RESULTS AND DISCUSSION

4.1. Population Distribution

The population of Pudukkottai has increased substantially over the years (Fig 3.1). In 1901 the total population in Pudukkottai town was around 20,347, it increased up to 28,776 in 1931. But 2001 population was 1,01,723, it had increased up to 1,08,341 in 2005. Population stabilization is an essential pre-requisite for sustainable human and social development with more equitable distribution. This rapid growth is mainly due to the urbanization.

4.2. Air Quality Status in Pudukkottai

The air quality has been determined with reference to SPM, SO$_2$ and NO$_2$ at selected places in Pudukkottai for four seasons separately and the results are presented in figures 4.1a to 4.9g.

4.2.1. Suspended Particulate Matter

Of all the four zones, commercial zone was found to have the highest SPM concentration. Commercial zone in “Urban Pudukkottai” exceeded the NAAQS (National Ambient Air Quality Standards). The prescribed level is 500mg/m$^3$ for industrial zone and 200 for residential /other zones. Commercial areas cannot be considered as industrial zone; even if considered, the SPM value in commercial zone of urban Pudukkottai exceeded the value prescribed for industrial zone.

The SPM values in commercial zone of suburban Pudukkottai were above 300mg/m$^3$ which were also in excess than the prescribed level for residential /other zone.

Of the four seasons, season IV (March –April) was found to have the maximum concentration of SPM and season I with minimum concentration in commercial area of urban Pudukkottai. Whereas, there were only slight variation in SPM concentration among the seasons in “Suburban Commercial”. As the March and April being the dry period (summer), the soil particles become loosened and wind-borne. Hence there was an increase in SPM in season IV. SPM concentration in industrial zone in all the seasons did not exceed the standard. It suggests that the industrial activities are not intense to pollute the environment in Pudukkottai.
SPM concentration in residential zone during all the seasons, both in urban and suburban did not exceed the standard.

In sensitive zone the SPM concentration exceeded the standard in all the seasons.

Quite surprisingly, the SPM concentration was found to be slightly higher in suburban areas of residential and sensitive zones. Wind-blown dust from open space and “kutcha” road in suburban areas may be attributed to this.

Based on statistical analysis the following conclusions have been arrived for SPM.

1. The SPM values among various zones during season I (June-July) didnot differ significantly.
2. The SPM values among various zones in all other seasons differ significantly (Table 4.1).

4.2.2. Sulphur di Oxide

Of all the four zones, commercial zone was found to have the highest SO₂ concentration. Commercial zone in ‘Urban Pudukkottai” exceeded the NAAQS. The prescribed level is 120mg/m³ for industrial zone, 80 mg/m³ for residential and 30 mg/m³ for sensitive zones. Commercial areas cannot be considered as industrial zone; even if considered, the SO₂ value in commercial zone of urban Pudukkottai exceeded the value prescribed for industrial zone.

The SO₂ values in commercial zone of suburban Pudukkottai did not exceeded the prescribed level.

SO₂ concentration in Industrial zone in all the seasons did not exceed the standard. It suggests that the industrial activities are not intense to pollute the environment in Pudukkottai.

SO₂ concentration in residential zone during all the seasons both in urban and suburban did not exceed the standard.
In sensitive zone, the SO\textsubscript{2} concentration exceeded the standard in all the seasons.

Quite a few number of shops, medium and small hotels are present in this area. Emission from these shops can be attributed to the presence of SO\textsubscript{2} in this area.

Night time SO\textsubscript{2} values were generally found to be higher than that of other times.

Statistical analysis revealed that SO\textsubscript{2} concentration did not differ significantly among the different zones (Table 4.2).

### 4.2.3. Nitrogen Oxides

Of all the four zones commercial zone was found to have the highest NO\textsubscript{2} concentration. Commercial zone in ‘Urban Pudukkottai’ exceeded the NAAQS. The prescribed level is 120 mg/m\textsuperscript{3} for industrial zone, 80 mg/m\textsuperscript{3} for residential and 30 mg/m\textsuperscript{3} for sensitive zone. Commercial areas cannot be considered as industrial zone; even if considered, the NO\textsubscript{2} value in commercial zone urban Pudukkottai exceeded the value prescribed for industrial zone.

The NO\textsubscript{2} values in commercial zone of suburban Pudukkottai did not exceeded the prescribed level. The results showed that there was no variation in NO\textsubscript{2} concentration among seasons.

Commercial zone is a busy area with number of medium to heavy vehicles. This can be attributed to the excessive nitrogen oxides in this area.

NO\textsubscript{2} concentration in industrial zone in all the seasons did not exceed the standard. It suggests that the industrial activities are not intense to pollute the environment in Pudukkottai.

NO\textsubscript{2} concentration in residential zone during all the seasons both in urban and suburban did not exceed the standard.

In sensitive zone, the NO\textsubscript{2} values exceeded the standard value in all the seasons in urban area and only in season II and III in suburban areas.
Statistical analysis reveals that NO₂ concentration varied significantly between urban and suburban areas. From the air quality determination it is found that SPM, SO₂ and NO₂ exceeded the standard in commercial zone and in sensitive zone (Table 4.3). It reveals that the urban growth has adverse effects on air quality of Pudukkottai.

4.3. Noise Assessment in Pudukkottai

Noise levels were observed for commercial zone, residential zone and silence zone in Pudukkottai for day time and night time separately on working days, holidays and festival days separately. From the observations Leq, L₅₀, L₉₀, Lmin and Lmax were computed and the results are presented in figures 4.10a to 4.16c.

- In all the zones, the noise levels were always higher in Urban Pudukkottai than that of sub urban Pudukkottai.
- On holidays, the Leq values exceeded the standard both during day and night times in all the zones in “Urban Pudukkottai”. Leq exceeded the standard in sub urban Pudukkottai at residential and commercial zones in day time and at commercial zone in night time.
- Of three zones the highest Leq values were found in commercial zone during holidays. This suggests that the commercial activities take place in commercial zone even during holidays.
- On working days, the Leq exceeded the standard on all the zones both during day and night times both in urban and suburban areas. It suggests that the day-to-day activities in these places contribute to high noise levels.
- On festival days, the Leq noise levels exceeded the standard in all the zones both during daytime and night time and both in urban and suburban Pudukkottai.
- Interestingly in all the zones, both during day and night times the Leq values were the lowest on holidays and the highest on festival days. They are in the following order. Leq on Holidays<Leq on working days< Leq on Festival days.
This suggests that the people generate more noise during the occasion of festivals. Loud speakers, crackers, musical display etc. on festival days could contribute additional noise to the existing background noise levels during festival celebration.

Statistical analysis (ANOVA) carried out to compare the Leq values among various zones of urban and sub urban Pudukkottai revealed that the Leq values vary significantly (Table 4.4a to 4.4c). This could be attributed to variation in intensity of activities etc.

From the above results, it is concluded that the urban growth certainly increased the noise levels in Pudukkottai. That is the urbanization of Pudukkottai have adverse environment impact due to noise pollution.

4.4. Water Quality in Pudukkottai

4.4.1. Ground Water Status

Ground water samples were collected during three seasons viz season I Monsoon (June – Sep), season II North east monsoon (Oct – Jan) and season III Pre monsoon (Feb – May). From selected places and analysed for physio–chemical characters. The results are presented in figures 4.17a to 4.37c.

**pH**

The standard for pH is 7.0 to 8.5. All the samples from both urban and suburban places had the pH values within the prescribed level there was a slight increase in commercial zone during season II and season III. In general the pH was low during season I (Monsoon) when compared with other season. The results further reveal that, the samples from urban zone in all the places had slightly high pH. During Northeast monsoon period (season I), the pH of ground water slightly increased. This may be due to the seepage of ions that increase the pH.

**EC**

EC values ranged from 0.7 mmho cm$^{-1}$ to 1.3 mmho cm$^{-1}$ in samples of urban area and 0.69 to 1.1mmho cm$^{-1}$ in samples of sub urban area. The results revealed that that EC is high in urban commercial zone and low in suburban commercial zone.
This may be due to street runoff from various shops. Of the three seasons, season-II (North east Monsoon) recorded high value and recorded low value in season I (Monsoon) of urban samples. This may be due to the dissolution of ions while rain water infiltrated. No seasonal change was observed in suburban samples.

**Temperature**

The temperature of the samples ranged from 27 to 29.5°C. Temperature of samples collected from suburban areas of all zones seem to have slightly higher temperature. The samples collected in season III-Premonsoon season (Feb-May) had the highest temperatures. As this season is summer, the water samples also had the maximum temperature.

**Turbidity**

Turbidity in all the samples were well below the prescribed limit of 5 NTUs. Of the seasonal variations, the turbidity of urban samples were high in season II (Northeast Monsoon) and no seasonal change was observed in suburban samples.

**TSS**

In Season III (Pre monsoon) high TSS values were observed in urban residential zone and silence zone. The presence of TSS in water bodies indicates contamination either by sewage or some industrial waste.

**Total Dissolved Solids**

The results showed that urban commercial zone had high TDS and sub urban sensitive zone had less TDS. The standard for total dissolved solids is 500mg/l. All the samples in the study conducted were having TDS concentration below the permissible limit.

Samples of season I (Monsoon) had high value and samples of season III (Pre Monsoon) had less in urban area. In sub urban samples there was no seasonal change.

**Total Solids**

The results showed that urban commercial zone had high TS and urban sensitive zone had less TS. Samples of season II (Northeast Monsoon) had high solids.
**Total Hardness**

300mg/l is the standard value for total hardness as CaCO₃. The water samples from urban areas ranged from 139.6 to 184.7 mg/l. Whereas in suburban areas it ranged from 121 to 146mg/l. Results further revealed that season II (Northeast Monsoon) had less hardness in urban samples. During northeast monsoon, Tamilnadu receives its maximum rainfall. The dilution effect of rainwater maybe attributed for low hardness during North-east monsoon season.

In all the zones, the hardness values were higher in urban areas. The percolation of water contaminants with hardness-causing substances as wastes from urban areas may be attributed for this. These substances may include, wasted drugs/medicines, lime etc. However, the total hardness did not exceed the standard in any of the samples.

**Calcium**

The result showed that calcium was high in urban commercial zone and low in sub urban sensitive zone. The calcium content ranged from 79.9 mg/l to 96.7 mg/l in urban areas and 75 mg/l to 88.8 mg/l in suburban areas. Of all the seasons, season I (Monsoon) had high calcium and season II (North-east Monsoon) had low value. This seasonal variation may be due to change in the amount of the percolation of washing and bathing waste water to the ground water.

**Magnesium**

Magnesium ranged from 55.8 to 93.2 in urban areas and 46.5 mg/l to 58.3 mg/l in suburban areas. Of the seasons magnesium was less in season II (North-east Monsoon) of urban samples, whereas in sub urban samples there was no seasonal change.

The seasonal variation in total hardness, calcium and magnesium was mainly due to variation in rainfall.

**Alkalinity**

The results showed that alkalinity was high in urban commercial zone and less in urban sensitive zone samples. Of the seasons, season II (North-east Monsoon) had high value and season III (Pre Monsoon) had low value.
This may be due to carbon dioxide and water attacking sedimentary carbonate rocks and dissolving out some of the carbonate to form bicarbonate solution. Most of the natural alkalinity in waters is due to HCO$_3^-$ which is produced by the action of ground water on lime stone. As more water percolates during north-east monsoon, there are chances that more dissolution of carbonates/bicarbonates (Mehta, 2003).

**Acidity**

The results showed that it was high in urban commercial zone and low in urban residential zone. Urban samples had high acidity in season I (Monsoon). This may be due to the percolation of strong minerals acids, weak acids such as carbonic and acetic and hydrolyzing salts such as iron or aluminium sulphates from various type of waste water (Ramakrishnan et al., 1991).

**Dissolved Oxygen**

The DO content ranged from 5.9 mg/l to 6.1 mg/l in urban samples and from 5.1 mg/l to 6.2 mg/l in suburban samples. Of all the seasons, season II (North-east Monsoon) had high DO. DO is an index of physical and biological processes going on in water. In general, the DO values in suburban samples were higher than that in urban samples. In urban areas, seepage of waste water in urban areas into ground water will reduce the DO content. Higher BOD and COD in urban areas also substantiate this.

**Biological Oxygen Demand**

The BOD values were around 1.2 mg/l in urban and 1.18 mg/l in suburban samples. However the BOD observed were well below the prescribed limit. Of the seasons, season II (North-east Monsoon) had less BOD.

**Chemical Oxygen Demand**

In urban samples it ranged from 9.3 mg/l to 10.2 mg/l whereas in suburban areas from 8.7 mg/l to 10.1 mg/l. The results further revealed that it was high in season III (Pre Monsoon) and season I (Monsoon) had less COD. This is an indication of pollution due to chemically oxidisable organic matter in the ground water due to seepage.
Nitrite

Nitrite values were higher in suburban samples in residential and commercial zones while the opposite was noticed in sensitive. Urban sensitive zone had high value and urban residential zone had less value of nitrite. This may be due to variation in the biological action of in the soil.

Nitrate

In general, nitrate was higher in suburban samples in all zones. It was high in season II (North-east Monsoon) and low in season I (Monsoon). The presence of nitrates indicates that the organic matter present in water is fully oxidised and the water is no longer harmful. Use of nitrogen fertilizers may also seep into the ground water to increase the nitrate content.

Chloride

It ranged from 23.1 mg/l to 27.9 mg/l. In urban samples it is high in season II (North-east Monsoon). This may be due to overland flow from various sources. Sewage contains more amount of chloride due to the fact that salt consumed in food is excreted by body.

Fluoride

In urban samples it was high in season II (North-east Monsoon), where as in season I (Monsoon) sub urban samples had high value. This may be due to the presence of fluoroapatite in water naturally associated with phosphate deposits. Fluoride in all the samples was well below the standard values.

Sulphate

Results showed that sulphate was high in sub urban commercial zone. Of all the three seasons, season II (North-east Monsoon) had high amount of sulphate and season I (Monsoon) had less amount. The sulphate ion is usually second to carbonate as the principal anion in water. This variation might be due to the principal anion present in water. This element can combine with metal and non metals to form many compounds.
E.Coli

E.Coli count ranged from 47 /100ml to 81.6/100ml in urban sample whereas from 36 /100ml to 53 /100ml in suburban samples. Season II (North-east Monsoon) had high E.Coli count in samples and season III (Pre Monsoon) had less count .This might be due to organic waste water pollution during season II. Improper drainage system and improper disposal of house-hold wastes may be attributed for high E.Coli.

Based on the water quality determination of ground water in Pudukkottai, it may be stated that ground water is not polluted except for E.Coli. Hence, it can be concluded that the urbanization of Pudukkottai have not posed any serious threat to the ground water quality.

Statistical analyses revealed that EC, temperature, TDS, Total hardness, DO, BOD, COD, Nitrate and Chloride values of samples did not differ significantly among the various zones while other parameters differed significantly in some seasons (Table 4.5a to 4.5u).

4.4.2. Surface Water Analysis

The results are presented in figures 4.38 to 4.53 .Surface water were collected during three seasons viz monsoon (season I), Northeast monsoon (season II) and premonsoon (season III) from selected places and analysed for physio-chemical characters.

pH

pH value was high in season I(Monsoon) in urban samples. Urban pH value ranged from 8.06 to 8.5.Whereas in suburban areas it ranged from 7.76 to 8.5 pH. There was no seasonal change within sub urban samples.

EC

Urban sample EC value was 1.6 mmho cm⁻¹ and sub urban EC ranged from 1.5 mmho cm⁻¹ to 4.7 mmho cm⁻¹ . It was high in season I (Monsoon) in sub urban samples.
Temperature

Urban samples, temperature ranged from 27°C to 30°C, in sub urban it ranged from 27°C to 30°C. It was high in season III (Pre Monsoon) and low in season I (Monsoon) in urban samples. Variation in water temperature was due to seasonal variation.

Turbidity

It was high in season II (Northeast Monsoon) and low in season I (Monsoon). Urban values ranged from 28NTU to 82NTU. Sub urban values varied from 36NTU to 94NTU. During Northeast monsoon, Tamil Nadu receives the maximum rainfall. Falling raindrops and subsequent runoff would have caused increased turbidity values. Open areas in sub-urban could be attributed to higher turbidity values relativity.

Total Solids

It was high in season II (Northeast Monsoon) and low in season I (Monsoon). Urban sample values ranged from 132mg/l to 346mg/l and suburban values ranged from 144mg/l to 336mg/l. Higher values of TS were observed in pond water, which was probably due to the waste disposal around the pond and dust also mixed with runoff. Rainfall during north-east monsoon and subsequent runoff would have brought more solids (both dissolved and suspended solids) to the water body and hence the high TS values during season II (Northeast monsoon).

Total Hardness

It was high in season III (Pre Monsoon) and less in season I (Monsoon). Urban samples had comparatively higher values such as 24mg/l to 43mg/l. Sub urban values ranged from 22mg/l to 31mg/l. But all samples are within permissible limit according to WHO, ICMR.

Total Alkalinity

It was high in season II (Northeast Monsoon) and low in season I (Monsoon). In urban samples it ranged form 106mg/l to 176mg/l and in sub urban from 114mg/l to 157mg/l. This may be due to runoff, which dissolves the carbonates and bicarbonates from soil/rocks.
Total Acidity

It was high in season I (Monsoon) and low in season III (Pre Monsoon). In urban samples it ranged from 1.8mg/l to 2.1mg/l; in suburban samples ranged from 1.4 mg/l to 2mg/l. This may be due to the percolation of strong minerals acids, weak acids such as carbonic and acetic and hydrolyzing salts such as iron or aluminium sulphates from various type of waste water. But all samples were within permissible limit according to WHO , ICMR.

Dissolved Oxygen

Urban samples values ranged from 6.2mg/l to 6.4mg/l. In sub urban samples it ranged from 5.2 to 6.3 Low DO 5.2mg/l in sub urban sample in season III may due to the waste water pollution. All samples were within prescribed level according to WHO , ICMR.

Biochemical Oxygen Demand

It was high in season I (Monsoon) and low in season II (Northeast Monsoon). Urban values ranged from 3.8 to 4.8mg/l.Sub urban ranged from 4.2 to 4.8mg/l. It was found that all waters had the BOD values within the limit.

Nitrite

It was high in season III (Pre Monsoon) and low in season I (Monsoon) in sub urban samples (2.6mg/l and 2.1mg/l). Whereas in urban samples it was high in season II (Northeast Monsoon) and low in season I (2.8mg/l and 2.2 mg/l). All samples were within permissible limit. Lower nitrite content during all the three seasons may due to biological oxidation of nitrites. But all samples are within permissible limit according to WHO , ICMR.

Total Chloride

There was no difference between urban and sub urban samples (16mg/l to 21.4mg/l). It was high in season III (Premonsoon) and low in season I (Monsoon). Chloride levels in all the samples were well within the permissible limits.

Fluoride

It was high in season II (Northeast Monsoon) and low in season I (Monsoon) in urban samples.
Where as in sub urban samples it was high in season II (Northeast Monsoon) and season III (Pre Monsoon) shows low value .This may be due to the dissolved salts form rocks. All samples slightly exceeded the permissible limit according to WHO, ICMR. High fluoride content is not desirable as it may cause dental/skeletal fluorosis.

**Sulphate**

It was high in season III (Pre Monsoon) and less in season I (Monsoon).The values ranged from 4.6 to 8.2mg/l. Sub urban sample values ranged from 4.9 to 4.2mg/l .Metal and non-metal elements combine to form sulphate ions in the water resource may be the reason for variation in the range (Tonapi,1980).

**Phosphate**

It was high in season III (Pre Monsoon) and low in season II (Northeast Monsoon) in sub urban samples (0.13mg/l and 0.04mg/l); where as in urban samples it was high (0.1mg/l) in season II (Post Monsoon).Phosphate fertilizer dissolved from surface runoff to water resource may be the reason of variation. There is no specific permissible limit for phosphates. Natural waters generally contain total phosphorous compounds less than 0.1mg/l.

**E.Coli**

It was high in season III (Pre Monsoon) and low in season I (Monsoon) in sub urban samples. Sub urban values ranged from 1800 to 3200/100ml, urban values ranged from 2000 to 3000/100ml.Washing and bathing activities of people and animals may be the reason for this high E.Coli.

Statistical analyses revealed that turbidity and BOD values of samples differ significantly among seasons *(Table 4.6a).*

**Planktons**

Plankton study were done in four seasons .It wais high in season I(June-July) and low in season IV(Sep-Oct) .This is mainly due to eutrophication in water bodies.More number of species were available in sub urban water samples(13 species). Within this seven species were Phytoplanktons; six were Zooplanktons but in uraban water samples totally six species were available.
There was no seasonal variation. Phytoplanktons like *Diatoma sp*, *Navicula closterium* were present in all the seasons of both urban and sub urban samples. Zooplanktons like *Filinia*, *Notholea* and *Branchionus quadridentatus* were present in only one season but *Keratella sp* was present in all the four seasons (Table 4.6b and 4.6c).

4.5. Soil Analysis

Soil samples were collected during three seasons viz., monsoon (June-Sep), North-east monsoon (Oct-Jan) and Premonsoon (Feb-May) from selected places and analysed for physico-chemical characters. The results are presented in figure 4.54a to 4.63c.

**pH**

The pH of the samples collected in urban area ranged from 7.72 to 8.4; in suburban area it ranged from 7.74 to 8.6. Season I (Monsoon) showed high pH and season III (Pre monsoon) showed low pH in all the zones. But in sub urban samples there was no seasonal change.

**EC**

A season wise representation result showed that urban commercial zone had high EC value. The samples of the urban areas had EC values ranging from 0.1 mmho cm\(^{-1}\) to 0.3mmho cm\(^{-1}\). In suburban areas the range was 0.19mmho cm\(^{-1}\) to 0.9mmho cm\(^{-1}\). Sub urban values were higher than urban values. Of the three seasons, season III (Pre monsoon) had high EC value and season I (Monsoon) had low value.

This variation might be due to the leaf decomposition. It changes soil pH and EC. Indiscriminate disposal of solid waste, discharges of sewage or waste water on land and use of chemical fertilizers, insecticides and pesticides also maybe the reason for this change during various seasons. The rain water will have dilution effect and hence variation.

**Total Organic Carbon**

The soil samples collected form urban had the organic carbon ranged from 0.3 % to 0.43%, where as in suburban areas the range was from 0.36% to 0.62%.
Season wise results depict that season III (Pre monsoon) had high TOC content in soil and season I (Monsoon) had less content.

This might be due to the high temperature in soil. Due to high temperatures organic carbon couldn’t accumulate. Soil temperature made interaction of soil micro organisms. Strong interaction may be possible between organic and inorganic portion (Anon, 2004).

**Total Organic matter**

Total organic matter values in urban area ranged from 0.68% to 0.9%.In suburban areas it ranged from 0.9% to 1.09%. Among seasons, season III (Pre monsoon) had high total organic matter in soil and season I (Monsoon) had less content.

This may be influenced by the availability of oxygen in the soil. In some cases there occurs strong interaction between the organic and inorganic portions of soil. Nitrogen fertilization and clipping management is also practiced here. This may be influenced to have more organic matter in soil (Badrinath, 1994). Disposal of garbage, street sweeping and market waste at some places may also play a major role in the concentration of total organic matter in these places.

**Total Nitrogen**

The total nitrogen content in the urban sample ranged from 0.81mg/g to 1.7mg/g. In suburban samples it ranged from 0.58 mg/g to 1.78 mg/g. Of all the seasons, season III (Premonsoon) had high nitrogen content and season I (Premonsoon) had low nitrogen content. However in urban commercial zone less nitrogen content in season III (Premonsoon) was noticed.

After rain during North east monsoon, nitrogen fertilizers washed out and reaches to the soil may be the reason for high amount of total nitrogen in the Premonsoon period. In the commercial zone there is no garden or field. This may the reason for less amount of nitrogen. The decay of dead plants (biomass) and animals, plant residues and faeces, urine of animals getting hydrolysed may be also reason for high nitrogen in this soil (Hundal et al., 1988).
Total Phosphorus

The phosphorus content in the urban sample ranged from 0.05 mg/g to 0.06 mg/g whereas in suburban sample, it ranged from 0.05 mg/g to 0.07 mg/g. Of the seasons, season III (Pre monsoon) had high content and season I (Premonsoon) had less phosphorus content.

Usage of phosphate containing detergents, soaps etc. could be the reason for high total phosphorous content at some places.

Total Potassium

Season wise representation results reveal that suburban commercial zone had high potassium content and suburban sensitive zone had less amounts. The potassium content present in the urban samples ranged from 1.1 mg/g to 1.3 mg/g. In suburban sample it ranged from 0.9 mg/g to 1.7 mg/g. Of all the seasons, season III (Pre monsoon) had high potassium and season I (Monsoon) had less potassium.

After rain some soil fungi produce chelating organic acids like citric acid which react with silicate minerals and release potassium. When pesticides undergo photochemical reactions they may also produce more amount of potassium in the soil (Rajamannar, 1994).

Total Sodium

Season wise representation results exhibit that sub urban commercial zone had high value of sodium. Total sodium ranged from 0.03 mg/g to 0.4 mg/g in urban sample and 0.05 mg/g to 1.4 mg/g in suburban sample. Of all seasons the Sodium content did not vary much seasonally in all the places except in sub urban residential zone and urban commercial zone.

Total Calcium

Seasonal representation results exhibit that sub urban residential zone had high calcium content. In urban sample total calcium content ranged from 0.69 mg/g to 1.07 mg/g. Where as in suburban sample it ranged from 0.66 mg/g to 2.3 mg/g. Sub urban soil samples had high calcium content than urban samples. There was no seasonal change in calcium content.
**Total Magnesium**

Total Magnesium in urban sample ranged from 0.5 mg/g to 0.64 mg/g. Whereas in suburban sample it ranged from 0.4 mg/g to 0.63 mg/g. Of all the seasons, season I (Monsoon) had high magnesium content and season III (Pre monsoon) had less magnesium content in soil samples. This slight increase might be due to weathering of rocks, new chemicals introduced for more crop yield (Sharma and Khar, 1995).

Based on the statistical analysis the following observations were made

1. Most of the parameters had high values in Pre monsoon period (season III). Premonsoon season follows the north-east monsoon in Tamil Nadu. The runoff water of rainfall may bring the ions and deposits over soil. This could be the possible reason for higher value of certain parameters.
2. Variations in concentration of certain parameters in sub urban soil samples were noticed after rainy season.
3. Sodium, Calcium, and Magnesium contents were high. NPK was found to be very less in all the urban soil samples.

ANOVA tests reveal that the concentration of many parameters did not vary significantly (Table 4.7a to 4.7j).

From the soil quality, it may be concluded that the urbanization/urban growth in Pudukkottai did not have much adverse impact on soil quality as of now.

### 4.6. Waste Water Characteristics and its Treatment

By the natural formation of the drainage system water pouring due to heavy rain will flow from east to west. The planning of the town has been laid in such a way that water will flow through the open drainage system. This drainage is available on both sides of the streets. To ensure the normal flow these canals are cleaned regularly. The water finally gets collected at the Kattuputhukulam that is on the western part of the town. The composition of the sewage is complex and hence it leads to some toxicity to live stocks. The characteristic feature of the sewage was studied and also simple biological treatment was attempted.
Collected waste water quality was analysed. After the analysis the nutrients were determined. As the waste water is rich in nutrients, the waste water was used for plant growth, as well as for treatment of waste water. Certain unwanted parameters should be brought down before the usage. So the aquatic weed lemna was selected and grown for 25 days for treating the waste water. Results were tabulated every 5 days interval. pH was reduced from 9.11 to 8.55. The determination of pH value of sewage is important due to the fact that certain treatment methods depend on proper pH value of sewage for their efficient working. Electrical conductivity had increased from 1.2 mmho cm$^{-1}$ to 5.2 mmho cm$^{-1}$. Hardness was reduced from 915 mg/l to 415 mg/l. Calcium was reduced from 106.2 mg/l to 4.008 mg/l. Magnesium also reduced from 219.9 mg/l to 99.87 mg/l. Dissolved oxygen has increased from 0 mg/l to 3 mg/l. Sewage has generally no dissolved oxygen. Its presence in the effluent after treatment indicates that considerable oxidation has been accomplished by the sewage treatment by Lemna. COD had decreased from 515.2 mg/l to 420.21 mg/l. BOD decreased from 32.23 mg/l to 30.4 mg/l. Chloride decreased from 303.9 mg/l to 199.98 mg/l. Sulphate decreased from 7 mg/l to 3.5 mg/l. Phosphorous became nil. Iron decreased from 0.98 mg/l to 0.68 mg/l. Nitrate decreased from 108.2 mg/l to 82 mg/l. Potassium decreased from 212 mg/l to 130 mg/l (Tables 4.8 and 4.9).

Thus treated water was used for the growth of Buffalo grass in a separate field. It is having the nature of absorbing more amount of water. It is a type of fodder grass. After the use of water for this fodder grass, the plant sample was also analysed. For the comparison purpose control plant was maintained with bore well water. Leaf length, fresh weight, dry weight, free sugar, phenol and total chlorophyll contents were analysed both in control plant sample and treated plant sample (Figure 4.64a to 4.64f).

**Leaf length**

Control plant leaf length was 7.16 cm. But the treated waste water plant sample had 10.1 cm leaf length.
Fresh weight of plant
Borewell water irrigated grass weight was 0.9mg/g, but waste water treated grass weight was 1.09mg/g.

Dry weight of plant sample
Control plant dry weight is 0.63mg/g, treated plant sample weight was 0.72mg/g.

Free Sugar
The control plant sample contained 0.9% free sugar, but the treated plant tissue had 1.28% of sugar. This may be due to the impact of high nutrient content of waste water.

Phenol
Control plant tissue contained 0.17% of phenol content, but the treated plant tissue had 0.23%.

Total Chlorophyll content
In control plant tissue total chlorophyll content was 82.8%, whereas in waste water treated plant it had increased to 99%.

Positive improvements were seen in treated plant growth. Statistical results revealed that leaf length and dry weight had significance increase (Table 4.10).

4.7. Solid Waste
In Pudukkottai district the total amount of solid waste collected around 45.5 tonnes/day which includes the solid wastes from Pudukkottai town. The town generates about 25 tonnes/day and it comes to be 6,2220.028 tonnes/year. 0.482kg/day was generated per day/person. Solid waste samples were collected from 15 sites consisting of residential, commercial and litter free zones. The samples were brought to the laboratory, sorted out, and analysed to determine their physical composition. The samples from each zone were collected during holidays, working days and festival days separately. Biodegradable wastes were found to be the highest in Zone I (residential zone). Biodegradable waste constituted more than 54% in residential zone. The percentage of biodegradable wastes did not vary much among holidays, working days and festival days in residential zone.
In Commercial zone, biodegradable wastes exceeded 50% during working days reached 52% during festival days and recorded 37.7% during holidays. In Litter free zone (zone III), they were 44.66%during festival days, 41.38% during working days and 39.86% during holidays (Table 4.11).

These results revealed the following

- Biodegradable wastes constitute the major portion of the MSW in Pudukkottai.
- Biodegradable wastes were maximum during festival days and minimum during holidays both in Zone II (commercial zone) and in Zone III (Litter free zone).
- Biodegradable wastes were maximum during holidays and minimum during working days in Zone I (Residential zone).
- Of all the three zones, residential zone recorded the maximum amount of biodegradable wastes.
- Papers and rags were found to be maximum during holidays and festival days in all the three zones.
- In general plastics were found to be maximum during festival days followed by holidays and then by working days.
- Glass wastes were found to be the highest (approximately three times) in Zone III during all the days.
- Other wastes varied differently.

From the above observations, it may be concluded that during holidays and festival days people generate more amounts of plastics and paper wastes. Perhaps, during these occasions, people buy the packed food/articles/items and the removal of wrappers, plastic bags might have contributed them more to MSW in Pudukkottai.

4.7.1. Characteristics of Solid Wastes

Chemical properties of solid waste

Collected solid wastes from residential, commercial and litter free zones were dried and powered for chemical analysis. The results are presented in table 4.
pH

It ranges from 7.06 to 7.22 in working days. 7.06 to 7.24 in holidays. 7.04 to 7.14 in festival days. There is no significance in urban zone (I), (III) samples. But in sub urban zone (II) showed significance in working day and festival day wastes.

Moisture content

Moisture content in the solid waste ranged from 42.6% to 49% in working days. 34% to 49% in holidays. 46.9 to 50% in festival days.

Ash

It ranged from 38.7% to 43% in working days; 38% in holidays collection sample. 36% to 45% in festival days sample.

Organic matter

It ranged from 57% to 61% in working day sample. 48% to 62% in holidays sample. 55% to 64% in festival days sample.

Carbon

It ranged from 34% to 35% in working days; 285 to 36% in holidays; and 32% to 37% in festival days.

Nitrogen

It ranged from 0.8% to 1.3% in working days; 0.6% to 1.2% in holidays; 0.6% to 1.3% in festival days.

C/N

It ranged from 27% to 47% in working days; 26% to 57% in holidays; 29% to 56% in festival days.

4.7.2. Solid Waste Management and Soil Quality Improvement

Biodegradable wastes were subjected for decomposition and bio compost was prepared. The properties of bio compost were analysed. The results are presented in figures 4.65a to 4.66d.
pH

On zero day pH was 6.7, then it had increased up to 6.9 during partial decomposition. On 20th day it declined to pH6.7. Then after that again gradually increased and finally reached the 7.1 pH (On 45th day).

Moisture content

On the zero day moisture percentage was 45%. At the time of decomposition it raised up to 52%.

Temperature

It ranged from 29°C to 27°C. The graph showed the increase and decrease of temperature.

C/N ratio

On the zero day, it was 32%. After the decomposition period it reduced to 15%.

Total solids

It reduced from 60% to 55% during decomposition period.

Volatile Solids

It had reduced from 62% to 58% during decomposition.

Ash content

It had increased from 50% to 60% after decomposition.

4.7.3. Nutrient components in bio compost

Carbon content

It was 26% in the partially decomposed solid waste. Then it reduced to 12.2% in the complete bio compost.
**Sulphate content**

It was 0.02 mg/g in the compost.

**Micro Nutrients**

Calcium increased from 0.4% to 0.5%, magnesium decreased from 0.3% to 0.2%, chlorides increased from 0.5% to 0.9%.

**Macro nutrients**

**NPK** amounts increased substantially in the final compost.

Based on the results during decomposition period pH increased from 6.7 ºC to 7.1 ºC. Temperature decreased from 28 ºC to 27 ºC. C/N ratio, ash, total solids and volatile solids were also decreased.

The bio compost obtained from the solid wastes was used for soil treatment. Bio compost played a major role in the improvement of soil quality and raises the yield of the plant. In this present study, Palmarosa plant were raised using the compost (Block-II). For comparision the Palmarosa plant were raised in control (Block-I). The results are presented in figure 4.67a to 4.70c.

### 4.7.4. Soil treatment with Bio-Compost

After the Palmarosa plant growth in block I the available nitrogen in soil ranged from 94 mg/g to 104 mg/g; in block II it ranged from 97 mg/g to 131 mg/g. Potassium content value ranged from 49 mg/g to 57 mg/g but in block II it ranged from 48 mg/g to 60 mg/g. Phosphate content ranged from 1.3 mg/g to 3.1 mg/g in block I. Whereas in block II it ranged from 1.1 mg/g to 4.2 mg/g. Zinc content ranged from 2.01 mg/g to 2.1 mg/g whereas in block II it ranged from 2.1 mg/g to 2.3 mg/g. Iron content ranged from 7.1 mg/g to 7.6 mg/g in block I whereas in block II it ranged from 7.6 mg/g to 7.9 mg/g. Manganese ranged from 6.5 mg/g to 6.8 mg/g in block I whereas in block II it ranged from 6.8 mg/g to 6.9 mg/g. Copper content ranged from 0.8 mg/g to 0.9 mg/g, whereas in block II it ranged from 0.9 mg/g to 0.95 mg/g. Bacterial content ranged from 40 mg/g to 68 mg/g in block I in block II it was from 40 mg/g to 68 mg/g. Actinomycetes content in soil was ranged
from 28 mg/g to 45mg/g in block I in block II it ranged from 28 mg/g to 45mg/g. This positive increase may be due to the addition of bio compost.

After the first and second harvest the yield also calculated as grass and oil. Palmarosa grass yield ranged from 420Kg to 455Kg at block-I in two harvests. 536 to 618 at block –II in both harvests. Palmarosa oil yield increased from 2.1 to 2.2 kg at block I whereas 2.4 to 3 at block-II in both harvests. This may be attributed to the bio compost. After I and II harvest the treated soil had high nutritive value, increased micro flora as well as better yield. Oil of Palmorosa is one of the most important essential oils of India.

Based on the statistical analysis the following observations were made:

1. After the first harvest macro nutrients N, P, K showed significant increase in the soil.
2. Micro nutrients also increased significantly.
3. Microbial count increased significantly.
4. Palmarosa grass and oil yield significantly increased.

This may be due to the impact of biocompost (Table 4.13 to 4.16).

4.8. Biodiversity

Flora and fauna present in Pudukkottai were observed and recorded for Urban zone and Sub urban zone separately. The total numbers are presented in tables 4.18 to 4.23.

Total numbers of species are comparatively less in urban area. This is mainly due to the anthropogenic disturbance.

**Urban Flora**

*Mollugo verticillata* species is abundant in eastside of the urban area. *Citrullus colocynthis, Morus alba, Hemidesmus indicus, Casuarina equisettifolia, Cucumis sativas* are frequent in Westside of the urban sampling site. *Eucalyptus species* is abundant in north side of the plot. *Musa paradisiaca* is abundant in south side sampling area. But 69 species are in rare condition within 126 species.
Seasonal Variation

*Cyanodon sp, Nelumbo nucifera, Acalipha indica* are frequent in season II (Sep-Oct) in eastside. *Cauarina* is abundant in season IV (Mar-April) in Westside. *Ervattamia coranaria, Bryophyllum, Hibiscus rosasinensis* are frequent in all the four seasons of northside. *Capsicum frustescens* is frequent in all the four seasons of the south side.

Sub urban Flora

*Oryza sativa, Calatropis gigantean, Pistia stratiotes* are abundant in Westside of the suburban area. *Eleucine coracana* is abundant in eastside sampling site. *Eclipta alba, oryza sativa, Tridax procumbens* are abundant in north side. *Phaseolus mungo, Phaseolus radiatus, Solanum melangena* are abundant in south side. But 83 species are rare condition within 172 species.

Seasonal Variation

*Chrysanthimum sp, Coriandram sp, Crossandra sp, Lausonia sp* are frequent in season II (Sep-Oct) in eastside. *Calendula officinalis, Eucalyptus globules, Saccharum sp, Zea maize* are frequent in season IV (Mar-April) in the Westside. *Cymbapogan citrates* is abundant in all the four seasons in the north side.

*Amaranthus blitum and Amaranthus viridis* are frequently present in all the four seasons of southside.

Based on the results suburban sampling area show rich in species. The maximum species occurrence in spring could be attributed to favourable climatic conditions while the prevalence of unfavourable climatic conditions during winter resulted in less floristic richness.

Fauna

The fauna present in residential zone, commercial zone, silence zones are presented in Table 4.24a to 4.25g.

Urban fauna

Insects such as giant water bug, giant water scorpion, small termites are common insects present only in urban sampling area. In the residential zone 21 species occurred. In commercial zone 14 species were observed.
In the industrial zone only 6 species were observed. This may be due to high noise and less flowering plants.

House crow, hen, small sun bird, Indian robin are common birds. This may be due to urbanization. In this urban area most of the plants are destroyed. So that the dependent insects, birds and other animals would have migrated to other places. This study area consists of Hen, House crow that are high in individual count.

This is widely distributed in all zones. In all sampling areas 268 of Hen species were recorded.

**Seasonal Variation in Avifauna**

Season I (June-July) and season IV (March-April) had more number of species.

**Sub urban fauna**

Insects such as paddy bug, plant lice and white termites were present only in sub urban zone. Residential zone sample contained 56 species within that 14 species were butterflies. The highest number of species was observed in this area. In the commercial zone it was observed up to 26 species of insects. In silence zone 12 species of insects were observed. Parrot, Koel and Duck were common sub urban birds. In the residential zone 23 species were observed. In Commercial zone 14 species were observed. In the silence zone 12 species were observed. This may due to the proper maintenance of dense forest near inside the old palace area.

**Seasonal Variation**

Season II (Sep-Oct) and season III (Dec-Jan) had maximum species.

Comparatively urban residential zone had more number of species. Urban sampling recorded 20 different insect orders and more than 56 species were present. But in sub urban sampling area number of species was also more and number of orders was also high.

From the above results, it may be concluded that urbanization certainly limits the number of species greatly. In other words, it may be said that biodiversity loss has occurred due to urbanization in Pudukkottai.
4.9. Socio Economic Status

Socio-economic status of Pudukkottai has been determined by random sampling using questionnaire. The results are presented in figures 4.71 to 4.75.

80% of the families in sub urban area and 60% of the families in urban area had small family size (4 or below).

More interestingly the urban families comprised the people of all ages while the ages between 20 and 30 and 40 and 50 were found to be predominant on sub urban families’ (Table 4.26). The reason for this variation is not known.

25% of the families in urban area and 50% of the families in sub urban area people had education up to bachelor level. 75% of urban family members and 25% of the sub urban people had still higher education (more than P.G. Degree). This may be due to the availability of transport and Institutions in the urban areas (Table 4.27).

90%of the people from sub urban areas are employed and earning less than Rs. 5000 but 7% are earning more than Rs. 5000/- from agriculture and 1% people involved in the family business such as general stores. In the urban area only 50% were employed members. Of this 25% people earn less than Rs. 5000/- and remaining earn more than Rs. 5000/-. The rest 20% people undertake family business such as Jewellery shops, Bakery, Fruit shops, Private bank etc. The rest are unemployed (Table 4.28).

When land use pattern is considered, the sub urban 25% was cultivated area and 75% was left as barren land. But in urban area 100% are utilized by building construction and other facilities such as roads, offices, bus stand etc. In urban residential zone 75% of the families reside in their own houses while others reside in rented houses. This implies that the economical status in reasonably high of Pudukkottai people to own a house. All type of home appliances was used by these people. They use public transport as well as private vehicles.

In sub urban area 90% of the families reside in rented houses and 10% only own their houses. They depend more on public transport. This may also be one of the reasons for less air pollution in sub urban areas.
Municipal water supply facility is available for about 80% of urban population; the remaining 20% depend on common water supply and bore well water. In suburban area municipal water supply facility is available only for 20% of the population. Other people depend on bore well water.

Drinking water supply was regular and sufficient during rainy season. But it was irregular and insufficient during summer in urban areas. It is obvious that in summer season, the availability of water would be scarce. In addition to this, population increases every year and this leads to increasing demand for water which ultimately manifests as insufficiency (Table 4.29).

25% of the rented houses in urban area had common toilets. In suburban area 27% houses had common toilets. The remaining houses had individual toilet and bathroom facility. Solid waste collection was done periodically and safely disposed in the urban areas. But in suburban areas it was not done periodically. There is no proper sewerage system for disposal of waste water in suburban area. In urban areas sewage water was properly channelised and sent through open sewerage system.

The houses are constructed in suburban areas without proper planning. This has resulted in poor solid waste collection system and poor sewerage system.