INTRODUCTION

The planet earth along with its living organisms and the atmosphere which sustains life forms the biosphere. There is a constant interaction between various individuals of its own species as well as other members of the community including microbes, plants, animals and man.

Environmental pollution may be described as an unfavourable alterations in our own surrounding that occur due to human activities. Rapid industrialization and urbanization have resulted into a steady deterioration of the air and water quality.

Pollution must have started at the time when man began to use the natural resources of the environment for his own benefit. In the early days of man's existence the amount of waste was small and could be disposed of locally but on establishment of larger human settlement and towns the disposal began to cause an obvious pollution of land and water streams. With the advent of industrialization in the nineteenth century and the development of modern technology when complex manufacturing processes and plants were developed; they added a large amount of solid, liquid and gaseous wastes in the environment. The problem of environmental pollution is more severe in developing countries like India because of limited economic and technological resources than other developed countries.
The pollution affects air, water and land. The effect of land pollution is varied and may range from chemical contamination to the physical disfigurement as well as the aesthetic degradation. There are various factors which are responsible for the soil pollution.

1) Industrial and urban wastes
2) Agricultural practices
3) Radioactive agents
4) Biological agents

Disposal of the industrial wastes (effluents) are the main sources of soil pollution. The contribution of chemical industries to the human welfare is evident by the range of chemicals used in drugs, cosmetics, paints etc., which are of either organic or inorganic origin. Other sources include the commercial and the domestic wastes including the dried sludge.

Perusal of the periodic table of elements reveals that some 84 of the currently known elements can be regarded as metals although the distinction between metals and non metals is not always a sharp one (Vouk, 1979). One of the commonest definitions of heavy metals is a metal with a density greater than 5g/cm³ (Passow et al., 1961). Trace elements are so called as they are normally present at very low concentrations in most parts of the biosphere and they include metals which are essential nutrients and metalloids which are toxic. Wood (1974) has classified metals as non critical toxic and very toxic elements.
Excessive levels of trace metals may occur naturally as a result of normal geological phenomenon such as ore formation, weathering of rocks, leaching etc., but a considerable amount is due to man's activities like the burning of the fossil fuels, mining, smelting, agriculture and domestic wastes which are made available to the environment. These metals become involved in complex biogeochemical reactions. The ultimate destination of these metals is the sediments. Metals are not usually removed rapidly nor are they readily detoxified by metabolic activities. In contrast to the herbicides these heavy metals do not undergo any degradation and remain in the sediments where they accumulate.

These metals enter the food chain as they are taken up by the producers from the soil, water and substratum in general. The metals then get incorporated to the higher trophic levels on consumption (Paul and Pillai, 1983, Ajmal et al., 1985). Sources of heavy metals are the naturally occurring geochemical materials. There are also other sources of heavy metals. They may be present in the street dust [Harrison (1979), Fergusson et al., (1980), Crump et al., (1980)] or in water (Jana & Choudhary, 1980, Nath & Nath, 1990). Bisoi et al., (1992), reported a combination of metals from the settlements around the steel plant of Rourkella. Heavy metals are of particular interest because of their use as micronutrients at low concentrations and their toxic effects at higher concentrations.
Many metals including some heavy metals like copper, zinc etc., are required by living organisms for their various metabolic processes (Whitton & Say, 1975). Valee & Ulmer (1972) considered the physiological and toxicological effects of metals as a biology continuum. According to Singh & Rai (1989), all metals are found in 3 states-

1) The deficiency state in which the biological activity of organisms may be limited because of deficiency of an essential element (nutrient).

2) The functional state at which there is restoration of biological activities leading to an optimum.

3) The state which is the toxic state where a higher concentration causes a detrimental effect.

Most of the heavy metals are found in the environment as an inorganic cation or as complexed species, origin of which may be due to weathering, leaching and various anthropogenic sources. Forstner & Whitmann (1979), have listed some of the sources of heavy metals. These are globally weathering, industrial processing of ores and metals, leaching of metals from solid wastes dumps and garbage and regular use of metals and metal containing items.
ALGAE AS INDICATOR OF POLLUTION

Algae are the lowest groups of plants which are primary producers in the soil and aquatic ecosystems. The role of some myxophytes or cyanophytes as nitrogen fixers is now very well documented. (De and Sulaiman, 1950, Okuda & Yamaguchi, 1956, De & Mandal, 1956) explained the importance of these nitrogen fixers in increasing the fertility of the rice fields.

Heavy metals are considered as serious contaminants of aquatic and soil eco-system due to an extended biological half life, inherent toxic nature at low concentrations and a high rate of bioaccumulation. Algae have been widely reported to accumulate heavy metals to a dangerous extent in metal contaminated localities. There are several workers who have reported a tendency of algae to concentrate metals within a living system (Fitzgerald & Faust, 1963, Laube et al., 1979, Pande et al., 1981). Different field studies have revealed a varied response of these metals to the algal population. There may be a decline in the tolerant forms while a total disappearance may occur of the less tolerant or susceptible species. The algal forms occurring in the polluted sites may become the indicators, if their occurrence correspond to the concentration of polluting metal species.

It is therefore, necessary to know the range of tolerance of these species to each metal. Those which can survive even in the presence of particular metal are the tolerant species while those which fail to do so are the sensitive species.
Harding and Whitton (1976), Say et al., (1977), Foster (1982a) have reported several algal forms which were either tolerant or resistant species. Stokes (1983) has postulated that algae appearing in the metal contaminated sites would either be metal tolerant or metal resistant species. Takamura et al. (1989) have reported the effects of Cu, Cd and Zn on 118 benthic algal strains. There are several reviews which deal with toxic effects of metal pollution to algae (Davies, 1983, Stokes, 1983, Whitton, 1983, Nyholm, 1993).

Heavy metal induced physiological and biochemical changes have been cited in a number of instances. Blinn et al. (1977), have reported the inhibition of $^{14}$CO$_2$ uptake by green algae due to Cadmium, while Sharda (1989) has reported a decrease in the chlorophyll content, heterocyst frequency of Anabaena oryzae due to zinc and mercury. Nickel was found to be toxic to Chlorella at concentration >4mg/ml (Wong & Wong 1990).

Copper, though an important micronutrient has been used as an algicide to control the algal bloom, the concentrations of which may be between 110-660 mg/ml of Cu (Courchene & Chapman, 1975). Copper Sulphate and stabilized copper are responsible for the entry of copper in the environment. Although some reports of Copper tolerance to various algal species have been reported (Stokes et al., 1973a, Stokes, 1981). On the other hand, there are several reports on the deleterious effects on algae. Copper has proved to be toxic to some marine
phytoplanktons even at a concentration of 17 & 30 ng/ml of Cu (Ibragim & Patin, 1975, Goering et al., 1977). Takamura et al. (1990) have reported an inhibition on the growth of some algal species.

The lead discharge in the environment is due to storage batteries, smelting and mining processes. A large amount of the metal is added by the vehicular exhaust to the environment. Lead is found to be of regular use, thus resulting in its accumulation in an environment from where it enters in the food chain. Gunale et al (1992) have reported a deleterious effect of the metal to plant, animals including the man. The effect of lead on algal growth has been well documented. An inhibition in growth of 34% in *Scenedesmus sps* and 24% in *Ankistrodesmus sps* due to lead was observed (Monahan, 1976). Trehar & Maneesha (1991) have reported an inhibition in nitrogenase activity in *Nostoc muscorum* due to lead.

Chromium is an important micronutrient required for the fat and carbohydrate metabolism (Sethi, Sethi & Iqbal, 1991). Hexavalent forms of Chromium are more toxic to both plants and animals. Chromium is dangerous as it accumulates in the living organisms. Some aquatic algae have been reported to concentrate 4000 times above the levels of their permissible limit of chromium in drinking water as recommended by W.H.O. i.e. 0.05 mg/litre. Wium & Anderson (1974) have shown that though Chromium affected *Chlorella pyrenoidosa* like copper, the latter was 100 times more toxic. Rai & Raizada (1988)
studied the biochemical effects of chromium toxicity and the regulatory mechanism on *Nostoc muscorum*.

Cadmium is a normal constituent of the soil. The main sources of the metal in the atmosphere are the mining activities, electroplating, sewage sludge, phosphate rocks etc. The metal is dangerous as many plants and animals absorb this metal and accumulate within their tissues. In 1955 Cadmium accumulation in rice and soyabean caused cadmium poisoning in Northern Japan. This was characterised by extreme lumbago, skeletal collapse, bone porosity apparently due to bone repair mechanism. The disease was called as "Itai Itai" due to the pain associated with it. Cadmium accumulation within the algal cells resulting into the alteration in their physiology has been reported a number of times. The green alga *Chlorella pyrenoidosa* accumulates cadmium from the surrounding medium which gets fixed to high molecular weight protein (Sorentino, 1979), Shiger *et al.* (1990) indicated the bioaccumulation of cadmium within *Chlorella Vulgaris* where in a concentration above 25 mg/L caused a total death of the cells.

A number of metals are known to show synergistic effects on algal cells. Visvik and Rachlin (1991) showed a deleterious effect of interaction of copper and cadmium on a marine alga *Dunaliela minuta*, when exposed to both acute and chronic levels. Jindal and Verma (1991) reported the synergistic effects of copper and cadmium, copper and lead, copper and nickel on the primary production of
the fresh water pond of Chandigarh where the synergism with cadmium showed a more toxic effect.

Ahmedabad is an important megacity in western India which houses several processing industries, a coal based thermal power station and more than a thousand small scale industries. Apart from these, there are copper smelters, electroplating industries and paint industries. Most of these release untreated effluents into the water body. These effluents contain large amount of heavy metals apart from various toxic chemicals. Of course, these industries have been instructed to give primary treatment to the effluents before discharging by Gujarat High Court.

The city of Ahmedabad has been rated to have the maximum number of two wheelers plying on the roads. More than 15,000 vehicles consume 54,000 litres of petrol per day. This further contributes to various air borne heavy metals like lead, zinc, cadmium etc. polluting the air which we breathe.

These heavy metals which are either air or water borne settle down onto the sediments and these are available for bioaccumulation by various trophic levels. With this in view, the present study was undertaken to investigate the effects of cadmium, chromium, copper and lead salts on the soil algal flora from an area which is devoid of these metal pollutants. Ten different sites of different locations of Gujarat University Campus were chosen (see the map).
A commonly occurring algal form *Microcystis robusta* was isolated to maintain an axenic culture. Various metabolic changes were studied when various concentrations of above mentioned metal salts were incorporated in the culture media.