	+	+	+	-	-	-	-	+	+	+	+	
71.	*Desmidium aptogonum* Breb.	+	+	+	+	-	-	-	-	+	+	+	+	
72.	*Desmidium baileyi* (Ralfs) Nordst. fa. *longiprocessum* Scott & Prescott.	+	+	+	+	+	+	+	+	+	+	+	+	
73.	*Desmidium swartzii* Agardh.	+	+	+	+	+	+	+	+	+	+	+	+	
74.	*Euastrum acanthophorum* Turn..	+	+	+	+	-	-	-	-	+	+	+	+	
75.	*Euastrum ansatum* Ehrbg.	+	+	+	+	-	-	-	-	+	+	+	+	

76.	*Euastrum moebii* (Borge) Scott & Prescott var. *burmense* West & West.	+	+	+	+	-	-	-	-	+	+	+	+	
77.	*Euastrum sinuosum* Lenorm. var. *capitatum* Prescott.	+	+	+	+	+	+	+	+	+	+	+	+	
78.	*Euastrum sinuosum* Lenorm. var. *reductum* West & West.	-	-	-	-	+	+	+	+	-	-	-	-	
79.	*Micrasterias foliacia* Bail var. *quadrinflata* Prescott.	+	+	+	+	-	-	-	-	+	+	+	+	
80.	*Micrasterias lux* Josh var. *brevibracchiata* Behre fa. *spinosa* Prescott.	+	+	+	+	+	+	+	+	+	+	+	+	
81.	*Micrasterias mahabuleshwarensis* Hobs. var. *surculifera* Lagerh.	+	+	+	+	+	+	+	+	+	+	+	+	
82.	*Micrasterias pinnatifida* (Kuetz.) Ralfs var. *pseudoscitans* Gronbl.	+	+	+	+	+	+	+	+	+	+	+	+	
83.	*Micrasterias radians* Turn.	+	+	+	+	-	-	-	-	+	+	+	+	
84.	*Onychonema laeve* Nordst. var. *latum* West & West.	-	-	-	-	+	+	+	+	-	-	-	-	
85.	*Spondylosium planum* (Wolle) West & West.	+	+	+	+	-	-	-	-	+	+	+	+	
86.	*Staurastrum anatinoides* Scott & Prescott var. *javanicum* Scott & Prescott.	+	+	+	+	-	-	-	-	+	+	+	+	
87.	*Staurastrum pinnatum* Turn var. *subpinnatum* (Sehm)West&West fa. *robustum* Krieg.	+	+	+	+	+	+	+	+	+	+	+	+	
88.	*Staurastrum setigerum* Cleve.	+	+	+	+	-	-	-	-	+	+	+	+	

89.	*Staurastrum tohopekaligense* Wolle var. *insigne* West & West.	+	+	+	+	-	-	-	-	+	+	+	+	
90.	*Staurastrum zonatum* Borges var. *majus* Presc.	+	+	+	+	+	+	+	+	+	+	+	+	
91.	*Staurastrum crenulatum* (Nag) Delp.	-	-	-	-	+	+	+	+	-	-	-	-	
92.	*Xanthidium sexmamillatum* West & West var. *pulneyense* Iyengar & Bai.	-	-	-	-	-	-	-	-	+	+	+	+	
93.	*Xanthidium. spinosum* (Josh.) West & West.	+	+	+	+	+	+	+	+	+	+	+	+	
94.	*Arthrodesmus convergens* Ehr.	+	+	+	+	+	+	+	+	+	+	+	+	
95.	*Arthrodesmus curvatus* Turn. var. *latus* Scott and Prescott.	+	+	+	+	-	-	-	-	+	+	+	+	
96.	*Hyalotheca dissiliens* (Smith) Breb. var. *hians* Wolle.	+	+	+	+	+	+	+	+	+	+	+	+	
97.	*Sphaerozosma granulatum* Roy & Biss.	+	+	+	+	+	+	+	+	+	+	+	+	
Cyanophyceae														
98.	*Anabaena sphaerica* var. *attenuata* Bharadwaja.	+	+	+	+	+	+	+	+	+	+	+	+	13
99.	*Aphanocapsa littoralis* Hansgirg.	+	+	+	+	+	+	+	+	+	+	+	+	
100.	*Arthrospira massartii* Kuffareth.	+	+	+	+	+	+	+	+	+	+	+	+	
101.	*Chroococcus turgidus* (Kuetz.) Nag.	-	-	-	-	+	+	+	+	-	-	-	-	
102.	*Gleocapsa atrata* (Corp.) Kuti.	+	+	+	+	+	+	+	+	+	+	+	+	
103.	*Lyngbya aestuarii* Liehm. Ex. Gomont.	-	-	-	-	+	+	+	+	-	-	-	-	
104.	*Merismopedia glauca* (Ehrenb). Nag.	-	-	-	-	+	+	+	+	-	-	-	-	

105.	*Oscillatoria formosa* Dory ex Gomont.	+	+	+	+	-	-	-	-	+	+	+	+	
106.	*Oscillatoria princeps* Vaucher ex Gomont.	-	-	-	-	+	+	+	+	-	-	-	-	
107.	*Spirulina labyrinthiformis* (Menegh.) Gomont.	+	+	+	+	+	+	+	+	+	+	+	+	
108.	*Spirulina princeps* Wet. G.S. West.	+	+	+	+	+	+	+	+	+	+	+	+	
109.	*Svnechocvstis aquatilis* Sauv.	+	+	+	+	-	-	-	-	+	+	+	+	
110.	*Synechoccus elongates* Nag.	+	+	+	+	+	+	+	+	+	+	+	+	
Euglenophyceae														
111.	*Euglena proxima* Dangeard.	+	+	+	+	+	+	+	+	+	+	+	+	
112.	*Euglena spirogyra* Ehr.	-	-	-	-	+	+	+	+	-	-	-	-	
113.	*Lepocinclis ovum* (Ehr.) Lemm. var. *butschlii* Conr.	+	+	+	+	+	+	+	+	+	+	+	+	
114.	*Trachelomonas armata* (Ehr.) Stein. var. *stenii* Lemm.	+	+	+	+	-	-	-	-	+	+	+	+	08
115.	*Trachelomonas dubia* (Swiremend) Defl.	+	+	+	+	+	+	+	+	+	+	+	+	
116.	*Trachelomonas hispida* (Perty) Stein var. *hispida.*	+	+	+	+	-	-	-	-	+	+	+	+	
117.	*Trachelomonas lacustris* Drez. var. *lacustris* Asual..	-	-	-	-	+	+	+	+	-	-	-	-	
118.	*Trachelomonas superba* (Swir.) Defl. var. *spinosa* Defl.	+	+	+	+	+	+	+	+	+	+	+	+	
	Total number of taxa recorded (Monthwise)	**100**	**100**	**100**	**100**	**80**	**80**	**80**	**80**	**102**	**102**	**102**	**102**	
	Total number of taxa recorded (Seasonwise)	**400**				**160**				**408**				

Table 4.29 First Year Plan -Monthwise Exploration of Algae.
(June 2011 to August 2011).

Sr. No.	Site Name	Date	Time	Temperature	Depth of Light	Identification
1	(SW_1)	15-6-2011	09 to 10 am	32.2^{0}C	Not found	Blue Green Algae seen in less number or in rare form.
2	(SW_2)	16-7-2011	09 to 10 am	27.8^{0}C	Not found	*Diatoms* seen in minimum proportion in rainy season. Blue green algae were present in rare form.
3	(SW_3)	11-8-2011	09 to 10 am	26.9^{0}C	1 feet.	*Spirullina* Turpin *ex* Gomont is observed in rare form in rainy season. Filamentous forms not found.
4	(SW_4)	25-8-2011	09 to 10 am	27.2^{0}C	1 feet.	Blue green algae are seen in very less in number. *Desmids* are not seen or in some times in very rare form. *Diatoms* are in rare.

Table 4.30 First Year Plan -Monthwise Exploration of Algae.
(September 2011 to November 2011)

Sr. No.	Site Name	Date	Time	Temperature	Depth of Light	Identification
1	(SW_1)	20-9-2011	09 to 10 am	27.5^{0}C	1 feet	Filamentous forms of algae were found in less number. Sometimes they are not found. *Diatoms* are very less in number. Blue green algae are smaller in number.
2	(SW_2)	10-10-2011	09 to 10 am	26.5^{0}C	1 feet	Same identification was found on this site.
3	(SW_3)	30-10-2011	09 to 10 am	23.2^{0}C	1 feet.	*Desmids* which are one or more in number at site SW1 and SW2 not seen in this site. The algae touch minimum during this season.
4	(SW_4)	18-11-2011	09 to 10 am	22.9^{0}C	1 feet.	The algae show minimum growth in this season because the rate of water current is fast in this season. The rate of water current is more or less inversely proportional to the total number of algae. These algae show inverse relationship with temperature.

Table 4.31 First Year Plan - Monthwise Exploration of Algae.
(December 2011 to February 2012)

Sr. No.	Site Name	Date	Time	Temperature	Depth of Light	Identification
1	(SW_1)	3-12-2011	09 to 10 am	20.7^{0}C	1 feet	Algae shows maximum growth during winter season *Desmids* less in number. *Euglenoid* flagellates like blue green algae are lesser in number. *Diatoms* from algal population in winter season.
2	(SW_2)	30-12-2011	09 to 10 am	20.6^{0}C	1 feet	*Desmids* are more in number seen on these sites. Blue green algae show maximum sometimes minimum in this season.
3	(SW_3)	21-1-2012	09 to 10 am	21.5^{0}C	1 feet.	Same above identification is found on these sites.
4	(SW_4)	22-2-2012	09 to 10 am	24.4^{0}C	1 feet.	Same observation is found on bank of Vena river. They show maximum development in this season. *Diatoms, Desmids,* and *Euglenoid* flagellates were sometimes more and less in number.

Table 4.32 First Year Plan -Monthwise Exploration of Algae.
(March 2012 to May 2012).

Sr. No.	Site Name	Date	Time	Temperature	Depth of Light	Identification
1	(SW_1)	3-3-2012	9 to 10 am	28.7^{0}C	1 feet	*Desmids* were seen more in number in these sites of Under bridge. Blue green algae attempt maximum development during summer season. *Eugleloid* flagellates more in number present during this summer season.
2	(SW_2)	20-3-2012	9 to 19 am	28.8^{0}C	2 feet	*Eugleloid* flagellates more in number present during this summer season. *Desmids* were seen more in number in these sites of Kawalghat Blue green algae attempt maximum development during summer season. In this season the water current is slow. There is a high temperature fluctuation this show direct correlation with oxidizable organic matter and water temperature inverse relationship with dissolved oxygen.
3	(SW_3)	25-4-2012	9 to 10 am	32.8^{0}C	2 feet.	Same above identification is found on these sites. Algae shows maximum development during this season desmids

						favoured by high summer temperature and total solids found more in number.
4	(SW_4)	16-5-2012	9 to 10 am	35^0C	2 feet.	Algae reaching maximum development during this summer season. High temperature accelerates the growth and multiplication of Chlorococcales. *Desmids* which are more in number at SW_2 and SW_3 stations shows more in proportion at site this *Euglenoid* flagellates are more in number on sand sides of Vena river.

Table 4.33 Second Year Plan -Monthwise Exploration of Algae.
(June 2012 to August 2012)

Sr. No.	Site Name	Date	Time	Temperature	Depth of Light	Identification
1	(SW_1)	10-6-2012	9 to 10 am	31.9^0C	Not found	Blue Green Algae seen in less number or in rare form.
2	(SW_2)	12-7-2012	9 to 10 am	28.2^0C	Not found	*Diatoms* seen in minimum proportion in rainy season. Blue green algae were present in rare form.
3	(SW_3)	17-8-2012	9 to 10 am	26.7^0C	1 feet.	*Spirullina* Turpin *ex* Gomont was observed in rare form in rainy season. Filamentous forms were not found.

4	(SW_4)	30-8-2012	9 to 10 am	27^0C	1 feet.	*Desmids* are not seen or in some times in very rare form. *Diatoms* are in rare. Same observation was seen on these sites. Blue green algae are seen in very less number.

Table 4.34 Second Year Plan -Monthwise Exploration of Algae. (September 2012 to November 2012).

Sr. No.	Site Name	Date	Time	Temperature	Depth of Light	Identification
1	(SW_1)	9-9-2012	9 to 10 am	27.3^0C	1 feet	*Diatoms* are very less in number. Blue green algae are smaller in number. Filamentus forms of algae were found in less number. In sometimes they are not found.
2	(SW_2)	21.10.2012	9 to 10 am	26.8^0C	1 feet	Same identification was found on this site.
3	(SW_3)	10-11-2012	9 to10 am	22.7^0C	1 feet.	*Desmids* which are one or more in number at site SW1 and SW2 not seen in this site. The algae were found minimum during this season.
4	(SW_4)	30-11-2012	9 to 10 am	22.8^0C	1 feet.	The algae show minimum growth in this season because the rate of water current is fast in this season. The rate of water current is more or less inversely proportional to the total number of algae. These algae show

						inverse relationship with temperature.

Table 4.35 Second Year Plan -Monthwise Exploration of Algae.
(December 2012 to February 2013).

Sr. No.	Site Name	Date	Time	Temparature	Depth of Light	Identification
1	(SW_1)	5-12-2012	9 to 10 am	21.1^{0}C	1 feet	Algae shows maximum growth during winter season *Desmids* less in number. *Euglenoid* flagellates like blue green algae are lesser in number. *Diatoms* form algal population in winter season.
2	(SW_2)	04-1-2013	9 to 19 am	21.9^{0}C	1 feet	*Desmids* are more in number seen on these sites. Blue green algae show maximum sometimes minimum in this season.
3	(SW_3)	13-2-2013	9 to 10 am	24^{0}C	1 feet.	Same above identification is found on these sites.
4	(SW_4)	28-2-2013	9 to 10 am	23.9^{0}C	1 feet.	Same observation is found on bank of Vena river. The shows miximum development in this season. *Diatoms Desmids Euglenoid* flagellates are sometimes more and less in number.

Table 4.36 Second Year Plan -Monthwise Exploration of Algae.
(March 2013 to May 2013).

Sr. No.	Site Name	Date	Time	Temp	Depth of Light	Identification
1	(SW_1)	5-3-2013	9 to 10 am	29^0C	1 feet	Blue green algae attempt maximum development during summer season. Flagellates more in number present during this summer season. *Desmid*s were seen more in number in this site of Under bridge.
2	(SW_2)	24-3-2013	9 to 10 am	29.1^0C	2 feet	*Eugleloid* flagellates more in number present during this summer season. *Desmid*s were seen more in number in these sites of Kawalghat. Blue green algae attempt maximum development during summer season. In this season the water current is slow. There is a high temperature fluctuation this show direct correlation with oxidizable organic matter and water temperature inverse relationship with dissolved oxygen.
3	(SW_3)	27-4-2013	9 to 10 am	33^0C	2 feet.	Same above identification is found on this site. Algae shows maximum development during this season desmids favoured by high summer temperature and total solids found more in

						number.
4	(SW_4)	18-5-2013	9 to 10 am	34.8^{0}C	2 feet.	Algae reaching maximum development during this summer season. High temperature accelerates the growth and multiplication of Chlorococcales. *Desmids* which are more in number 2 and 3 stations shows more in proportion at this stations. *Eugleloid* flagellates are more in number on sand sides of Vena river.

4.4 Monthwise Exploration of Algae from Different sites:

Table 4.37 Monthwise exploration of Algae (Site SW_1) (June 2011 to May 2012).

Date	O_2 absorbed (mg/l)	Temperature (^{0}C)	pH	Dominant Class
15-6-2011	34.23	32.2	7.31	Cyanophyceae
9-7-2011	11.27	27.9	7.8	Cyanophyceae
7-8-2011	2.41	27	8.7	Cyanophyceae
20-9-2011	10.06	27.5	8.2	Chlorophyceae
4-10-2011	3.22	26.4	7.35	Chlorophyceae
3-11-2011	13.29	23.0	8.64	Chlorophyceae
3-12-2011	10.06	20.7	7.68	Bacillariophyceae
7-1-2012	12.08	21.6	8.57	Bacillariophyceae
7-2-2012	21.74	24.5	8.2	Bacillariophyceae
3-3-2012	20.13	28.7	7.79	Bacillariophyceae
10-4-2012	11.67	32.9	8.21	Euglenophyceae
7-5-2012	18.92	35.2	7.46	Cyanophyceae

Table 4.38 Monthwise exploration of Algae (Site SW_2) (June 2011 to May 2012)

Date	O_2 absorbed (mg/l)	Temp. (^{0}C)	pH	Dominant Class
9-6-2011	19.73	32.1	7.21	Cyanophyceae
16-7-2011	10.06	27.8	7.1	Cyanophyceae
9-8-2011	2.01	27.1	8.35	Cyanophyceae
8-9-2011	2.41	27.4	8.21	Chlorophyceae
10-10-2011	16.91	26.5	7.3	Chlorophyceae
8-11-2011	11.67	23.1	8.53	Chlorophyceae
30-12-2011	8.45	20.6	7.71	Bacillariophyceae
8-1-2012	12.88	21.7	7.03	Bacillariophyceae
9-2-2012	35.44	24.6	7.11	Bacillariophyceae
20-3-2012	34.63	28.8	7.23	Bacillariophyceae
14-4-2012	8.84	33.0	7.3	Euglenophyceae
17-5-2012	30.2	35.1	7.33	Cyanophyceae

Table 4.39 Monthwise exploration of Algae (Site SW_3) (June 2011 to May 2012)

Date	O_2 absorbed (mg/l)	Temp. (^{0}C)	pH	Dominant Class
11-6-2011	6.84	32.1	7.8	Cyanophyceae
13-7-2011	10.47	27.7	8.02	Cyanophyceae
11-8-2011	2.41	26.9	8.54	Cyanophyceae
16-9-2011	4.83	27.6	8.33	Chlorophyceae
30-10-2011	15.3	26.3	7.45	Chlorophyceae
13-11-2011	8.86	23.2	8.65	Chlorophyceae
11-12-2011	10.06	20.8	8.11	Bacillariophyceae
21-1-2012	16.1	21.5	7.04	Bacillariophyceae
21-2-2012	17.72	24.5	7.33	Bacillariophyceae
14-3-2012	10.47	28.6	7.33	Bacillariophyceae
25-4-2012	4.02	32.8	7.85	Euglenophyceae
19-5-2012	14.09	35.1	6.69	Cyanophyceae

Table 4.40 Monthwise exploration of Algae (Site SW_4) (June 2011 to May 2012)

Date	O_2 absorbed (mg/l)	Temp. (^{0}C)	pH	Dominant Class
20-6-2011	20.26	32.0	7.44	Cyanophyceae
17-7-2011	10.6	28.0	7.64	Cyanophyceae
25-8-2011	2.27	27.2	8.53	Cyanophyceae
17-9-2011	5.76	27.5	8.24	Chlrophyceae
9-10-2011	11.81	26.6	7.36	Chlrophyceae
18-11-2011	11.27	22.9	8.6	Chlrophyceae
13-12-2011	9.52	20.7	7.83	Bacillariophyceae
21-1-2012	13.68	21.6	7.54	Bacillariophyceae
22-2-2012	24.96	24.4	7.54	Bacillariophyceae
17-3-2012	21.74	28.7	7.45	Bacillariophyceae
17-4-2012	8.17	32.9	7.78	Euglenophyceae
16-5-2012	21.07	35.0	7.16	Cyanophyceae

Table 4.41 Monthwise exploration of Algae (Site SW_1) (June 2012 to May 2013).

Date	O_2 absorbed (mg/l)	Temp. (^{0}C)	pH	Dominant Class
10-6-2012	24.16	31.9	6.25	Cyanophyceae
9-7-2012	16.1	28.1	9.03	Cyanophyceae
7-8-2012	16.51	26.9	8.8	Cyanophyceae
9-9-2012	16.1	27.3	7.52	Chlrophyceae
4-10-2012	20.94	26.9	8.71	Chlrophyceae
3-11-2012	13.29	22.8	8.61	Chlrophyceae
5-12-2012	8.86	21.1	8.53	Bacillariophyceae
7-1-2013	11.27	21.8	6.7	Bacillariophyceae
7-2-2013	6.84	23.9	6.36	Bacillariophyceae
5-3-2013	2.416	29.0	7.1	Bacillariophyceae
10-4-2013	9.66	33.1	8.4	Euglenophyceae
7-5-2013	10.06	34.8	8.56	Cyanophyceae

Table 4.42 Monthwise exploration of Algae (Site SW_2) (June 2012 to May 2013)

Date	O_2 absorbed (mg/l)	Temp. (^{0}C)	pH	Dominant Class
9-6-2012	24.16	31.8	6.1	Cyanophyceae
12-7-2012	16.1	28.2	9.09	Cyanophyceae
9-8-2012	18.21	26.8	10.8	Cyanophyceae
8-9-2012	14.9	27.4	7.46	Chlorophyceae
21-10-2012	22.15	26.8	8.61	Chlorophyceae
8-11-2012	13.39	22.9	8.65	Chlorophyceae
6-12-2012	6.84	21.0	8.1	Bacillariophyceae
4-1-2013	10.06	21.9	6.75	Bacillariophyceae
9-2-2013	6.84	23.8	6.23	Bacillariophyceae
24-3-2013	2.013	29.1	7.15	Bacillariophyceae
14-4-2013	9.66	33.2	8.26	Eugleniophyceae
17-5-2013	11.67	34.9	8.5	Cyanophyceae

Table 4.43 Monthwise exploration of Algae (Site SW_3) (June 2012 to May 2013)

Date	O_2 absorbed (mg/l)	Temp. (^{0}C)	pH	Dominant Class
11-6-2012	24.16	31.8	6.2	Cyanophyceae
13-7-2012	16.1	28.0	8.75	Cyanophyceae
17-8-2012	18.92	26.7	9.5	Cyanophyceae
16-9-2012	14.49	27.2	7.47	Chlorophyceae
4-10-2012	20.94	27.0	7.69	Chlorophyceae
10-11-2012	14.9	22.7	8.65	Chlorophyceae
11-12-2012	8.056	21.2	8.37	Bacillariophyceae
19-1-2013	14.06	21.7	7.8	Bacillariophyceae
13-2-2013	5.63	24.0	6.34	Bacillariophyceae
14-3-2013	2.013	29.2	7.29	Bacillariophyceae
27-4-2013	10.06	33.0	8.21	Euglenophyceae
19-5-2013	11.27	34.7	8.34	Cyanophyceae

Table 4.44 Monthwise exploration of Algae (Site SW_4) (June 2012 to May 2013)

Date	O_2 absorbed (mg/l)	Temp. (^{0}C)	pH	Dominant Class
20-6-2012	24.16	31.9	6.18	Cyanophyceae
17-7-2012	16.1	28.2	8.95	Cyanophyceae
15-8-2012	17.88	27.0	9.7	Cyanophyceae
17-9-2012	15.16	27.3	7.48	Chlorophyceae
9-10-2012	21.34	26.8	8.33	Chlorophyceae
15-11-2012	13.86	22.8	8.63	Chlorophyceae
13-12-2012	7.91	21.3	8.33	Bacillariophyceae
21-1-2013	11.79	21.9	7.08	Bacillariophyceae
24-2-2013	6.43	23.9	6.31	Bacillariophyceae
17-3-2013	2.147	28.9	7.18	Bacillariophyceae
17-4-2013	9.79	33.2	8.29	Euglenophyceae
21-5-2013	11	34.8	8.46	Cyanophyceae

4.5Influence of nutrients on growth of algae:

Table 4.45 Influence of Carbon (mg/l) on algal growth

Concentration in mg/l	*Oscillatoria*	*Oscillatoria*	*Selenastrum*	*Coelastrum*
1	27	1.303	1.21	1.248
2	29	1.323	1.22	1.289
2.266	28	1.374	1.298	1.263
4	26	1.31	1.021	1.107
8	27	1.108	1.2	1.028
12	22	1.028	0.932	0.942
16	21	1.026	0.913	0.931

Table 4.46 Influence of Nitrogen(mg/l) on algal growth.

Concentration in mg/l	*Oscillatoria*	*Chloroceocum*	*Selenastrum*	*Coelastrum*
200	25	1.592	1.501	1.682
242	22	1.602	1.5	1.598
250	25	1.604	1.522	1.684
200	28	1.611	1.599	1.701
350	22	1.503	1.41	1.68
400	19	1.59	1.51	1.675
450	20	1.541	1.44	1.638

Table 4.47 Influence of Phosphorous (mg/l) on algal growth.

Concentration in mg/l	*Oscillatoria*	*Chloroceocum*	*Selenastrum*	*Coelastrum*
4	21	1.246	1.181	1.271
7.1	18	1.405	1.39	1.423
8	17	1.33	1.278	1.383
16	15	1.421	1.372	1.489
32	14	1.278	1.2	1.421
64	12	1.227	1.157	1.253
128	10	1.69	1.068	1.198

Table 4.48 Influence of Magnessium (mg/l) on algal growth.

Concentration in mg/l	*Oscillatoria*	*Chloroceocum*	*Selenastrum*	*Coelastrum*
4	23	1.482	1.435	1.512
7.3	26	1.605	1.525	1.64
8	29	1.55	1.509	1.586
16	25	1.588	1.579	1.721
32	23	1.703	1.528	1.623
64	21	1.698	1.528	1.737
128	18	1.233	1.539	1.5

Table 4.49 Influence of Potassium (mg/l) on algal growth.

Concentration in mg/l	*Oscillatoria*	*Chloroceocum*	*Selenastrum*	*Coelastrum*
4	29	1.307	1.279	1.34
8	17	1.405	1.38	1.423
1.6	21	3.99	1.374	1.427
17.95	23	1.39	1.369	1.421
32	14	1.426	1.401	1.42
64	13	1.41	1.393	1.441
128	9	1.4	1.373	1.425

Table 4.50 Influence of Chloride (mg/l) on algal growth.

Concentration in mg/l	*Oscillatoria*	*Chloroceocum*	*Selenastrum*	*Coelastrum*
4	23	1.397	1.309	1.482
8	24	1.425	1.345	1.537
16	28	1.432	1.343	1.535
23.99	24	1.403	1.318	1.492
32	23	1.438	1.35	1.551
64	21	1.41	1.325	1.506
128	18	1.341	1.253	1.44

Table 4.51 Influence of Iron (mg/l) on algal growth.

Concentration in mg/l	*Oscillatoria*	*Chloroceocum*	*Selenastrum*	*Coelastrum*
0.2	24	1.72	1.58	1.75
1.20	28	1.737	1.598	1.805
2	22	1.7	1.591	1.8
4	21	1.32	1.231	1.421
8	18	1.29	1.582	1.41
16	16	1.24	1.18	1.441

Table 4.52 Growth of *Chlorococcum humicolumn* in BG-11 and modified medium.

Amount of medium employed	Growth in BG-11 medium (OD)	Growth in modified medium (OD)
10 ml	2.933	3.261
25ml	3.286	3.954
50ml	2.702	3.063

Table 4.53 Growth of *Oscillatoria amphibia* in BG-11 and modified medium

Amount of medium employed	Growth in BG-11 medium (OD)	Growth in modified medium (OD)
10.00 ml	22.00	29.00
25.00ml	23.00	31.00
50.00ml	20.00	26.00

Table 4.54 Growth of *Selenastrum westii* in BG-11 and modifid medium

Amount of medium employed	Growth in BG-11 medium (OD)	Growth in modified medium (OD)
10.00 ml	3.56	3.842
25.00ml	3.863	4.653
50.00ml	3.268	3.762

Table 4.55 Growth of *Coelastrum sphaericum* in BG-11 and modified medium

Amount of medium employed	Growth in BG-11 medium (OD)	Growth in modified medium (OD)
10.00 ml	2.604	2.940
25.00ml	2.917	3.597
50.00ml	2.398	2.767

4.6 Description of algal forms recorded from study area:

Baccilariophyceae:

1. ***Cymbella cistula* (Hemprich) Grun. var. *woosangisis* Virget** (Plate I, Fig. 1)

   Sarode and Kamat, 1984 p.176 pl.20 Fig.123

   Valves strongly asymmetric, naviculoid in shape with dorsal sides convex, ventral sides concave with a median expansion; raphae eccentric, broad, dorsally convex; axial area narrow, some what widened at the middle; transverse striations radiate, 6-9 in 10 µm, with punctae about 18-22 µm ; median ventral striations ending in two or more dots.

   Habitat: In SW_1 underbridge.

   Found in site : **SW_1** [pH 6.2; Temp 20.7^{0}C]

2. ***Dinobryon sertularia* Ehrenberg** (Plate I, Fig. 2)

   Prescott, G.W., 1951, p. 378, pl. 98, Fig. 10

   Colonies slightly diverging. Loricas fusiform-campanulate; posterior blunt-pointed; lateral margins smooth, convex, narrowed above the midregion and then slightly flaring to a wide mouth; 10-14 µm in diameter, 30-40 µm long.

   Habitat: Kawalghat

   Found in site: **SW_2** [pH 5.9; Temp 27.8^{0}C]

3. ***Eunotia camelus* Ehr. var. *karveerensis* Gandhi** (Plate I, Fig. 3)

   Gandhi, H.P., 1957. p.49, Fig. 11-13

   Valves strongly arcuate with dorsal side convex having four uniform strong rounded humps, ventral side concave; ends strongly narrowed on the dorsal side, produced, rounded subcapitate; terminal nodules and raphe small distinct at the apices of the ventral margin of the valve; striae coarsely lineate. Length 28 µm; breadth 5 µm; striae, 12-14 µm.

Habitat: Smashanbhoomi.

Found in site: **SW_3** [pH 7.4; Temp 26.9^{0}C]

4. ***Fragilaria virescens*** **Ralfs** ((Plate I, Fig. 4)

Sarode and Kamat, p.11

Frustules in girdle view linear rectangular, united together to form long bands, ribbon shaped colonies; valves linear with parallel sides, unilateral central area, 70-120 µm long and 5=15 µm broad; pseudoraphed, striation distinct but absent in the middle region, striae 5-10 in 10 µm.

Habitat: Shahalangadi.

Found in site**: SW_4** [pH 9.8; Temp 27.2^{0}C]

5. ***Frustulia rhomboides*** **(Ehr) De Toni var.** ***saxonica*** **(Rabenhorst) DeToni** (Plate I, Fig. 5) Krammer and Lange-Bertalot, 1986, p. 259, Fig. 95:4, 5

Valves upto 40-70 µm long and 12-20 µm broad, striae 30-35 in 10 µm.

Habitat: Shahalangadi.

Found in site: **SW_4** [pH 9.8; Temp 22.9^{0}C]

6. ***Gomphonema elegans*** **Grun**. (Plate I, Fig. 6)

Cleve, pl.3, Fig. 3

Frustules small linear-cuneate, asymmetrical, end truncate, both base obtuse, 10-25 µm long and 5-10 µm broad, striation distinct, marginal, parallel, striae 8-10 in 10 µm

Habitat: Smashanbhoomi.

Found in site : **SW_3** [pH 7.3; Temp 23.2^{0}C]

7. ***Gomphonema vidarbhense*** **Kamath** (Plate I, Fig. 7)

Sarode and Kamath 1984, p. 200, Plate 23, f. 546

Valves 65-78 μm long, 11.5-14 μm broad, clavate, more gibbous in the middle with broadly rounded apex and attenuated base; raphe thick with curved terminal fissures; axial area narrow, linear; central area slightly unilateral with an isolated stigma on the opposite side; striae 8-9 in 10 μm radial, finely punctate, central striae distantly set from one another.

Habitat: Kawalghat

Found in site: **SW_2** [pH 8.9; Temp 26.5^{0}C]

8. ***Melosira granulata* (Ehrenberg) Ralfs** (Plate I, Fig. 8)

Hustedt 1930, p.87, Fig. 44

Frustules 5.5-8.3 μm in diameter, cylindrical, united in short or long chains, semicells 7-25.6 μm high; end cells with spines, furrows and straight rows of areoles; rows of areoles 10-14 in 10 μm spirally disposed.

Habit: Underbridge.

Found in site: **SW_1** [pH 5.9; Temp 27.5^{0}C]

9. ***Navicula cari* Ehr. fa. *indica* Gandhi** (Plate II, Fig. 9)

Sarode and Kamat, 1984. p. 104, pl.11, f. 246

Valves 39-42 μm long, 7.3-8.1 μm broad, narrowly lanceolate, tapering towards the end with somewhat produced and broadly rounded ends; raphe thin and straight; axial area narrow; central area large, transversely extended, quadrangular; striae 12 in 10 μm, convergent towards the ends, middle striae shorter.

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.1; Temp 24.4^{0}C]

10. ***Navicula cryptocephala* Kuetz.** (Plate II, Fig. 10)

Sarode, 1984, pp. 106, p1.12, Fig. 254.

Plate- Plate-VII, Fig. 33.

Valves 22.7 µm long 35.5 µm. broad, lanceolate with produced, rounded ends; raphe thin and straight; axial area narrow; central area slightly extended transversely, small; striae 10-12 in 10 µm, stongly radial in the middle and slightly convergent at the ends.

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.1; Temp 24.4^{0}C]

11. ***Navicula cuspidata* Kuetz. var. *ambigua* (Ehr.) Cleve** (Plate II, Fig. 11)

Hustedt, F., 1930. p.268, Fig. 434

Valves long, broadly lanceolate with narrowly constricted much produced, flately rostrate capitates ends; raphe thin, straight, median with distinct, unilaterally bent central nodules and curved terminal fissures; axial area narrow, linear; central area moderately wide and longitudinally elongated; valve surface striated, transverse striae lineate, parallel interrupted by longitudinal striae. Length 81 µm.breadth, 21 µm, transverse and longitudinal striae 18-22 µm.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 28.7^{0}C]

12. ***Navicula pupula* Kuetz. var. *capitata* Hustedt** (Plate 2, Fig. 12)

Hustedt, F., 1930. p.281, Fig. 467a

Valves 18-35.5 µm.long, 7.3-10.9 µm broad, linear lanceolate or subelliptical with broadly rounded and slightly constricted ends; raphe thin and straight; polar areas present; axial area narrow, linear; central area rectangular, transversely widened; striae 16-18 µm.in 10 µm, fine, radial and slightly curved.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 20.6^{0}C]

13. ***Navicula viridula*** **Kuetzing** (Plate II, Fig. 13)

Hustedt, F., 1930. p.297, Fig. 503

Valves 62-70 µm long, 12-14 µm broad, linear lanceolate with produced and roasted ends; raphe thin enclosed in siliceous ribs, central pores unilaterally bent, terminal fissures distinct; axial area narrow; central area wide and suborbicular; striae 7-8 in 10 µm.in the middle and upto 10 in at the ends, thick, radial in the middle and convergent at the ends.

Habitat: Smashanbhoomi

Found in site: **SW_3** [pH 8.7; Temp 21.5^{0}C]

14. ***Peridinium cinctum*** **(Muller) Ehrenberg** (Plate II, Fig. 14)

G.W.Prescott, 1951, p. 432, pl. 91, Fig. 1-4

Cells ovoid to spherical, slightly flattened dorsiventrally, epitheca sometimes larger than hypotheca, 35-73 x 40-75 µm; girdle median or slightly posterior to center of cell; chromatophores numerous, parietal, dark brown.

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 35^{0}C]

15. ***Phacus caudatus*** **var.** ***tenuis*** **Swirenko** (Plate II, Fig. 15)

Wolowski, 1998, p. 80, Fig. 277

Cells 34.5-39.0 µm long, 25.0-29.0 µm wide, ovoid, each with long curved cauda at the posterior end.

Habitat: Smashanbhoomi

Found in site: **SW_3** [pH 8.7; Temp 21.5^{0}C]

16. ***Pinnularia acrosphaeria*** **(Breb.)W.Smith** (Plate II, Fig. 16)

Hustedt, F., 1930. p. 330, Fig. 610

Valves solitary, free-floating, linear, very slightly swollen in the middle; ends slightly constricted and broadly rounded; raphe thin, straight with distinct central nodules, terminal fissures bent on one side of the valve; axial area broad about half of the breadth of the valve; central area some what elliptical; striae fine, lineate, short,marginal. Length, 37 µm; breadth, 6-7 µm; striae 14-16 in 10 µm.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 20.6^{0}C]

17. ***Pinnularia brevicostata* Cleve var. *indica* Gandhi** (Plate III, Fig. 17)

Sarode and Kamat 1984, p. 138, pl. 15, f. 357

Valves 87.5-97 µm long, 19.5-21 µm broad, linear elliptical with rounded ends; raphe thick with central pores unilaterally bent and terminal fissures slightly curved; axial areawide, lanceolate; central area not obvious; striae 6 in 10 µm, very coarse, radial in the middle and slightly convergent at the ends.

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 35^{0}C]

18. ***Pinnularia gibba* Ehr.** (Plate III, Fig. 18)

Hustedt 1930, p. 327, f. 600 a,b

Valves 65-74 µm long, 12-12.5 µm broad, linar lanceolate with abruptly swollen, broadly rounded ends; raphe thin and straight with central pores unilaterally bent and terminal fissures curved; axial area narrowly lanceolate; central area very large, rhomboid, reaching the margins; striae 9-10 in 10 µm, very coarse, radial in the middle and convergent at the ends.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 20.6^{0}C]

19. ***Pinnularia major*** **(Kuetz.) Cleve var.** ***linearis*** **Cleve** (Plate III, Fig. 19)

Sarode and Kamat 1984, p. 133, pl.17, Fig.387

Valves 95-126 µm long, 16-18 µm broad, linearwith veryslightly inflatedmargins in the middle part and somewhat cuneately rounded ends; raphe thick and complex; axial area fairly wide; central area broader; striae 7-8 in 10 µm slightly radian in themiddle and convergent at the ends.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 29^0C]

20. ***Rhodomonas baltica*** **Karst** (Plate III, Fig. 20)

Fritsch, 1935, p. 652, Fig. 216 H.

Individuals occur singly with tubular gullet from the anterior end of the furrow; single parietal chromatophore, diverse shades of brown are the most frequent pigmentation; nucleus usually situated near the posterior extremity and in contact with the pyrenoid. Several pyrenoid embedded in an enlargement of the chromatophore.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 28.2^0C]

21. ***Stauroneis anceps*** **var.** ***gracilis*** **(Ehr) Cleve** (Plate III, Fig. 21)

Hustedt, F., 1930. p. 256, Fig. 406

Valves solitary, free-floating, linear, elliptical-lanceolate, gradually attenuated with suddenly constricted broadly produced capitate ends; raphe thin, straight, median, slightly curved at apices; axial area narrow, linear; central area stauroid reaching the sides; striae very fine, lineate, strongly radiate and parallel throughout the valve. Length, 58 µm; bredth, 9 µm ;striae 26-28 in 10 µm.

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 23.9^{0}C]

22. ***Stauroneis phoenicenteron* (Nitzsch) Ehr. var. *intermidia* Dippel.** (Plate III, Fig. 22)

Desikachary 1989, p.7, pl. 701, Fig. 4-5

Epilithic in water current; Valves up to 70120 µm long and 16-22 µm broad, striae 20-23 in 10 µm.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 21.1^{0}C]

23. ***Synura uvella* Ehrenberg** (Plate III, Fig. 23)

G.W.Prescott, 1951, p. 376, pl. 92, Fig. 6,7

Free swimming colony of 32-64 short pyriformcells which have several short, sharp spines in the anterior region of the wall; cells 2-3.5 µm in diameter, 8-12 µm long.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 21.9^{0}C]

24. ***Tabellaria fenestrata* (Lyngbye) Kuetzing** (Plate III, Fig. 24)

Tiffany 1952, p. 227, pl. 61, Fig. 692, 693

Cells 3-9 x 30-140 µm, with 4 intercalary bands, and 4 septa, forming zigzag chains; valves elongate, with finely punctate striations, 18-20 in 10 µm inflated in the middle and at the poles; pseudoraphe narrow.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 29^{0}C]

Chlorophyceae

25. ***Closterium acerosum* var. *angolense* West and West** (Plate IV, Fig. 25)

West and G.S.West, 190IV, p 149, pl 18, f 6

Cell wall smooth, colourless; chloroplast showing a series of anastomosing ribbons; 52.6 μm in diameter; 740 μm long.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 26.8^{0}C]

26. ***Triploceras gracile* Bail var. *undulatum* Scott & Pres** (Plate IV, Fig. 26)

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Cell body 206- (310-360) -668 μm long, (20-28) -53 μm wide (including spines), L/W=10-15; semicells not swelled at base, slightly tapered at terminal, wavy lateral margin with short spines, 2 arm-like projections at each end, each projection equipped with two spines; cellwall smooth; axial Chloroplasts with radially-arranged laminae.

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 24.4^{0}C]

27. ***Ankistrodesmus falcatus* (Corda) Rails.** (Plate IV, Fig. 27)

Forest, 1954, pp. 107, Fig. 122.

Cells in radiating bundles, straight or curved, 2-3 μm broad and 70-80 μm long.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 21.1^{0}C]

28. ***Ankistrodesmus falcatus* (Corda) Ralfs var. *acicularis* (A. Braun) G.S.West** (Plate IV, Fig. 28)

M.T. Philipose, 1967, p. 213, Fig. 121 c

Cells mostly single, straight or slightely curved and with pointed ends. Cells 2.0-4.5 μm broad, 35-80, rarely up to 210 μm long.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 29.1^{0}C]

29. ***Ankistrodesmus spiralis* (Turner) Lemmermann** (Plate IV, Fig. 29)

M.T. Philipose, 1967, p. 210, Fig. 119 a-c

Cells acicular with acute apices; in colonies of usually 4-8-16, rarely two, cells spirally twisted round one another in themedian region, but free at the ends. Chloroplast single and without a pyrenoid. Cells 1-3 µm broad, 20-45 µm long.

Habitat : Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 22.8^{0}C]

30. ***Chlorella vulgaris* Beyer. (Smith)** (Plate IV, Fig. 30)

Forest, 1954, pp. 110, Fig. 128.

Cells spherical, scattered among other algae or some times occurring in almost pure growths; chloroplast a parietal cup, some times without a pyrenoids; cells 5-8.5 µm in diameter.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 29^{0}C]

31. ***Coelastrum cambricum* Archer var. *intermidium* (Bohlin) G.S.West** (Plate IV, Fig. 31)

M.T. Philipose, 1967, p. 230, Fig. 138 a

Differs from the type in the outer face of the external cells being subspherical and gradually arched. The outstanding projections are also blunt and rounded and not truncate. Interspaces between cells more or less triangular. Cells 13-21 µm in diameter. Colonies upto 108 µm in diameter.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 21.9^{0}C]

32. ***Coelastrum sphaerium*** **Naeg.** (Plate IV, Fig. 32)

M.T.Phillipose, 1967, p 229 Fig. 136.

Colonies spherical or ellipsoid, of 4-8-16-32, regularly arranged cells cells ovoid with the narrow end directed outwords; side of cells where they are in contact with each other flattend and the outer free side strongly curved. Intercellular spaces about half the dameter of the cells or larger4. Cells 6-25 µm in diameter

Habitat: Shahalangadi

Found in site: $\mathbf{SW_4}$ [pH 8.2; Temp 34.8^0C]

33. ***Coelastrum microporum*** **Naegeli** (Plate V, Fig. 33)

M.T. Philipose, 1967, p. 228, Fig. 135

Colonies more or less spherical and of 8-16-32-64 (usually 16-32) cells with small intercellular spaces. Cells spherical to ovoid, enclosed by delicate gelatinous sheaths and interconnected by almost imperceptible gelatinous processes. Cells with sheath 4 - 27 µm diameter. Colonies 20-90 µm in diameter.

Habitat: Underbridge.

Found in site: $\mathbf{SW_1}$ [pH 8.1; Temp 23.9^0C]

34. ***Dimorphococcus lunatus*** **A. Braun** (Plate V, Fig. 34)

M.T. Philipose, 1967, p. 205, Fig. 115

Colonies irregular. Cells in groups of four and arranged alternately in a zigzag fashion. Outer cells of each group reniformor somewhat crescent shaped. Inner cells elongated-ovoid to ellipsoid. Ends of cells rounded. Chloroplast a parietal plate nearly covering the entire cellwall in mature cells. Cells 4-15 µm broad, 9-25 µm long. Colonies up to 100 µm in diameter.

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 23.9^{0}C]

35. ***Eudorina elegans* Ehrenberg**. (Plate V, Fig. 35)

M.O.P. Iyengar and T.V. Desikachary, 1981, p. 429, pl. 252, Fig. 1-28, pl. 254, Fig. 1-12

Cells 10-20 µm in diameter; colony spherical, ellipsoidal or ovate-ellipsoidal, 60-200 µm long and 62-83 µm broad; colonial envelope smooth in outline, rounded at the ends, at time the posterior end flattened ormamillate; colonies 16-celled, or 32-celled with cells in tiers of 4,8,8,8 and 4 cells or rarelywith 64 cells; cells arranged in distinct tierswith a confluent double-layered gelatinous envelope; all cells equal in size or the anterior tier of cells (4 cells) slightly reduced in size in a 32-celled colony; chloroplast cup shaped, radially striated, pyrenoids three tomany randomlyarranged; eyespot anterior, progressively smaller in the next posterior tiers; asexual reproduction by the production of daughter colonies by all cells, sexual reproduction heterogamous and dioecious.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 28.8^{0}C]

36. ***Gonatozygon aculeatum* Hast.** (Plate V, Fig. 36)

Prescott, 1961, p. 8, pl. 1, Fig. 7

Cell body 126-175 µm long, 12-14 µm wide.

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 27.2^{0}C]

37. ***Gonatozygon monotaenium* De Bary** (Plate V, Fig. 37)

Prescott, 1961, p. 9, pl. 1, Fig. 9, 10

Cell body cylindrical (74-145) -284 µm long, 7.5-11.5 µm wide, L/W, cell wall granulated, both ends slightly swelled, 2 chloroplasts with 4-10 pyrenoids in each.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 20.7^{0}C]

38. ***Nephrocytium agardhianum*** **Naegeli** (Plate 5, Fig. 38)

M.T. Philipose, 1967, p. 189, Fig. 104

Cells more or less reniformwith rounded ends and usually in colonies of 4, 8, or rarely 1,2, or 16 cells,within a gelatinous envelope. Cells arranged somewhat spirally in young and irregularly in old colonies. Chloroplast single, parietal and with one pyrenoid. Young cells 2-7 µm broad and 3-6 µm times as long. Adult cells 8-22 µm broad and double as long. Colonies 40-95 µm in diameter.

Habitat: Smashanbhoomi

Found in site: **SW_3** [pH 8.7; Temp 22.7^{0}C]

39. ***Nephrocytium lunatum*** **W.West** (Plate V, Fig. 39)

M.T. Philipose, 1967, p. 189, Fig. 103

Cells more or less moon to sickle-shaped with one side convex and the other concave and ends pointed. Cells spirally arranged within an ellipsoid to oblong hyaline gelatinous envelope to form 4-8 celled colonies. Chloroplast single, parietal, and with a pyrenoid. Cells 4-7.9 µm broad, 14-21 µm long. Colonies 25-37 µm broad, 38-75 µm long.

Habitat: Smashanbhoomi

Found in site: **SW_3** [pH 8.7; Temp 20.6^{0}C]

40. ***Netrium digitus*** **(Ehrbg.) Itzigs. &Rothe** (Plate V, Fig. 40)

Prescott, 1961, p. 8, pl. 1, Fig. 5

Cell body147-153 μm long,44-45 μm wide; chloroplast parietal with fabricate margins.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 21.1^{0}C]

41. ***Oocystis elliptica* W. West** (Plate VI, Fig. 41)

M.T. Philipose, 1967, p. 186, Fig. 100

Usuallyin 4-8 celled colonies with the envelope narrow, rarely solitary. Cells elongate-ellipsoid, about 2 (2.5) times as long as broad and with broadly rounded ends which are not thickened. Chromatophores numerous (about 10-20) and in the form of parietal discs without pyrenoids. Cells 11-15 μm broad and 20-25 μm ling.

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 22.9^{0}C]

42. ***Pandorina cylindricum* Iyengar**(Plate 6, Fig. 42)

M.O.P. Iyengar and T.V. Desikachary, 1981, p. 420, pl. 245, Fig. 1-17

Colonies cylindrical with rounded ends, anterior slightly broader than the posterior, 30-50 μm in diameter and 47.2- 64 μm long; 16-celled, cells arranged in four alternating tiers of 4 cells each; cells pyramidal with the broad side directed outwards, cells compactly arranged and slightly angular through mutual pressure, chloroplasts cup-shaped with a single median pyrenoid, not striated; nucleus single in the hollow of the chloroplast cup; asexual and sexual reproduction present; the latter is dioecious, female colonies larger,male colonies smaller.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 20.7^{0}C]

43. ***Pandorina morum* (Mull.) Bory** (Plate VI, Fig. 43)

M.O.P. Iyengar and T.V. Desikachary, 1981, p. 418, pl. 243, Fig. 1-16

Colonies short-ellipsoidal or nearly spherical, both ends broadly rounded, 8-16 celled, embedded in a commonmatrix; 20-42 μm min diameter, up to 60 μm long or longer; cells obovate or wedge shaped, broadside turned towards the outside, narrower and rounded posteriorly, towards the inside angular by mutual compression when closely packed, 8-17 μm long and as much broad; chloroplast massive, cup-shaped coveringmost of the surface of the cell, often longitudinally striated, with one basal pyrenoid; eyespot large, hemispherical on the outer surface of the cell; flagella two, contractile vacuoles 2, anterior; asexual reproduction and sexual reproduction present; zygotewall smooth.

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 34.8^{0}C]

44. ***Pediastrum tetras* (Ehr.) Ralfs**(Plate VI, Fig. 44)

M.T. Philipose, 1967, p. 128, Fig. 45 a-c

Colonies rectangular, ovalor circular of 4-8-16 (-32) cells without intercellular spaces. Marginal cells divided into two lobes bya deep linear to cuneate incision on outer side reaching to the middle of the cells. Each lobe truncate, slightly marginate, or further divided into two lobes. Inner cells 4-6 sided with a single linear incision. Diameter of cells 5-15 (-27) μm. Eight-celled colonies 20-33 μm and 16- celled colonies up to 50 μm in diameter.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 28.7^{0}C]

45. ***Pediastrum biradiatum* Meyen non Ralfs var. *longicornutum* Gutwinski** (Plate VI, Fig. 45)

M.T. Philipose, 1967, p. 128, Fig. 44 b,d

Differs from the type in the lobes ofmarginal cells being bifid instead of being incised as in the type of the species and in the lobes ending in long horn like processes. Colonies four-celled with a central perforation or 8-16 celled with a circular central outline and with 4-8 perforations. Cells slightly concave at the sides. Cell membrane smooth and punctate. Cells 8-15 µm broad, 14-24 µm long. Four-celled colony 30 µm and eight-celled colony up to 63 µm in diameter.

Habitat: Smashanbhoomi

Found in site: **SW_3** [pH 8.7; Temp 24^0C]

46. ***Pediastrum duplex*** **Meyen var.** ***coronatum*** **Raciborski** (Plate VI, Fig. 46)

M.T. Philipose, 1967, p. 121, Fig. 43 k, l

Colonies 16-32-64 celled. Inner cells four cornered with a small lens-shaped perforation in front and another at the back. Marginal cells usually longer than broad and in lateral contact along one third the length. Processes of marginal cells ending in short spines. Cell membrane with a net work of punctae. Inner cells 18-26 µm broad, 18-25 µm long. Marginal cells 21-26 µm broad, 25-26 µm long. Colonies 120-214 µm in diameter.

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 35^0C]

47. ***Pleodorina californica*** **Shaw** (Plate VI, Fig. 47)

M.O.P. Iyengar and T.V. Desikachary, 1981, p. 444, pl. 261, Fig. 1- 20

Colonies spherical to ellipsoidal, 175 -250 µm in diameter; 128-celled, also sometimes 32-, 64- celled; cells irregularly distributed within the colonial mucilaginous envelope; chloroplast cup-shaped with 1-3 pyrenoids; eyespot anterior; asexual and sexual reproduction present.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 31.1^{0}C]

48. ***Pleurotaenium baculoides*** **(Roy & Biss) Playf.** (Plate VI, Fig. 48)

Prescott, 1961, p. 14, pl. 3, Fig. 5

Cell body elongated; (265-470)-648 µm long, 13-(15-55)-23 µm wide; L/W= 20-40; secondary constriction conspicous; 3-4 chloroplasts band-form.

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 22.9^{0}C]

49. ***Pleurotaenium nodosum*** **(Bail.)Lund.** (Plate VII, Fig. 49)

Prescott, 1961, p. 16, pl. 5, Fig. 3, 4

Cells 280-360 µm, 51-71 µm wide at the base, 23-33 µm wide at the poles, isthamus 20-30 µm.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 28.7^{0}C]

50. ***Pleurotaenium trabecula*** **(Ehrbg) Nag** (Plate VII, Fig. 50)

Prescott, 1961, p. 18, pl. 3, Fig. 4

Cells cylindrical, 260-660 µm long, 24-45 µm diameter L/W=11-18, constricted at center, semicells bulged at base; chloroplast elongate, with 3-4 laminae; cellwall dotted.

Habitat: Smashanbhoomi

Found in site: **SW_3** [pH 8.7; Temp 20.6^{0}C]

51. ***Pleurotaenium trabecula*** **(Ehrbg) Nag var.** ***maximum*** **(Reinsch) Roll** (Plate VII, Fig. 51)

Prescott, 1961, p. 18, pl. 3, Fig. 11

Cells cylindrical, 660-750 μm 45-50 μm diameter at base, 27-32 μm at the poles; two deep constrictions above the basal inflation; chloroplast elongate, with 3-4 laminae.

Habitat: Smashanbhoomi

Found in site: **SW_3** [pH 8.7; Temp 33^0C]

52. ***Scenedesmus arcuatus*** **(Lemmarmann) Lemmarmann** (Plate VII, Fig. 52)

M.T. Philipose, 1967, p. 213, Fig. 121 c

Colonies usually eight-celled, rarely 4 or 16 celled, curved andwith small intercellular spaces. Cells in eight-celled colonies in two series, oblong-ovoid, sometimes slightly angular at the base due to mutual pressure. Cell wall smooth,without teeth or spines.Cells 3.5-9.5 μm broad, 8.5-18 μm long.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 27.3^0C]

53. ***Scenedesmus bijugatus*** **(Turpin) Kuetzing** (Plate VII, Fig. 53)

M.T. Philipose, 1967, p. 213, Fig. 121 c

Colonies flat or slightly curved, of 2-4-8 cells arranged in a single linear series. Cells oblong ellipsoid to ovoid with the ends broadly rounded. Cells 3.5-7 μm broad, 7-23 μm long.

Habitat: Smashanbhoomi

Found in site: **SW_3** [pH 8.7; Temp 32.8^0C]

54. ***Scenedesmus dimorphus*** **(Turpin) Kuetzing** (Plate VII, Fig. 54)

M.T. Philipose, 1967, p. 213, Fig. 121 c

Colonies 4-8 celled with the cells arranged in a linear or subalternating series (Eight-celled colonies always in subalternating series). Differ from *S. obliquus* in the outer

cells of the colonybeing more or less lunate and the apices of the cells being attenuated. Cells 2-8 μm broad and 14-35 μm long.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 29^0C]

55. ***Scenedesmus perforatus* Lemmermann** (Plate 7, Fig. 55)

M.T. Philipose, 1967, p. 213, Fig. 121 c

Colonies usuallyeight celled, some times four celled. Cells with capitate ends. Outer face of external cells slightly convex, inner face concave; poles curved outwards and with a long recurved spine. Internal cells with concave sides and with linear to lenticular perforations between adjacent cells. Cells 3-10 μm broad, 10-28 μm long. Perforations 1.5-2.5 μm long. Spines 10-20 μm long.

Habitat: Smashanbhoomi

Found in site: **SW_3** [pH 8.7; Temp 27.8^0C]

56. ***Scenedesmus perforatus* (Lemmermann) var. *major* (Turner) Philipose** (Plate VII, Fig. 56)

M.T. Philipose, 1967, p. 213, Fig. 121 c

Colonies four-eight celled, much larger than in the type, and sometimeswith a long spine from the poles of some of the internal cells. Pyrenoids one to three in each cell. Cells 10-16.5 μm broad, 27-33 μm long. Perforations 1-2.5 μm long. Central pyrenoid 8-10 μm in diameter. Spines 8-25 μm long. The maximum dimensions of cells appear to be 10 μm x28 μm and the minimum 3 μm x10 μm.

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 22.9^0C]

57. ***Scenedesmus quadricauda* (Turpin) Brebisson Var. *bicaudatus* Hansgirg** (Plate VIII, Fig. 57)

M.T. Philipose, 1967, p. 213, Fig. 121 c

Colonies 2-4-8 celled. Terminal cells with a long spine fromone pole only, the spine of one terminal cell being at an angle opposite to that of the other terminal cell. Internal cells without spines from their poles. Cells 4-5 µm broad, 8-12 µm long, spines 7-8.8 µm long.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 29^0C]

58. ***Scenedesmus quadricauda* (Turpin) Brebisson Var. *longispina* (Chodat) G.M.Smith** (Plate VIII, Fig. 58)

M.T. Philipose, 1967, p. 213, Fig. 121 c

Colonies usually 2-4 celled, rarely 8-celled. Cells ovoid to cylindrical with the cells narrower than in the type and the spines proportionately longer, compared to the length of the cells. Internal cells sometimes with veryshort delicate spines fromsome of their poles. Cells 2.5-5 µm broad, 8-15.3 µm long. Spines 7.5-15 µm long..

Habitat: Smashanbhoomi

Found in site: **SW_3** [pH 8.7; Temp 23.2^0C]

59. ***Scenedesmus quadricauda* v. *quadrispina* (Cho.) G.M. Smith**. (Plate VIII, Fig. 59)

Forest, 1954, pp. 142, Fig. 194.Plate- Plate-VI, Fig. 30.

Colonies usually 2 celled. Cells broadly ovoid and about twice as long as broad. Poles of terminal cells with ashort recurved spine. Cells 3.5-8.5 µm long, 8.5-15.19 µm long. Spines 2.5-5.5 µm long.

Habitat: Smashanbhoomi

Found in site: **SW_3** [pH 8.7; Temp 33^0C]

60. ***Spirogyra ternata*** **Ripart** (Plate VIII, Fig. 60)

Yamagishi 1966, p. 97, pl. 6, Fig. 4-6; Islam 1984, p. 212, pl. 4, Fig. 44-46

Vegetative cells 49-66 µm x 66-149 µm; septa plane; chloroplasts 3, making 0.5-2 turns. Conjugation scalariform; tubes formed byboth gametangia; female gametangia cylindric, zygospore ellipsoid, 42-53 µm x 59-73 µm, mesospore yellow-brown and smooth.

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 24.4^0C]

61. ***Tetraedron enorme*** **(Ralfs) Hansg var.** ***pentaedricum*** **Prescott** (Plate VIII, Fig. 61)

G.W. Prescott, 1944, p 358, pl. 1, f 17

Cells five-sided with the sides straight or slightly convex and with pairs of narrow bifurcate processes extending in all planes. Processes ending in short spines. Cells 27-55 µm in diameter. The variety differs from the type in the straight (instead of concave) margins and the narrow difurcated processes extending from the angles.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 29^0C]

62. ***Tetraedron limneticum*** **Borge var.** ***gracile*** **Prescott** (Plate VIII, Fig. 62)

G.W. Prescott, 1944, p 358, pl 1, f 18; 1951, p 266, pl 60, f 5

Differs from the type in having much narrower processes which almost adjoin at the base, there being scarcely any cell body. Cells 35.2-46.8 µm in diameter. Base of processes 5.3-8 µm broad.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 27.8^0C]

63. ***Tetraedron trigonum*** **(Naeg) Hansg. fa.** ***gracile*** **(Reinsch) De Toni** ((Plate VIII, Fig. 63)

M.T. Philipose, 1967, p. 142, Fig. 58 a

Cells with more markedly concave sides than in the type. Cell membrane smooth. Cells19-35 µm in diameter, 6-8 µm thick. Spines 6.2-7 µm long.

Habitat: Smashanbhoomi

Found in site: $\mathbf{SW_3}$ [pH 8.7; Temp 26.7^{0}C]

64. ***Tetraspora gelatinosa*** **(Vauch.)** ***Desv.*** (Plate VIII, Fig. 64)

Forest, 1954, pp. 66, Fig. 47.

The irregular saccate colonies are softer and more lumpy.

Habitat: Underbridge.

Found in site: $\mathbf{SW_1}$ [pH 8.1; Temp 27.5^{0}C]

65. ***Cosmarium auriculatum*** **Reinsch** (Plate IX, Fig. 65)

Prescott, 1961, p. 54, pl. 26, Fig. 4

Cells 48-50 µm long, 58-59 µm wide, isthmus 25 µm.

Habitat: Underbridge.

Found in site: $\mathbf{SW_1}$ [pH 8.1; Temp 28.7^{0}C]

66. ***Cosmarium contractum*** **Kirchner var.** ***pachydermum*** **Scott&Prescott** (Plate IX, Fig. 65)

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Cell body dorso-ventrallycompressed, with strong constriction at the center, transverse section elliptical or diamond-shaped. Cell body 34 µm long, 27 µm wide, isthmus 7µm wide, L/W=1.3; apex of semicells slightly flat; cellwall smooth.

Habitat: Smashanbhoomi

Found in site: **SW_3** [pH 8.7; Temp 21.5^{0}C]

67. ***Cosmarium cuneatum*** **Josh** (Plate 9 IX, Fig. 65)

Prescott, 1961, p. 57, pl. 30, Fig. 3

Cell body 40-42 µm long, 45-48 µm wide, isthmus 13-14 µm wide

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 20.7^{0}C]

68. ***Cosmarium quadrifarium*** **Lund** (Plate IX, Fig. 65)

Prescott, 1961, p. 67, pl. 30, Fig. 10

Cell body 42 µm long, 33 µm wide, isthmus 25 µm wide

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 28.7^{0}C]

69. ***Cosmarium quadrum*** **Lund var.** ***minus*** **Nordst** (Plate IX, Fig. 69)

Illustrations of the Japanese fresh-water algae, 1977

Cell body rectangular, 53-90 µm long, 47.6-85 µm wide, isthmus 19-30 µm wide; semicells subrectangular, with rounded corners; side view nearly circular; apical view elongated ellipsoidal marginal granules 34-37 in number.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 21.1^{0}C]

70. ***Cosmarium geminatum*** **Lund fa.** ***ornatum*** **Behre** (Plate IX, Fig. 70)

Prescott, 1961, p. 59, pl. 31, Fig. 9

Cell body 24µm long, 25 µm wide, isthmus 8 µm wide

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 23.9^{0}C]

71. ***Desmidium aptogonum*** **Breb** (Plate IX, Fig. 71)

Prescott, 1961, p. 124, pl. 62, Fig. 5 - 7

Cell body 15 µm long, 25 µm wide. Cell body short, with a deep constriction at the corner, apical view fusiform or radially symmetrical; cell apexes without spiny projections; intermediate zone or folded structure appeared during celldivision; zygospores remain within their mother cells.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 27.3^{0}C]

72. ***Desmidium baileyi* (Ralfs) Nordst f. *longisprocessum* Scott &Prescott** (Plate IX, Fig. 72)

Prescott, 1961, p. 124, pl. 62, Fig. 10, 11

Vertical view quadrangular. Differs in themuch longer apical process, which show a slight indentation at the point of eversion.Cells 16µm long, 21 µm wide

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 26.5^{O}C^{0}C]

73. ***Desmidium swartzii* Agardh** (Plate X, Fig. 73)

Prescott, 1961, p. 125, pl. 63, Fig. 8

Cell body constricted in the middle, sinus narrow-linear part but acutely open outward, 11-22 µm long, 24-39 µm. L/W=2, constriction 21-28 µm wide; vertical view of cells triangular, side straight, angles rounded; apex broad with a short connecting process at each apical angle, excavated in the middle and forming a oblong hollow cavity between the adjacent cells; semicells transversely subrectangular, lateral margins obliquely truncate; filaments twisted.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 21.1^{0}C]

74. ***Euastrum acanthophorum* Turn.** (Plate X, Fig. 74)

Prescott, 1961, p. 22, pl. 13, Fig. 4, 5

Cell body34-36 µm. long , 24-29 µm wide, isthmus 6-7 µm wide.

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 22.8^{0}C]

75. ***Euastrum ansatum* Ehrbg** (Plate X, Fig. 75)

Prescott, 1961, p. 22, pl. 9, Fig. 1

Cellbody 87-90 µm. long, 40-42 µm wide, T 30 µm. cell body medium in size, elongate, pyramid shaped, side margins concaved, 87-95 µm. long , 39-42 µm wide, L/W=2, isthmus 11-14 µm wide. Cell wall dotted, with 5 bulges conspicuous (2central, 3 basal).

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 27.3^{0}C]

76. ***Euastrum moebii* (Borge) Scott & Presc var. *burmense*West &West** (Plate X, Fig. 76)

Prescott, 1961, p. 36, pl. 7, Fig. 4

Cell body 126-131 87-95 µm. long , 39133-135 µm wide, at the base, 102-105 µm wide at the polar lobe, isthmus 37-39 µm wide .

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 23.9^{0}C]

77. ***Euastrum sinuosum* Lenorm. var. *capitatum* Prescott** (Plate X , Fig. 77)

Prescott, 1961, p. 39, pl. 7, Fig. 8, 9

Cell body 84-96 µm. long , 46-50 µm wide, isthmus13-15 µm wide.

Habitat: Smashanbhoomi

Found in site: **SW_3** [pH 8.7; Temp 26.7^{O}C]

78. ***Euastrum sinuosum*** **Lenorm. var.** ***reductum*** **West &West** (Plate X, Fig. 78)

Prescott, 1961, p. 40, pl. 9, Fig. 8

Cell body 46 µm. long , 32 µm wide, isthmus10 µm wide.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 26.5^{0}C]

79. ***Micrasterias foliacia*** **Bail var.** ***quadrinflata*** **Prescott** (Plate X Fig. 79)

Prescott, 1961, p. 48, pl. 15, Fig. 5-8

Cell body 69-72 µm. long , 63-72 µm wide, isthmus12µm wide. Each semicell has two large and prominent semi ellipsoidal hollowswellings at the base of the lateral lobes, each bearing a long spine at the narrow ends.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 20.7^{0}C]

80. ***Micrasterias lux*** **Josh var.** ***brevibracchiata*** **Behre fa.** ***spinosa*** **Prescott** (Plate X, Fig. 80)

Prescott, 1961, p. 49, pl. 17, Fig. 5

Cell body 186-207µm. long, 168-186 µm wide, isthmus 23-24µm wide. A row of small spines across the base of the semicell, and a few spines on the polar lobe and near the adjacent margin of the lateral lobes.

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 24.4^{0}C]

81. ***Micrasterias mahabuleshwarensis*** **Hobs. var.** ***surculifera*** **Lagerh.** (Plate XI, Fig. 81)

Prescott, 1961, p. 50, pl. 16, Fig. 1, 2

Cell body147-152 µm. long, 131-138 µm wide, isthmus 24µm wide

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 22.9^{0}C]

82. ***Micrasterias pinnatifida* (Kutz) Ralfs** (Plate XI, Fig. 82)

Prescott, 1961, p. 51, pl. 12, Fig. 6; pl. 14, Fig. 17, 18

Cell body 77µm. long, 73 µm wide.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 26.5^{0}C]

83. ***Micrasterias radians* Turn.** (Plate XI, Fig. 83)

Prescott, 1961, p. 51, pl. 23, Fig. 1

Cell body117-135 µm. long, 105-125 µm wide, isthmus 18-21 µm wide

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 34.8^{0}C]

84. ***Onychonema laeve* Nordst var. *latum* West &West** (Plate XI, Fig. 84)

Prescott, 1961, p. 121, pl. 60, Fig. 13

Cell body 15-22 µm. long, 17-25 µm wide, constriction 7-8.6 µm wide; semicells elongated, ellipsoidal or broad hexagonal reniform, fromboth sides two short spines directing inward; apex flat with two long projections to connect with adjoining cell.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 26.8^{0}C]

85. ***Spondylosium planum* (Wolle)West &West** (Plate XI, Fig. 85)

Illustrations of the Japanese Fresh-waterAlgae, 1977

Cell body 8.4 µm. long, 8.4-12 µm wide, constriction 4.2-4.8 µm wide

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 26.5^{0}C]

86. ***Staurastrum anatinoides*** **Scott and Presc. var.** ***javanicum*** **Prescott** (Plate XI, Fig. 86)

Prescott, 1961, p. 86, pl. 56, Fig. 5

Size and shape of cells similar to those of the species. Differs in the possession of a ring of small sharp teeth just above and below the isthmus, about six visible in each ring, and in the replacement of the six apical teeth by six emarginate verrucae. Cell body 33 µm. long, 50 µm wide, isthmus 10 µm .

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 21.1^{0}C]

87. ***Staurastrum pinnatum*** **Turn var.** ***subpinnatum*** **(Sehm) West &West fa.** ***robustum*** **Krieg.** (Plate XI, Fig. 87)

Prescott, 1961, p. 101, pl. 46, Fig. 9, 10

Cell body 48 µm. long, 51µm wide, isthmus 15 µm .

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 24.4^{0}C]

88. ***Staurastrum setigerum*** **Cleve** (Plate XI, Fig. 88)

Prescott, 1961, p. 107, pl. 56, Fig. 2

Cell body 36-43 µm. long, 36-54 µm wide, isthmus 13 µm.

Habitat: Smashanbhoomi

Found in site: **SW_3** [pH 8.7; Temp 26.9^{0}C]

89. ***Staurastrum tohopekaligense*** **Wolle var.** ***insigne*** **West & West**. (Plate XII, Fig. 89)

Prescott, 1961, p. 113, pl. 47, Fig. 12 - 15

Cell body 39-96 µm long, 28-120 µm wide, isthmus 18 µm.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 26.8^{0}C]

90. ***Staurastrum zonatum*** **Borges var.** ***majus*** **Presc.** (Plate XII, Fig. 90)

Prescott, 1961, p. 119, pl. 46, Fig. 8; pl 48, Fig. 7, 8

Larger than the species and with much longer processes. In front view differs in the shape of the semicellswhich aremore cyathiformand proportionately wider at the top; processesmuch longer, 5-dentate at the ends, and withmore rings of granules; apex biundulate with some small teeth visible. In vertical view4-, 5- or 6- radiate, lateralmargins of the body undulate and with two smallemarginate verrucae on each undulation; apical areawith two pairs of small conical teeth intramarginally opposite each side. Cell body 39-75 µm long, 79-93 µm wide, isthmus 14-15 µm.

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 22.8^{0}C]

91. ***Staurastrum crenulatum*** **(Nag) Delp** (Plate XII, Fig. 91)

Prescott, 1961, p. 88, pl. 59, Fig. 10

Cell body 23 µm long, 28 µm wide, isthmus 7.5 µm.

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 27^{0}C]

92. ***Xanthidium sexmamillatum*** **West & West var.** ***pulneyense*** **Iyangar & Bai** (Plate XII, Fig. 92)

Prescott, 1961, p. 84, pl. 39, Fig. 2

Cell body 50-102 µm long, 45-102 µm wide, isthmus 12-15 µm.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 23.2^{0}C]

93. ***Xanthidium spinosum*** **(Josh)West &West** (Plate XII, Fig. 93)

Prescott, 1961, p. 84, pl. 37, Fig. 2, 3

Cell body 48-55 μm long, 49-61 μm wide, isthmus 29 μm.

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 27.2^{0}C]

94. ***Arthrodesmus convergens*** **Ehrenberg** (Plate XII, Fig. 94)

Prescott, 1961, p. 74, pl. 34, Fig. 7-10

Cells 38-48 μm broad without spines; 36-40 μm long; isthmus 16-18 μm wide.

Habitat: Smashanbhoomi

Found in site: **SW_3** [pH 8.7; Temp 24^{0}C]

95. ***Arthrodesmus curvatus*** **Turner var.** ***latus*** **Prescott** (Plate XII, Fig. 95)

Prescott, 1961, p. 76, pl. 33, Fig. 1-3

Larger and much wider than the species, both with and without spines. Chloroplast furcated with one pyrenoid per semicell. Cells W.ssp. 31 μm ; W csp. 62 μm long, isthmus 9.3 μm wide.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 27.3^{0}C]

96. ***Hyalotheca dissiliens*** **(Smith) Brebisson var.** ***hians*** **Wolle** (Plate XIII, Fig. 97)

Prescott, 1961, p. 122, pl. 61, Fig. 2

Cell body 18-19.5 μm long, 11.5-12.5 μm wide.

Habitat: Smashanbhoomi

Found in site: **SW_3** [pH 8.7; Temp 21.5^{0}C]

97. ***Sphaerozosma granulatum*** **Roy & Biss**(Plate XIII, Fig. 98)

Prescott, 1961, p. 120, pl. 60, Fig. 5

Cell body12-13 μm long, 13-17 μm wide, isthmus 6-7 μm wide.

Habitat: Smashanbhoomi

Found in site: **SW_3** [pH 8.7; Temp 26.7^{0}C]

Cyanophyceae

98. ***Anabaena sphaerica*** **var.** ***attenuata*** **Bharadwaja** (Plate XIII, Fig.99)

T.V. Desikachary, 1959, p. 395, pl. 71, Fig. 8

Thallus floccose, gelatinous, thin, free-floating, pale blue-green; trichomes blue-green, curved or straight,more or less entangled with each other; slightly attenuated at the ends,with rounded endcells, without amucilage sheath; cells spherical or slightly barrel-shaped, 3-6 μm long; heterocysts intercalary; spores single on one or both sides of the heterocysts, spherical or oval, 10.5-12.6 μm broad and 10.5-14.7 μm long,with smooth yellowouter wall.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 26.8^{0}C]

99. ***Aphanocapsa littoralis*** **Hansgirg** (Plate XIII, Fig.100)

Desikachary, 1959, up.131, pl. 21, Fig. 1.

Thallus amorphous without any definite shape, mucilaginous, blue green **or** yellowish; cells spherical to sub spherical, 4-6 μm in diameter, single or in twos, densely or sparsely aggregated.

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 22.9^{0}C]

100.Arthrospira massartii **Kuffareth** (Plate XIII, Fig. 96)

T.V. Desikachary, 1959, p. 191, pl. 35, Fig. 9, 10

Trichomes loosely coiled, spirals 28 μm broad, distance between spirals 60-90 μm, cells 5-6

μm broad, 2-4 μm long, greyish blue-green; end-cells rounded conical, cross-walls not granulated, no gas vacuoles.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 21.9^{0}C]

***101.Chroococcus turgidus* (Kuetz) Nag.** (Plate XIII, Fig.101)

T.V. Desikachary, 1959, p. 101, pl. 26, Fig. 6

Cells spherical or ellipsoidal single, or in groups of mostly 2-4, very seldom many, blue-green, olive green or yellowish,without sheath 8-32 μm, withsheath 13-25 μm in diameter; sheath colourless, not distinctly lamellated.

Habitat: Smashanbhoomi

Found in site: **SW_3** [pH 8.7; Temp 26.9^{0}C]

***102.Gleocapsa atrata* (Corp.) Kuti.** (Plate XIII, Fig.102)

Desikachary, 1959, pp.116, pl. 24, Fig. 8.

Thallus crustaceous, mucilaginous, blackish; cells without sheath 3.5-4.5 μm in diameter, with sheath 9-14.5 μm in diameter, pale blue green, mostly many in a colony; sheath colourless or pale bluish, thick unlamellated or indistinctly lamellated.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 31.9^{0}C]

***103.Lyngbya aestuarii* Liehrn. ex. Gornont** (Plate XIII, Fig.103)

Desikachary,1959, pp. 305, pl. 52, lig. II. Forest, 1954, pp. 377, Fig. 580.

Filaments single or forming a brown or dull blue-green Thant's, sometimes having false branches, nearly straight or coiled, sometimes with calcium incrustations; sheath at first thin, later thick, yellow brown, lamellated, only sometimes brownish on the inside and colourless outside, not coloured violet by chlor-zinc-iodide; cells 8-24 μm ordinarily 10-16 μm broad, 1/3 - 1/6 times as long as broad, 2.7-5.6 μm long, not constricted at the cross-walls, cross-walls often granulated, contents sometimes with gas-vacuoles; end cells flat with thickened membrane, slightly attenuated.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 20.6^{0}C]

104.***Merismopedia glauca*** **(Ehrenb). Nag.** (Plate XIII, Fig.104)

Desikachary, 1959, pp.155, p1.29, Fig. 5.

Colonies mostly small with 16-64 cells, rarely more, 45-150 μm diameter, cells oval or spherical, closely arranged, 3-6 μm broad, pale blue green.

Habitat: Smashanbhoomi

Found in site: **SW_3** [pH 8.7; Temp 23.2^{0}C]

105.***Oscillatoria formosa*** **Dory ex Gomont.** (Plate XIV, Fig.105)

Desikachary, 1959, pp. 232 pl. 40, Fig. 15.

Thallus blue-green; trichomes straight, slightly constricted at the cross 4 μm broad, bright blue-green, attenuated at the ends and bent; cells nea quadrate, upto 1/2 as long as broad, 2.5-5μm long, septa sometimes slightiy granulated; end-cells nearly obtuse, apitates absent, not apitates.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 28.8^{0}C]

106.Oscillatoria princeps **Vaucher ex Gomont** (Plate XIV, Fig.106)

T.V. Desikachary, 1959, p. 210

Trichomes blue-green, more or less brownish, violet ro reddish,mostlyforming a thallus,mostly straight, not constricted at the cross-walls, 16-60 µm broad, commonly 25-50 µm, end-cells flatly rounded, slightly capitate.

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 27.2^{0}C]

107.Spirulina labyrinthiformis **(Menegh.) Gomont** (Plate XIV, Fig.107)

T.V. Desikachary, 1959, p. 195, pl. 36, Fig. 11 &pl. 49, Fig. 1

Trichome 1 µm broad, green, very regularly coiled forming a dirty, dark-green thallus; spirals

close to each other, spirals 2-2.7 µm broad.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 32.2^{0}C]

108.Spirulina princeps **Wet. G.S. West** (Plate XIV, Fig.108)

T.V. Desikachary, 1959, p. 197, pl. 36, Fig. 7

Trichome 4.5-5 µm broad, blue-green, regularlyspirally coiled, spirals 11-12 µm broad and 9.5-11 µm distant.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 28.8^{0}C]

109.Synechocystis aquatilis **Sauv.** (Plate XIV, Fig.109)

Desikachary, 1959, pp.143, pl. 25, Fig. 7,8.

Cells spherical 5-16 µm broad upto 30 µm long, single or 2-4 together pale blue green.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 27.3^{0}C]

*110.**Synechoccus elongates*** **Nag.** (Plate XIV, Fig.110)

Desikachary, 1959, pp.143, pl. 25, Fig. 7,8.

Cells cylindrical, 1.4-2 µm broad, 1.5-3 times as long as broad, single or 2-4 cells together; contents homogeneous and light blue green.

Habitat: Smashanbhoomi

Found in site: **SW_3** [pH 8.7; Temp 22.7^{0}C]

Euglenophyceae

*111.**Euglena proxima*** **Dangeard** (Plate XV, Fig.111)

Wolowski, 1998, p. 100, pl. IV, Fig. 4

Cells 43.4-78.5 µm long, 11.0-21.5 µm wide, fusiform; each cell slightly narrowing at the anterior end, posterior end tapering into short hyaline tail piece.

Habitat : Smashanbhoomi

Found in site : **SW_3** [pH 8.7; Temp 21.5^{0}C]

*112.**Euglena spirogyra*** **var.** ***spirogyra*** **Klebs** (Plate XV, Fig.112)

Wolowski, 1998, p. 17, Fig. 28-32

Cells 77.0-120.0 µm long, 11.0-18.8 µm wide, each cell longitudinally cylindrical, slightly narrowing and rounded at the anterior end, tapering at the posterior end into sharp, short tail piece.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 29^{0}C]

*113.**Lepocinclis ovum*** **(Eherenberg)Minkiewic var.** ***ovum*** **(Starmach)** (Plate XV, Fig.113)

Wolowski, 1998, p. 66, Fig. 208-210

Cell 18.0-37.0 μm long, 12.0-22.3 μm wide, broadly elliptical eachwith small, short, rounded extension at the posterior end.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 28.8^{0}C]

*114.**Trachelomonas armata*** **var. *longispina*** **(Playfair) Deflandre** (Plate XV, Fig.114)

Prescott, 1951, p. 411, pl. 83, Fig.26

Test broadly obovate; flagellum aperture without a collar, but witha circle of erect spines at the margin; anterior regionwith short spines, posterior portion with stout spines; both short and long; test 30-31 μm in diameter, 41-48 μm long.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 26.8^{O}C]

*115.**Trachelomonas dubia*** **(Swirenko) Deflandre** (Plate XV, Fig.115)

Wolowski, 1998, p. 63, Fig. 200

Test cylindrical, broadly rounded posteriorly, truncate at the anterior end and abruptly narrowed to form a short cylindrical collar; wall smooth, thickened at the base of the collar; test 11- 14 μm broad, 26-28 μm long.

Habitat: Smashanbhoomi

Found in site: **SW_3** [pH 8.7; Temp 21.5^{0}C]

*116.**Trachelomonas hispida*** **(Perty) Stein var. *hispida*** **(Starmach)** (Plate XV, Fig.116)

Wolowski, 1998, p. 56, Fig. 186-187

Lorica 22.5-30.0 μml ong, 12.5-25.2 μm wide, elliptical or broadly elliptical, covered with spines and small pores.

Habitat: Shahalangadi

Found in site: **SW_4** [pH 8.2; Temp 22.9^{0}C]

*117.**Trachelomonas lacustris*** **Drezepolski var. *klebsii*** **(Deflandre) Popova** (Plate XV, Fig.117)

Wolowski, 1998, p. 54, Fig. 181-182

Lorica 23.7-26.0 µml ong, 13.5-16.0 µm wide, cylindrical, thickly coveredwith short spines, yellow-brown.

Habitat: Kawalghat

Found in site: **SW_2** [pH 6.3; Temp 20.6^{0}C]

*118.**Trachelomonas superba*** **var. *duplex*** (Plate XV, Fig.118)

Prescott, 1951, p. 417, pl. 84, Fig.11

Test broadly oval, furnished with spines all throughout, spines of equal length. test 28.0-29.2 µm broad, 36-38 µm long.

Habitat: Underbridge.

Found in site: **SW_1** [pH 8.1; Temp 27.3^{0}C]

PLATE I

Baccilariophyceae

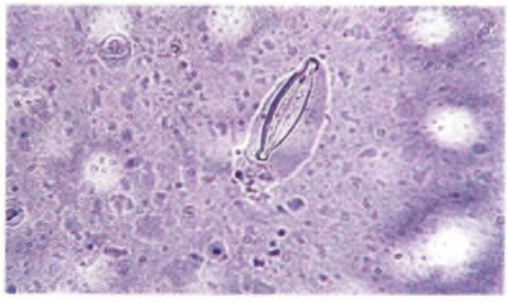


Fig. 1. *Cymbella cistula* (Hemprich) Grun. var. *woosangisis*Virget

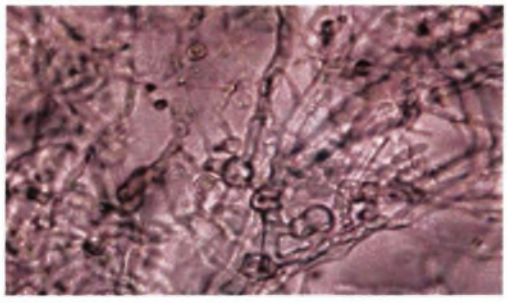


Fig. 2 *Dinobryon sertularia* Ehrenberg

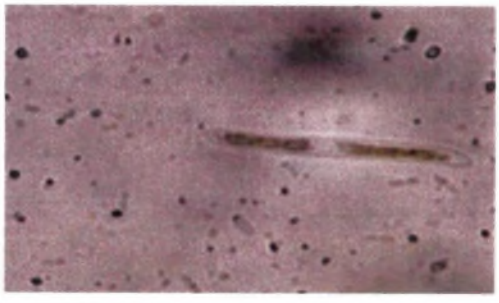


Fig. 3 *Eunotia camelus* Ehr. var. *karveerensis* Gandhi

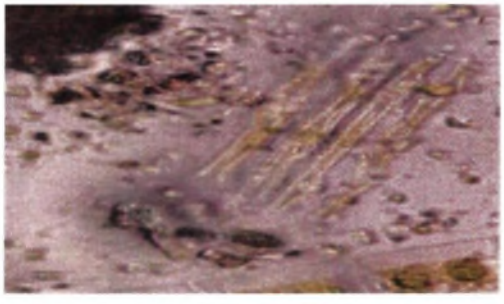


Fig. 4 *Fragilaria virescens* Ralfs

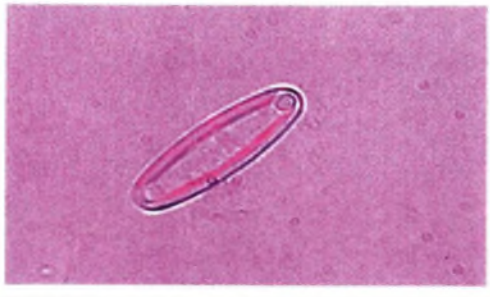


Fig. 5 *Frustulia rhomboides* (Ehr) De Toni var. *saxonica* (Rabenhorst) DeToni

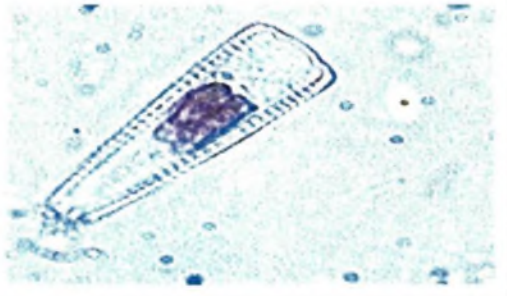


Fig. 6 *Gomphonema elegans* Grun

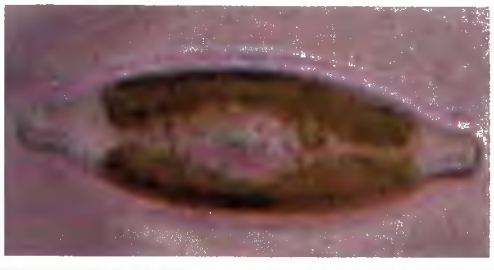


Fig. 7 *Gomphonema vidarbhense* Kamath

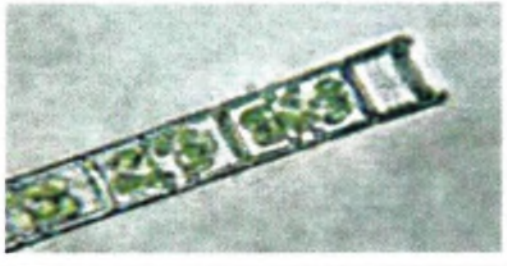


Fig. 8 *Melosira granulata* (Ehr.) Ralfs.

PLATE II

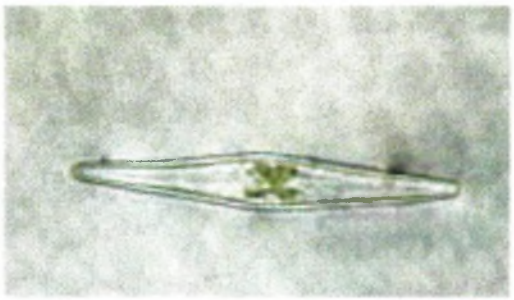


Fig. 9 *Navicula cari* Ehr. *fa. indica* Sarode et Kamat.

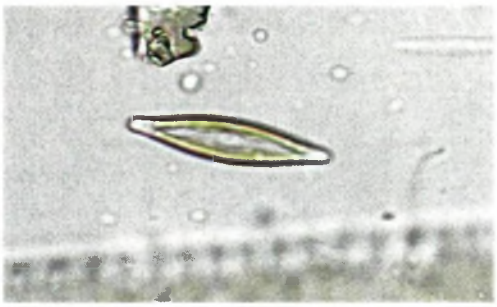


Fig. 10 *Navicula cryptocephala* Kuetz

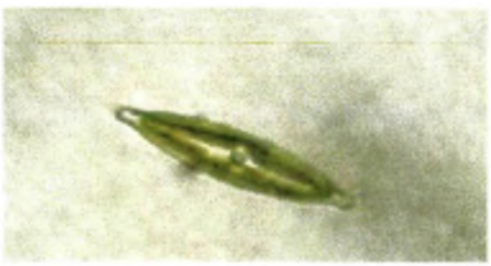


Fig. 11 *Navicula cuspidata* Kuetz. var.*ambigua* (Ehr.) Cleve.

Fig. 12 *Navicula pupula* Kuetz. var. *capitata* Hustedt.

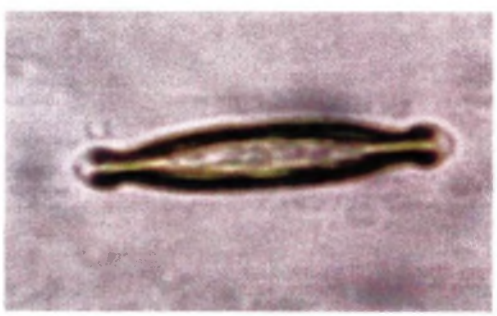


Fig. 13 *Navicula viridula* Kuetzing

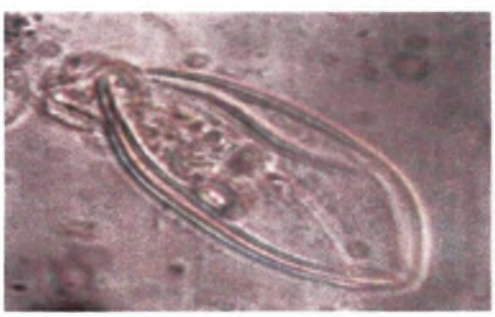


Fig. 14 *Peridinium cinctum* (Muller) Ehrenberg Swirenko

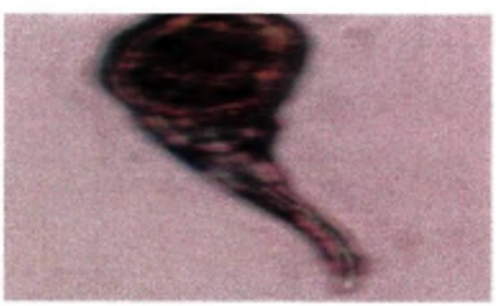


Fig. 15 *Phacus caudatus* var. *tenuis*

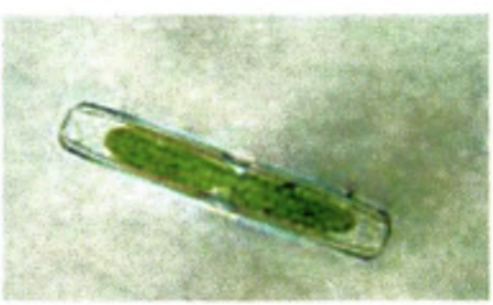


Fig. 16 *Pinnularia acrosphaeria* (Breb.)W.Smith

PLATE III

Fig. 17 *Pinnularia brevicostata* Cleve var. *indica* Gandhi.

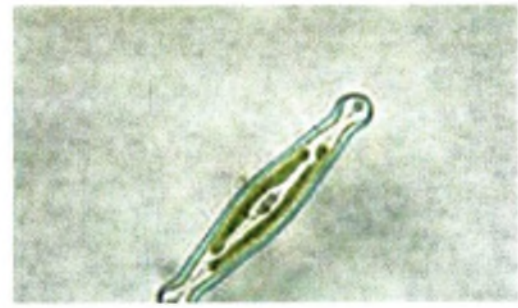


Fig. 18 *Pinnularia gibba* Ehr

Fig. 19 *Pinnularia major* (Kuetz.) Cleve var. *linearis* Cleve.

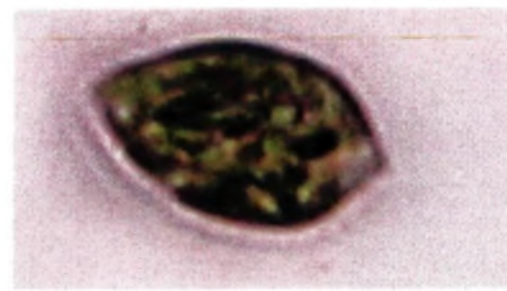


Fig. 20 *Rhodomonas baltica* Karst

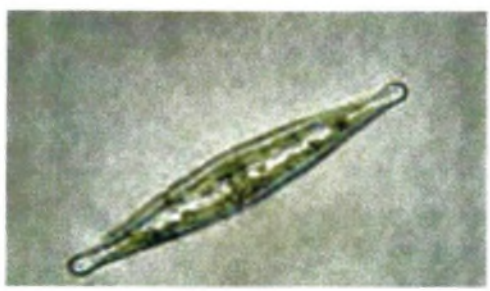


Fig. 21 *Stauroneis anceps* var. *gracilis*

Fig. 22 *Stauroneis phoenicenteron* (Nitzsch) Ehr. var. *intermidia* Dippel.

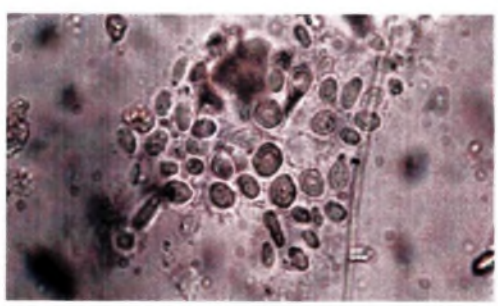


Fig. 23 *Synura uvella* Ehrenberg

Fig. 24 *Tabellaria fenestrata* (Lyngbye) Kuetzing

PLATE IV
Chlorophyceae

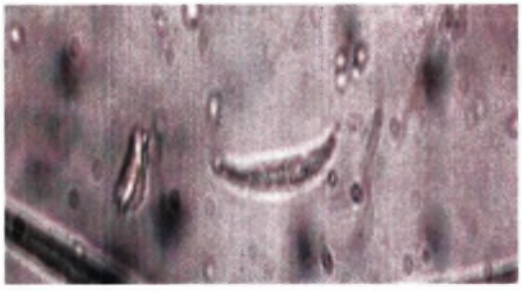


Fig. 25 *Closterium acerosum* var. *angolense* West and West

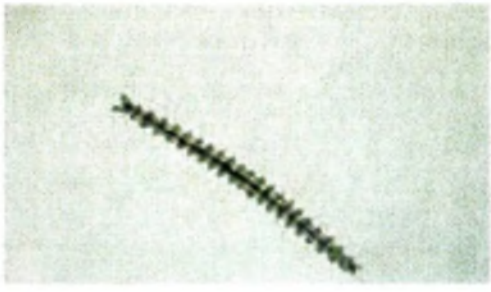


Fig. 26 *Triploceras gracile* Bail var. *undulatum* Scott & Pres

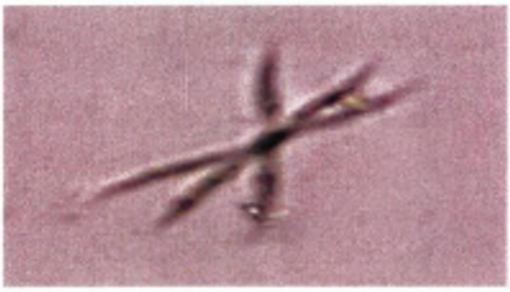


Fig. 27 *Ankistrodesmus falcatms* (Corda) Rails

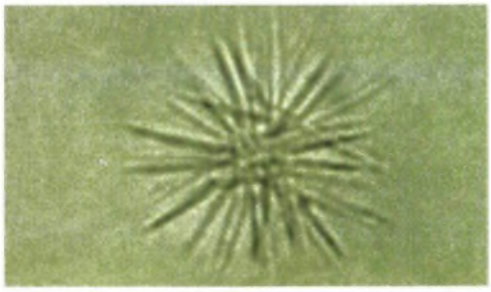


Fig. 28 *Ankistrodesmus falcatus* (Corda) Ralfs var. *acicularis* (A. Braun) G.S.West

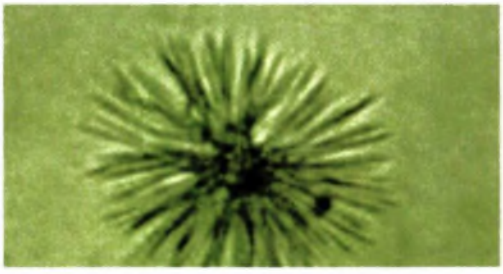


Fig. 29 *Ankistrodesmus spiralis* (Turner) Lemm.

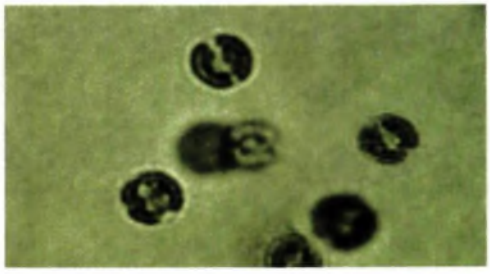


Fig. 30 *Chlorella vulgaris* Beyer. (Smith)

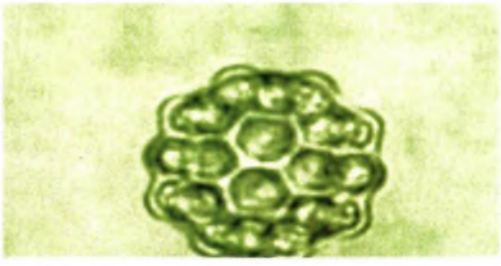


Fig. 31 *Coelastrum cambricum* Archer var. *intermidium* (Bohlin) G.S.West

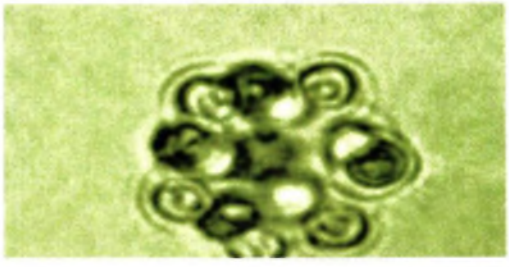


Fig. 32 *Coelastrum sphaerium* Naeg

PLATE V

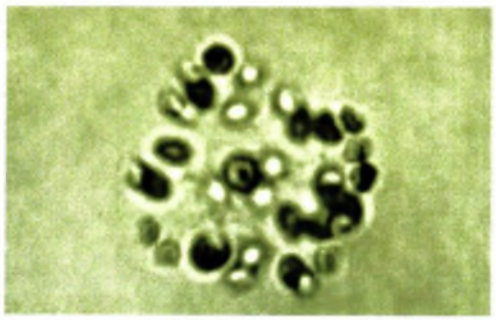


Fig. 33 *Dictyosphaerium ehrenbergianum* Naegeli

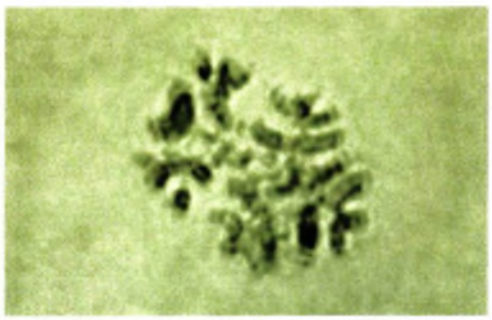


Fig. 34 *Dimorphococcus lunatus* A. Braun.

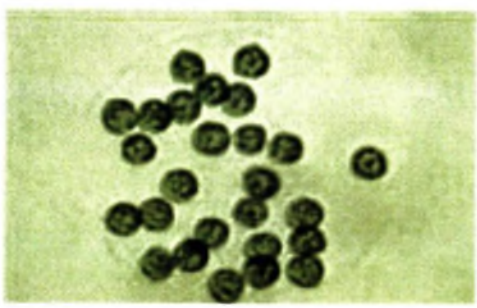


Fig. 35 *Eudorina elegans* Ehr.

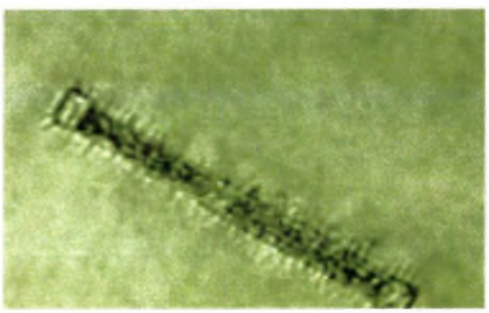


Fig. 36 *Gonatozygon aculeatum* Hast.

Fig. 37 *Gonatozygon monotaenium* De Bary

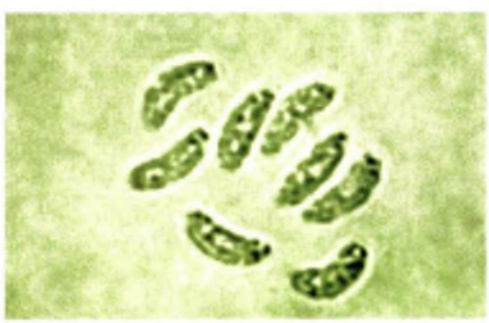


Fig. 38 *Nephrocytium agardhianum* Nag.

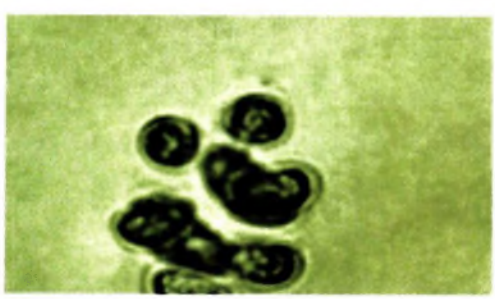


Fig. 39 *Nephrocytium lunatum* W.West

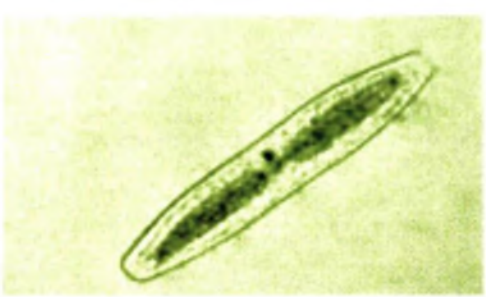


Fig. 40 *Netrium digitus* (Ehrbg.) Itzigs. &Rothe

PLATE VI

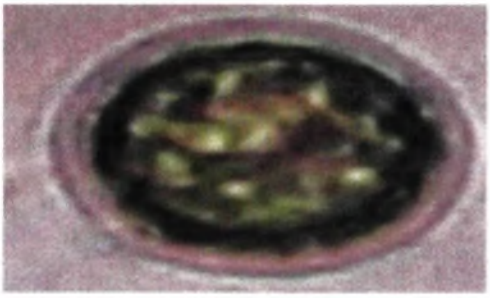


Fig. 41 *Oocystis elliptica* W. West

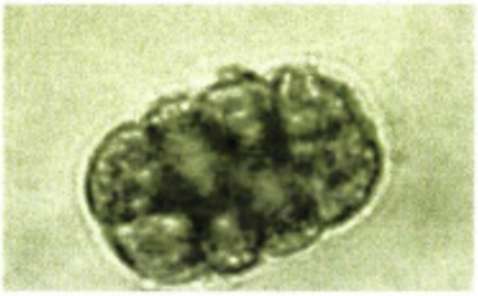


Fig. 42 *Pandorina cylindricum* Iyengar

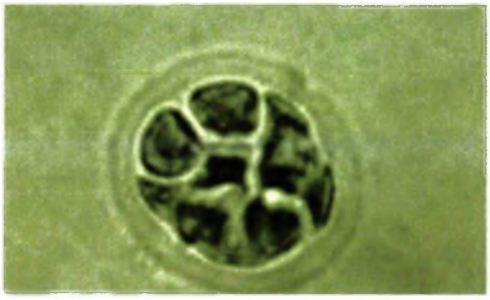


Fig. 43 *Pandorina. morum* (Mull.) Bory

Fig. 44 *Pediastrum tetras* (Ehr.) Ralfs

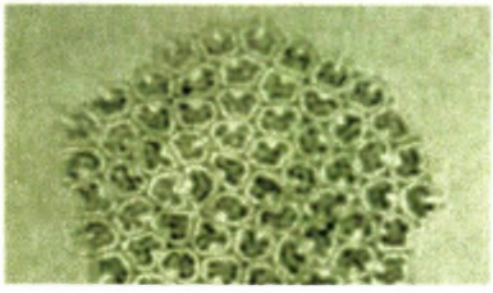


Fig. 45 *Pediastrum biradiatum* Meyen non Ralfs var. *longicornutum* Gutwinski

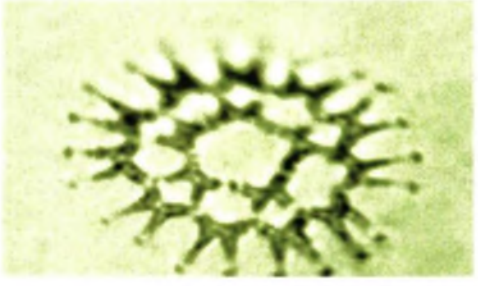


Fig. 46 *Pediastrum duplex* Meyen var. *coronatum* Raciborski

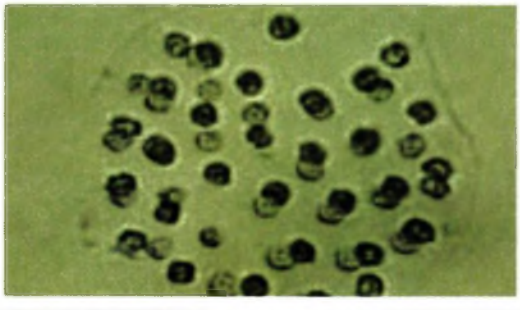


Fig. 47 *Pleodorina californica* Shaw

Fig. 48 *Pleurotaenium baculoides* (Roy & Biss) Playf

PLATE VII

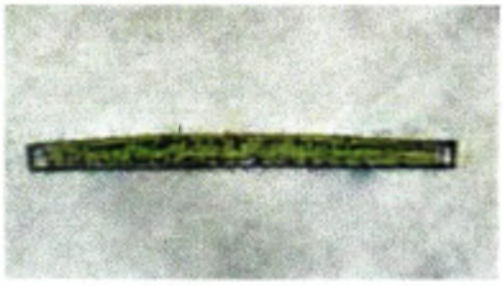


Fig. 49 *Pleurotaenium nodosum* (Bail.)Lund.

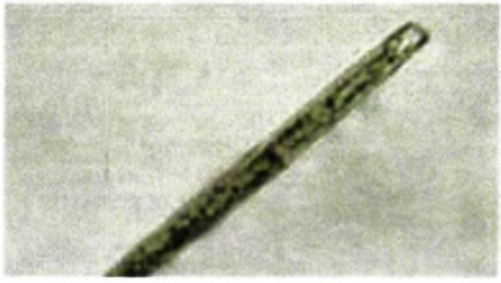


Fig. 50 *Pleurotaenium trabecula* (Ehrbg) Nag

Fig. 51*Pleurotaenium trabecula* (Ehrbg) Nag var. *maximum* (Reinsch) Roll

Fig. 52 *Scenedesmus arcuatus* (Lemmarmann) Lemmarmann

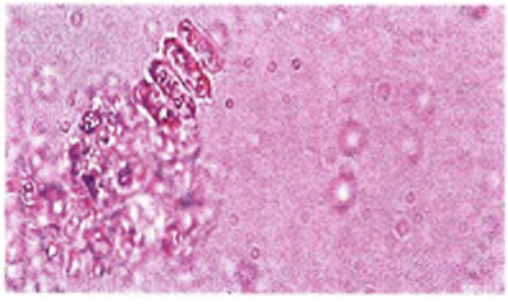


Fig. 53 *Scenedesmus bijugatus* (Turp.) Kuetz

Fig. 54 *Scenedesmus dimorphus* (Turpin) Kuetzing

Fig. 55 *Scenedesmus perforatus* (Lemmermann)

Fig. 56 *Scenedesmus perforatus* (Lemmermann) var. *major* (Turner) Philipose

PLATE VIII

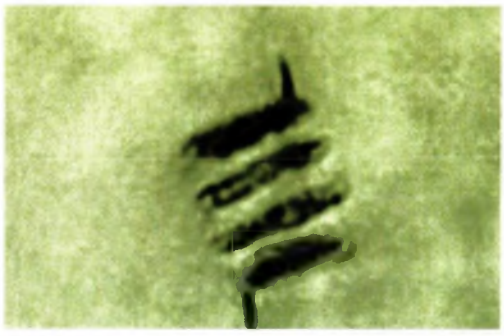


Fig. 57 *Scenedesmus quadricauda* (Turpin) Brebisson Var. *bicaudatus* Hansgirg

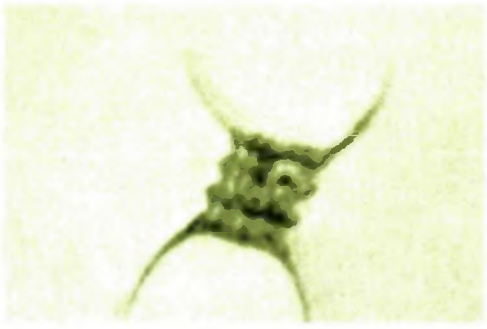


Fig. 58 *Scenedesmus quadricauda* (Turpin) Brebisson Var. *longispina* (Chodat) G.M.Smith

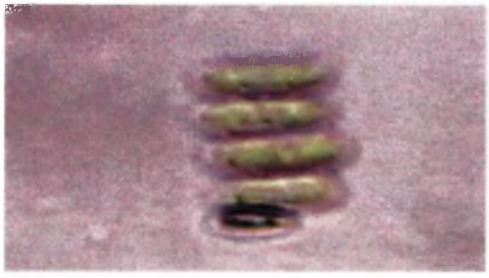


Fig. 59 *Scenedesmus quadricauda* v. qttadrispina (ChM.) G.M. Smith

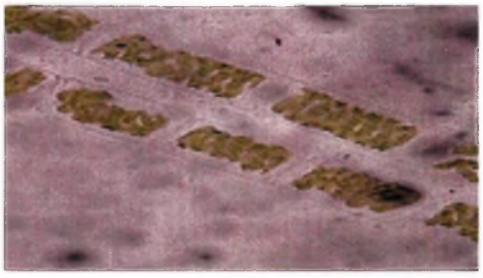


Fig. 60 *Spirogyra ternata* Ripart

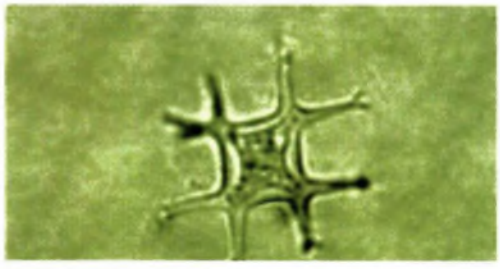


Fig. 61 *Tetraedron enorme* (Ralfs) Hansg var. *pentaedricum* Prescott

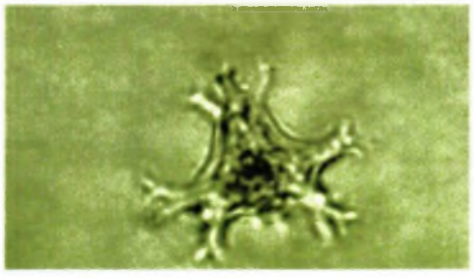


Fig. 62 *Tetraedron limneticum* Borge

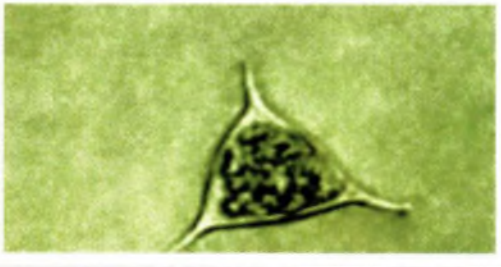


Fig. 63 *Tetraedron trigonum* (Naeg) Hansg. fa. *gracile* (Reinsch) De Toni

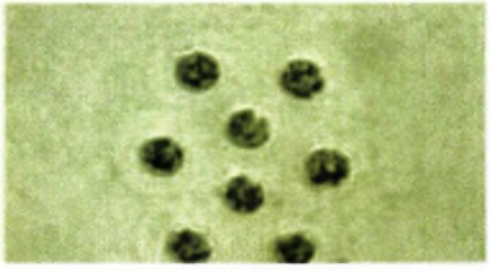


Fig. 64 *Tetraspora gelatinosa* (Vauch.) *Desv*

PLATE IX

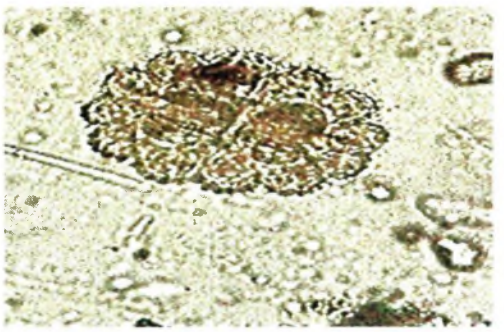


Fig. 65 *Cosmarium auriculatum* Reinsch

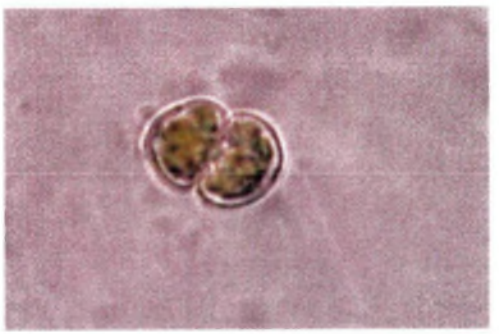


Fig. 66 *Cosmarium contractum* Kirchner var. *pachydermum* Scott&Prescott

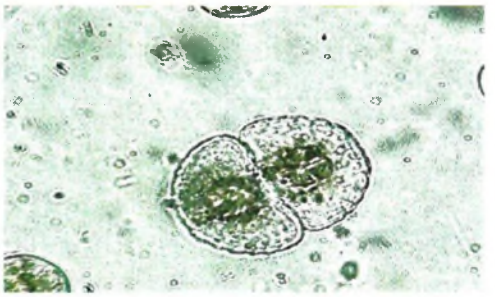


Fig. 67 *Cosmarium cuneatum* Joshua

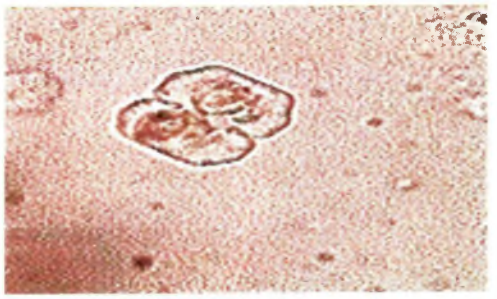


Fig. 68 *Cosmarium quadrifarium* Lund.

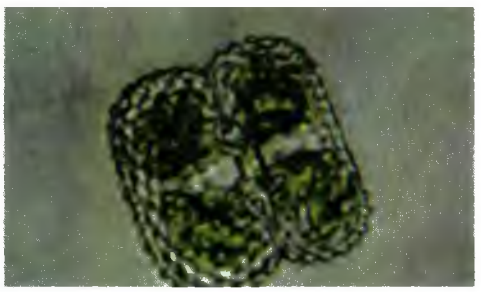


Fig. 69 *Cosmarium quadrum* Lund var. *minus* Nordst

Fig. 70 *Cosmarium geminatum* Lund.var. *ornatum* Behre.

Fig. 71 *Desmidium aptogonum* Breb.

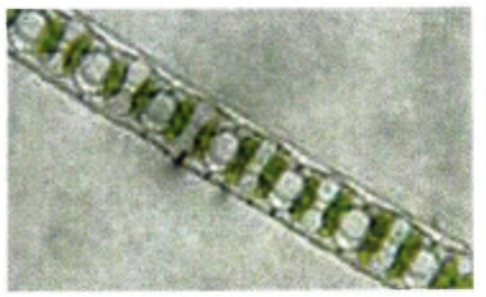


Fig. 72 *Desmidium baileyi* (Ralfs) Nordst. fa. *longiprocessum* Scott & Prescott.

PLATE X

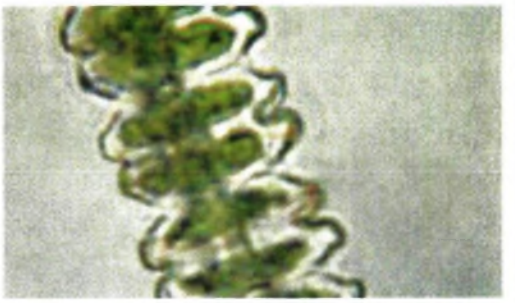


Fig. 73 *Desmidium swartzii* Agardh.

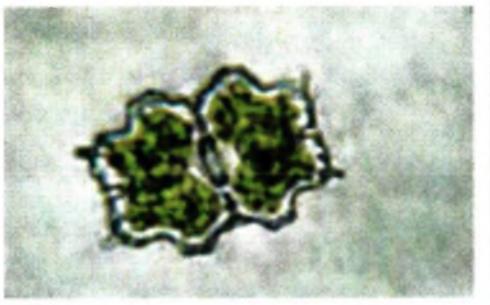


Fig. 74 *Euastrum acanthophorum* Turn.

Fig. 75*Euastrum ansatum* Ehrbg

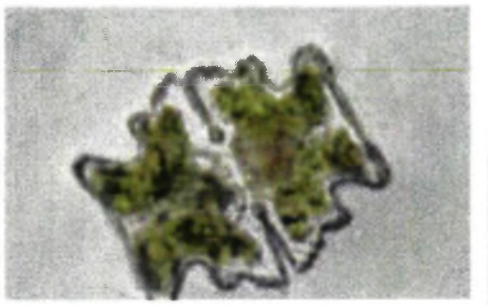


Fig. 76 *Euastrum moebii* (Borge) Scott & Prescott var. *burmense* West & West

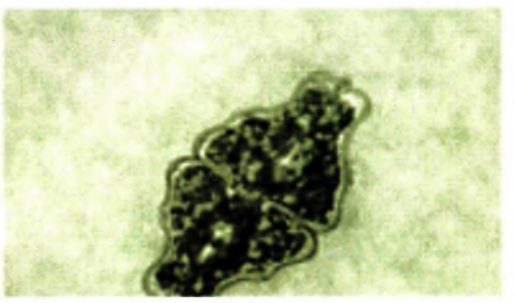


Fig. 77 *Euastrum sinuosum* Lenorm. var. *capitatum* Prescott

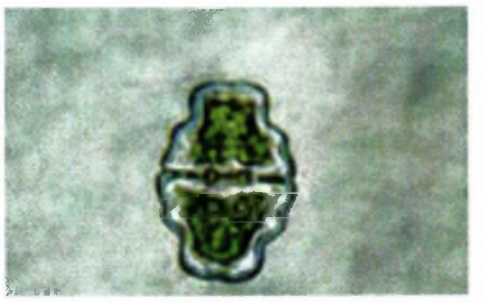


Fig. 78 *Euastrum sinuosum* Lenorm. var. *reductum* West & West.

Fig. 79 *Micrasterias foliacia* Bail var. *quadrinflata* Prescott

Fig. 80 *Micrasterias lux* Josh var. *brevibracchiata* Behre fa. *spinosa* Prescott

PLATE XI

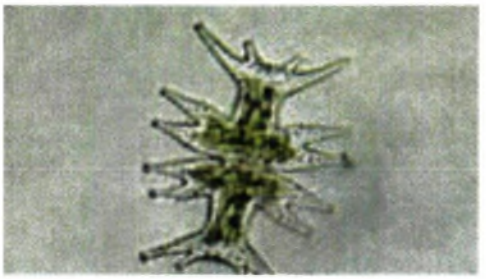


Fig. 81 *Micrasterias mahabuleshwarensis* Hobs. var. *surculifera* Lagerh.

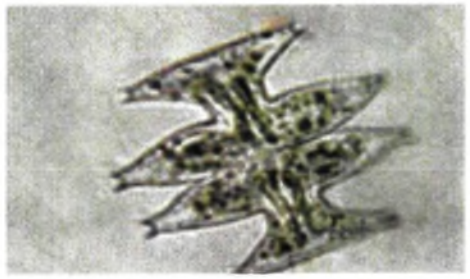


Fig. 82 *Micrasterias pinnatifida* (Kuetz.) Ralfs var. *pseudoscitans* Gronbl.

Fig. 83 *Micrasterias radians* Turn.

Fig. 84 *Onychonema laeve* Nordst. var. *latum* West & West

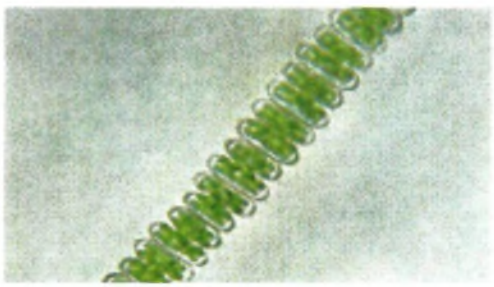


Fig. 85 *Spondylosium planum* (Wolle)West & West.

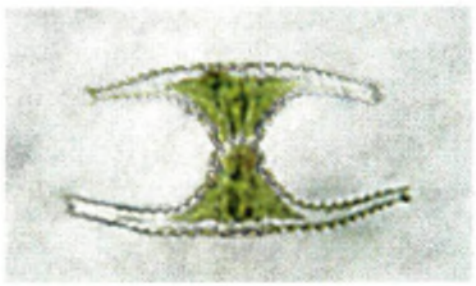


Fig. 86*Staurastrum anatinoides* Scott & Prescott var. *javanicum* Scott & Prescott.

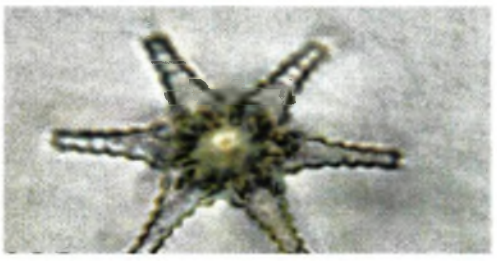


Fig. 87 *Staurastrum pinnatum* Turn var. *subpinnatum* (Sehm)West&West fa. *robustum* Krieg

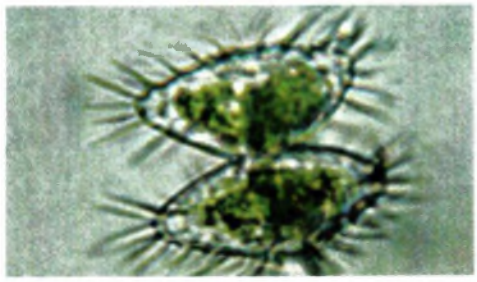


Fig. 88 *Staurastrum setigerum* Cleve.

PLATE XII

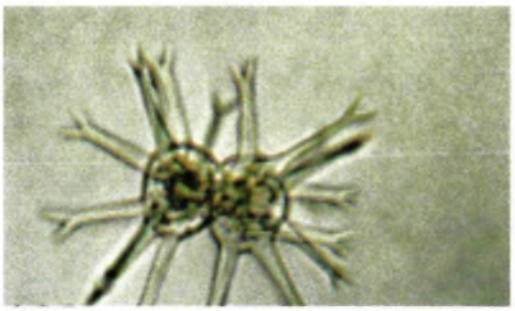


Fig.89. *Staurastrum tohopekaligense* Wolle var. *insigne* West & West.

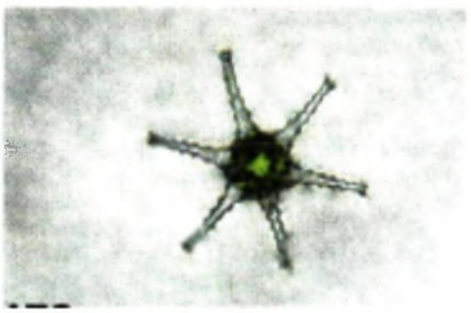


Fig. 90 *Staurastrum zonatum* Borges var. *majus* Presc.

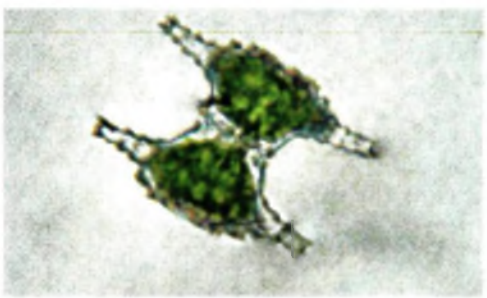


Fig. 91 *Staurastrum crenulatum* (Nag) Delp

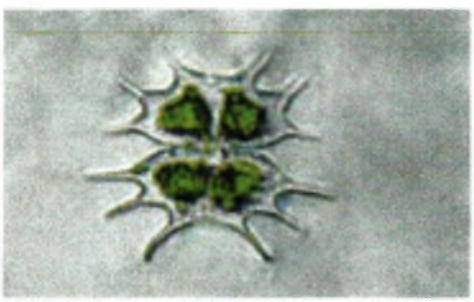


Fig. 92 *Xanthidium sexmamillatum* West & West var. *pulneyense* Iyengar & Bai

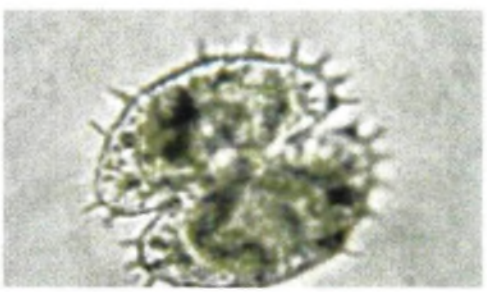


Fig. 93 *Xanthidium. spinosum* (Josh.) West & West

Fig. 94 *Arthrodesmus convergens* Ehr.

Fig. 95 *Arthrodesmus curvatus* Turn. var. *latus* Scott and Prescott

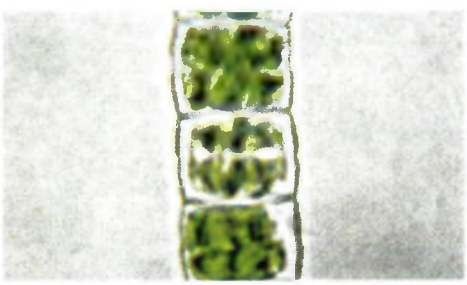


Fig. 96 *Hyalotheca dissiliens* (Smith) Breb. var. *hians* Wolle.

PLATE XIII

Fig. 97 *Sphaerozosma granulatum* Roy & Biss

Fig. 98 *Anabaena sphaerica* var. *attenuata* Bharadwaja.

Cyanophyceae

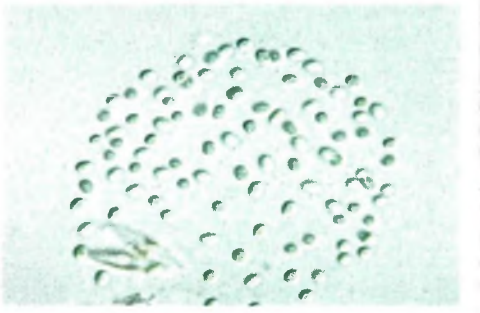


Fig. 99 *Aphanocapsa littoralis* Hansgirg

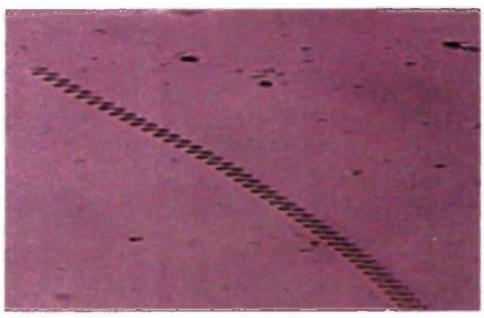


Fig. 96 *Arthrospira massartii* Kuffareth

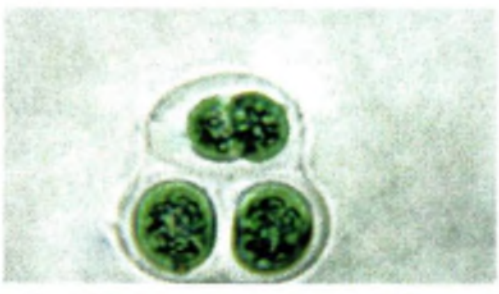


Fig. 101 *Chroococcus turgidus* (Kuetz.) Nag.

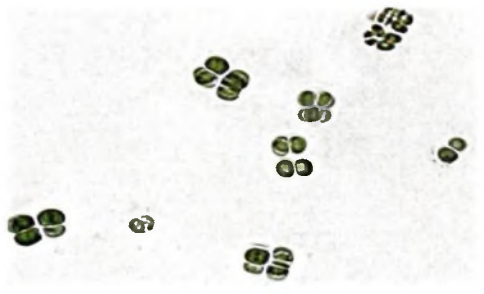


Fig.102 *Gleocapsa atrata* (Corp.) Kuti

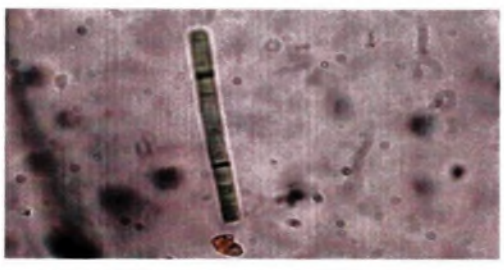


Fig.103 *Lyngbya aestuarii* Liehm. Ex. Gomont

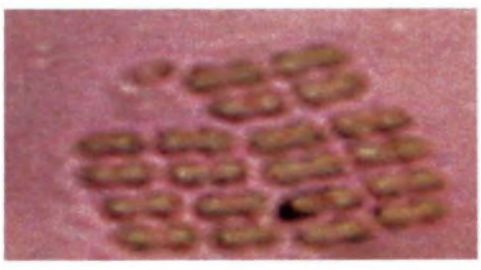


Fig.104 *Merismopedia glauca* (Ehrenb). Nag.

PLATE XIV

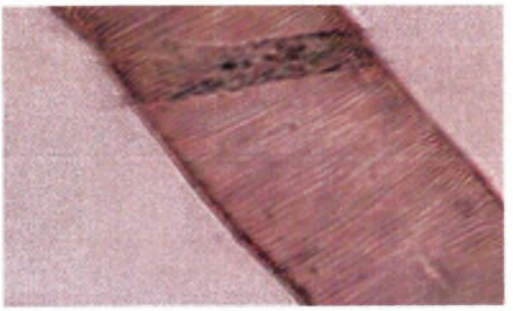


Fig.105 *Oscillatoria formosa* Dory ex Gomont

Fig.106 *Oscillatoria princeps* Vaucher ex Gomont

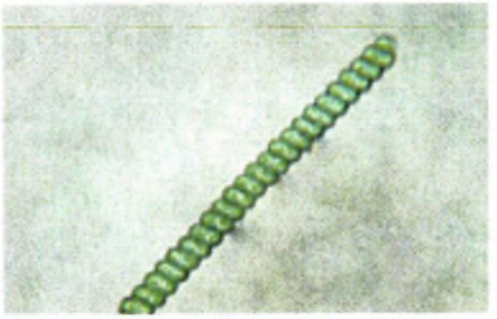


Fig.107 *Spirulina labyrinthiformis* (Menegh.) Gomont.

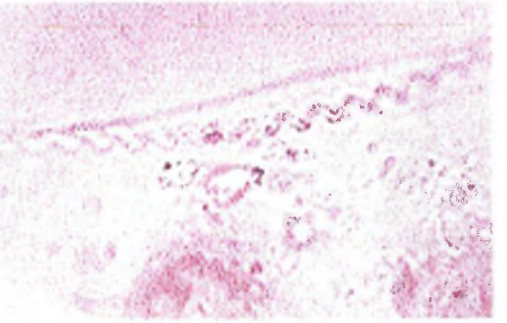


Fig.108 *Spirulina princeps* Wet. G.S. West

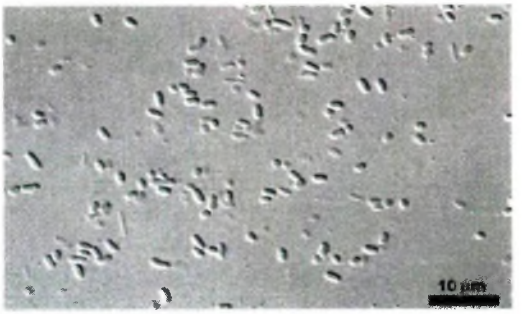


Fig.109 *Svnechocvstis aquatilis* Sauv.

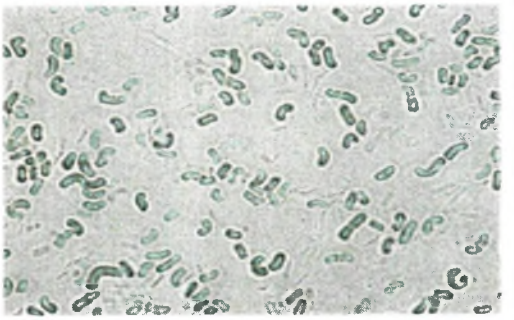


Fig.110 *Synechoccus elongates* Nag.

PLATE XV

Euglenophyceae

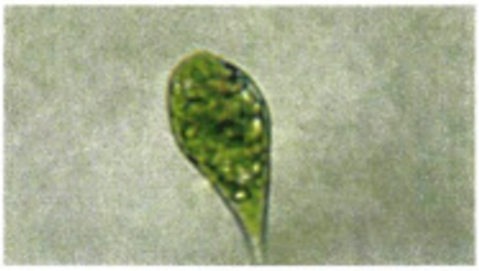


Fig.111 *Euglena proxima* Dangeard.

Fig.112 *Euglena spirogyra* Ehr.

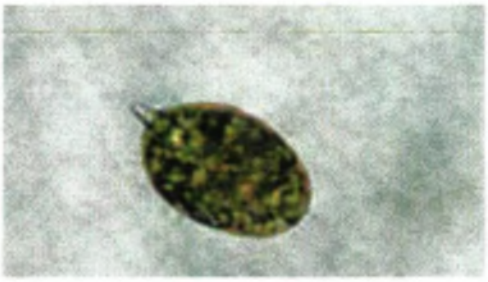


Fig.113 *Lepocinclis ovum* (Eherenberg)Minkiewic var. *ovum* (Starmach)

Fig.114 *Trachelomonas armata* var. *longispina* (Playfair) Deflandre

Fig.115 *Trachelomonas dubia* (Swiremend) Defl.

Fig.116*Trachelomonas hispida* (Perty) Stein var. *hispida*

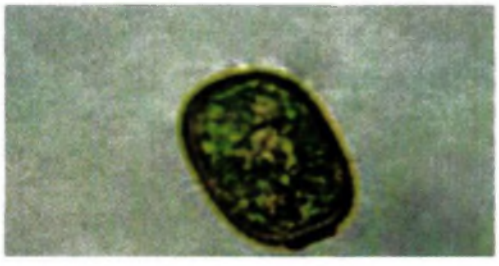


Fig.117 *Trachelomonas lacustris* Drezepolski var. *klebsii* (Deflandre) Popova

Fig.118*Trachelomonas superba* var. *duplex* Defl

PLATE XVI

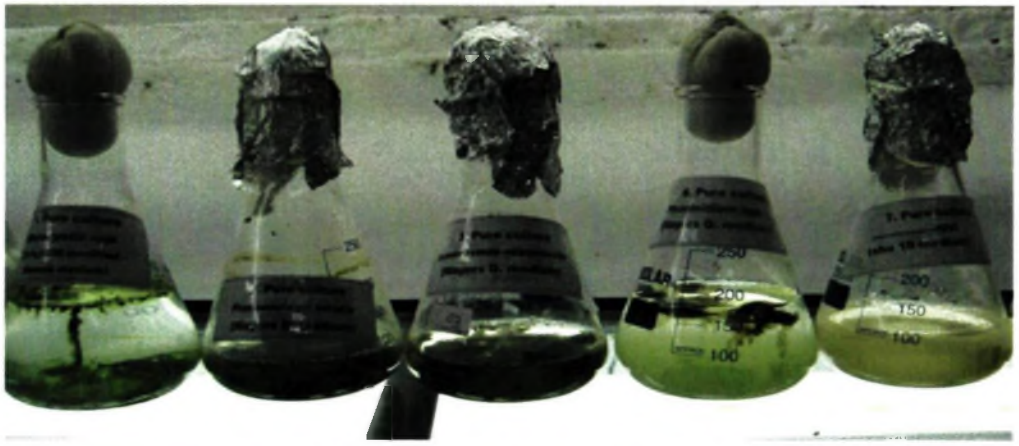


Fig. 119 Isolated Culture Flask

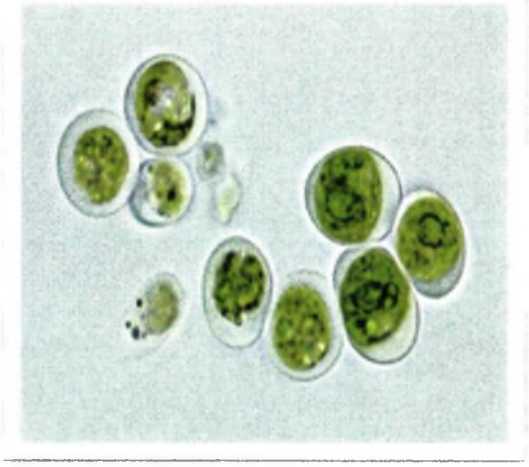


Fig. 120 ***Chlorococcum humicolum***

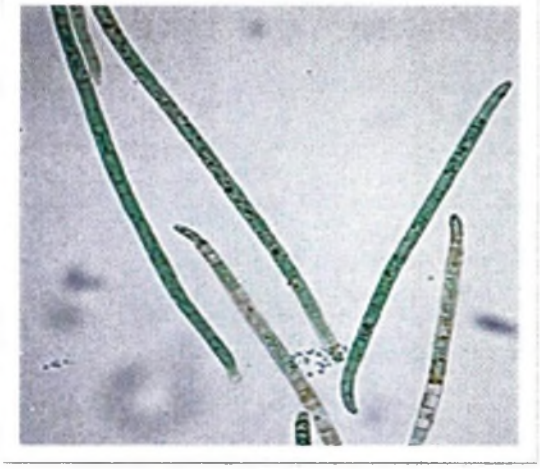


Fig. 121 ***Oscillatoria amphibia***

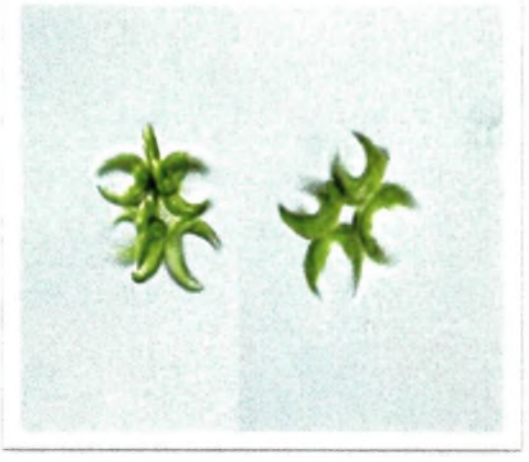


Fig. 122 ***Selenastrum westii***

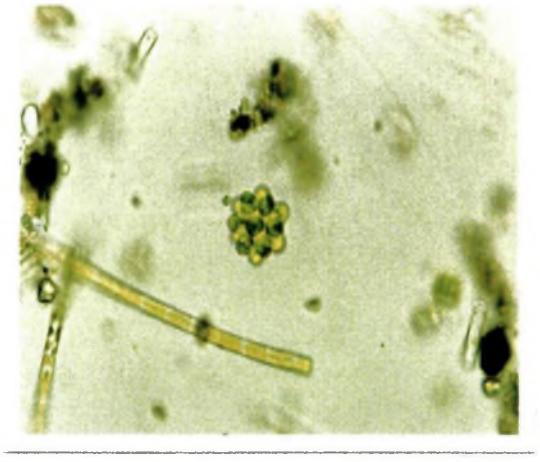


Fig. 123 ***Coelastrum sphaericum***

Chapter - 5

Result & Discussion

RESULT AND DISCUSSION

Contents:

The Chapter V deals with the Result and Discussions of topic concerned. The following were the findings noted during the two years of extensive studies.

5.1 *Physico-chemical characteristics:*

5.1.1. Monthwise variation in Physico-chemical parameters:

Physico-chemical characteristics of water are very important since they have a profound effect on the diversity of living organisms dwelling in it. The physico-chemical complexes of river water of the distribution of algae already had been described, (Venkateswarlu, 1969 a,b) on the reports of river Moosi, Hyderabad. The seasonal variations in physico–chemical parameters were represented in theTables 4.1 to 4.20.

The water regulates the structural, and functional processes in an ecosystem. The chemistry of water determines the presence, absence, and also the type of Biota. The biological compositions of an ecosystem in different climatic conditions are different because of differentiation in their physico-chemical characteristics. Therefore, the study of physico-chemical properties is necessary to understand the phytoplanktons in an ecosystem.

In the present study, APHA, (1989) was followed for the estimation of all physico-chemical characteristics of Vena river in Hinganghat area of Wardha district. The monthly variations in the physico-chemical parameters such as temperature, pH,

dissolved oxygen (DO), free CO_2, alkalinity, calcium, magnesium, hardness, phosphate, nitrate, and total dissolved solids (TDS) were studied.

5.1.1.1 Temperature: (Table 4.1 and 4.2 and Graph 5.1 and 5.2)

Temperature is one of the most important physical factors. It not only plays vital role in self purification of the aquatic ecosystem but also regulates the rate and intensity of biochemical reactions. Water temperature highly influences the oxidation of organic matter. The temperature of air and water is an important factor governing the quality of water. It influences aquatic life due to change in concentration of dissolved gases such as O_2, CO_2, and other elements such as Calcium, Magnesium, and Phosphate, etc.

During the period of June 2011 to May 2012 the Vena river showed (Table 4.1) maximum temperature was 35.2^0C at SW_1, and minimum 20.6^0C at SW_2. The minimum temperature i. e. 20.6^0C at SW_2 was recorded only for one month i. e. in the month of December at all the stations. From January onwards gradual increase in temperature was recorded. The maximum temperature was recorded i. e. 35.2^0C at SW_2 in the month of May and it was maintained for a period of three months i. e. April, May, and June. In the month of August mercury level slipped little bit to lower 26.9^0C at SW_3. From the month of August onwards temperature continues to decrease in till 20.6^0C at SW_2.

During June 2012 to May 2013 the Vena river showed recognizable deviation in the highest and lowest limits of temperature (Table 4.2). The minimum temperature of 21^0C at SW_2 was recorded in the month of December and highest i. e. 34.9^0C at SW_2 in the month of May. The minimum level of temperature was recorded in December at all the stations and then in January, it raised suddenly to 21.9^0C at SW_4 to increase by two degree in the month of February. From the month of March, suddenly temperature

increase up to 29.2^{0}C at SW_3, and again rose by four degree in next month i.e. April. Again in May mercury reached higher level. Then for successive three months i.e. June, July, and August there was again fall back. Months of September, and October were recorded as the months of moderate warmth.

Edges of water bodies showed shallow water, it responded quickly to atmospheric fluctuations. Therefore, water samples were collected from the edges of the water bodies. Welch, (1952) showed that shallow water reacts more quickly with atmospheric temperatures.

The gradual increase in air, and water temperature from January to September was attributed to longer days and increased in the intensity of solar radiations. Similarly, the decreases in temperature from September to December were due to decrease in length of days and the intensity of solar radiations. Munawar, (1970) and Harshey, *et al.*, (1982) reported a direct relationship between water temperature and intensity of solar radiation. Sahu, *et al.*, (1995) noted the lowest temperature at 6 am and highest at 3 pm, which was in accordance with changes in air temperatures. The relationship between air and water temperature shows diurnal variation at different places differently.

Maximum and minimum temperature recorded for all the sites of Vena river were distinctly different during the study period. The reasons possibly lie in urbanization of Hinganghat, air pollution, discharge of textile mills, sugar factory, and oil refineries, and cement concrete buildings which were responsible for increase in radiation heat in atmosphere. All together was facilitated the higher temperature throughout the year.

It was observed that the temperature was highest in the month of May in both the period. During June 2011 to May 2012 the site SW_1 was with highest temperature i.e. 35.2^0 C and from June 2012 to May 2013 the site SW_2 was with highest temperature i.e.

34.9^0 C. the lowest temperature recorded in the month of December in both the period. During June 2011 to May 2012 the site SW_2 was with lowest temperature i.e. 20.6^0 C and from June 2012 to May 2013 the site SW_2 was with lowest temperature i.e. 21.0^0 C. The similar observations were also recorded by Sawane, (2002) and Khinchi *et al.*, (2011).

5.1.1.2 pH: (Table no. 4.3 and 4.4; Graph 5.3 and 5.4)

pH is one of the important attributes of any aquatic ecosystem. The growth and life activities of the phytoplankton were controlled by the pH of surrounding water; because specificity of all biochemical reactions were pH dependant. It was a known fact that pH of natural water were controlled by the interaction of hydrogen ions resulting from dissociation of carbonic acid and hydroxyl ions arising from the hydrolysis of bicarbonates. pH values for study sites were shown in Table 4.3 and 4.4 and represented by Graph 5.3 and 5.4.

Findings of Vena river confirmed the fact that, all the Indian rivers were slightly alkaline. The recorded pH values for Vena river during June 2011 to May 2012 (Table 4.3) showed that the minimum value i. e. 6.69 was recorded at SW_3 in the month of May. While, highest pH value i.e, 8.7 was recorded at SW_1 in the month of August. The observed pH range appears to be narrow. pH fluctuations for 21 major rivers of India were recorded by Sabata and Nayar, (1995) and they pointed out that Indian rivers shown narrow range of variations and fluctuations. The present study showed similarity with the above findings. The water of Vena river was slightly acidic at Station SW_3 in the month of May due to high pollution level. These findings coincides with slightly acidic conditions of Bramhaputra, Ganga, Hoogly, Kshipra and Yamuna recorded previously.

It was reported that pH of water during June 2011 to May 2012 at all sites on an average varied within the range of 6.69 (SW_3) to 8.7 (SW_1). Of the four stations studied, SW_3 was severally polluted while, SW_1 and SW_4 received only domestic pollutants. This was in contrast with the observations made by Singh *et al.,* (1999) where, pH was noted at low values at effluent receiving point. The increase and decrease in pH is directly related to water temperature. Sahu *et al.,* (1995) shown diurnal variation of pH of water and reported that pH increased from 6 am to 3 pm and decreased from 3 pm to 6 am where the water were free from pollutants. Sreenivasan, (1964), and Vyas and Kumar, (1968) have reported seasonal fluctuation in pH.

During the period of June 2012 to may 2013 Vena river (Table 4.4), showed minimum or lowest pH value 6.1 in the month of June at SW_2 station. This value was towards acidic nature of water. The maximum value of 10.8 was recorded at the same station during August.

Sahai and Sinha, (1969), Sharma *et al.,* (1978 a,b), and Sharma *et al.,* (1981) had reported that most of the small water bodies were alkaline in nature. In most of the period of the year the water remains alkaline, except flowing water. At all stations except at SW_3 in January higher pH values were recorded during the month of July, and August. Tripathi and Pandey, (1990) were also noted maximum pH values during rainy season in pond water of Kanpur. Blum, (1957), Singh, (1960), and Venketeswarlu, (1969a) had also reported the same observations. Low pH in the month of June attributed to temperature condition stimulating the early summer. Rice, (1938) recorded such conditions in summer. However acidic nature of water during January, and February was not explained on the basis of work done by earlier workers. The range of pH value recorded during June 2011 to May 2012 and June 2012 to May 2013 was almost equal.

Kodarkar, (1995) reported that in urban centers, pH of water was also highly influenced by the nature of pollution in the form of sewage and industrial effluents. Generally pH of water were influenced by geology of catchment and buffering capacity of the water.

It was observed that the pH was highest in the month of August during June 2011 to May 2012 at the site SW_1 i.e. 8.7 and lowest pH at site SW_3 in the month of May i.e.6.69 and from June 2012 to May 2013 pH was highest in the month of August at the site SW_2 i.e. 10.8 and lowest pH at site SW_2 in the month of June i.e. 6.1. The similar observations were also recorded by Narain and Chauhan, (2000) and also by Bandela *et al.*, (1998) and Khalique,(1995).

5.1.1.3 Dissolved Oxygen (DO): (Table no. 4.5 and 4.6; Graph 5.5 and 5.6)

Dissolved oxygen (DO) is one of the most important parameters to indicate water purity and to determine the distribution and abundance of various algal groups. Its presence in water may be either due to direct diffusion from air or photosynthetic activity of autotrophs or because of both together. Diffusion of oxygen into water is dependent on temperature, free CO_2, salinity, total dissolved solids, water velocity etc. The various metabolic activities of different organism require dissolved oxygen. This was discussed by many ecologists. Dissolved oxygen recorded for present study was shown in table 4.5 and 4.6.

During the months of June 2011 to May 2012, the station SW_1 of Vena river showed dissolved oxygen value was lowest 2.41 mg/l in the month of August and the highest value i.e. 34.23 mg/l was recorded in the month of June. At the station SW_2 dissolved oxygen value was lowest 2.01 mg/l and the highest i.e. 35.44 mg/l, SW_3 at its lowest shows only 2.41 mg/l and the highest showed only 17.72 mg/l, where as SW_4 at its lowest 2.27 mg/l and at its highest 24.96 mg/l in the month of August and February

respectively. But uniformly the minimum level of dissolved oxygen was showed by all the four stations in the month of August (Table 4.5).

In the month of August dissolved oxygen decreased because of higher water temperature. As solubility of oxygen decrease with increase in temperature was reported by Sabata and Nayar, (1995). Similarly, increase in dissolved oxygen is obviously related to decrease in temperature as was recorded for the month of February. The lowest figure in the tally of maximum were shown at SW_2. This can be attributed to the higher pollution of the study area.

In the period between the months of June 2012 to May 2013, all the four stations showed uniform changes in dissolved oxygen throughout the year. The lowest dissolved oxygen concentration at all the four sites, in the range of 2.013 mg/l to 2.416 mg/l was noted in the months of March. The highest concentrations were noted to be 24.16 mg/l in the month of June.

The observations during the months of June 2011 to May 2012 and from the months of June 2012 to May 2013 were almost similar.

It was observed that the DO was highest in the month of February during June 2011 to May 2012 at the site SW_2 i.e. 35.44 mg/l and lowest DO at site SW_2 in the month of August i.e. 2.01mg/l and from June 2012 to May 2013 DO was highest in the month of June at the site SW_1, SW_2, SW_3 and SW_4 i.e. 24.16 mg/l and lowest DO at site SW_2 and SW_3 in the month of March i.e. 2.013 mg/l. The present results correlate with the findings of Bansal, (1989), Mohanta and Patra, (2000), Khinchi *et al.*, (2011). The maximum values of that the solubility of dissolved oxygen increases with the decrease in water temperature This observations recorded by Arvind Kumar and Singh, (2002) showed similarity with present results.

5.1.1.4 Free Corbon Dioxide (Table 4.7and 4.8; Graph 5.7 and 5.8)

The variations in free carbon dioxide showed direct relationship with the day and night. During day time the concentration of free CO_2 is used for photosynthesis, if the free CO_2 was measured throughout the day during mid-day concentrations may be even zero (Sahu *et al.*, 1995; and Jindal and Gheta, 1991).

During the period of June 2011 to May 2012 (Table 4.7), the maximum free CO_2 concentration was found in August at all the four stations of Vena river i. e. SW_1, SW_2, SW_3, and SW_4, of which SW_3 being the highest with 572 mg/l. The total absence of free CO_2 was reported in the month of June for all the stations. Wide range of fluctuations in the concentration of CO_2 was not apparently related to temperature or rainfall. The wide range of fluctuation was related to the growth of phytoplankton and algae. The large floating patches of algal blooms prevent upward movement of dissolved gases resulting in accumulation of CO_2 in water in morning hours. The wide fluctuations in CO_2 concentration was explained easily when we take into consideration the periodic water release from Rama Dam, of Wadgaon Nagpur District.

During the period of months June 2012 to May 2013 (Table 4.8), the maximum free CO_2 concentration was 418 mg/l reported in the months of April at station SW_4. In SW_1, SW_2, and SW_3 the maximum CO_2 concentration was noted in March, of which SW_3 being the highest at 145.2 mg/l followed by SW_2 with 114.4 mg/l and SW_1 with 94.6 mg/l. The total absence of free CO_2 was observed during the months of June for all the stations. The wide range of fluctuation may be related to growth of phytoplanktons and algae.

It was observed that the Free CO_2 was highest in the month of August during June 2011 to May 2012 at the site SW_3 i.e. 572 mg/l and lowest Free CO_2 at site SW_1 in the month of April i.e.22 mg/l and from June 2012 to May 2013 Free CO_2 was highest

in the month of April at the site SW_4 i.e. 418 mg/l and lowest Free CO_2 at site SW_1 in the month of October i.e. 8.8 mg/l.

5.1.1.5 Total Hardness:

The salts of Calcium, and Magnesium contribute ordinarily to the total hardness of water (NEERI Course Manual, 1979). Calcium, and Magnesium were selected for present study. Calcium, and Magnesium hardness of Vena river water during the months of June 2011 to May 2012 and June 2012 to May 2013 were noted in present investigation. Hardness is governed by the content of Calcium, and Magnesium salts combined with carbonates and bicarbonates.

4.1.1.5.1 Calcium: (Table 4.9 and 4.10; Graph 5.9 and 5.10)

Calcium plays very important role in metabolism and growth of flora of ecosystem. It directly affects the pH, and carbonate content of the system.

Table 4.9 indicates that, during the months of June 2011 to May 2012, of all the stations of Vena river, highest calcium concentration were reported in the month of April for SW_2. For SW_1, SW_2, SW_3, and SW_4, Calcium concentrations were 129 mg/l, 140.28 mg/l, 132.2 mg/l and 139.8 mg/l respectively. There was a drastic changes in calcium concentration from the month of May and the values were 26.45 mg/l, 20.04 mg/l, 25.65 mg/l and 21 mg/l respectively. From the months June onwards, the concentrations were found to rise consistently though there were some monthly variations. The highest Calcium concentration during summer upto April at various places was recorded by Sreenivasan, *et al.,* (1974); Tripathi and Pandey, (1990), and Salodia, (1996). The present study also revealed consistent increase in Calcium ion concentrations. The minimum value which was recorded in the month of May was not even surprising as periodically water being released from Rama Dam, Wadgaon of

Nagpur Disrict. The samples were preserved just after the river was flooded by Dam water.

Calcium values at their highest in the month of April showed that SW_2, SW_3, and SW_4 were having more calcium hardness than SW_1. As SW_2, SW_3, and SW_4 received the sewage from the city and also from the nearby industries and naturally became more polluted. Similarly, increased Calcium hardness can also be due to sewage has been earlier recorded by Trivedi and Goel, (1984) and Kaur *et al.,* (1996), concluding that, high values of hardness can also be due to regular addition of detergents along with sewage. Again high values were recorded in the months of February for SW_1-100.02 mg/l, for SW_2-96.99 mg/l, for SW_3-96.19 mg/l, and for SW_4-95.99 mg/l. The correlation between increase in Calcium hardness and its pollution status has been shown by Prasad and Saxena, (1980). The high values of total hardness; in the month of February for Kultadi Lake was recorded by Abbasi *et al.,* (1966).

Table 4.10 indicates that during the months of June 2012 to May 2013, the highest values of Calcium concentration for the station SW_1, SW_2, SW_3, and SW_4, were different in different months. The maximum Calcium ion concentrations of 52.1 mg/l were reported at SW_2 in the month of November. SW_3 had the maximum value of 43.28 mg/l in the month of September, SW_1 was at its highest Calcium concentration of 39.27 mg/l in the month of March and SW_4 was at its highest Calcium concentration of 35.07 mg/l in the month of December. The minimum values for Calcium ion concentration for SW_2 and SW_3 were 4.008 mg/l during the months of February and for SW_4 it was 3.006 mg/l in the same month and for SW_1 it was 12.02 mg/l during April. Month wise fluctuations in Calcium concentrations were much drastic. There was no correlation was found between calcium ion concentration and temperature. April, and May were the months of low calcium ion concentration for all the four stations. This could be correlated to the dilution resulted from the release of water from Rama Dam, Wadgaon

of Nagpur District. Usually during the month of March water level reduces and to restore the water level water is released from Dam to Vena river. The calcium values above 25.0 mg/l were considered to be calcium rich (Ohle, 1934). According to this standard water of Vena river was Calcium rich.

It was observed that the Calcium was highest in the month of May during June 2011 to May 2012 at the site SW_2 i.e. 140.28 mg/l and lowest Calcium at site SW_2 in the month of May i.e. 20.04 mg/l and from June 2012 to May 2013 Calcium was highest in the month of November at the site SW_4 i.e. 51.9 mg/l and lowest Calcium at site SW_4 in the month of February i.e. 3.006 mg/l.

5.1.1.5. 2 Magnesium: (Table no. 4.11 and 4.12; Graph 5.11 and 5.12)

Like calcium, Magnesium also affects the algal population. Generally, it was observed that Magnesium concentrations exhibit positive relationship with total phytoplanktons. Table 4.11 showed the record of Magnesium contents during the months of June 2011 to May 2012 and table 4.12 showed the record of Magnesium contents of stations studied during the months of June 2012 to May 2013.

Of the four stations of Vena river during the months of June 2011 to May 2012, SW_3 was reported to have the maximum Magnesium concentrations valued 82.56 mg/l. during May. The minimum concentrations of Magnesium, 6.41 mg/l, was recorded at SW_1 station during the months of October. Stations SW_1, SW_2, and SW_4 were also exhibited highest concentration (during May 37.71 mg/l, 76.15 mg/l and 76.15 mg/l respectively). However, the lowest value for SW_2, SW_3, and SW_4 (8.8 mg/l, 8.016 mg/l, and 8.9 mg/l) were reported in the months of January. The highest values can be easily correlated with the receeding water level during summer. The lowest value for SW_2, SW_3 and SW_4, in the months of January can be explained if we take into consideration the periodic water release from Rama Dam, Wadgaon of Nagpur District.

Table 4.12 showed that, maximum concentration was in September at all the four stations during the months of June 2012 to May 2013. Highest values for SW_1, SW_2, SW_3, and SW_4 were not much different though SW_2 exhibited the highest concentration i.e. 131.4 mg/l. Similarly, the lowest Magnesium concentration at all the four stations was again recorded in one and the same month i.e. the months of July. Lowest values at four stations were not much different in concentration though SW_3 exhibited the lowest concentration of Magnesium i.e. 21.64 mg/l.

It was observed that the Magnesium was highest in the month of May during June 2011 to May 2012 at the site SW_3 i.e. 82.56 mg/l and lowest Magnesium at site SW_1 in the month of October i.e. 6.41 mg/l and from June 2012 to May 2013 Magnesium was highest in the month of September at the site SW_2 i.e. 131.4 mg/l and lowest Magnesium at site SW_3 in the month of July i.e. 21.64 mg/l.

5.1.1.6 Alkalinity: (Table no. 4.13 and 4.14; Graph 5.13 and 5.14)

Alkalinity and acidity play an important role in controlling enzyme activity. Sverdrup *et al.,* (1942) reported that water alkalinity was a measure of acid present in the water and of the cations balanced against them. In water cations of weak bases are present in negligible concentrations and the only anions that need to be considered were carbonic and boric acid. However, in polluted system OH^- release from industries plays an important role in increasing the alkalinity of the water system. Alkalinity of water at four stations of Vena river during the study period of June 2011 to May 2012 and June 2012 to May 2013 were recorded in table 4.13 and 4.14 respectively.

All the stations of Vena river during the study period of June 2011 to May 2012 conspicuously showed absence of OH^-alkalinity (i. e. Phenolphthalein alkalinity). However, alkalinity had a wide range of fluctuations. The minimum value 21.64 mg/l was noted at SW_3 station in the month of July. The maximum values of 131.4 mg/l was

noted at SW_2 in the month of September. As far as different stations of the Vena river were concerned individual stations showed different values of alkalinity in different months.

Amongst higher values of stations SW_2 ranks first with alkalinity values of 131.4 mg/l followed by SW_4 with alkalinity values were 130.4 mg/l; SW_1 with alkalinity values were 129.8 mg/l and SW_3 with alkalinity values were 121.68 mg/l. Robert,(1977) reported that high concentration of sewage results into increase in alkalinity. This contradicts our findings of stations SW_2 were less polluted than stations SW_4, SW_1 and stations SW_3. The possible explanation lies with the fact that Vena river receives effluents from textile industries at stations SW_4, SW_1 and SW_3 and may be that the presence of chemicals in the effluents interact with sewage which ultimately reducing the carbonates, and bicarbonates in the water.

Data depicted in Table 4.14 showed observations of alkalinity at four stations of Vena river during the study period of June 2012 to May 2013. The recorded observations represents the Vena river conspicuously indicates the absence of OH^- alkalinity (Phenolphthalein alkalinity) but carbonate, and bicarbonates alkalinity (Methyl orange alkalinity), however, it exhibites a wide range of fluctuations. The minimum values recorded were 19.66 mg/l and noted at station SW_3 in the month of July. The maximum values 129.6 mg/l were noted at the station SW_2 in the month of September. As far as other stations were concerned individual station showed different values of alkalinity in different months.

From the above observations, it was clear that alkalinity during the months of June, July, and August were remainedat lower magnitude, while, it swang to maximum in the months of September. Consistent low alkalinity during the months of June, July,

and August were because of heavy rainfall leading to dilute ionic content of the water body (Bisop,1973; Ray, *et al.,*1966; Pahwa and Mehrotra.,1966, and Singh *et al.*,1999).

However, during the present study periods alkalinity sharply dropped in the months of March, and May due to release of water from Rama Dam, Wadgaon to Vena river stimulating the conditions of June, July, and August. George *et al.,* (1966) suggested that in an ecosystem with pH range of 7-9 alkalinity remains high. This is not true to the present study where even though alkalinity had decreased pH remains within the range of 6-8.65. Masood Ahmad and Krishnamurthy., (1990) reported the maximum bicarbonate alkalinity during the month of June, July, and August and least in the months of October, November, and December in second year of their observations on Wohar reservoir of Aurangabad. Though, no climatological conditions were reported by them, possibly water level might have depleted that year due to some or the other reasons during this month. High alkalinity values were the indicators of eutrophic nature of water bodies. Philipose, (1960) suggested that water bodies with alkaline values more than 100 mg/l were nutritionally rich. By this standard in some months of the water of Vena river was oligotrophic

It was observed that the total alkalinity was highest in the month of September during June 2011 to May 2012 at the site SW_2 i.e. 131.4 mg/l and lowest total alkalinity at site SW_3 in the month of July i.e. 21.64 mg/l and from June 2012 to May 2013 total alkalinity was highest in the month of September at the site SW_2 i.e. 129.6 mg/l and lowest total alkalinity at site SW_3 in the month of July i.e. 19.66 mg/l.

5.1.1.7 Phosphate: (Table no. 4.15 and 4.16; Graph 5.15 and 5.16)

The phosphates are essential for the growth of algae and their concentration controls algal growth in the ponds and river. A phosphate was a primary limiting

nutrients in ponds and river (Schindler, 1971). They were usually present in low concentrations in naturally unpolluted water.

Observations reported on Vena river during the months of June 2011 to May 2012 (Table 4.15) reveals that stations SW_2, SW_3, and SW_4 were richer in phosphate content than SW_1. The highest concentration of phosphates was during the months of April at all the three stations except SW_1. Station SW_3 station had the values of 11.25 mg/l; at station SW_2 values was a little less i.e. 0.8 mg/l; at station SW_4 values was again lesser i.e. 9.7 mg/l and at stations SW_1 values was found to be only 6.7 mg/l. During the months of November stations SW_2, SW_3, and SW_4 stations showed lowest phosphate levels i.e. 0.52 mg/l, 0.33 mg/l, and 0.45 mg/l respectively. However, lowest value for stations SW_1 were found during the months of May (0.23 mg/l). Observations at the station SW_2, SW_3 and SW_4 made during May showed drastic decrease in phosphates. Thus, the water of Vena river showed much fluctuations in the phosphate level during the months of two years study periods.

Sabata and Nayar, (1995) reported the phosphate concentrations of different rivers. The highest phosphate value was reported for Ganga at Kanpur i. e.7 mg/l and lowest for river Moossi i.e. 0.2 mg/l. The phosphate level fluctuations showed by Vena river were of great range. The maximum concentrations i.e. 11.25 mg/l were much higher than 7 mg/l. The higher concentrations of phosphates can be attributed to the pollutants that were poured in Vena river. The increase in phosphate level as a result of sewage contamination was reported by Welch, (1952)., and Hutchinson, (1957). The authors viz, Gonzalves and Joshi, (1946), Singh, (1960), and Zafar, (1966) had noted the changes in phosphate concentrations season-wise. They reported highest phosphate concentrations level during summer followed by rainy season, and lowest during the winter. Our findings showed that from the months of September to March, though, there was slight increase in phosphate concentrations, over all, it remained at lower mark as

compared to the concentrations in the months of March, and April. The month of April was the month of higher concentration. There was sudden decrease in phosphate concentration in May which can be attributed to the release of water from Rama Dam, Wadgaon to Vena river and later there was a gradual increase in the months of June and July.

During the study periods of months June 2012 to May 2013, the maximum concentrations was noted to be 11.3 mg/l at stations SW_3 during the months of April. All the values remained below this mark reaching 0.39 mg/l during the months of November. Such a low concentration of phosphate in the water indicates its unpolluted nature. Sabata and Nayar, (1995) states that usually phosphates were present in low concentration in naturally unpolluted rivers. Ganpati, (1960) on the contrary was of the opinion that in tropical waters, phosphates were always present in sufficient quantities. However, our findings on the Vena river do not agree with him.

It was observed that the phosphate was highest in the month of April during June 2011 to May 2012 at the site SW_3 i.e. 11.25 mg/l and lowest phosphate at site SW_1 in the month of May i.e. 0.23 mg/l and from June 2012 to May 2013 phosphate was highest in the month of April at the site SW_3 i.e. 11.3 mg/l and phosphate at site SW_1 in the month of May i.e. 0.25 mg/l.

5.1.1.8 Nitrate: (Table 4.17 and 4.18; Graph 5.17 and 5.18)

Nitrate is a factor governed by biotic and environmental parameters. Its concentration depends mainly on the activity of nitrifying bacteria which inturn is influenced by the presence of dissolved oxygen (DO).

It appears that during entire study tenure of Vena river showed quite low concentration of nitrates. Sabata and Nayar, (1995) showed that the nitrate concentrations of Adyar river varies from 11.10 mg/l to 15.20 mg/l. The lowest

concentration i. e. no presence of nitrate concentration was recorded for Moosi, and Vaigai rivers. Earlier studies regarding Indian rivers reported very low concentration of nitrates.

During study periods of months June 2011 to May 2012, the highest values for nitrate was 0.34 mg/l in the month of August at stations SW_3 and lowest of 0.06 mg/l in the month of September at SW_4 station (Table 4.17). All the four stations were showed variations within this range only. The highest concentration in the month of August has been earlier observed after the onset of rains by Prasad and Saxena, (1980).

During the months of June 2012 to May 2013, study stations of Vena river showed highest nitrate concentration during the months of January for SW_2 and SW_4 was 0.5 mg/l and it was 0.42 mg/l for SW_3 and 0.29 mg/l for SW_1. These values were comparatively higher, may be due to increased human activities. High nitrate level on account of pollution due to domestic sewage was reported by Chandrashekhar, (1997) in Saroor Nagar Lake, Hyderabad. The lowest value of nitrate concentratation i.e. 0.01 mg/l was observed for SW_1 and for station SW_3 it was 0.015 mg/l in the months of March and 0.02 mg/l for station SW_2 in the month of March, while, station SW_4 showed 0.02 mg/l again in the month of March, and November.

The nitrate concentrations increased for Zhelum river due to human activities as reported by Raina, *et al.,* (1984). The higher nitrate contents from organically polluted water was reported by different workers like, Brinley, (1942), Lackey, (1942), Butcher, (1949), and Blum, (1957). However, Blum, (1957) reported that the unpolluted stations of the Saline river were richer in nitrate content.

Therefore, it was appeared that factors contributing to concentrations of nitrates were not clearly understood. However, our findings support the view that organic pollution was the cause of higher nitrates.

It was observed that the nitrate was highest in the month of August during June 2011 to May 2012 at the site SW_3 i.e. 0.34 mg/l and lowest nitrate at site SW_4 in the month of September i.e. 0.06 mg/l and from June 2012 to May 2013 nitrate was highest in the month of January at the site SW_3 i.e. 0.42 mg/l and nitrate at site SW_1 in the month of March i.e. 0.01 mg/l.

5.1.1.9 Total Dissolved Salts (TDS): (Table no. 4.19 and 4.20; Graph 5.19 and 5.20)

The turbidity of water increases with suspended particles, soil particles, and disposed organic matter which interfere with penetration of light. It affects the growth of microorganisms growing at depths. High values of total dissolved solids (TDS) in water bodies indicates that the water is not suitable for human use. The water of Vena river under study area were used for drinking purposes. Therefore, from public health point of view the Total dissolved Solids (TDS) values were of two years of intensive investigations and were depicted in table 4.19 and table 4.20.

During the months of June 2011, to May 2012 (Table 4.19), the Vena river showed highest values of 0.919 ppm, 0.953 ppm, 0.989 ppm and 0.953 ppm at all the four stations were recorded in the month of June for stations SW_1, SW_2, SW_3, and SW_4 respectively. The lowest values were found in the month of November i. e. 0.181 ppm, 0.196 ppm, 0.181 ppm and 0.197 ppm at stations SW_1, SW_2, SW_3, and SW_4 respectively. From the months of November onwards increase in TDS was observed up to the month of April. Whereas the months of May the values decreased because of water was released from Rama Dam, of Wadgaon Dist. Nagpur to the Vena river. In the month of June, the TDS concentrations was reported the highest which immediately was brought down to half during the months of July by heavy rains. From the months of July to October, the fluctuations observed were in accordance with the rainfall received during the respective months. The minimum values of TDS during the months of

November were again decreased because of the water release from Rama Dam, Wadgaon of District Nagpur.

During the period of June 2012 to May 2013 (Table 4.20), highest values for all the four stations of Vena river were recorded in the month of June i. e. 0.909 ppm, 0.95 ppm, 0.978 ppm, and 0.945 ppm for stations SW_1, SW_2, SW_3, and SW_4 respectively. The minimum values recorded were 0.17 ppm, 0.18 ppm, 0.179 ppm, and 0.189 ppm respectively for the stations SW_1, SW_2, SW_3, and SW_4 in the months of November. The values showed in table 4.20 indicates a very narrow but steady range of increase in values from the months of November to April. During the months of May, values decrease due to water released from Rama Dam to Vena river. In the months of June concentrations was highest which became half during the months of July due to heavy rains. During the months of July to October, fluctuations were reported because of variations in rainfall during these months. The minimum values of TDS were also observed in the months of November again because of may be water release from Rama Dam to Vena river.

It was observed that the total dissolved salts was highest in the month of June during June 2011 to May 2012 at the site SW_3 i.e. 0.989 mg/l and lowest total dissolved salts at site SW_1 and SW_3 in the month of November i.e. 0.181 mg/l and from June 2012 to May 2013 total dissolved salts was highest in the month of June at the site SW_3 i.e. 0.978 mg/l and total dissolved salts at site SW_1 in the month of Novemberi.e.0.17 mg/l.

5.1.2 Seasonal values of Physico-chemical parameters:

5.1.2.1 Result:

Physico – chemical characteristics are very important since they have a profound effect on the diversity of living organisms dwelling in them. The seasonal variations in physico – chemical parameters are represented in Tables 4.21 to 4.24.

From the observation Table 4.21 to 4.24 it was noticed that the water temperature at site SW_1, SW_2, SW_3, and SW_4 were 27.63±3.8, 27.23±3.8, 27.61±3.78, and 27.56±3.7 respectively, The pH of water at site SW_1, SW_2, SW_3, and SW_4 were 7.6±1.16, 7.83±1.47, 7.72±1.20, and 7.725±1.20 respectively. The Dissolved O_2 of water at site SW_1, SW_2, SW_3, and SW_4 were 14.15±11.47, 14.76 ±11.14, 12.54±8.38, and 13.79±9.86 respectively.The free CO_2 of water at site SW_1, SW_2, SW_3, and SW_4 were 182.23±256.3, 201.26±262.2, 244.9±316.1, and 239.53±297.96 respectively. The total hardness (Calcium) of water at site SW_1, SW_2, SW_3, and SW_4 were 56.76±38.86, 55.30±36.87, 49.14±39.58, and 56.82±38.79 respectively. The total hardness (Magnesium) of water at site SW_1, SW_2, SW_3, and SW_4 were 56.76±45.54, 60.63±49.96, 62.89±48.99, and 60.23±56.19 respectively. The total alkalinity of water at site SW_1, SW_2, SW_3, and SW_4 were 69.3±99.03, 75.23±35.36, 74.85±37.03, and 74.69±35.07 respectively. The Phosphate of water at site SW_1, SW_2, SW_3, and SW_4 were 1.88±1.55, 3.64±2.83, 3.625±2.851, and 3.38±2.741 respectively. The Nitrate of water at site SW_1, SW_2, SW_3, and SW_4 were 0.118±0.098, 0.179±0.137, 0.170±0.142, and 0.155±0.125 respectively. The total dissolved solids at site SW_1, SW_2, SW_3, and SW_4 were 0.634±0.198, 0.663±0.211, 0.69±0.227, and 1.766±1.488 respectively.

5.1.2.2 Discussion:

5.1.2.2.1 Water Temperature:

Water Temperature is an important factor in aquatic medium which determines the quality of water. In the present investigation maximum water temperature recorded during summer and minimum during winter season. Similar observation were also recorded by Sawane (2002), and Khinchi *et al.,* (2011).

5.1.2.2.2 pH:

According to George (1997) pH is an important parameter of water, since most of the aquatic organisms are adapted to average pH and do not withstand abrupt changes. During study period river maintained well alkaline nature in the study area. Maximum pH was recorded during summer and minimum during monsoon season. Narain and Chauhan., (2000) recorded maximum pH in summer and minimum in monsoon, similar observations were also reported by Bandela *et al.*, (1998) and Khalique, (1995).

5.1.2.2.3 Total Hardness :

Total Hardness of water is the sum of the concentration of alkaline earth metal cations. In the present investigation, maximum Total hardness was recorded during summer season at stations SW_2 may be due to low water level and addition of calcium and magnesium salts used for different anthropogenic acitivites in the vicinity. However low values during rainy season attributed to dilution on account of heavy precipitation. Same was reported by Rajlakshmi, and Shreelatha.,(2005) in river Gautami Godvari at Yanam.

5.1.2.2.4 Total Alkalinity :

Alkalinity is the measure of buffering capacity of the water. It is generally imported by the salts of carbonates, bicarbonates, phosphate nitrates etc (Yellavarthi, 2002).

In the present investigation maximum value of Total Alkalinity was recorded during summer & minimum during mansoon season. Sankaran,(1988) in Adyar River reported high values of alkalinity in summer and low during rainy season.

5.1.2.2.5 Dissolved oxygen:

Dissolved oxygen is extensively used as parameter determining the weater quality and to evaluate the degree of freshness of lotic ecosystem.

In the present investigation the maxium D.O. was recorded during winter moderate during monsoon, and low during summer. Present results correlate with the findings of Bansal, (1989) Mohanta and Patra, (2000), Khinchi *et al.*, (2011) maximum values of that the solubility of D.O increases with the decrease in water temperature (Arvind Kumar, and Singh.,2002).

5.1.2.2.6 Phosphate:

Phosphate is considered as the most critical single element for biological productivity Banerjee, (1967).

In the present investigation, maximum concentration of phosphate was recorded in summer and minimum in winter season. Similarly, Ansari,(1993) reported high values of phosphate in summer in river Godavari at Nanded; Koshy and Nayar,(2000) reported that the major sources of phosphate in water are domestic sewage, agricultural runoff, industrial effluents and fertilizer.

5.1.2.2.7 Nitrate:

Nitrate is an excellent parameter to judge organic pollution and it represent the higher oxidised form of nitrogen. The present investigation redeems the maximum value of Nitrate during monsoon and minimum during summer season.

Arvind Kumar, and Singh.,(2002) reported high value of Nitrate during rainy season and attributed it to influx of nitrogen rich flood water that bring large amont of contaminated sewage.

Most of the parameter were maximum in summer may be due to high temperature high evaporation and low water level and minimum in winter due to increased water level.

5.2 Exploration of Algae:

The algal flora of the Vena river in Hinganghat area comprised 118 taxa belonging to 61 genera and was described systematically in Chapter 4. The taxonomic analysis revealed that the phytoplankton of the study area belonged to four classes, The classes of algae represented are Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae, Chlorophyceae (green algae) was the major group comprised 73 taxa (61.86%) belonging to 32 genera. Bacillariophyceae (diatoms) was represented by 24 taxa (20.33%) belonging to 15 genera, Euglenophyceae represented by 8 taxa (6.77%) belonging to 3 genera and Cyanophyceae (blue green algae) represented by 13 taxa (11.01%) belonging to 11 genera were found in the study area (Table 4.25).

Scenedesmus (08), *Cosmarium* (06), *Euastrum* (05), *Navicula* (05), *Staurastrum* (05), *Micrasterias* (04), Pinnularia (4), *Pleurotaenium* (04), A*nkistrodesmus* (03), *Pediastrum* (03), *Tetraedron* (03), Desmidium (03), and *Trachelomonas* (03) were the diverse genera (Table 4.25) found in the study area. The numbers of phytoplankton taxa and genera observed at different stations were given in Table 4.25. Species of *Navicula Pinnularia*, *Scenedesmus*, *Cosmarium, Micrasterias*, *Euastrum Staurastrum*, *Gleocapsa, Synechocystis and Euglena* were recorded from all the stations studied (Table 4.25). *Cymbella, Dinobryon, Eunotia, Fragilaria, Frustulia, Gomphonema. Melosira, Peridinium, Phacus , Rhodomonas , Stauroneis Synura, Tabellaria, Triploceras, Ankistrodesmus, Chlorella, Coelastrum, Dictyosphaerium, Dimorphococcus, Gonatozygon, Nephrocytium, Netrium, Pandorina, Pediastrum, Pleodorina, Pleurotaenium, Spirogyra, Tetraedron, Tetraspora, Desmidium, Micrasterias, Onychonema, Spondylosium, Xanthidium*, *Arthrodesmus*, *Arthrospira*, *Hyalotheca,*

Spherozosma, Anabaena, Aphanocapsa, Chroococcus, Merismopedia, Micrasterias, Oscillatoria, Spirulina, Synechoccus, and *Trachelomonas* were found in three stations. Closterium, Eudorina, Netrium, Lyngbya and Lepocinclis were found only in two stations (Table 4.25).

The phytoplnktons recorded from study area were divided into Bacillariophyceae, Cyanophyceae, Chlorophyceae and Euglenophyceae. It was found that Chlorophyceae (73 taxa) were dominant followed by Bacillariophyceae (24 taxa), Cyanophyceae (13 taxa), and Euglenphyceae (08 taxa) (Table 4.26).

Three seasons viz. premonsoon, monsoon and winter were considered for analysis. It was observed that the number of phytoplanktons were maximum during winter (408 taxon) followed by premonsoon (400 taxon) and lowest during monsoon (160 taxon) (Table 4.26).

The number of phytoplanktons recorded were analysed by considering stations like SW_1, SW_2, SW_3, and SW_4. The maximum taxa were recorded from SW_1 (104), followed by SW_4 (79), SW_3 (72), and lowest SW_2 (68). The maximum genera were recorded from SW_1 (51), followed by SW_4 (50), SW_3 (43), and lowest SW_2 (42) (Table 4.25).

The number of phytoplanktons recorded were analysed by considering various taxa recorded as per sites. It was observed that the maximum taxa were recorded for SW_1 were *Scenedesmus* (8 taxa), followed by *Cosmarium* and *Staurastrum* (6 Taxa each), *Navicula, Euastrum* and *Trachelomonas* (5 taxa each), *Pleurotaenium* and *Micrasterias* (4 taxa each), *Ankistrodesmum, Pediastrum, Tetraedron, and Desmidium* (3 taxa each), *Gomphonema, Pinnularia, Stauroneis, Coelastrum, Pandorina, Xanthidium, Arthrodesmus, Oscillatoria, Spirulina, and Euglena* (2 Taxa each) *and lowest Dinobryon, Eunotia, Fragilaria, Melosira, Peridinium, Phacus, Synura,*

*Tabellaria, Closterium, Chlorella, Dictyosphaerium, Dimorphococcus, Netrium, Oocystis, Pleodorina, Spirogyra, Onychonema, Spondylosium, Arthrospira, Hyalotheca, Anabaena, Aphanocapsa, Gleocapsa, Lyngbya, Micrasterias, Svnechocvstis, Synechoccus,*and *Lepocinclis* (1 taxa each). *Cymbella, Rhodomonas, Triploceras, Gonatozygon, Nephrocytium, Tetraspora, Spherozosma, Chroococcus,and Merismopedia* were not recorded in this site SW_1 i.e. Underbrige,(Table 4.25).

It was observed that the maximum taxa were recorded for SW_2 were *Scenedesmus* (7 taxa), followed by *Staurastrum* and *Trachelomonas* (4Taxa each), *Cosmarium , Euastrum* and *Navicula,* (3 taxa each), *Gomphonema, Pandorina, Desmidium, Xanthidium, Spirulina, and Euglena* (2 Taxa each), *Cymbella, Eunotia, Frustulia, Melosira, Peridinium, Pinnularia, Rhodomonas, Phacus, Stauroneis, Tabellaria Triploceras, Chlorella, Dictyosphaerium, Dimorphococcus, Gonatozygon, Nephrocytium, Netrium, Pleodorina, Pleurotaenium, Spirogyra, Tetraspora, Micrasterias, Spondylosium, Hyalotheca, Spherozosma, Anabaena, Chroococcus, Gleocapsa, Merismopedia, Oscillatoria, Svnechocvstis,and Lepocinclis*. (1 Taxa each); *Dinobryon , Fragilaria, Synura, Closterium, Ankistrodesmus, Coelastrum, Eudorina, Oocystis, Pediastrum, Tetraedron, Onychonema, Arthrodesmus, Arthrospira, Aphanocapsa, Lyngbya, Micrasterias, Synechoccus , Rhodomonas, Triploceras, Gonatozygon, Nephrocytium, Tetraspora, Spherozosma, Chroococcus,and Merismopedia* were not recorded in this site SW_2 i.e. Kawalghat,(Table 4.25).

It was observed that the maximum taxa were recorded for SW_3 were *Navicula,and Euastrum* (5 taxa each), followed by *Pinnularia,Scenedesmus, Cosmarium, and Staurastrum* (4Taxa each), T*etraedron* (3 taxa), *Stauroneis, Ankistrodesmus, Gonatozygon, Nephrocytium, Pediastrum, Desmidium, Micrasterias, and Arthrodesmus* (2 Taxa each), *Cymbella, Dinobryon, Eunotia, Fragilaria, Frustulia, Melosira, Phacus, Rhodomonas, Synura, Triploceras, Coelastrum, Eudorina,*

Pandorina, Pleodorina, Tetraspora, Onychonema, Arthrospira, Spherozosma, Anabaena, Chroococcus, Gleocapsa, Merismopedia, Micrasterias, Oscillatoria, Svnechocvstis, Synechoccus, and Euglena (1 Taxa each); *Peridinium, Tabellaria, Closterium, Chlorella, Dictyosphaerium, Dimorphococcus, Netrium, Oocystis, Pleurotaenium, Spirogyra, Spondylosium, Xanthidium, Hyalotheca, Aphanocapsa, Lyngbya, Spirulina, Lepocinclis, Trachelomonas,and Gomphonema* were not recorded in this site SW_3 i.e. Smashanbhoomi (Table 4.25).

It was observed that the maximum taxa were recorded for SW_4 were *Navicula,and Euastrum* (5 taxa each), followed by *Pinnularia, Pleurotaenium, and Micrasterias* (4Taxa each), *Scenedesmus, and Cosmarium* (3 taxa), *Gomphonema, Coelastrum, Nephrocytium, Tetraedron, Staurastrum, Arthrodesmus, Spirulina, and Trachelomonas* (2 Taxa each), *Cymbella, Dinobryon, Fragilaria, Frustulia, Peridinium, Phacus, Rhodomonas, Synura, Tabellaria, Triploceras, Ankistrodesmus, Chlorella, Dictyosphaerium, Dimorphococcus, Gonatozygon, Netrium, Oocystis, Pediastrum, Spirogyra, Tetraspora, Onychonema, Spondylosium, Xanthidium, Arthrospira, Hyalotheca, Spherozosma, Aphanocapsa, Chroococcus, Gleocapsa, Lyngbya, Merismopedia, Micrasterias, Svnechocvstis, Synechoccus*, and *Euglena* (1 Taxa each); *Eunotia, Melosira, Stauroneis, Closterium, Eudorina, Pandorina, Pleodorina, Desmidium, Anabaena,Oscillatoria,* and *Lepocinclis*.were not recorded in this site SW_4 i.e. Shahlangadi (Table 4.25).

The whole tenure of study was divided into periods of three months each i.e. June to August (2011), September to November (2011), December (2011) to February (2012), March to May (2012), June to August (2012), September to November (2012), December (2012) to February (2013) and March to May (2013) at four different sites for the exploration of algal flora.

At site SW_1, during June to August (2011) Blue Green Algae seen in less number or in rare form. During September to November (2011), Filamentous forms of algae were found in less number. Sometimes they are not found. *Diatoms* are very less in number. Blue green algae are smaller in number. During December (2011) to February (2012) Algae shows maximum growth during winter season *Desmids* less in number. *Euglenoid* flagellates like blue green algae are lesser in number. *Diatoms* from algal population in winter season. During March to May (2012), *Desmids* were seen more in number in these sites of Under bridge. Blue green algae attempt maximum development during summer season. *Eugleloid* flagellates more in number present during this summer season.

At site SW_2, during June to August (2011) *Diatom*s seen in minimum proportion in rainy season. Blue green algae were present in rare form. During September to November (2011), Filamentous forms of algae were found in less number. Sometimes they are not found. *Diatoms* are very less in number. Blue green algae are smaller in number. During December (2011) to February (2012), *Desmids* are more in number seen on these sites. Blue green algae shows maximum sometimes minimum in this season. During March to May (2012), *Euglenoid* flagellates more in number present during this summer season. *Desmids* were seen more in number in these sites of Kawalghat Blue green algae attempt maximum development during summer season. In this season the water current is slow. There is a high temperature fluctuation. This shows direct correlation with oxidizable organic matter and water temperature inverse relationship with dissolved oxygen.

At site SW_3, during June to August (2011) *Spirullina* Turpin *ex* Gomont is observed in rare form in rainy season. Filamentous forms not found. During September to November (2011) *Desmids* which are one or more in number at site SW_1 and SW_2 not seen in this site. The algae touch minimum during this season. During December (2011)

to February (2012) Same above identification is found on these sites. During March to May (2012) Same above identification is found on these sites. Algae shows maximum development during this season desmids favoured by high summer temperature and total solids found more in number.

At site SW_4, during June to August (2011) Blue green algae are seen in very less in number. *Desmids* are not seen or in some times in very rare form. *Diatoms* are in rare. During September to November (2011) the algae show minimum growth in this season because the rate of water current is fast in this season. The rate of water current is more or less inversely proportional to the total number of algae. These algae show inverse relationship with temperature. During December (2011) to February (2012) Same observation is found on bank of Vena river. They show maximum development in this season. *Diatoms, Desmids,* and *Euglenoid* flagellates were sometimes more and less in number. During March to May (2012) Algae reaching maximum development during this summer season. High temperature accelerates the growth and multiplication of Chlorococcales. *Desmids* which are more in number at SW_2 and SW_3 stations shows more in proportion at site this *Euglenoid* flagellates are more in number on sand sides of Vena river.

At site SW_1, during June to August (2012) Blue Green Algae seen in less number or in rare form. During September to November (2012) Diatoms are very less in number. Blue green algae are smaller in number. Filamentus forms of algae were found in less number. In sometimes they are not found During December (2012) to February (2013) Algae shows maximum growth during winter season Desmids less in number. Euglenoid flagellates like blue green algae are lesser in number. Diatoms form algal population in winter season. During March to May (2013) Blue green algae attempted maximum development during summer season. Flagellates were more in number present during this summer season. Desmids observed maximum in this under bridge site.

At site SW_2, during June to August (2012), Diatoms observed in minimum proportion in rainy season. Blue green algae were present in rare form. During September to November (2012) same identification was found on this site as SW_1. During December (2012) to February (2013) Desmids are more in number seen on these sites. Blue green algae show maximum sometimes minimum in this season during March to May (2013) Eugleloid flagellates more in number present during this summer season. Desmids were seen more in number in these sites of Kawalghat. Blue green algae attempt maximum development during summer season. In this season the water current is slow. There is a high temperature fluctuation this show direct correlation with oxidizable organic matter and water temperature inverse relationship with dissolved oxygen.

At site SW_3, during June to August (2012) Spirullina Turpin ex Gomont was observed in rare form in rainy season. Filamentous forms were not found. During September to November (2012), Desmids which were one or more in number at site SW_1 and SW_2 not observed in this site. The algae were found minimum during this season. During December (2012) to February (2013) Desmids are more in number seen on these sites. Blue green algae show maximum sometimes minimum in this season. During March to May (2013) Eugleloid flagellates more in number present during this summer season. Desmids were seen more in number in these sites of Kawalghat. Algae shows maximum development during this season desmids favoured by high summer temperature and total solids found more in number.

At site SW_4, during June to August (2012) Desmids are not seen or in sometimes in very rare form. Diatoms are in rare. Same observation was seen on these sites. Blue green algae are seen in very less number. During September to November (2012), the algae show minimum growth in this season because the rate of water current is fast in this season. The rate of water current is more or less inversely proportional to the total

number of algae. These algae show inverse relationship with temperature. During December (2012) to February (2013) same observation is found on bank of Vena river. They show mixiumum development in this season. Diatoms Desmids Euglenoid flagellates are sometimes more and less in number. During March to May (2013) Algae reaching maximum development during this summer season. High temperature accelerates the growth and multiplication of Chlorococcales. Desmids which are more in number SW_2 and SW_3 stations shows more in proportion at this stations. Eugleloid flagellates are more in number on sand sides of Vena river.

5.3 Influence of nutrients on growth algae:

5.3.1 Result :

In this investigation the maximum growth of *Chloroccocum humicalum* and *Selenastrum westii* was recorded as same concentration of carbonate as basal medium.

The maximum growth of *Chloroccocum humicalum* was observed at 225.6 mg/l and *Oscillatoria amphibia* was 225.9 mg/l of nitrogen.

In the present investigation calcium requirement is 16 mg/l for *Oscillatoria amphibia* and *Selenastrum westii* and 32 mg/l for *Choroccum humicolum* and *Coelastrum sphaericum.* Calcium requirement differs from species to species In present investigation magnesium requirement of *Chlorococcum humicolum* is 32.00 mg/l, *Oscillatoria amphibia* 8 mg/l, *Selastrum sps* was 7.2 mg/l and *Coelastrum sphaericum* 6.4 mg/l many workers reported maximum growh of algae at various level the tolerance of *Chlorella vulgaris* in high concentration of mg salt and grow considerably over in 0.42 moles mg/l were recorded by Trelease and Selsam,(1939).

The results of investigation in accordance with (Sharon and Belinger,1976) who noted optimum uptake occurs at about 8 mg/l and lower concentration of $MgSO_4$ inhibit growth of algae.

In our investigation sodium requirement for *Chloroccoum humicolum, Oscillatoria amphibia, Selenastrum westii* and *Coelastrum sphaericum*, were 370 mg/l.

In the present study maximum growth of *Chloroccoum humicolum* and *Selenastrum westii* were found at 32 mg/l and *Oscillatoria amphibia* at 4 mg/l and *Coelastrum sphaericum* at 64 mg/l. The result similar to *Chlorella vulgaris* at 2 mg/l of potassium.

In this study *Chlorococcum humicolum* and *Coelastrum species* requires 32 mg/l *Oscillatoria amphibia* requires 28 mg/l while *Selenastrum westii* requires 9.7 mg/l of sulphur similar to concentration of in basal BG-11 medium.

In this study, 32 mg/l chlorides require maximum growth and *Chloroccoum humicolum*, *Selenastrum westii* and *Coelastrum sphaericum*.

In present investigation 1.20 mg/l iron is required for *Chlarococcum sphaericum* is as equal to iron in basal medium.The optimum amount of iron required for growth depends upon species as well as on the composition of media concentration of 1.8×10^{-7} M to 2.6×10^{-8} M was found adequate for the growth of *Chlorella* (Myers,1944; Hopkins,1930) for the heterotrophic growth of *Chlorella pyrenoidosa* has found to be 1×10^{-9} m while for autotrophic growth it is 1.8×10^{-5} (Esyter, 1962).

In present investigation maximum growth of all algae was obtained at 6 mg/l as equal to basal medium.

In present result EDTA shows maximum growth in basal medium.

5.3.2 Discussion:

The major nutrients for plants are C, N, P, H, O_2 form basis of energy metabolism and synthesis of macronutrients on phytoplankton. Silicon is needed for diatom for build to cellwalls. Sulphur is essential of protein production by phytoplankton.These elements are required inlarge amounts known as major elements.Minor elements are those required in trace amount that include zinc, iron,magnese, cupper.

For maximum growth of algae the relative amounts and concentrations of major nutrients, nitrogen source, micronutrients composition taking into considerations in this investigation.

5.3.2.1 Carbon:

Carbon is constituents of all organic compound protoplasm. It is derived from CO_2 carbonates, bicarbonates or organic compounds. The most common method of carbon estimated in algae through photosynthesis. Infact investigators depicted role of bicarbonate and CO_2 for *Spirullina, Chlorella*, marine diatoms phaecodyctulum tricoruntum (Richmond *et. al*, 1982), Dixon and Merrett, (1988); CO_2 is only carbon compound which support growth. The amount of CO_2 bicarbonate and carbonate ions present in the medium is in equlirbium.

Carbon was 2.266 mg/l in medium. The concentration of carbon in BG11 were 1,2,4,8,12,16 mg/l selected to find its influence on algal growth.

The growth of *Chlorococum humicolum* and *Selenastrum wastii* were maximum in 2.26 mg/l as equal to carbon in basal medium and growth of *Oscillotaria amphibian* and *Coelastrum spharicum* were obtained in 2.00 mg/l.

5.3.2.2 Nitrogen :

Nitrogen is one of important constituent of many compounds involved in plant metal. It is an essential part of living cells. Nitrogen become limiting factors for growth of algae as they utilized NO_3, NO_2 and NH_4 as Nitrogen source But some flagellates especially Euglenoids NO_3 and NO_2 are not much essential as nitrate can take their place it becomes toxic at higher concentration.

The normal requirement of Nitrogen in cultures of various species of green algae obserbed by Ketchum and Redfied, (1949), is about 6.5 -8.3% of ash free dry weight Number of workers reported concentration of required for maximum growth of algae. Rodhe, (1948), Chu, (1942), and Gerloff *et al.*, (1950), reported low concentration of Nitrogen 10.2, 13.6 mg/l respectively where Tanda, (1951), Scott, (1944) Mayers and Clark, (1944), Craig *et al.,* (1937), and Geoghegen, (1953), reported higher requirement that is 87, 106, 350, 305 mg/l of nitrogen respectively.

The growth rate in case of closterium and Nitzschia are independent of nitrate - Nitrogen concentration between 0.005-0.5 mg/l (Ketchum, 1939).

The influence of N on algal growth in test experiments, the range of 200-400 mg/l as against normal Nitrogen 247.48 mg/l in BG-11 medium. The maximum growth of *Chlorococum humicolum, Oscillotaria amphibian, Selenastrum wastii,* and *Coelastrum spharicum.*

5.3.2.3 Phosphorous:

It is important constituents of ATP which plays vital role in energy metabolism of cell.It involvs metabolism of plants. Major constituent in algae for normal growth (Myers, 1951; Ketchum, 1954, Krauss, 1958, Provasoli, 1960).The phosphorous requirement for optimum algal growth differs from species to species.Higher concentration of phosphorous inhibit the growth (Chu, 1942) In this investigation phosphorous requirement for *Oscillatoria amphibia* and selanastrum wastii was 7.1 mg/l

as equal to phosphorous in basal medium and chloroccoum humicolum and coelastrum sps was 16 mg/l.

Various researches reported different requirement of phosphorous Rodhe, (1948), (Chu, 1942) Gerloff, *et al.*, (1950), recorded low requirement of phosphorous in these media.Tanda, (1951), Scott, (1944) Myers and Clark, (1944), Craig *et al.*, (1993), reported calcium is essential element for all chlorophyll containing plants.

The requirement of calcium has been reported for *Chlorella* (Noack *et al.,* 1940) a *Nitzschi closterium* (Hutner 1949; Chu 1949) indicates maximum requirement of calcium depeneds on species and media used.

Phosphate range were from 4.00 mg/l to 128 mg/l. The maximum growth of *Oscillatoria amphibia* and *Selenastrum wastii* were observed at 7.1 mg/l equal to phosphate and maximum growth of *Chlorococum humicolum* and *Coelastrum spharicum* were observed at the concentration of 16 mg/l.

5.3.2.4 Magnesium:

Magnesium is a component of chloroplast counter ion of ATP important for protein biosynthesis. Magnesium is needed by algae species because nearly all algae have chlorophyll.

An adequate concentration of mg for algae may quite low of *Ankistrodesmus sp* 0.1 mg/l. The concentration of magnesium was 7.38 mg/l in basal medium. The elements concentrations taken were 4, 8, 16, 32 and 128 mg/l. The maximum growth of *Oscillatoria amphibian* obtained at the concentration of 8.00 mg/l. Maximum growth of *Chlorococum humicolum* were at 64 mg/l.

5.3.2.5 Sodium:

Cyanobacteria show specific growth require for sodium (Allen, and Arnon.,1953; Myers,1953; Allen,1952) found the need of sodium in accelerate growth

of various blue green algae Emerson and Lewis, (1942) reported high sodium and low potassium require for *Chlorococcus*. The absence of sodium give rise to change in their habit photosynthesis (Apte and Thomes, 1983); Kalpana *et. al.,* 1984; Miller, 1984; Fernendez *et. al.*, 1991. Allen, 1952 found 23 strains of blue green algae that could grow in sodium salt. Kratz and Myers, (1955) found that logarithemic growth of *Anabaena varibilis, Nostoc mascorum* and *Anacystis nidulans*, elevating the sodium level increase the growth rate.

5.3.2.6 Potassium:

It is required for all algae under deficient condition. It is major element in algae.

5.3.2.7 Sulphur:

In nature sulphate is abundant in form. Under deficiency of sulphur cells grow normally upto earlier stage.Such cells are provided with sulphur under photosynthetic condition; these cells are still unable to perform cell division (Hase, *et.al.*, 1959). This results in acordance with (Tanda, 1951) who reported 8.4 and 13 mg/l sulphur for growth of diatoms and *Chlorella*. Shaheen, (1996) reported high concentration 32 mg/l SO_4^{-3} for their growth medium. Sliehata, and Whitton., (1982) noted 32.3 mg/l and Kratz and Myers., (1955) stated 33.31 mg/l.

Sulphur were 9.7 mg/l. The range were 4.00 - 128.00 mg/l showed the influence of sulphur on algal growth. The maximum growth of *Chlorococum humicolum* at 8.00 mg/l to concentration of sulphur in basal medium and *Selenastrum wastii* at 9.7 mg/l concentration.

5.3.2.8 Chloride:

It is essential for photosynthesis in algae.It is needed for Hill reactions ATP formation. FMN catalysed photophosphonylation reaction (Vernon, *et al.,* 1965) and 16 different requirement of chloride for Phytoplankton Whitton and Shehata different

requirement of chloride for phytoplankton. Sliehata, and Whitton., (1982) reported 26.46 mg/l Antarikanonda, (1982) indicated 139.6 mg/l chloride for cyanophyceae where as Guillard, (1973) noted 17.35 mg/l cloride in medium for diatoms.

In the experiment, chloride with the range of 4.00 - 129.00 mg/l, the growth of *Chlorococum humicolum* and *Coelastrum spharicum* were maximum at 32.00 mg/l *Oscillatoria amphibian* showed maximum growth at 16.00 mg/l.

5.3.2.9 Iron:

Iron is a key elements in plant metabolism the rate of photosynthesis is lowered by iron deficiency. The iron requirement in biological oxidation reduction applies to algae as well as to other living organisms. A direct correlation between photosynthetic activity and chlorophyll content was demonstrated in *Chlorella pyrinoidosa* by Emerson, (1929) who reported that reduced chlorophyll content is the only factor responsible for reduction of photosynthesis iron deficient cells. Iron has been reported to be involved in nitrate reduction by *Chlorella.* (Trubochev *et al.,* 1976) and nitrate has been demonstrated in sub cellular preparation of *Anabaena cylindrica* (Hattori and Yesugi,1968). The level of iron is directly related to the next of hydrogenre development in *Scenedesmus* (Yanagi and Saba, 1966).

The range at 0.2 mgl^{-1} and 16.00 mg/l against 1.2 mg/l iron in BG-11, maximum growth of *Oscillatoria amphibian* and *Selenastrum wastii* were the same in basal medium and 2.00 mg/l for *Chlorococcum humicolumn.*

5.3.2.10 Citric acid:

Citric acid acts as complexing agent or reducing agent and as works as pH buffer. Krauss, (1958) and Lynn, (1938) reported that Ferric salt and citric acid to carbondioxide and ferrous citrate which in turn can be oxidized to ferric citrate. Shankhadarwar, (2002),

The concentration of citric acid were 6.00 mg/l in BG-11 medium and the range were 3.00 - 64.00 mg/l. The maximum growth of *Chlorococcum humicolumn* and *Oscillatoria amphibian* and *Selenastrum wastii* in these concentration.

5.3.2.11 EDTA:

The common use of EDTA is for complexing metal ions in artificial culture medium. It is most widely used chelate in fresh water media and it not redially metabolized by algae but soluble in water. The results are also similar with results of (Pradhan, 1992) and Shankhadarwar, (2002), Shaheen, (1996), recorded in maximum growth at 2 mg/l culture. The common use of EDTA as chelating compound have proved of invitable value in culture experiment which are metabolically inactive forms complexes with other elements preventing their precipitation (Hutner *et. al.*, 1950). Chelating coumpound EDTA is the best known and widely used (Myers, 1951).

The normal concentration of EDTA in medium were 1 mg/l and the range in experiment were 1.00 -12.00 mg/l.

5.3.2.12 Nitrogen and Sodium:

Sodium and nitrogen elements were in concentration of 405 mg/l and 147 mg/l respectively in combination in the form of 150 mg/l $NaNo_3$ in BG.11 medium. In an influence of individual elemental test study, maximum growth of *Chlorococcum humicolum, Oscillatoria amphibia, Selenastrum westii and Coelastrum sphaericum* were recorded at 370 mg/l of Na as compouned to control 247.08 mg/l. The growths of algae were taken into account to select 370 mg/l of Na and 225 mg/l of N in a salt of $NaNO_3$. The difference in growth of algae at 247 g/l and 225 g/l of N were examined and 1.37 g/l of $NaNO_3$ were reported most suitable in a modified medium as compared to 150 mg/l of basal medium.

5.3.2.13 Potassium and Phosphate:

Potassium and phosphate element were in the concentrations of 17.95 mg/l and 7.1 mg/l respecively in combination in the form of 40 g/l K_2HPO_4 of BG-11 medium. The influence of individual element study reveals that *Chlorococcum humicolum* showed the maximum growth at 32 mg/l potassium as compare to control 7.1 mg/l. Potassium at 32 mg/l were taken into consideration for maximum growth of *Chlorococcum humiculum*. Phosphate deceased to 12.65 mg/l were significant difference in growth of this alga at 12.65 mg/l and 16 mg/l in modified medium were observed, therefore, employed 60 mg/l of K_2HPO_4 as compare to control 40 g/l of K_2HPO_4.

Maximum growth of *Oscillatoria amphibia* in basal medium were 4 mg/l potassium and 4 mg/l of phosphate for which preferred 22.5 g/l of K_2HPO_4 as compare to control 40 g/l of K_2HPO_4 in the basal BG-11 medium. Maximum growth of *Coelastrum species* and *Selenastrum westii* were at 16 mg/l and 32 mg/l for potassium and 64 mg/l and 7.1mg/l for phosphate respectively for which prefered 71.2 mg/l K_2HPO_4 in modified medium as compare to control 40 g/l.

5.3.2.14 Magnesium and Sulphate:

The concentrations of Magnesium and Sulphate were 7.3 mg/l and 9.7 mg/l respectively in (75.0 g/l $MgSO_4$) basal medium. Maximum growth of *Chlorococum humicolum* were recorded at 32.0 mg/l of magnesium as compare to 7.3 mg/l and 32.0 mg/l of sulphur as compare to control 9.7 mg/l in basal medium. The concentration of sulphur increases to 4.251 mg/l when magnesium 32.0 mg/l were taken into account. There was a slight change in growth of alga in modified medium.Therefore employed 60.00 mg/l $MgSO_4$ as compare to control 75.0 g/l of $MgSO_4$. Slightly high concentration were reported to be needed for *Coelastrum sphaericum*, it was maximum in 32.0 mg/l of magnesium and 32.0 mg/l of sulphur for which use preferred 337.50 mg/l of $MgSO_4$ as

compare to control 75.0 mg/l. The maximum growth of *Oscillatoria amphibia* were obtained at 8.0 mg/l of magnesium and 8.0 mg/l of sulphate for which prefered 82.19 g/l of $MgSO_4$ in modified medim as compare to 7.50 g/l in control. Whereas, significant growths of *Selenastrum westii* were obtained at 7.3 mg/l of magnesim, and 9.7 mg/l of sulphate, therefore, we prefered 90.75 mg/l of $MgSO_4$ in modified medium as compare to 75 g/l of $MgSO_4$ in control medium.

5.3.2.15 Calcium and Chloride:

Basal medium contains 13.0 g/l Ca and 23.0 g/l. *Chlorococcum humicoum* showed optimum growth at 32.0 mg/l as compared to control 13.0 mg/l calcium and 23.0 mg/l chloride. If calcium 32.0 mg/l taken into account, chloride more or less to 56.60 mg/l. If 13.0 mg/l of calcium taken into account 32.0 mg/l chloride in modified medium, growth of *Chlorococcum humicolum* recorded maximum at modified medium as compare to BG-11 medium. Therefore, the concentration 88.56 g/l of $CaCl_2$ in modified medium was enough for maximum growth of algae as compare to control 36.0 mg/l, $CaCl_2$. *Oscillatoria amphibia* showed the maximum growth at 16.0 mg/l calcium and 16.0 mg/l chloride for which selected 44.36 g/l $CaCl_2$. In modified medium as compare to control 36 g/l $CaCl_2$. In modified medium the maximum growth of *Selenastrum westii* were obtained at 16.0 mg/l of calcium and 32.0 mg/l of chloride in modified medium where, 44.28 g/l of $CaCl_2$ were selected as compared to 36.0 mg/l of $CaCl_2$ in control. The growth of *Coelastrum sphaericum* were maximum at 32.0 mg/l of calcium and 32.0 mg/l of chloride in modified medium enables to select 88.56 g/l of $CaCl_2$ in modified medium as compare to 36.0 g/l in basal media.

The range were 4 - 128 mg/l. The maximum growth of *Oscillatoria sp* and *Selenastrum sp* were maximum at 16 mg/l and maximum growth of *Chloroccum sp* and *Coelastrum sp* were 32 mg/l.

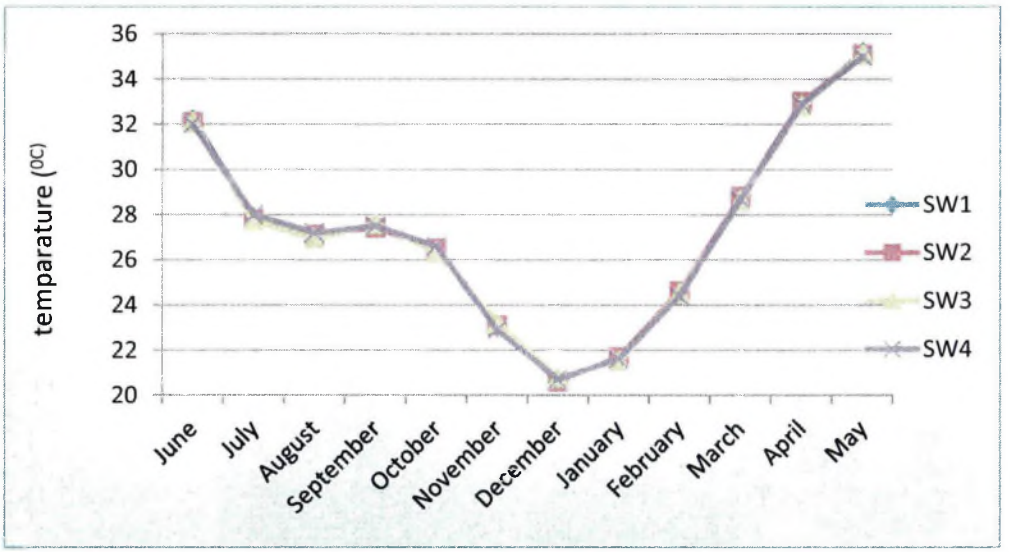
5.3.2.16 Citric acid, Iron and EDTA:

The maximum growth of all selected algae recorded in modified medium absent in the normal concentration of citric acid, iron and EDTA in basal medium, thus same concentrations of citric acid, iron and EDTA were prefered in modified medium BG-11.

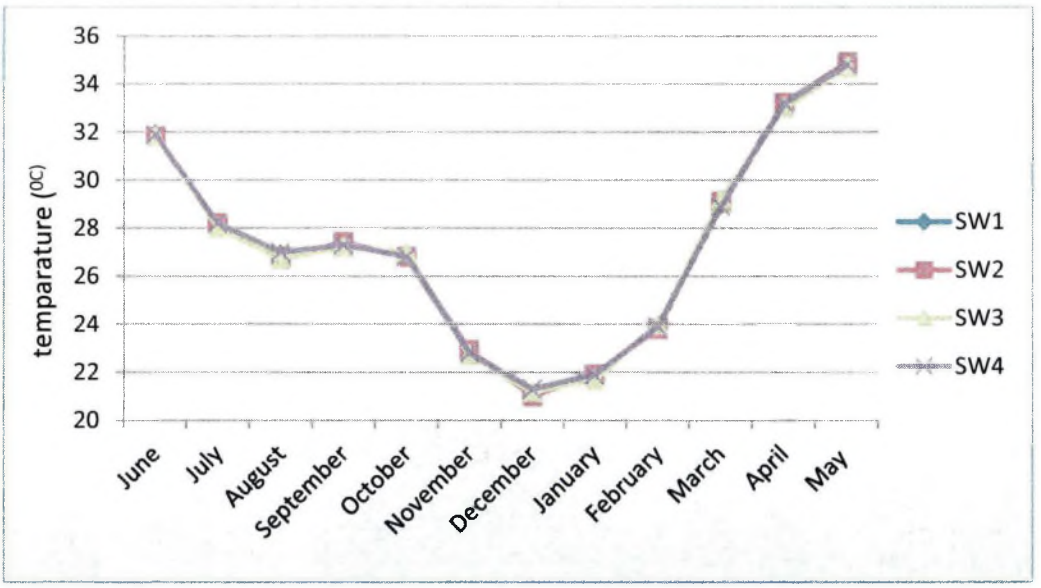
5.3.2.17 Sodium and Carbonate:

Chlorococcum humicolum and *Selenastrum westii* were showed the maximum growth at 2.0 mg/l of sodium carbonate that lead to use stock 15.0 g/l of Na_2CO_3 in modified medium as compare to control 20.0 g/l. However, *Oscilatoria amphibia* and *Coelastrum sphaericum* showed the maximum growth at 220 mg/l of sodium carbonate as equal to 2.2 mg/l in basal medium. Same concentrations were chosen in modifed medium.

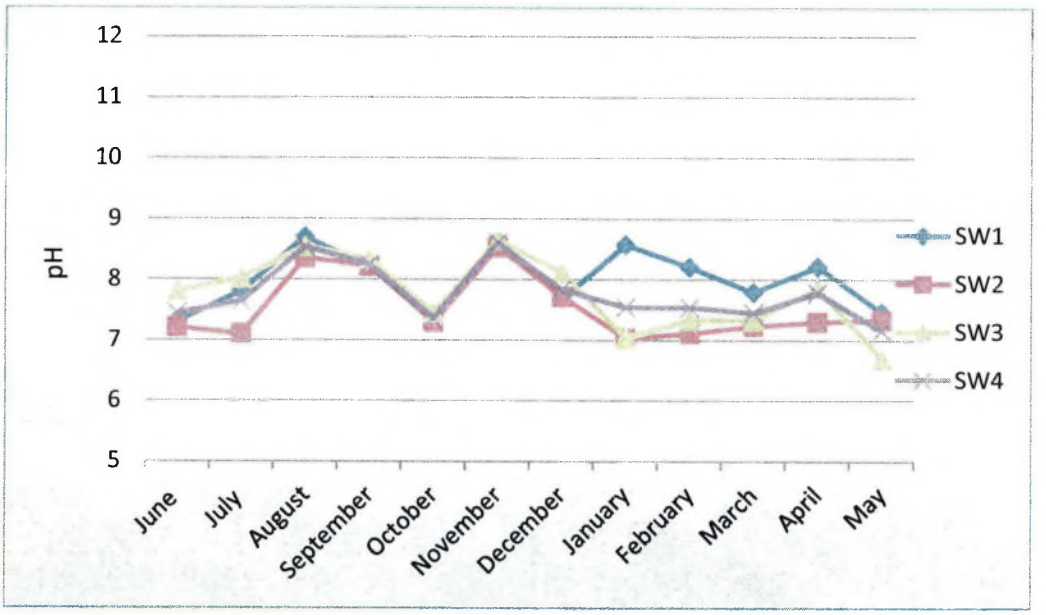
In considering the influence of all the elements following four modified BG-11 media can be recommended for selected algae.



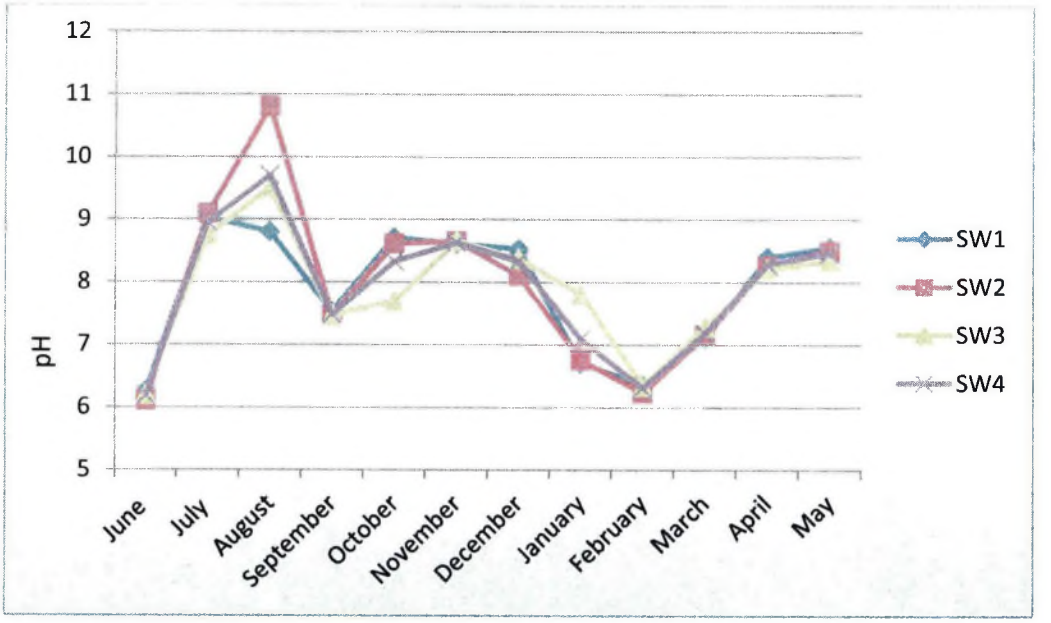
Graph 5.1 Monthly variations in temperature at different stations from June 2011 to May 2012.



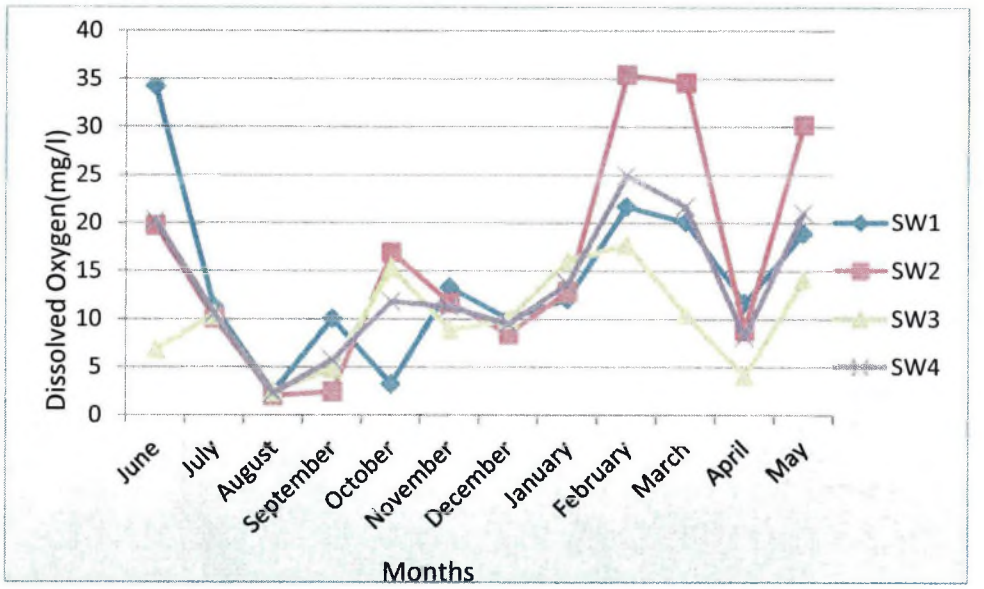
Graph 5.2 Monthly variations in temperature at different stations from June 2012 to May 2013.



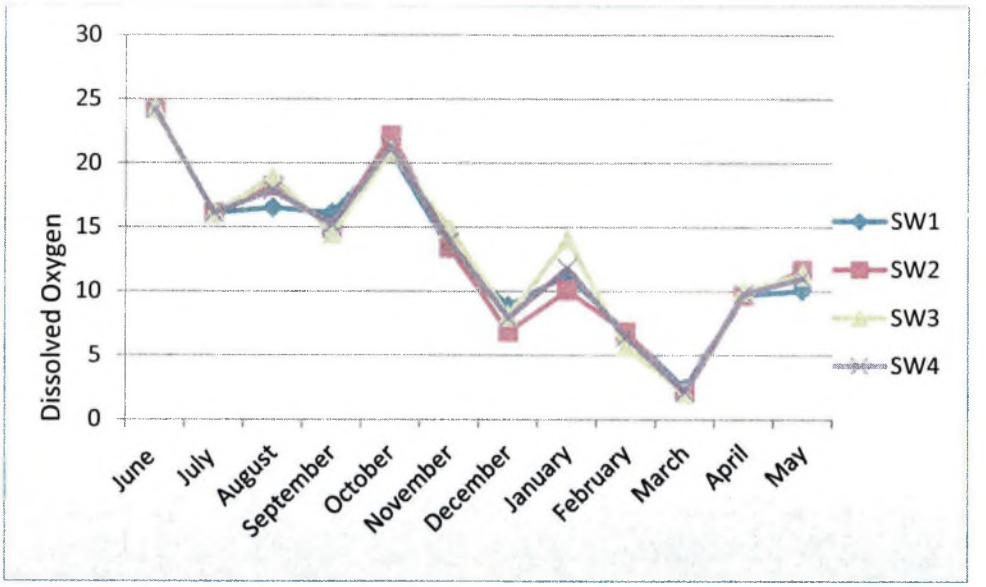
Graph 5.3 Monthly variation in pH at different stations from June 2011 to May 2012.



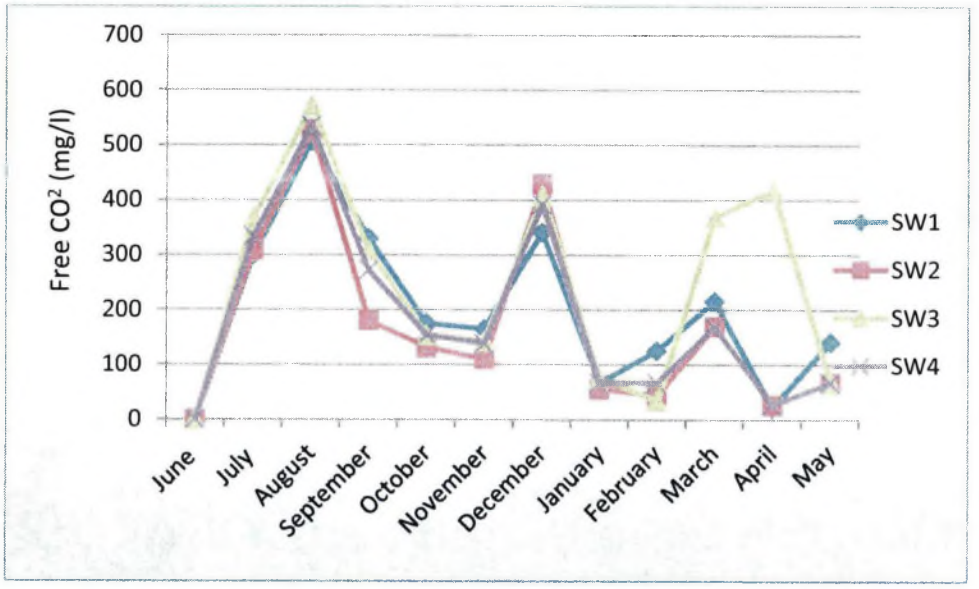
Graph 5.4 Monthly variation in pH at different stations from June 2012 to May 2013.



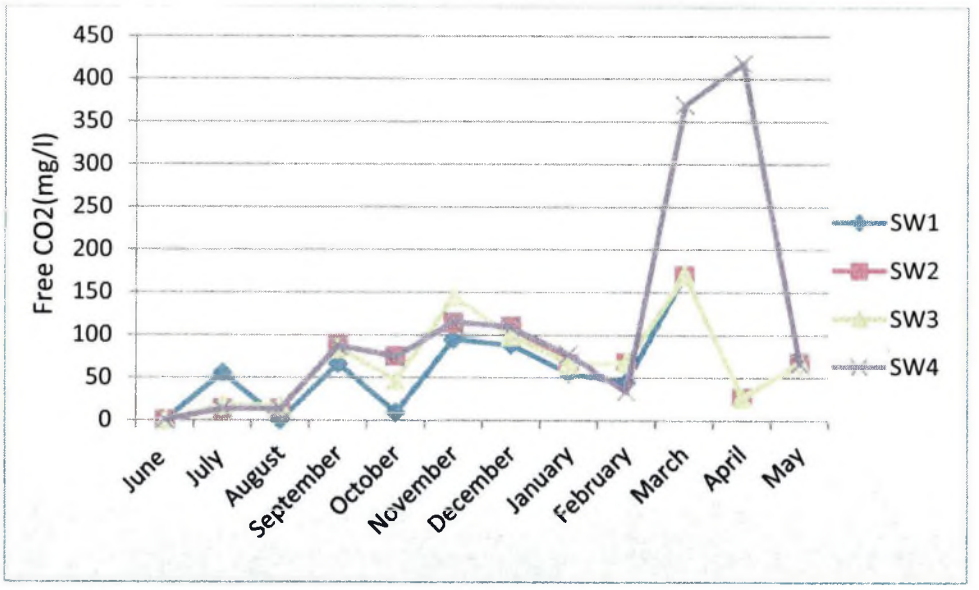
Graph 5.5 Monthly variation in Dissolved Oxygen (DO) at different stations from June 2011 to May 2012.



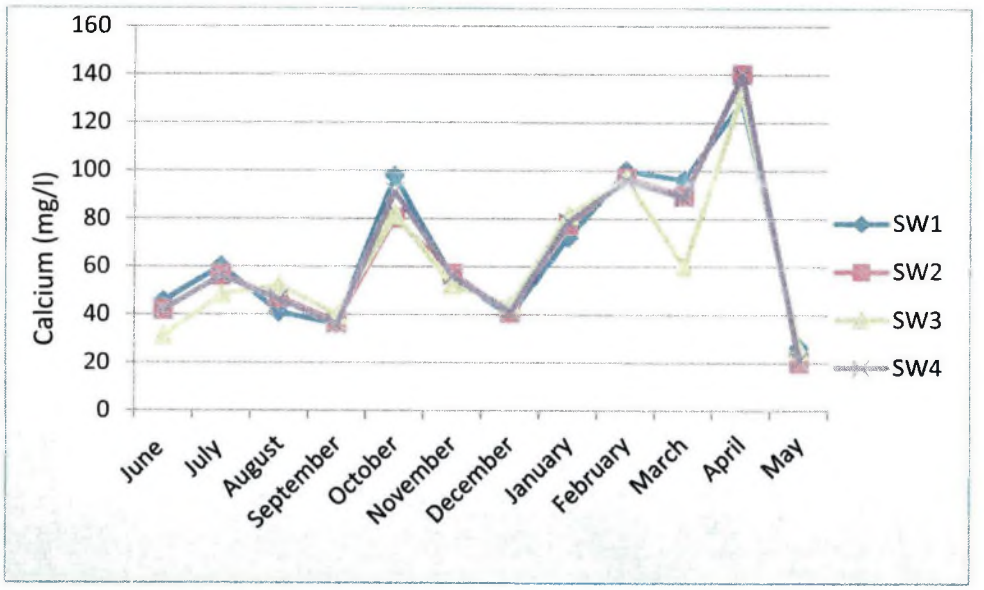
Graph 5.6 Monthly variation in Dissolved Oxygen (DO) at different stations from June 2012 to May 2013



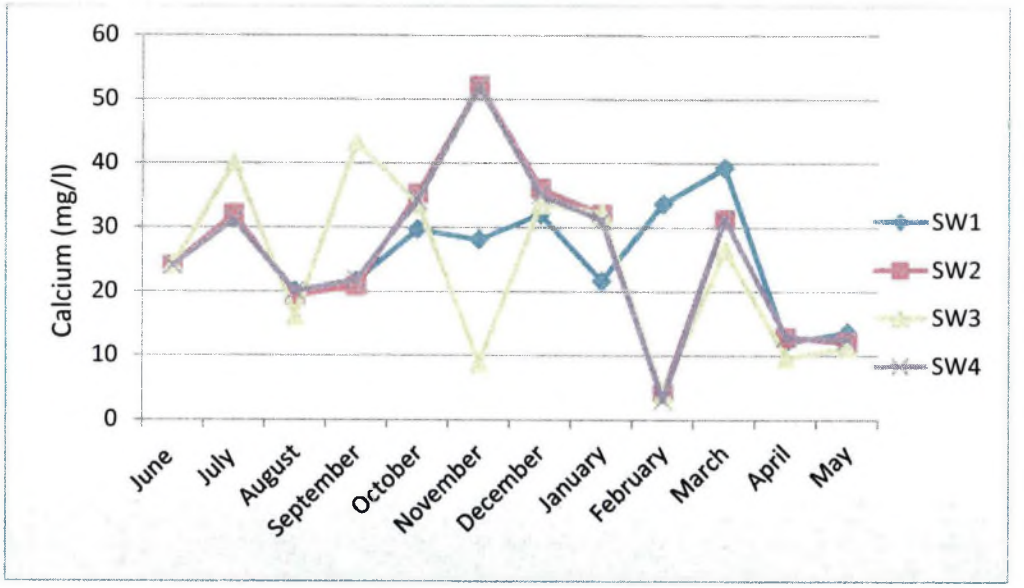
Graph 5.7 Monthly variation in Free CO_2 at different stations from June 2011 to May 2012.



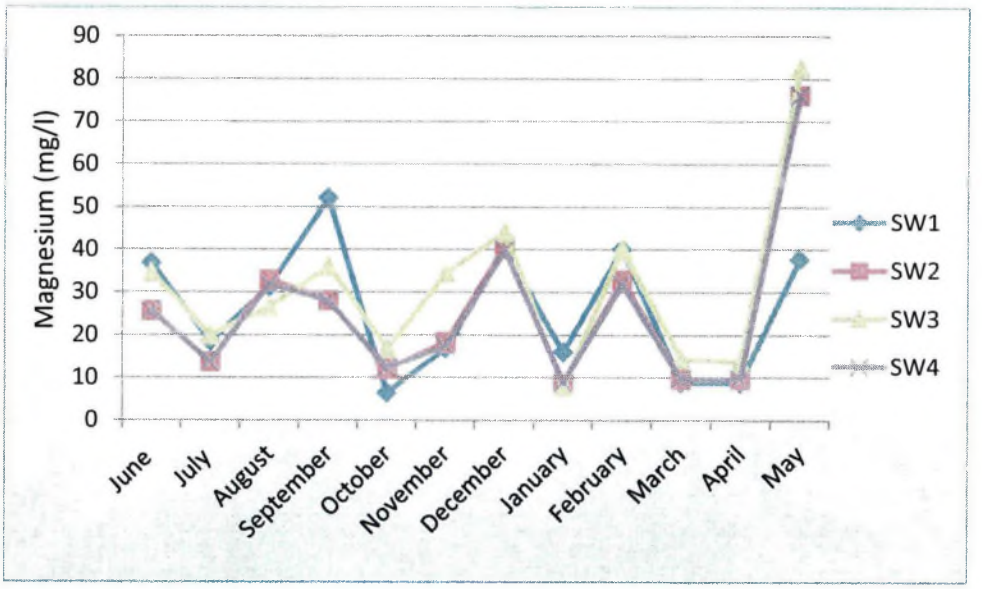
Graph 5.8 Monthly variation in Free CO_2 at different stations from June 2012 to May 2013.



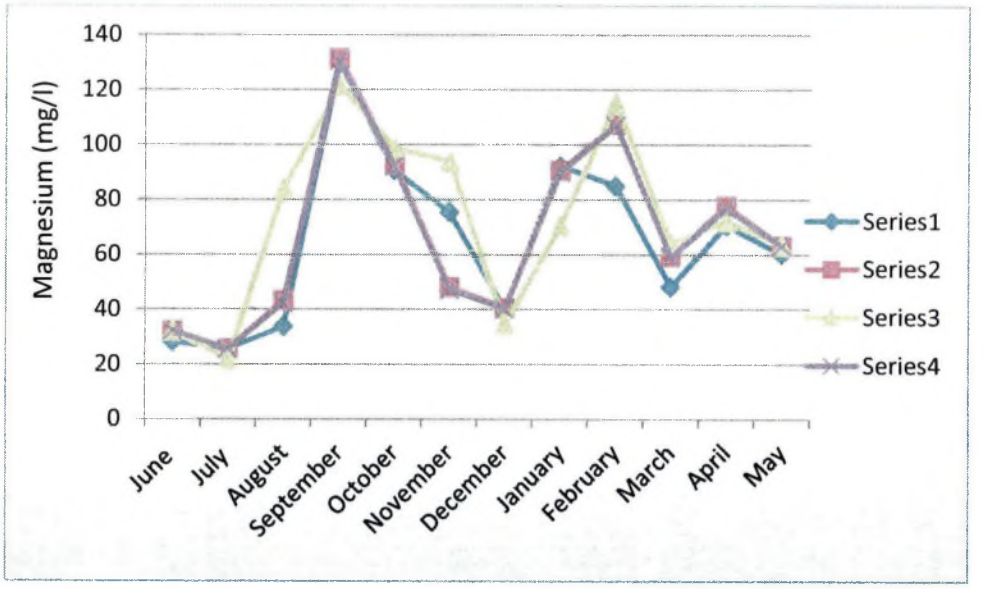
Graph 5.9 Monthly variation in Calcium at different stations from June 2011 to May 2012.



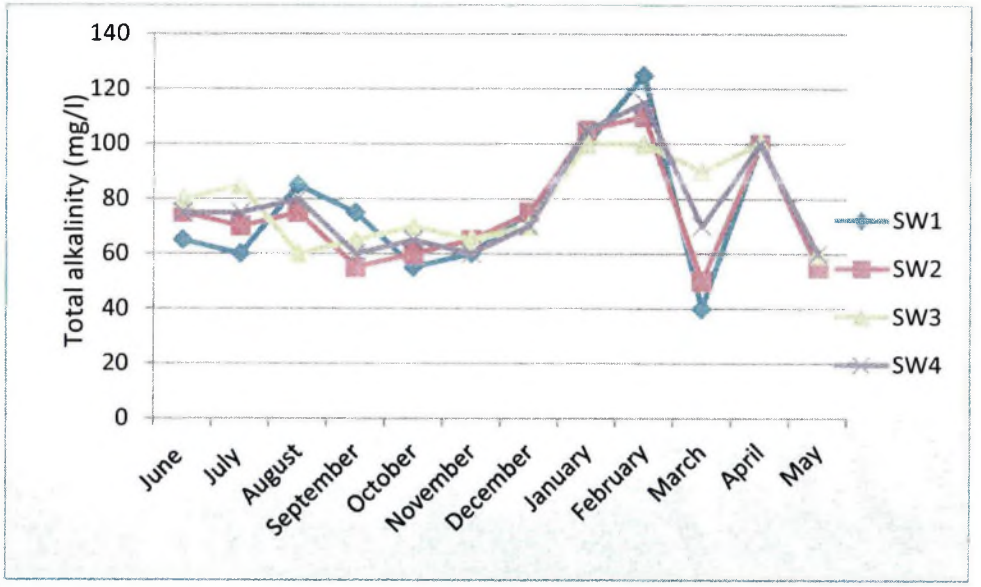
Graph 5.10. Monthly variation in Calcium at different stations from June 2012 to May 2013.



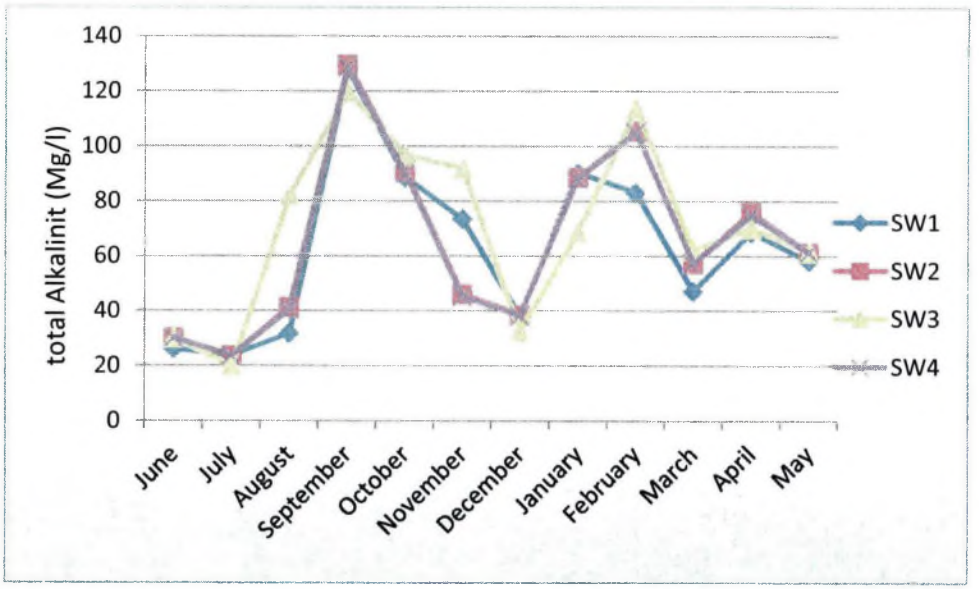
Graph 5.11. Monthly variation in Calcium at different stations (June 2011 to May 2012).



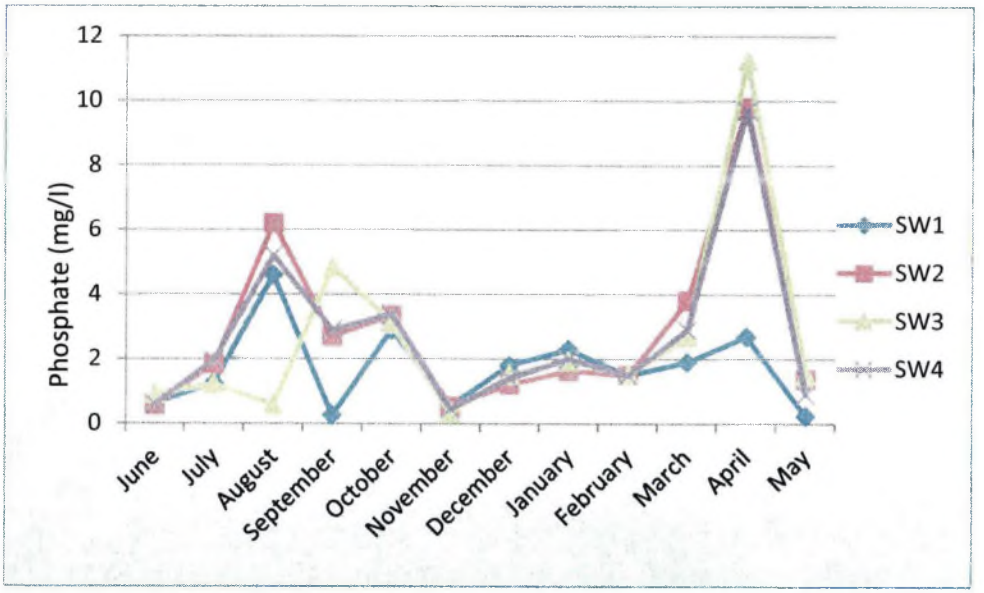
Graph 5.12. Monthly variation in Magnesium at different from June 2012 to May 2013.



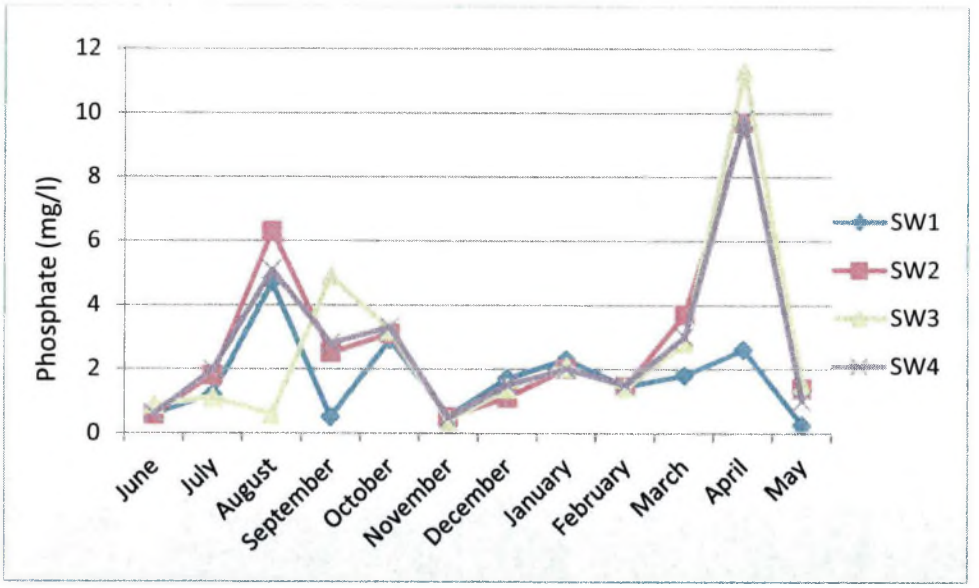
Graph 5.13 Monthly variation in Alkalinity at different stations (June 2011 to May 2012).



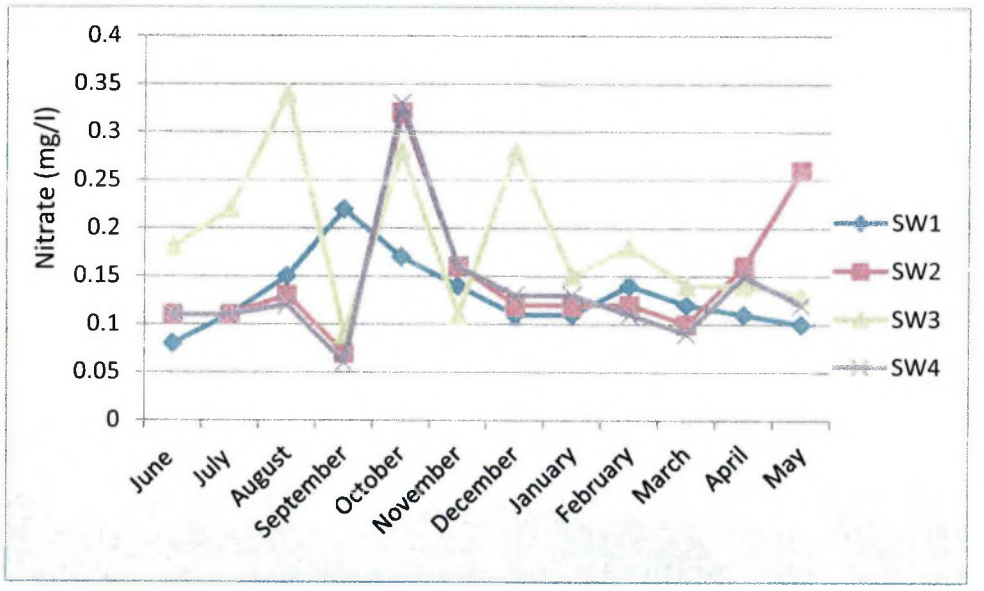
Graph 5.14 Monthly variation in Alkalinity at different stations (June 2012 to May 2013).



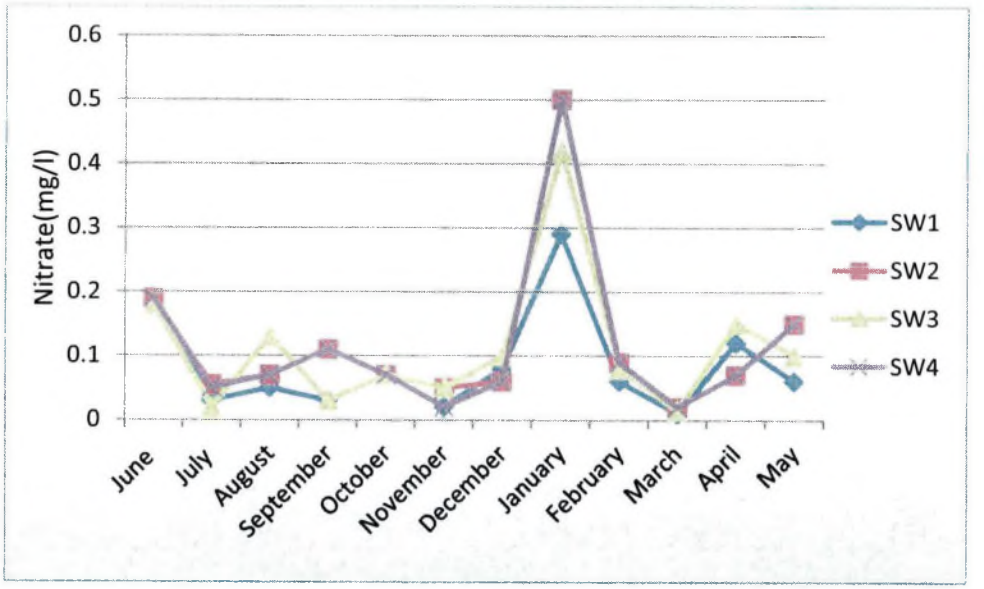
Graph 5.15 Monthly variation in Phosphate at different stations (June 2011 to May 2012).



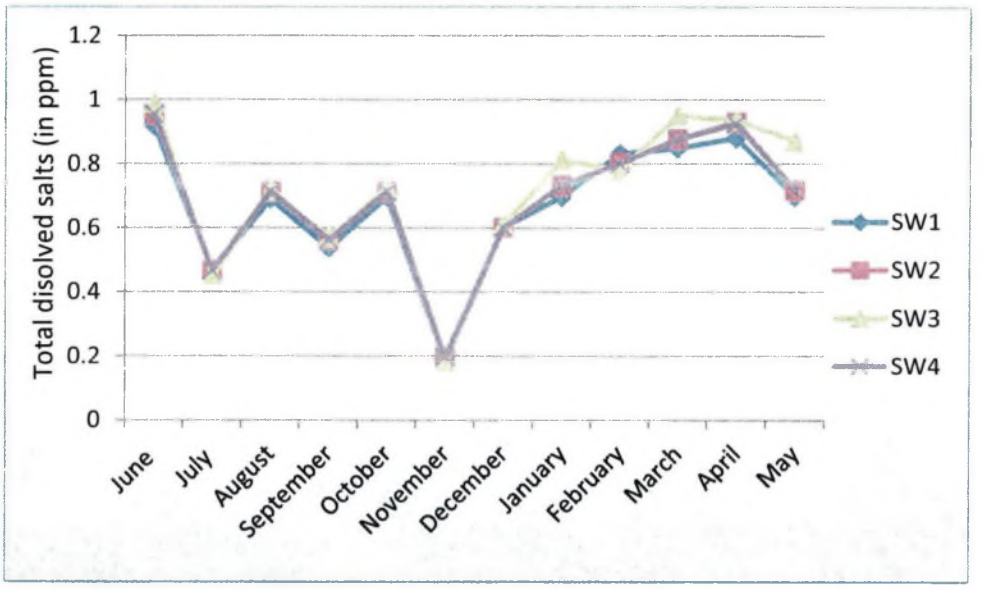
Graph 5.16 Monthly variation in Phosphate at different stations (June 2012 to May 2013).



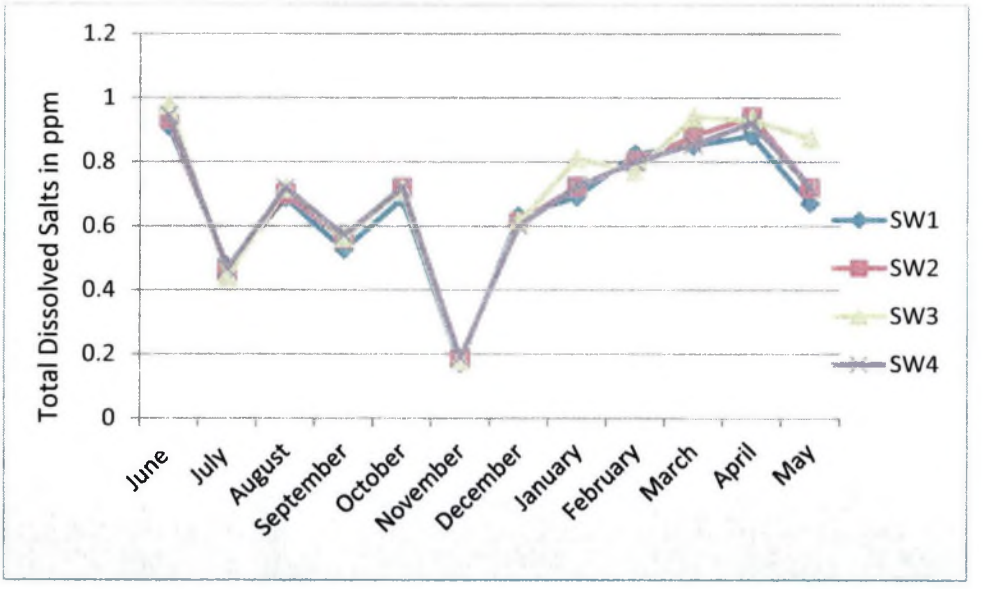
Graph 5.17 Monthly variation in Nitrates at different stations from June 2011 to May 2012.



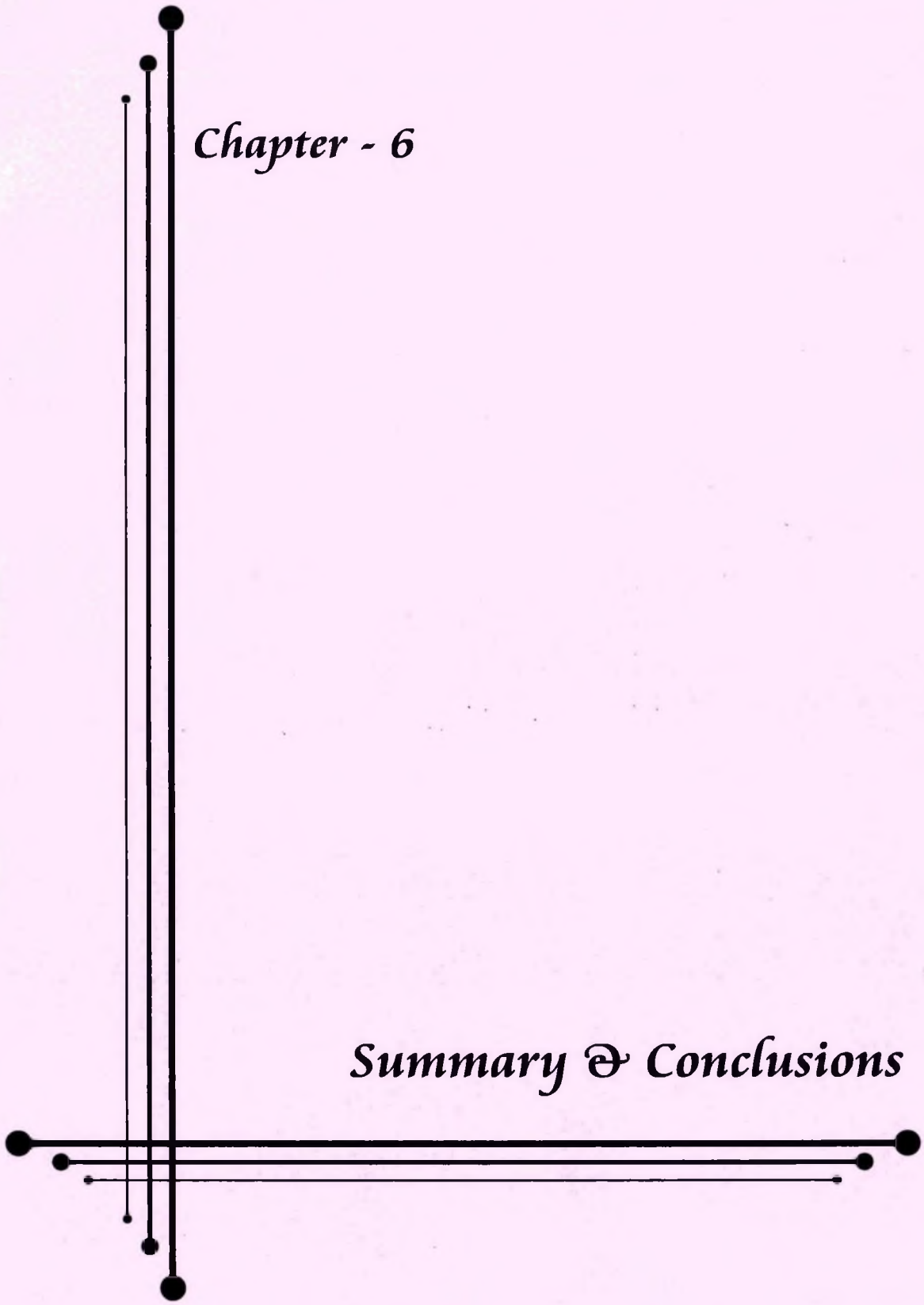
Graph 5.18 Monthly variation in Nitrates at different stations from June 2012 to May 2013.



Graph 5.19 Monthly variation in Total Dissolved Salts (TDS) at different stations (June 2011 to May 2012).



Graph 5.20 Monthly variation in Total Dissolved Salts (TDS) at different stations (June 2012 to May 2013).



Chapter - 6

Summary & Conclusions

SUMMARY AND CONCLUSIONS

Contents:

The chapter VI deals with the summary and conclusions.

6.1 Summary:

6.1.1 Introduction: The present research enables a comprehensive and systematic analysis of the algal flora of the Vena river in Hinganghat area of Wardha district, which is a part of Vidarbha, Maharashtra state for two years of intensive study i.e. June 2011 to May 2013.

Hinganghat is one of the tehsils of Wardha District situated in $20^0 18'$ to $20^0 49'$ N and $78^0 32'$ to $79^0 14'$ E latitude. The town is located on the bank of river Vena, a tributary of the Wardha river which joins the big river Pranhita ahead at a distance place, which ultimately merges into the Godavari river later. In British India, Hinganghat was the centre of India, but after the partition of Hindusthan into India, and Pakistan, Nagpur is considered as the center (heart place) of India. At Vena river pump house, there is a historical old stone, on which it was mentioned that Hinganghat is the centre of India.

Major portion of the total annual rainfall is received from the months of June to September of every year. The average rainfall of Hinganghat Tahsil is 1071.70 mm, and has a dry tropical weather climate. The climate is hot , and dry. Max temp. in ^{0}C were noted as 47.9 ^{0}C and Min. temp. in ^{0}C were noted as 10.2 ^{0}C. The seasons of a year were divided according climates into three namely cold, hot and monsoon.

Wardha District has a typical seasonal monsoon, where people are engaged in agriculture. Hinganghat city lies in the south east of Wardha District. Its South East border touches Chandrapur District, and South west border touches to Yeotmal District. The land scape of the city faces towards the south with fast running streams. Vena River borders the north, west, and south sides of the city. The city is rich in fauna, and flora and water sources.

In Hinganghat area, Vena river is a fresh water body, and is one of the prominent river of Vidarbha, Maharashtra. It. is Perennial River of this area. It is supposed to be the life line of the Wardha district, but due to expanding needs of growing population, it is faces many adversities or changes. The water of river is mainly used for agriculture and in some extent for drinking purposes of wild animals, and human beings. The sewage of effluents of several cotton mills is like Gima Text, Daga Mills, Pee Vee Textile mills, Suguna Oil Industries, Sugar factory etc are directly discharged into Vena river without any treatment due to which it get polluted.

The river Vena has received little attention from botanists, ecologists and specially phycologist as such and moreover, the scientific approach was not holistic. The study of the algal flora of this river is of great importance, can be known to the peoples, and may be the heritage of future generation. Hence, it is a need of hour to know each and every thing of this plant world. For this purpose, the research has made an attempt to gather the information reported by researcher in past.

Most of algae found in Vena river were rather free floating or attached in tufts or mats to the substratum. Environmental factors such as temperature, Oxygen and osmotic concentration, play important role in the cultivation of phytoplanktons. The most important elements needed by algae are carbon, oxygen, nitrogen, hydrogen, sulphur,

phosphorous, potassium, calcium, magnesium and iron for their successful growth in the culture medium.

The physico-chemical parameters were studied in the upstream and downstream of Vena river of Hinganghat locality. The parameters analysed during the study to ensure good quality of water were water temperature (^{0}C), pH, dissolved oxygen (mg/l), Free CO_2 (mg/l), total dissolved solids (ppm), alkalinity (mg/l), total hardness (mg/l), and Nitrates (mg/l), and Phosphates (mg/l).

The two years of intensive investigations were carried out i.e. from June 2011 to May 2013 with the following objectives.

1. To gather information regarding the diversity of freshwater algae in the area studied.
2. To evaluate the seasonal, and spatial variations of algal flora.
3. To compare the physico-chemical aspects of water in relation to the diversity of algae.
4. To analyze the effect of various nutrients on the growth of some algae of the area studied.

The significance of the present investigations are as follows.

1. It is found to be useful to the researchers, planners, and policy makers as the fresh water biodiversity of Hinganghat region received very little attention.
2. It shows the freshwater habitats in Hinganghat region are under severe stress due to anthropogenic interventions like deforestation, sand and clay mining, monoculture plantations, and intensive agriculture.
3. It is a mile stone in the documentation of the freshwater biodiversity of Vena river.

4. It is useful to find possible biodiversity loss which was not yet quantified in Vena river.
5. The present work adds the information to taxonomic account of algae or on the quantitative account of plankton present in the Vena river in Hinganghat area of Wardha district.
6. The investigations give more information regarding the species richness, species composition, and distribution of algal flora.
7. The investigation focus on limnological studies related to algal biodiversity had been done in Wardha district.
8. It is a practical work on the taxonomy, species diversity, seasonal and spatial variation of algae in the Vena river in Hinganghat area.
9. The quantitative estimation of phytoplankton, and hydrographic parameters of the present study would highlight the present status of algal diversity of Vena river, and the probable involvement of phytoplankton to the total organic production.
10. Therefore, the present study will undoubtedly furnish valuable information on the algal flora of Hinganghat region.

6.1.2 Review of Literature:

The Chapter II deals with the Review of Literature of topic concerned. In this the researchers consulted the various literatures available in the various libraries, published research papers, reviews from various literatures. The studies we reviewed were elaborated in the topic concerned.

6.1.3 Materials and Methods:

The Chapter III deals with the Materials and Methods of topic concerned. The samples from four sites were studied. The algal forms were collected by forceps and

brought to laboratory. Some algal forms were stored in laboratory for further investigations and remaining algal forms were used in culturing process. The collected plankton samples were fixed with acidified formaldehyde solution and were labeled for further analysis. The details about, place of water body, time, serial numbers, preservative and collection's name were recorded. For quantitative analysis one drop of sample was taken on clean glass slide and phytoplankton was counted by Lackey's drop count method. Herbarium sheets were prepared. The permanent preparation of slide for morphological study and identification was done by using suitable method. The phytoplankton analyzed was assigned to major groups viz; green algae (Chlorophyceae), blue green algae (Cyanophyceae), diatoms (Bacillariophyceae) and Euglenophyceae. The algal forms were identified with the help of classical works of Cupp, (1943); Prescott, (1954); Desikachary, (1959, 1987); Fritch, (1971), algal monographs and recent literature, available books, flora, research papers etc.

The whole tenure of study divided into periods of three months each i.e. June to August (2011), September to November (2011), December (2011) to February (2012), March to May (2012), June to August (2012), September to November (2012), December (2012) to February (2013), and March to May (2013). Samples of free floating aquatic algae were collected from Vena river of Hinganghat area from four different stations viz. under bridge (SW_1), Kawalghat (SW_2), Smashanbhumi (SW_3), and Shahalangadi (SW_4), by means of plankton net.

The researcher studied the physico-chemical and ecophysiological parameters of Vena river. One Standard methods for collection, preservation, and analysis were adopted, APHA, (1985).

The algal culture obtained from a culture collection and also raised in the laboratory. Bold's basal medium, Bold, (1949); Allen's, and Arnon's medium, Arnon, *et*

al., (1974); and B.G.11 medium were first tried in both solid and liquid forms. The effects of elements on growth of some algae were noticed which includes carbon, oxygen, nitrogen, hydrogen, sulphur, phosphorous, potassium, calcium, magnesium and iron for their successful growth in the culture medium.

All observations were made with Research microscope optics. Used Objectives vertical, horizontal and reading of mechanical stage was taken, and the photomicrographs were taken with the help of MIS (Micrscope Image System).

6.1.4 Observations:

Monthly variation in water temperature (^{0}C), pH, dissolved oxygen (mg/l), Free CO_2 (mg/l), total hardness (mg/l) (Ca and Mg), total alkalinity (mg/l), Phosphates (mg/l) Nitrate (mg/l), and total dissolved salts (ppm) at different stations during study period i.e. June 2011 to May 2013 were depicted in the Table 4.1 to 4.20.

Seasonal value of Physico- Chemical parameters in river Vena like Monsoon, Winter and Summer at stations like SW_1-Under bridge, SW_2-Kawalghat, SW_3-Smashanbhoomi, and SW_4-Shahalangadi during June 2011 to May 2013 were depicted in the Table 4.21 to 4.24.

Spatial variation of the algal genera, and number of taxa found in Vena river in Hinganghat area like genera of Baccilariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae at stations like SW_1-Under bridge (50 genera with 103 taxa), SW_2-Kawalghat,(43 genera with 68 taxa), SW_3- Smashanbhoomi (41 genera with 71 taxa) and SW_4-Shahalangadi (49 genera with 78 taxa) during the study period were depicted in the Table 4.25.

The phytoplankton recorded from study area in Vena river in Hinganghat area during Monsoon (160 taxa), Winter (408 taxa) and Summer (400 taxa) in which

Baccilariophyceae (24 taxa), Chlorophyceae (73 taxa), Cyanophyceae (13 taxa) and Euglenophyceae (8 taxa) were depicted in Table 4.26.

The various genera recorded during exploration of the different sites from the classes like Baccilariophyceae, Chlorophyceae, Cyanophyceae, and Euglenophyceae during the study period were rare in monsoon, minimum in summer and maximum in winter season were depicted in Table 4.27.

In two years of Exploration during study period i.e. June 2011 to May 2013 from the classes like Baccilariophyceae, Chlorophyceae, Cyanophyceae, and Euglenophyceae seasonwise and monthwise were depicted in Table 4.28.

Monthwise exploration of algae at different sites during the study period by considering date, time, temperature, depth of light, and identification of taxa were depicted in the Table 4.29 to 4.36.

Monthwise exploration of Algae at different sites during the study period by considering date, O_2 absorbed, temperature, and pH, and dominant class were depicted in the Table 4.37 to 4.44.

Influence of nutrients on growth of algae for *Chlorococcum, Oscillatoria, Selenastrum,* and *Coelastrum* were studied for Carbon, Nitrogen, Phosphorous, Magnesium, Potassium, Chloride, and Iron were depicted in the Table 4.45 to 4.4.51

The growth of algae like *Chlorococcum humicolumn, Oscillatoria amphibia, Selenastrum, westii* and *Coelastrum spheriecum.*were studied in relation to amount of BG-11 medium (OD) and in modified BG-11 medium employed. These were depicted in Table 4.52 to 4.55.

Brief description of algal forms, and their Photomicrographs were taken. The cultured algae, and beakers showing cultures of algae from study area was briefly illustrated and their photo micrographs were shown in the Plates I to XVI.

6.1.5 Result and Discussion:

6.1.5.1 Monthwise variations in Physicochemical Characteristics:

6.1.5.1.1 Temperature: During the first year of study the minimum temperature was recorded only in the month of December and January onwards there was gradual increase in temperature. The maximum temperature was in the month of May, and it was maintained for a period of three months i.e. April, May, and June and August onwards temperature continues to decrease.

During the second year of study the minimum level of temperature was recorded in December and then in January it rose suddenly by two degree in the month of February and March temperature increased and again rose by four degree in April. In May mercury reached higher level. From June to August there was again fall back. The Months September, and October were recorded as the months of moderate warmth. The similar observations were also recorded by Sawane, (2002) and Khinchi *et al.*, (2011).

The gradual increase in water temperature from January to September was attributed to longer days and increase in the intensity of solar radiations. Similarly, the decreases in temperature from September to December were due to decrease in length of days and in the intensity of solar radiations. Munawar, (1970), and Harshey, *et al.*, (1982) reported a direct relationship between water temperature, and intensity of solar radiation. Sahu, *et al.*, (1995) noted the lowest temperature at 6 am and highest at 3 pm, which was in accordance with changes in air temperatures. The relationship between air and water temperature shows diurnal variation at different places differently.

Maximum and minimum temperature recorded for all the sites of Vena river were distinctly different during the study period. The reasons possibly lie in urbanization of Hinganghat, air pollution, discharge of textile mills, sugar factory, and oil refineries, and cement concrete buildings which were responsible for increase in radiation heat in atmosphere. All together was facilitated the higher temperature throughout the year.

6.1.5.1.2 pH: Findings of Vena river confirmed the fact that, all the Indian rivers were slightly alkaline. The recorded pH values for first year of study minimum value in the month of May and maximum in the month of August. The similar observations were also recorded by Narain and Chauhan., (2000) and also by Bandela *et al.,* (1998) and Khalique, (1995). The observed pH range appears to be narrow shows similarity with record of Sabata and Nayar, (1995). The water of Vena river was slightly acidic in the month of May, the findings coincides with slightly acidic conditions of Bramhaputra, Ganga, Hoogly, Kshipra and Yamuna recorded previously.

During the first year of study pH varied within the range of 6.69 - 8.7. The increase and decrease in pH is directly related to water temperature. The findings correlated with the findings of Sahu *et al.,* (1995), Sreenivasan, (1964) and Vyas and Kumar, (1968).

During the second year of study the lowest pH value 6.1 in the month of June and the maximum value of 10.8 was recorded during August. It was correlated with the findings of Tripathi and Pandey, (1990), Blum, (1957), Singh, (1960), and. Venketeswarlu, (1969a). Low pH in the month of June attributed to temperature condition stimulating the early summer as was recorded by Rice, (1938). However acidic nature of water during January, and February was not explained on the basis of work done by earlier workers.

6.1.5.1.3 Dissolved Oxygen (DO): In the first year of study dissolved oxygen value was lowest in August, and the highest in June. At SW_1. While other stations showed lowest in August and highest in February. In the month of August dissolved oxygen decreased because of higher water temperature. As solubility of oxygen decrease with increase in temperature was reported by Sabata and Nayar, (1995). Similarly, increase in dissolved oxygen is obviously related to decrease in temperature as was recorded for the month of February.

During second year of study all the four stations showed uniform changes in dissolved oxygen throughout the year. The present results correlate with the findings of Bansal, (1989), Mohanta and Patra, (2000), Khinchi *et al.*, (2011). The maximum values of that the solubility of dissolved oxygen increases with the decrease in water temperature. This observations recorded by Arvind Kumar and Singh, (2002) showed similarity with present results.

6.1.5.1.4 Free Corbon Dioxide: During first year of study maximum free CO_2 concentration was found in August and the total absence was reported in the month of June for all the stations. The wide range of fluctuation was related to the growth of phytoplankton and algae. The wide fluctuations in CO_2 concentration was explained easily when we take into consideration the periodic water release from Rama Dam, of Wadgaon, Nagpur District.

During second year of study the maximum free CO_2 concentration was 418 mg/l reported in the months of March and April, and the total absence of free CO_2 was observed during the months of June for all the stations. The wide range of fluctuation may be related to growth of phytoplanktons and algae.

6.1.5.1.5 Total Hardness: Calcium plays very important role in metabolism and growth of flora of ecosystem. It directly affects the pH, and carbonate content of the system.

During first year of study, highest calcium concentration were reported in the month of April then there was drastic change from May and from June onwards, the concentrations were found to rise consistently with some monthly variations. These findings may correlate with the reports of Sreenivasan *et al.,* (1974); Tripathi and Pandey, (1990), and Salodia, (1996). The minimum value which was recorded in the month of May was not even surprising as periodically water being released from Rama Dam, Wadgaon of Nagpur Disrict. The samples were preserved just after the river was flooded by Dam water. The correlation between increase in Calcium hardness, and its pollution status has been shown by Prasad and Saxena, (1980).

During second year of study the highest values of Calcium concentration for the stations were different in various months. The minimum values for Calcium ion concentration in February and April. Month wise fluctuations in Calcium concentrations were much drastic. No correlation was observed between calcium ion concentration, and temperature. April, and May were the months of low calcium ion concentration for all the four stations. This could be correlated to the dilution resulted from the release of water from Rama Dam, Wadgaon of Nagpur District. Usually during the month of March water is released from Dam. The calcium values above 25.0 mg/l were considered to be calcium rich (Ohle, 1934). According to this standard water of Vena river was Calcium rich.

Like calcium, Magnesium also affects the algal population. Generally, it was observed that Magnesium concentrations exhibit positive relationship with total phytoplanktons. During first year of study, maximum Magnesium concentrations value in May, and the minimum concentrations of Magnesium in October, and January. The highest values can be easily correlated with the receeding water level during summer.

The lowest value in January can be explained if we take into consideration the periodic water release from Dam.

During second year of study the maximum concentration was in September, and lowest in July.

6.1.5.1.6 Alkalinity: During first year of study alkalinity had a wide range of fluctuations. The present finding showed the minimum value of alkalinity in July, and the maximum in September. Robert, (1977) reported that high concentration of sewage results into increase in alkalinity. This contradicts our findings of stations SW_2 were less polluted than stations SW_4, SW_1 and stations SW_3. The possible explanation lies with the fact that Vena river receives effluents from textile industries at stations SW_4, SW_1 and SW_3, and may be that the presence of chemicals in the effluents interact with sewage which ultimately reducing the carbonates, and bicarbonates in the water.

During second year of study alkalinity showed wide range of fluctuations. The minimum values in July and the maximum values in September. From the above findings it was clear that alkalinity during the months of June, July, and August were remained at lower magnitude, due to heavy rainfall leading to dilute ionic content of the water body (Bisop, 1973: Ray, *et al.,* 1966; Pahwa and Mehrotra, 1966, and Singh *et al.*, 1999). While, it swing to maximum in the months of September. However, during the present study periods alkalinity sharply dropped in the months of March, and May due to release of water from Dam. High alkalinity values were the indicators of eutrophic nature of water bodies. Philipose, (1960) suggested that water bodies with alkaline values more than 100 mg/l were nutritionally rich. By this standard in some months of the water of Vena river was oligotrophic

6.1.5.1.7 Phosphate: During the first year of study the highest concentration of phosphates in April, and lowest in November except SW_1 in May. Thus, the water

showed much fluctuation in the phosphate level. The higher concentrations of phosphates can be attributed to the pollutants that were poured in Vena river, the above findings correlated with the reports of Welch, (1952) and Hutchinson, (1957). The season-wise changes in phosphate concentrations were reported by Gonzalves and Joshi, (1946), Singh, (1960), and Zafar, (1966). There was sudden decrease in phosphate concentration in May which can be attributed to the release of water from Dam.

During the Second year of study the maximum concentrations was noted in April and lowest during November. Our finding showed similarity with reports of Sabata and Nayar, (1995) and not agree with the reports of Ganpati, (1960)

6.1.5.1.8 Nitrate: It appears that during entire study showed quite low concentration of nitrates. During the first year of study the highest concentration of nitrate was in August and lowest in September. All the stations were showed variations within this range only. The highest concentration in the month of August has been earlier observed after the onset of rains by Prasad and Saxena, (1980).

During the second year of study the highest concentration nitrate was in January and the lowest value of nitrate concentratation in March. Therefore, it was appeared that factors contributing to concentrations of nitrates were not clearly understood. However, our findings support the view that organic pollution was the cause of higher nitrates.

6.1.5.1.9 Total Dissolved Salts (TDS): In the first year of study the highest concentration of Total Dissolved Salts in June and the lowest values were found in November. From the months of November onwards increase in TDS was observed up to the month of April. Whereas in the months of May the values decreased because of water was released from Dam. In the month of June, the TDS concentrations was reported the highest which immediately was brought down to half during the months of

July by heavy rains. From the months of July to October, the fluctuations observed were in accordance with the rainfall received during the respective months. The minimum values of TDS during the months of November were again decreased because of the water release from Dam.

During the second year of study highest values in June, and the minimum values in November. The values showed a very narrow but steady range of increase in values from the months of November to April. In the months of May, values decrease due to water released from Dam and in June, concentrations was highest which became half during the months of July due to heavy rains. During the months of July to October, fluctuations were reported because of variations in rainfall during these months. The minimum values of TDS were also observed in the months of November again may be because of water release from Dam.

6.1.5.2 **Seasonal values of Physico-chemical parameters:** In the present research study maximum water temperature recorded during summer and minimum during winter season. Maximum pH was recorded during summer and minimum during monsoon season. Maximum Total hardness was recorded during summer season. However, low values during rainy season attributed to dilution on account of heavy precipitation. Maximum value of Total Alkalinity was recorded during summer & minimum during monsoon season. The maxium D.O. was recorded during winter moderate during monsoon, and low during summer. The maximum concentration of phosphate was recorded in summer, and minimum in winter season. Most of the parameter were maximum in summer because of high temperature, high evaporation, and low water level and minimum in winter due to increased water level.

6.1.5.3 Exploration of Algae: The algal flora of the Vena river in Hinganghat area comprised 118 taxa belonging to 61 genera, and was described systematically. The

taxonomic analysis revealed that the phytoplankton of the study area belonged to four classes, The classes of algae represented are Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae, Chlorophyceae (green algae) was the major group comprised of 73 taxa (61.86%) belonging to 32 genera. Bacillariophyceae (diatoms) was represented by 24 taxa (20.33%) belonging to 15 genera, Euglenophyceae represented by 8 taxa (6.77%) belonging to 3 genera and Cyanophyceae (blue green algae) represented by 13 taxa (11.01%) belonging to 11 genera were found in the study area.

Three seasons viz. summer, monsoon and winter were taken into account for analysis. It has been observed that the number of phytoplanktons were maximum during winter (408 taxon) followed by summer (400 taxon), and lowest during monsoon (160 taxon).

The number of phytoplanktons recorded were analysed by considering stations like SW_1, SW_2, SW_3, and SW_4. The maximum taxa were recorded from SW_1 (104), followed by SW_4 (79), SW_3 (72), and lowest SW_2 (68). The maximum genera were recorded from SW_1 (51), followed by SW_4 (50), SW_3 (43), and lowest SW_2 (42)

6.1.5.4 Influence of nutrients on growth of algae: Carbon is constituents of all organic compound of protoplasm. The growth of *Chlorococum humicolum* and *Selenastrum wastii* were maximum in 2.26 mg/l as equal to carbon in basal medium and growth of *Oscillatoria amphibian* and *Coelastrum spharicum* were obtained in 2.00 mg/l. The influence of N on algal growth in test experiments, the range of 200-400 mg/l as against normal Nitrogen 247.48 mg/l in BG-11 medium. The maximum growth of *Chlorococcum sp, Oscillatoria sp., Seleanstrum sp.,* and *Coelastrum sp.* were 300 mg/l. Phosphate range were from 4.00 mg/l to 128 mg/l. The maximum growth of *Oscilatoria sp* and *Selenastrum sp* were observed at 7.1 mg/l equal to phosphate and maximum

growth of *Chlorococcum sp.,* and *Coelastrum sp.* were observed at the concentration of 16 mg/l.

The maximum growth of *Oscillatoria amphibian* obtained at the concentration of 8.00 mg/l. equal to Magnesium and maximum growth of *Chloroccocum sp* were at 64 mg/l. Elevating the sodium level increase the growth rate. The potassium required for all algae under deficient condition. It is major element in algae. The maximum growth of *Chlorococcum sp* at 8.00 mg/l to concentration of sulphur in basal medium and *Selenastrum sp* at 9.7 mg/l concentration. In the experiment, chloride with the range of 4.00 - 129.00 mg/l, the growth of *Chlorococcum sp.,* and *Coelastrum sp.* were maximum at 32.00 mg/l *Oscillatoria amphibian* showed maximum growth at 16.00 mg/l. The range at 0.2 mg/l and 16.00 mg/l against 1.2 mg/l iron in BG-11, maximum growth of *Oscillatoria sp.* and *Selenstrum sp* were the same in basal medium and 2.00 mg/l for *Chloroceocum sp.* The concentration of citric acid were 6.00 mg/l in BG-11 medium and the range were 3.00 - 64.00 mg/l. The maximum growth of *Chloroccocum sp* and *Oscillatoria sp* and *Selenastrum sp* in these concentration. The normal concentration of EDTA in medium were 1 mg/l and the range in experiment were 1.00 - 12.00 mg/l.

6.2 Conclusions:

6.2.1 Physicochemical Characteristics in relation to phytoplanktons studied:

From the above result and discussion it has been observed that the number of phytoplanktons were maximum during winter (408 taxon) followed by summer (400 taxon) and lowest during monsoon (160 taxon) it may be due to the minimum temperature in winter and January onwards there was gradual increase in temperature decreases the number of phytoplanktons. The maximum temperature was in summer because of the number of phytoplanktons retain moderate. During monsoon temperature

continued to decrease in the number of phytoplanktons. The similar findings were also recorded by Sawane, (2002) and Khinchi *et al.*, (2011).

It has been found that the number of maximum taxa of phytoplanktons recorded from SW_1 (104). It may be due to minimum temperature, and as temperature there is decrease in number of taxa as observed in followed by SW_4 (79), SW_3 (72), and lowest SW_2 (68). The maximum genera were recorded from SW_1 (51), followed by SW_4 (50), SW_3 (43), and lowest SW_2 (42) it may be due to maximum and minimum temperature recorded for all the sites of Vena river were distinctly different during the study period.

From above result and discussion it has been concluded that the number of phytoplanktons were maximum during winter (408 taxon) followed by summer (400 taxon) and lowest during monsoon (160 taxon) it may be due to the minimum pH values during winter favoured the growth of phytoplanktons and maximum during monsoon which decreases the number of phytoplanktons. The increase and decrease in pH is directly related to water temperature. It is observed that the pH was highest in the monsoon decreases the number of phytoplanktons while lowest pH in winter resulted increase in the number of phytoplanktons The similar observations were also recorded by Narain, and Chauhan,(2000) and also by Bandela *et al.,* (1998) and Khalique.,(1995).

It has been observed that the number of phytoplanktons recorded were maximum in SW_1 (104), it may be due to lower pH value and as pH value increases there is decrease in the number of phytoplanktons as observed in SW_4 (79), SW_3 (72), and lowest SW_2 (68). The maximum genera were recorded from SW_1 (51), followed by SW_4 (50), SW_3 (43), and lowest SW_2 (42).

From above result and discussion it has been concluded that the number of phytoplanktons were maximum during winter (408 taxon) followed by summer (400 taxon) and lowest during monsoon (160 taxon) it may be due to dissolved oxygen value

was lowest in monsoon, moderate in summer, and highest in winter. As water temperature increases there is decrease in dissolved oxygen.

It has been found that the number of phytoplanktons recorded were maximum in SW_1 (104), it may be due to highest dissolved oxygen value, and as dissolved oxygen value decreases there is decrease in the number of phytoplanktons as observed in SW_4 (79), SW_3 (72), and lowest SW_2 (68). The maximum genera were recorded from SW_1 (51), followed by SW_4 (50), SW_3 (43), and lowest SW_2 (42).

It has been drawn conclusion that the number of phytoplanktons were maximum during winter (408 taxon) followed by summer (400 taxon), and lowest during monsoon (160 taxon) as to maximum free CO_2 concentration was found in monsoon followed by summer and minimum in winter.

It has been observed that the number of phytoplanktons recorded were maximum in SW_1 (104), it may be due to lowest value of free CO_2 and as free CO_2 value increases there is decrease in the number of phytoplanktons as observed in SW_4 (79), SW_3 (72), and lowest SW_2 (68). The maximum genera were recorded from SW_1 (51), followed by SW_4 (50), SW_3 (43), and lowest SW_2 (42). The wide range of fluctuation may be related to growth of phytoplanktons, and algae.

It has been concluded that the number of phytoplanktons were maximum during winter (408 taxon) followed by summer (400 taxon), and lowest during monsoon (160 taxon) as to highest calcium concentration were reported in summer shows moderate number of phytoplanktons then there was drastic increase in calcium concentration in monsoon results in decrease in number of phytoplanktons further decrease in calcium concentration increases the number of phytoplanktonsifrom in winter. There was no correlation was found between calcium ion concentration and temperature.

It has been observed that the number of phytoplanktons recorded were maximum in SW_1 (104), it may be due to lowest value of calcium. As concentration of calcium value increases there is decrease in the number of phytoplanktons as observed in SW_4 (79), SW_3 (72), and lowest SW_2 (68). The maximum genera were recorded from SW_1 (51), followed by SW_4 (50), SW_3 (43), and lowest SW_2 (42). The wide range of fluctuation may be related to growth of phytoplanktons and algae.

In present investigation it was observed that Magnesium concentrations exhibit positive relationship with total phytoplanktons.

It has been proved that the number of phytoplanktons were maximum during winter (408 taxon) followed by summer (400 taxon) and lowest during monsoon (160 taxon) it may be due to minimum value of alkalinity in early monsoon initiates the unfavourable condition for the growth of phytoplanktons and the maximum at the end of monsoon initiate the most favourable condition for the growth of phytoplanktons. It is cleared that alkalinity during the months of June, July, and August were remaind at lower magnitude, because of heavy rainfall leading to dilute ionic content of the water body leading to decrease in number of phytoplanktons.

The number of phytoplanktons recorded were maximum in SW_1 (104), as a result of highest value of alkalinity. As alkalinity value decreases there is decrease in the number of phytoplanktons as observed in SW_4 (79), SW_3 (72), and lowest SW_2 (68). The maximum genera were recorded from SW_1 (51), followed by SW_4 (50), SW_3 (43), and lowest SW_2 (42).

It has been concluded that the number of phytoplanktons were maximum during winter (408 taxon) followed by summer (400 taxon), and lowest during monsoon (160 taxon) due to highest concentration of phosphates was during summer and lowest in winter. As the highest concentration made moderate condition for growth of

phytoplanktons, lowest phosphate concentration made most favourable condition for the growth of phytoplanktons while moderate phosphate concentration made lowest growth of phytoplanktons.

The number of phytoplanktons recorded were maximum in SW_1 (104), it may be due to lowest concentration of phosphate. As phosphate values increases there is decrease in the number of phytoplanktons as observed in SW_4 (79), SW_3 (72), and lowest SW_2 (68). The maximum genera were recorded from SW_1 (51), followed by SW_4 (50), SW_3 (43), and lowest SW_2 (42).

The number of phytoplanktons were maximum during winter (408 taxon) followed by summer (400 taxon), and lowest during monsoon (160 taxon) it may be due to highest concentration of nitrate was in the beginning of monsoon, and lowest in the initiation of winter season. Lower nitrate concentration favours the growth of phytoplanktons while higher nitrate concentration decreases the growth of phytoplanktons.

It has been concluded that the number of phytoplanktons recorded were maximum in SW_1 (104), because of lowest concentration of nitrate. As nitrate values increases there is decrease in the number of phytoplanktons as observed in SW_4 (79), SW_3 (72), and lowest SW_2 (68). The maximum genera were recorded from SW_1 (51), followed by SW_4 (50), SW_3 (43), and lowest SW_2 (42).

From above result and discussion it has been concluded that the number of phytoplanktons were maximum during winter (408 taxon) followed by summer (400 taxon), and lowest during monsoon (160 taxon) it may be due to the highest concentration of Total Dissolved Salts in the beginning of monsoon, and the lowest values were found in the middle of winter. It may be indicated that highest concentration of Total Dissolved Salts makes the condition unfavourable for the growth

of phytoplanktons. As concentration of TDS becames lower the growth of phytoplanktons were luxuriant.

The number of phytoplanktons recorded were maximum in SW_1 (104), it may be due to lowest concentration of Total Dissolved Salts. As Total Dissolved Salts values increases there is decrease in the number of phytoplanktons as observed in SW_4 (79), SW_3 (72), and lowest SW_2 (68). The maximum genera were recorded from SW_1 (51), followed by SW_4 (50), SW_3 (43), and lowest SW_2 (42).

The analysis of water provided the indication of the chemical quality of the Vena river Hinganghat area. The water temperature during the period of study fluctuated from 20.6^0C to 35.2^0C. The temperature showed significant negative correlation with DO. The pH of water ranged from 6.69 to 8.7. and 6.1 to 10.8 during the June 2011 to May 2012 and June 2012 to May 2013 respectively. The dissolved oxygen varied between 2.01 mg/L and 35.44 mg/l, free CO2 from 8.8 to 572 mg/l, the total alkalinity between 19.66 mg/l and 131.4 mg/l, the total hardness from 6.41 mg/l to 140.28 mg/l, the phosphate between 0.23 mg/l and 11.25 mg/l, the nitrate between 0.01 mg/l and 0.42 mg/l and total dissolved salts between 0.17 mg/l and 0.98 mg/l during the present investigation. The DO showed significant positive correlation with desmids, total Chlorophyceae, and number of taxa,

6.2.2 Exploration of Algae:

The following major conclusions are derived from the investigation. The algal flora of the Vena river in Hinganghat area comprised 118 taxa belong to 61 genera and described systematically. The taxonomic analysis revealed that the phytoplankton of the study area belong to four classes, The classes of algae represented such as Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae, Chlorophyceae (green algae) was the major group comprised 73 taxa (61.86%) belong to 32 genera.

Bacillariophyceae (diatoms) represented by 24 taxa (20.33%) belong to 15 genera, Euglenophyceae represented by 8 taxa (6.77%) to 3 genera and Cyanophyceae (blue green algae) by 13 taxa (11.01%) to 11 genera were found in the study area.

Three seasons viz. summer, monsoon and winter were considered for analysis. It is observed that the number of phytoplanktons were maximum during winter (408 taxon) followed by summer (400 taxon) and lowest during monsoon (160 taxon).

The number of phytoplanktons recorded are analysed by considering stations like SW_1, SW_2, SW_3, and SW_4. The maximum taxa were recorded from SW_1 (104), followed by SW_4 (79), SW_3 (72), and lowest in SW_2 (68). The maximum genera were recorded from SW_1 (51), followed by SW_4 (50), SW_3 (43), and lowest in SW_2 (42).

6.2.3 Effect of nutrients on growth of algae:

Carbon is one of the major constituents of all organic compound protoplasm. The growth of *Chlorococum humicolum* and *Selenastrum wastii* were maximum in 2.26 mg/l as equal to carbon in basal medium and growth of *Oscillatoria amphibian* and *Coelastrum spharicum* were obtained in 2.00 mg/l. The influence of N on algal growth in test experiments, the range of 200-400 mg/l as against normal Nitrogen 247.48 mg/l in BG-11 medium. The maximum growth of *Chlorococum sp. Oscillatoria sp., Seleanstrum sp,* and *Coelastrum sp* were 300 mg/l. Phosphates range were from 4.00 mg/l to 128 mg/l. The maximum growth of *Oscilatoria sp* and *Selenastrum sp* were observed at 7.1 mg/l equal to phosphate, and maximum growth of *Chlorococcum sp* and *Coelastrum sp* were found at the concentration of 16 mg/l.

The maximum growth of *Oscillatoria amphibian* obtained at the concentration of 8.00 mg/l. equal to Magnesium, and maximum growth of *Chloroccocum sp* were at 64 mg/l. Elevating the sodium level increases the growth rate. The potassium requires

for all algae under deficient condition. It is major element in algae. The maximum growth of *Chlorococcum sp* at 8.00 mg/l to concentration of sulphur in basal medium, and *Selenastrum sp* at 9.7 mg/l concentration. In the experiment, chloride with the range of 4.00 - 129.00 mg/l, the growth of *Chlorocaum sp* and *Coelastrum sp* were maximum at 32.00 mg/l *Oscillatoria amphibian* showed maximum growth at 16.00 mg/l. The range at 0.2 mg/l and 16.00 mg/l against 1.2 mg/l iron in BG-11, maximum growth of *Oscillatoria sp.* and *Selenstrum sp* were same in basal medium and 2.00 mg/l for *Chloroceocum sp.* The concentration of citric acid were 6.00 mg/l in BG-11 medium and the range were 3.00 - 64.00 mg/l. The maximum growth of *Chloroccocum sp* and *Oscillatoria sp* and *Selenastrum sp* in these concentration. The normal concentration of EDTA in medium were 1 mg/l and the range in experiment were 1.00 -12.00 mg/l.

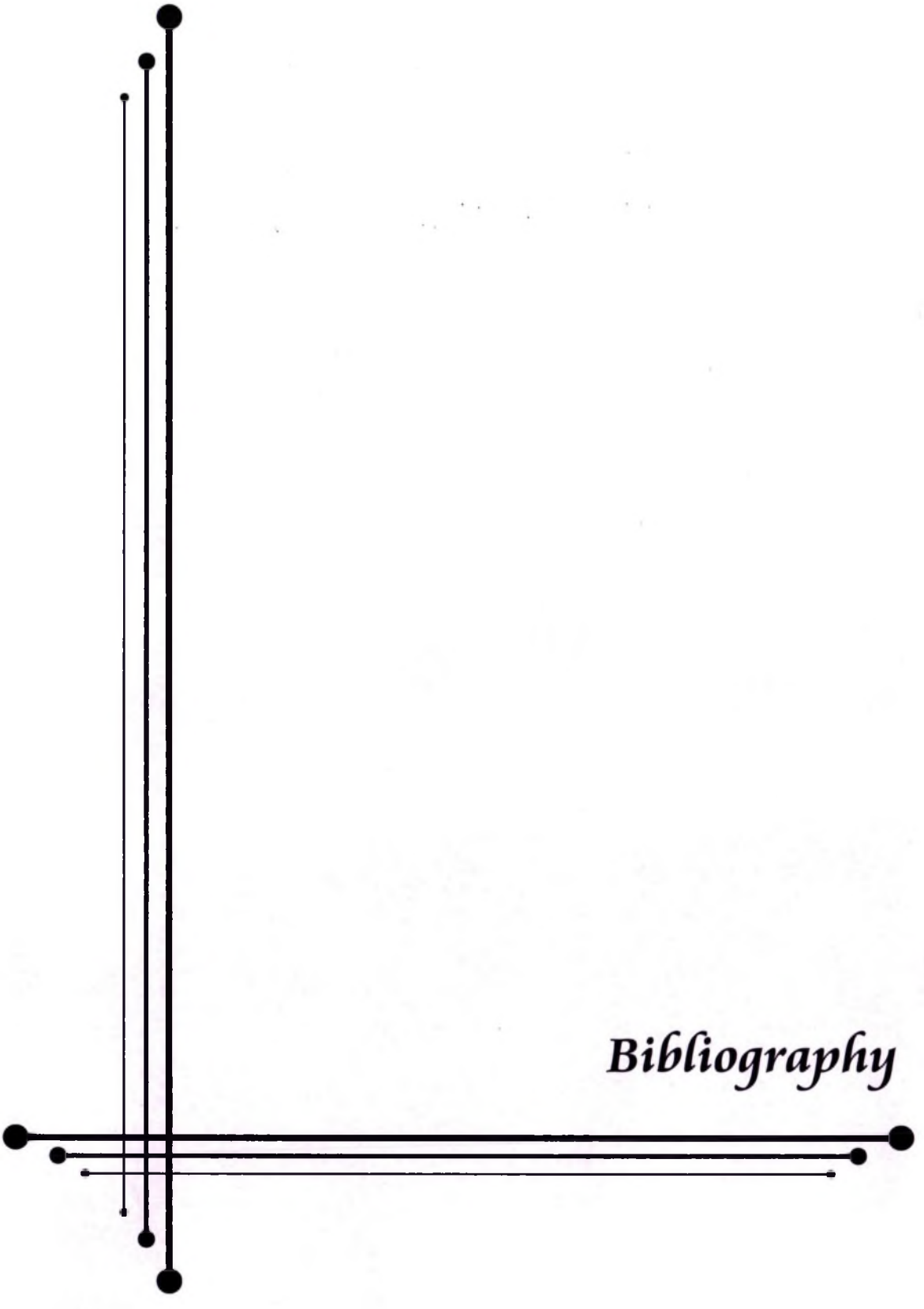
6.3 Implications:

This investigation enable the people to give attention to river Vena, as it was received little attention from botanists, ecologists and specially phycologist as such and moreover, the scientific approach was not holistic. Even in dealing with the floristic pattern, habitats of various algal groups were overlooked. This study of the algal flora of the Vena river is of great importance because an algal biodiversity can be known to the peoples and may be the heritage of future generation. Hence, it is a need of an hour to know each and every thing of this plant world. The present studies provide information to understand quality of water to every person who makes use of it. As the water of Vena river is mainly used for agriculture and to some extent for drinking purposes of wild animals and human beings.

The study provides the information about discharge of sewage into Vena River without any treatment and also makes the people alert about water whether it is suitable for drinking and domestic purpose or not. Similarly, the sewage of effluents of

several cotton mills is discharged into Vena river without any treatment. The study gathers the information regarding the diversity of freshwater algae in the Vena river of Hinganghat area of Wardha district up to the species level. The study is found useful to evaluate the seasonal and spatial variation of algal flora and to assess the relative abundance of algae in the study area.

The study is helpful to compare the physico-chemical aspects of water in relation of the diversity of algae of the Vena river in Hinganghat area of Wardha district.



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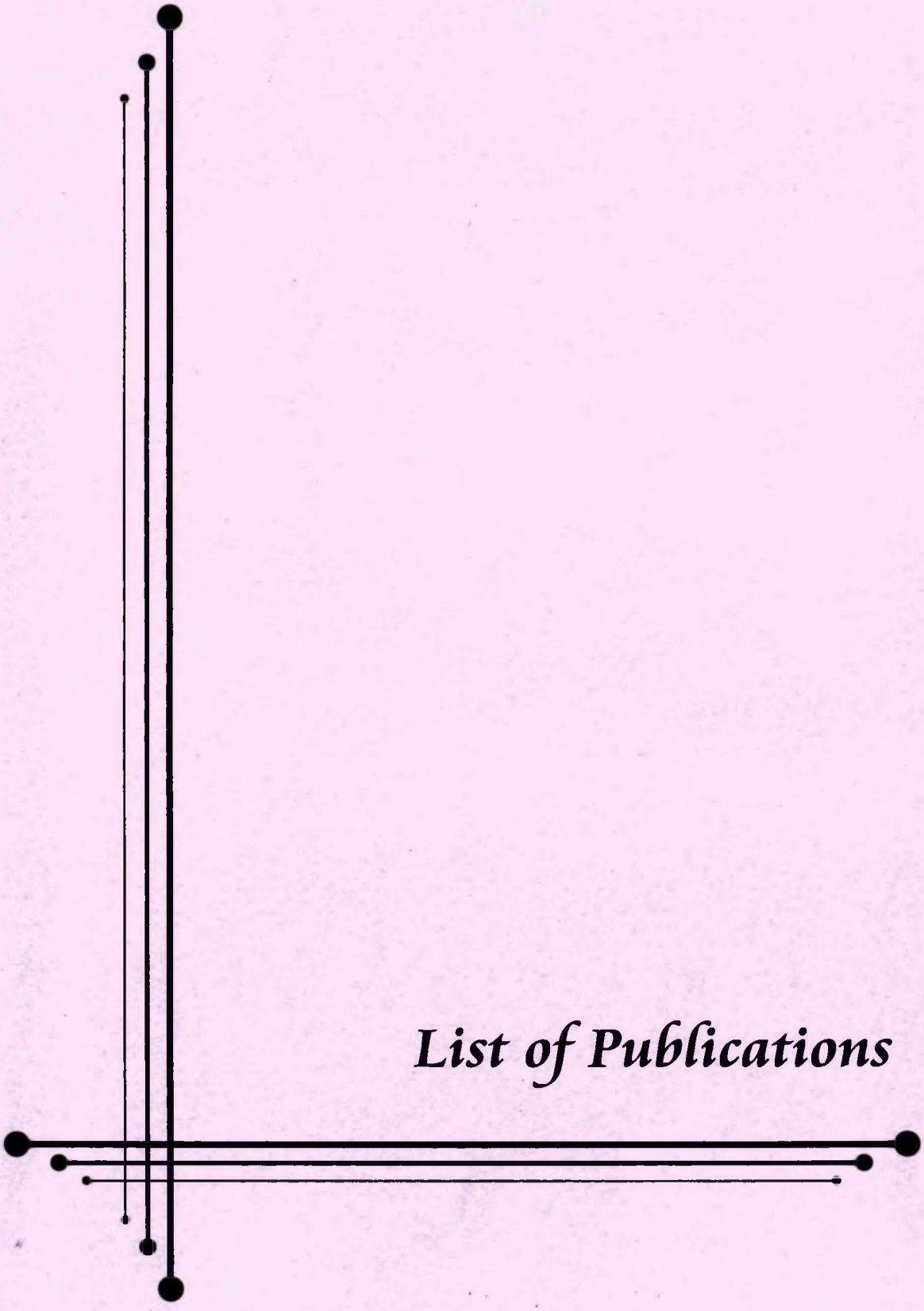

List of Publications

PUBLICATIONS

Rajurkar, B.M. and L.P. Dalal 2014. Fresh Water Algae from Vena River Hinganghat Dist. Wardha Maharashtra, India. *IOSR Journal of Pharmacy and Biological Sciences (IOSR-JPBS)* e-ISSN: 2278-3008, p-ISSN: 2319-7676. **9(3,I):**99-104. (*I.F. 1.138*).

Rajurkar, B.M. and L.P. Dalal 2014. Ecophysiological studies of some fresh water samples from Vena river of Hinganghat area of Wardha District, Maharashtra, India. *International Journal of Advanced Scientific and Technical Research (IJAST)* e-ISSN: 2249-9954, **4(4):**130-138. (*I.F.2.94*).

Rajurkar, B.M. and L.P. Dalal 2015. Physico-Chemical Characteristics of Vena River in Hinganghat Area of Wardha District. *International Journal of Science and Research (IJSR)* e-ISSN: 2319-7064. **4(2):**959-967. (*I. F. 4. 438*).