SUMMARY AND CONCLUSION
Air pollution monitoring has gained innumerous importance in an industrial town Bhadravthi which had two large-scale industries and number of small scale industries. In view of this, Ambient Air Quality Monitoring was carried out for the years 2006-07 and 2007-08 using High volume air sampler APM-410 and 411 to know the status of ambient air quality in Bhadravathi town. During the study, five sampling sites were selected; Site-1 (Hosmane), Site-2 (New colony), Site-3 (Rangappa circle), Site-4 (Maruthi Nagar near MPM industry) and Site-5 (Paper town) representing residential, sensitive, commercial, industrial and industrial cum residential zones respectively to know the concentration of three primary air pollutants viz., SPM, SO₂ and NOₓ. The obtained results were then compared with the concentration of air pollutants at control site (Kuvempu University campus, Shankaraghatta).

Meteorological parameters were studied during the study period. The temperature was maximum during the summer season while, the minimum was found during the winter season. On the other hand, the relative humidity was found to be high during rainy season followed by winter and summer seasons. Maximum rainfall was observed during the months of July and August for the years 2006-07 and 2007-08 respectively. Wind rose diagrams for the study period showed that the predominant wind directions are NE, SW and NW. The wind speed was found to be maximum during the winter season followed by rainy and summer seasons.
By 24 hours continuous air quality monitoring it is found that, the concentration of SPM was very high at site-3 and site-4 although it hasn’t crossed the threshold limits. On the other hand, the concentration of \( \text{SO}_2 \) and \( \text{NO}_x \) were well within the limit prescribed by CPCB at all the sampling sites. Moreover, it is evident from the study that, the concentrations of all the air pollutants at all the sampling sites were comparatively higher than at control site.

The SPM concentration ranged from 13.60 to 328 \( \mu \text{gm/m}^3 \) while, the \( \text{SO}_2 \) concentration was below detectable level to 22.50 \( \mu \text{gm/m}^3 \) and \( \text{NO}_x \) concentration ranged from below detectable level to 30.00 \( \mu \text{gm/m}^3 \) at study area.

The seasonal concentrations of air pollutants were found to be highest during winter followed by summer and rainy seasons through out the study period.

Air Quality Index calculated for the obtained concentrations of air pollutants witnessed sites 1, 2 and 5 had clean air while, at site-3 the AQI value is closer to the moderately polluted category. Among the five sampling sites, ambient air quality at site-4 was poorer and rated as moderately polluted area and as per the obtained AQI values the air pollution had the increasing order of Site-2< Site-1< Site-5 < Site-3 < Site-4.

The effect of air pollution on vegetation in the study area was evaluated by determining the pH, chlorophyll content, water content and ascorbic acid in the leaf extracts of eight selected plants. Eight plants include four trees and four shrubs; \textit{Polyalthia longifolia}, \textit{Mangifera indica}, \textit{Pongamia pinnata}, \textit{Acacia auriculiformis}, \textit{Calatropis procera}, \textit{Nerium indicum}, \textit{Chromalena odorata} and \textit{Lantana camara}.

Chlorophyll contents, relative water content and ascorbic acid have showed decreasing tendency in their concentration from that of plants in control area to the sampling sites at study area. On the other hand, pH of the leaf extracts showed mixed
response by showing increasing tendency in a couple of plant species. However, the tested plants have showed varied response to the air pollutant concentration at different sampling sites.

Among the eight selected plants, *A. auriculiformis* ranked as most tolerant while, *C. procera* was found to be sensitive by having least Air Pollution Tolerance Index. All the tested plants showed increasing sensitivity to increasing air pollution from site to site. The tolerance ranking in the study area holds the order of *A. auriculiformis* > *L. camara* > *M. indica* > *P. longifolia* > *P. pinnata* > *N. indicum* > *C. odorata* > *C. procera*.

Lichens are known to be very sensitive to air pollution. During recent years a number of different species of lichens have been found (species richness) and the presence of indicator species has been studied to characterize regional air quality impact on lichen populations.

The lichens monitoring was done in the present study to know their sensitivity by adopting the European guideline. As per the guidance, the lichens were monitored at five selected sampling sites where the air pollution monitoring was done and the diversity values were compared with that of lichen diversity values at control site.

Totally nine genera were identified belonging to epiphytic lichens and the obtained lichen diversity indices showed varied response correlating with deteriorating air quality from site to site. Lichen species of the genus *Pyxine* was dominated with high LDV and rated as tolerant to air pollution while, lichen species belonging to genus *Ramalina* was rated as sensitive to air pollution among the nine genera.

From the present study, it is evident that the air pollution scenario pertaining to the SPM concentration in the town is reached alarming stage at a couple of sites. On the
other hand concentration of SO$_2$ and NO$_x$ were well within the limit though they have showed comparatively higher value than the control site. The obtained results are directly attributed to the emissions from two large scale industries (MPM and VISP) and other small scale industries in the study area. On the other hand, the poor roads, automobiles, heavy tonnage vehicles have worsening the situation. Thus there is a need for combating air pollution in the study area by proper management planning in Bhadravathi and surrounding areas.

The varied concentration of air pollutants during the summer, winter and rainy seasons is directly attributed to the variation in meteorological parameters such as temperature, relative humidity, precipitation, wind direction and wind speed. On the other hand the concentrations of air pollutants are maximum during the winter season accredited to the thermal inversions due to fall in temperature during the winter nights.

Obtained results regarding to the effect of air pollution on vegetation showed significant correlation with the concentration of air pollutants at respective sampling sites. It is suggestible that the resistant plants manifest in the investigation can be employed in abatement of air pollution. They can be grown in and around the industries and road side to reduce the pollutants in air. Secondary benefits can be derived from them, as some of them have medicinal importance and yield edible fruits. *P.pinnata* seeds will be made use in the production of bio-fuel as well.

The present investigation gives a strong evidence that the vegetation of the town were affected by the air pollution and the study further provides information about the extent of effect of air pollution on vegetation in the study area.
Moreover, a relationship has been between the lichen community existing at sampling sites and degree of air pollution. The absence of naturally appearing lichen in severely polluted areas limits the spatial differences of polluted areas.

Lichens are especially sensitive to air pollutants because they have no outer impermeable layer of tissue to exclude gases and particles that impair their metabolism. Consequently, accumulation of pollutants is greater than it is in the foliage of vascular plants, which have impermeable cuticles. Lichens accumulate unusually large amounts of deposits, including heavy metals, which eventually reach toxic concentrations. Lichens are therefore, excellent bio-indicators and bio-monitors. As bio-indicators, the presence/absence of sensitive species is used to look for distribution patterns that reflect pollutant deposition. Zones based on epiphytic lichen vegetation provide a better indication of air pollution intensity than distribution maps of particular species. Hence, documentation of the lichen species at the study area will be of greater importance in future.

The only effective policy response to air pollution problems in Bhadravthi town is to reduce pollution at source, through a cutback in demand, energy conservation measures; fuel-switching and technical pollution controls. The biological impacts of pollution outlined constitute a serious problem for biodiversity in the study area. They are another, compelling, reason for reducing pollution at source. This needs to be achieved through an array of different strategies, including technical pollution controls.
RECOMMENDATIONS

Strategic management plans to mitigate air pollution

An Environ Management Plan (EMP) should be delineated during regional environmental impact assessment studies indicating the actions required to be undertaken by the industries and the feedback on implementation of EMP should be taken.

Control options

Point sources

Technology means for air pollution controls from point sources are numerous, varied and can be tailored as per the requirements of an industrial unit. The air environment management plan recommended for the industries include:

- Cleaner technology options
- Cleaner fuel options
- Dispersion
- Change in operational schedules to utilize air assimilative capacity
- Reduction in particulate matter emissions by proper storage loading and unloading and carrying out batch operations in enclosed sheds of VISP.
- Reduction in particulate matter emissions from Kraft, soda, limekiln, chemical and dissolver tank vents processes.
Different types of control systems, such as multicyclones, fabric filter and wet scrubbers, Electro Static Precipitators (ESP), Mechanical collector etc., can be used for reducing the air pollutants.

The objective is to first estimate the quantum of the likely emissions of the major pollutants SPM, SO₂ and NOₓ which are emitted due to the combustion of fuels, used at different sources and then make recommendations on technological interventions for air pollution control to reduce these emissions. Emissions from each industry vary from one another greatly with respect to characteristic and quantity in relation to production capacity of the plant, type of fuel used, type and complexity of the processes employed, air pollution control measures in use and degree of maintenance in force and therefore, each industry needs specific attention towards air pollution control management.

Two major air polluting industries are located in Bhadravthi town which significantly influence the air quality in the study area. The main sources of air pollution are blast furnaces, steel melting shop, sintering plant, power house, coke oven, coal and ore handling plant, boilers and furnaces.

**Line sources**

Vehicles contribute a whole range of air pollutants. Diesel vehicles mainly emit smoke, SO₂ and NOₓ. The quantity of pollutants emitted by the vehicles is directly proportional to the number of vehicles plying on the road. The intensity of pollution potential depends on several contributory factors, such as geographical locations, inadequate and ill maintained roads as well as heavy tonnage vehicles plying on the roads, unplanned traffic management, meteorological and climatic conditions and non
availability of adequate emissions control technology and therefore requires proper traffic management.

**Area sources**

Area sources emissions (domestic sources) were estimated for different areas on per capita basis and average value of domestic emission rate is considered.

**Environment Auditing**

The industries in the town have to submit the environmental audit report to the authorities every year, mandatory. Audit of an air quality monitoring is to be performed on a regular basis by an audit team. Audit is to be performed in two parts. Technical system auditing is a qualitative on-site evaluation of a measurement system and allows assessment and documentation of all facilities, equipments systems, record keepings, data validations, operations, maintenance, calibration procedures, reporting requirements and quality control procedures. While, performance audit is a quantitative evaluation of the measurement system which involved measuring or analyzing a reference material that is associated with a known value or composition.

**Vehicular Emission Standards**

The mass emission norms for vehicles at manufacturing stage as well as in use have been notified and constantly revised (1991, 1996, 1998 and 2000). Euro – I norms for vehicles were notified in 1997 and it has now become mandatory for all the vehicles throughout India. The Euro –III norms are mandatory in Metropolitan cities. The quality of diesel and gasoline with respect to environment related parameters have been notified
in April 1996. The specifications include use of low leaded gasoline, unleaded gasoline and low sulfur diesel (CPCB / NAAQMS/14/1999 -2000).

A standing vehicle with its engine switched on emits higher smoke level than a vehicle running on the road. Hence more of red lights and traffic jam means more pollution. So greater emphasis may be given for effective traffic management. Aged vehicles may be replaced in phased manner.

Alternate Fuel Options

Bio-diesel is a renewable fuel produced mainly from vegetables oils and fats. The oil extracted from seeds of *P.pinnata* and *J.curcas* may be extensively used instead of diesel.

Air pollution modeling

Uses of air pollution models for evaluation of air pollution control strategies, short period predictions and warnings.

Dispersion from tall stacks

The use of very tall tacks has increased during the past few years. Many new stacks discharge effluents at height of more than 200m above ground level. Also, such stacks are usually designed to accommodate large volumes of effluents normally at high temperatures.
Thus the effective emission heights for these stacks frequently are as high as 400m. The transport and dispersion characteristics of the atmosphere at these heights are frequently different from those observed near ground level.

Air flow at elevations of a few hundred meters is not influenced as much by mechanical and thermal features of the ground surface and changes in atmosphere stability frequency occur at these elevations. Therefore dispersion models for regions having very tall stacks should be modified to account for the dispersion of plumes at elevations of several hundred meters.

Air pollution meteorologist

Air pollution meteorologist plays an important role in the development of contingency plans for stagnation periods and in describing the fate of pollutants in the atmosphere.

Zonation of areas

Proper zonation of the areas in the study area is needed.
SUGGESTIONS FOR FUTURE STUDY

- The interaction between noise and air pollution in Bhadravthi town.

- Health effects due to air pollution in the town.

- Development of Air quality models.

- Air quality monitoring with respect to Respirable Suspended Particulate Matter (RSPM).

- Effect of extent of air pollution on vegetation can be monitored by selecting more number of plants.

- Mapping of lichens and interpretation with air pollution.