RESULTS & DISCUSSION
Cement dust is a particulate pollutant near cement factory and construction sites. Cement dust is considered as one of the most dangerous dusts of industrial origin. As cement dust particles are heavier they settle on the soil due to gravitational power. Thus cement dust settles on the surrounding fields and vegetation near the industry and affect plant growth directly by covering leaf surface and indirectly through effects via the soil. Although soil acts as biological filter yet some pollutants remain and affect the environment. Thus in the present study soil physicochemical and biochemical processes in relation to cement dust pollution are studied, which provides an asessment of toxicity which is essential for better management of polluted soil to improve soil fertility and crop production.
Table - 1

Texture, and Name of soils collected at different distances from Cement factory.

<table>
<thead>
<tr>
<th>Distance (approx) from factory</th>
<th>Sand(%)</th>
<th>Silt(%)</th>
<th>Clay(%)</th>
<th>Soil name</th>
</tr>
</thead>
<tbody>
<tr>
<td>0km (Polluted soil.1)</td>
<td>64.34</td>
<td>30.83</td>
<td>4.33</td>
<td>Sandy loam</td>
</tr>
<tr>
<td>2km (Polluted soil.2)</td>
<td>68.4</td>
<td>25.93</td>
<td>4.67</td>
<td>Sandy loam</td>
</tr>
<tr>
<td>4km (Control soil)</td>
<td>80.1</td>
<td>16.6</td>
<td>3.3</td>
<td>Sandy loam</td>
</tr>
</tbody>
</table>

Each value is an average of triplicate.
SOIL PHYSICOCHEMICAL CHARACTERISTICS

Table 1. shows the percentage of sand, silt and clay in soil samples and also the soil name which is derived from the triangle (Alexander, 1970), according to the percentage of soil particles. All soils are of sandy loam type.

The soil samples collected from the cement dust polluted fields showed an increase in soil pH and electrical conductivity when compared to nonpolluted control soil. As shown in the Fig.1 the soil pH increased as the distance from the cement industry decreased.

Soil pH is one of the most indicative measurements of a soil because it is an important factor for the survival of legume bacteria (Durghi and Bottomley, 1983; Evans et al., 1988), the occurrence of blue-green algae (Granhall and Aenrikson, 1969) and free-living non-symbiotic nitrogen fixing microorganisms. Alexander, 1977). Soil pH has important role in soil fertility because it does play an important role in nutrient availability and nutrient uptake by plant roots.

The cement kiln dust contains a large amount of alkaline soluble calcium salts and nearly 8% of the dust is
EFFECT OF CEMENT DUST ON pH

Fig. 1
lime, which is soluble in water. The cement kiln dust is reported to be alkaline in the nature with pH 10-12, which gives an immediate alkaline reaction with phenolphthalein (Anderson, 1910; Prasad et al., 1991). Thus the increased soil pH in the cement dust polluted soils may have been caused by the hydroxides of calcium and aluminium formed during hydration (Stratman and Van Hant, 1956; Pajen Kamp, 1961; Czaza, 1966). The specific effect of increased pH in polluted soils on plants appears due to three reasons (1) high caustic alkalinity (2) toxicity of the carbonate ion (3) effects of exchangeable sodium. The increased pH above 9 in polluted soil may cause in the formation of soluble sodium humates by dissolving plant roots and organic matter.

In the present study a significant difference in the soil pH is observed in the two polluted soils. The pH at 0 km is 9.4 and at 2 km is 7.34. The soil pH increased as we move near by to the factory from 7.04 to 9.4 (Fig.1). This agrees with previous observations of Dubey et al., (1988); Arslan, et al., (1980;) and Salem, et al., (1990). Sjostek Marian (1986) reported that the pH was 6.9-7.4 at 1.4-1.7 km and 7.7-7.9 at 0.5-0.6 km from the factory. Parthasarathy et al., (1975) reported that the cement dust particles were heavy and settle down in the immediate vicinity of the factory and also reported that the dust
deposition was more near the factory. Thus soil pH increased as the rate of cement dust deposition increased. Paj et al., (1982) and Shukla et al., (1990) reported similar observations in the cement dust applied soils. Singh and Rao (1968), reported that the pH increase was not proportional to the amount of cement dust added to the soil. Perhaps, the buffering capacity of soil checked the increase of pH to a certain extent.

Availability of Mn, Cu, Zn and Fe to plants generally decrease with increase in soil pH (Kamprath and Foy, 1985), Babich and Stotzky (1974) suggested that increase in pH might be responsible for decreased microbial growth. Thus the alkaline nature of cement dust has adverse effects on both plants and soil microorganisms.

Thus increased pH of soil and presence of calcium in cement dust which is added to soil reduces root length as well as nodulation (Paz, et.al., 1982; Indhirabai, et.al., 1988;1989). The cement dust pollution caused shift in a soil pH to alkaline side which may be unfavourable for plant growth (Schonbeck, 1980; Scheffer, et.al., 1961; Czaza, 1962; Pathmanaban, 1979) resulting in the decreasing vegetation as we move near to the factory.
EFFECT OF CEMENT DUST ON EC

FIG. 2
Increase in electrical conductivity \( (Ec) \) of polluted soils collected at different distances from the factory (Fig. 2) may be due to the increased concentration of the soluble salts in cement dust polluted soils. The soil Ec was 539.3 \( \mu \) mhos/cm at 0 km, 280 \( \mu m \) hos/cm at 2 km and 200 \( \mu m \) hos on at 4 km from the factory. This is agreeable with the earlier studies. (Dubey et al., 1988; Salem et al., 1990).

Shukla et al., (1990) reported a direct proportional increase in the soil conductivity to the ratios cement applied to the plots. As cement dust is a better conductor of heat than air, Parthasarathy et al., (1975); and Madhu Singh, (1982), reported increased thermal conductivity and specific heat in cement dust deposited field soils.

Data in the Table 2 reveals the physical single value constants of polluted and control soils. Apparent density and absolute density increased in 0 km soil than 2 km and 4 km soil. Whereas the percentage of pore space and percentage water holding capacity decreased as we move near to the factory. Decrease in water holding capacity is more pronounced in 0 km soil.
Table - 2
Physical single value constants of Cement dust polluted and unpolluted soils

<table>
<thead>
<tr>
<th>Parameter</th>
<th>0km (Polluted soils)</th>
<th>2km (Polluted soils)</th>
<th>4km (Control soil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparent density, g/cc</td>
<td>1.57</td>
<td>1.33</td>
<td>1.24</td>
</tr>
<tr>
<td>Absolute density, g/cc</td>
<td>2.72</td>
<td>2.41</td>
<td>2.22</td>
</tr>
<tr>
<td>Percentage pore space</td>
<td>40.75</td>
<td>45.95</td>
<td>41.45</td>
</tr>
<tr>
<td>Percentage water holding capacity</td>
<td>28.74</td>
<td>41.45</td>
<td>49.53</td>
</tr>
</tbody>
</table>

Each vale is an average of triplicate.
The soils collected from the cement dust polluted fields showed increased apparent density and absolute density when compared to non-polluted soil. (Table 2). The change in these physical properties may be due to the occupation of cement dust in the voids of the soil in the polluted area compared to non polluted area.

The pore space and in turn, the water-holding capacity are decreased in polluted soils compared to unpolluted soil. This was attributed to the occupation of the pores in soil by the cement dust pollutants. As the base of factory has more rate of cement dust fall, there is a maximum reduction in the water holding capacity and percentage of pore space in the soil collected at the base of the factory. All these altered factors in polluted soils affect the crop growth. These results are confirming the previous reports of Parthasarathy et al., (1975); and Madhu singh, (1982).

Carbon occurs in soils in four forms-(1) carbonate mineral forms \( (\text{CaCO}_3, \text{MgCO}_3) \) (2) highly condensed nearly elemental organic carbon as charcoal, graphite and coal, (3) altered and resistant organic residues of plants, animals and microorganisms called humus, and (4) little altered organic residues of plants and animals and living
and dead microorganisms easily decomposable. The total carbon of soils obviously include all four, but the organic carbon includes later three only. In the present study, the percentage of organic carbon was more in polluted soils, compared to the control soil (Fig. 3). The percentage of organic carbon is as 1.15 at base of the factory and 5.76 at 2km and 0.598 at 4km control soil. The increased concentration of organic carbon in polluted soils can be attributed to the composition of the cement dust as it contains some unburnt carbon and other plant nutrients except nitrogen. (Sai and Mishra, 1987). The unburnt carbon which is elemental organic carbon (second form of organic form) and thus increases the total organic carbon percentage in polluted soils. Similarly percentages of organic carbon in cement dust polluted soil (Churk, U.P) was 0.52 and that in control was 0.43 (Singh and Rao unpublished data). It appears that the organic carbon of soils is directly related to their pH values, i.e., the higher the pH the greater the carbon content. (Singh and Rao, 1968). It is very likely that, in soils of higher pH, the microbial activity is reduced, by which the decomposition rate of organic matter may be lowered. Thus increase in organic carbon in polluted soils is due to lowered organic matter decomposition, and unburnt carbon in cement dust.
EFFECT OF CEMENT DUST
ON % ORGANIC CARBON

Fig. 3
The growth reduction in the plant system is undoubtedly complex including toxic affects from excess quantities of micronutrients, heavy metals, decomposition products and salt toxicity as well as effects on soil structure, porosity and aeration as reported by Dolar et al., (1972).

According to Arslan et al., (1980) the general composition of cement dust is similar to cement or its raw materials. Ca, Si, Al, Fe are main constituents of cement dust. Cement dust is chemically mixture of oxides of Ca, K, Al, Si and Na which sets into a hard mass when in contact with water. (Puri and Sharma, 1984; Parthasarathy et al., 1975; Madhusingh, 1992).

The studies of many workers showed the composition of cement kiln dust to be approximately 50 % CaO, 1.5 % MgO, 0.5 % Na2O, 2.0 % K2O. (Ali and Mir Akbar, 1986; Toda et al., 1986; Banerjee and Pandey, 1987). Anderson (1914) reported that 8 % of cement dust was lime which cause alkalinity.

In the present study concentrations of exchangeable Na, K, Ca, Mg and available P increased in
Ca content of the soil plays an essential role in ion absorption, especially in the selectivity of cation absorption and inhibits absorption of heavy metals by plant roots. (Kawasaki and Moritsugu 1987). The presence of excess amounts of soluble salts of Ca and Mg cause injuries to plant system (Israelsen and Hansen, 1962). Cement kiln dust in mild doses induced lateral root formation at early stage due to the presence of calcium in cement kiln dust (Emanuelsson, 1984). The deposition of calcium was considerably more in plants grown in Cement dust polluted areas (prasad etal., 1991). It was reported that Ca depressed the translocation of Zn from roots to shoots. (Kawasaki and Moritsugu, 1987).

Calcium silicate (CaO SiO₂) and calcium aluminate (CaO Al₂O₃) present in cement dust form colloidal gels, which after crystallization and solidification develop into a hard crust. (Czaza, 1962, 1986; Pathmanabhan et.al., 1979). Such a crust will make surfaces of soil and plant compact, rendering them more or less impervious to water and thereby upsetting their physicochemical properties. In the polluted soils compared to control soil (Table.3) which is similar to the earlier studies. (Szostek Marian, 1986).
Table - 3

Inorganic nutrients in Cement dust Polluted and unpolluted soils

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Distance (approx) from factory</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0km</td>
</tr>
<tr>
<td></td>
<td>(Polluted soils)</td>
</tr>
<tr>
<td>Exchangeable sodium</td>
<td>398.15</td>
</tr>
<tr>
<td>(ppm)</td>
<td></td>
</tr>
<tr>
<td>Exchangeable potassium</td>
<td>303.77</td>
</tr>
<tr>
<td>(ppm)</td>
<td></td>
</tr>
<tr>
<td>Exchangeable calcium</td>
<td>2155.04</td>
</tr>
<tr>
<td>(ppm)</td>
<td></td>
</tr>
<tr>
<td>Available magnesium</td>
<td>4.86</td>
</tr>
<tr>
<td>(meq./100g soil)</td>
<td></td>
</tr>
<tr>
<td>Available phosphorus</td>
<td>8.47</td>
</tr>
<tr>
<td>(μg/g soil)</td>
<td></td>
</tr>
</tbody>
</table>

Each value is an average of triplicates.
long run, these changes may drastically alter the biological functions of soil and plants. In the long run, the increase in concentration of Ca will make the soil alkaline, thus raising the pH and osmotic pressure of soil to undesirable levels.

For absorption of water through roots the osmotic pressure of root cells must be considerably greater than the soil solution. Due to the increased levels of available Na, K, Ca, Mg in cement dust the polluted fields, the osmotic pressure of soil solution may be greater than the root cells, which results the water flow to pass back ward from roots to soil. As pH of polluted soil is 9.4, and also soil may be charged with alkali salts at high concentrations as the crops may be unable to take up water as that of the crops in unpolluted region. Thus resulting in less vegetation and decreased growth of crops in the polluted fields compared to control unpolluted fields.

Table 3 represents the increased exchangeable Na in polluted soils than that of the control soil. The influence of increased exchangeable Na has received importance because it exerts effect in promoting poor physical conditions of soil and bringing about unbalanced nutrition of plants. Na dominates in soil only in alkaline
Soils with high exchangeable Na are readily deflocculated and puddle at even low moisture content.

Phosphate is fixed by precipitation with iron and anion exchange in acidic soils and there is an increase in phosphate solubility near neutrality. The increased available P in polluted soils can also be due to the high exchangeable Na in these soils. Under this Na dominant conditions P solubility increases rapidly because of the formation of soluble sodium phosphate compounds. As the polluted soils are having high Ca with appreciable exchangeable Na, phosphate solubility is usually high because Ca solubility is depressed and sodium phosphates are formed. Even though there is an increase in available P in polluted soils it is less readily assimilated because of alkaline conditions, (Arnon, Fratzke, and Johnson (1942); Pratt and Thorne (1948).

Biddapa et.al., (1987) reported that the absorption of P, K, Ca and Mg in coconut is affected by heavy metals such as Al and Cr. Al and Cr reduces leaf P and Mg concentrations. But Ca, K concentrations were reduced by Al and increased by Cr.
There is a general agreement that the presence of certain metals in the environment is of potential risk, even at very low concentrations. (Patterson, 1975; Forstner and Wittmann, 1983). The excessive concentrations of metals in soils may be caused by refuse disposal, agricultural sources, the presence of undisturbed ore bodies near the surface (geochemical anomalies) or may be the result of mining. Many waste products from mining activities are contaminated with metal at toxic levels and can produce large scale pollution. (Ramaut, 1964; Hilton 1967).

In the present study heavy metals like Ni, Cd, Al, Cr are estimated in the polluted and unpolluted soils and are represented in the Table.4. There is no significant change in the soil Ni concentration in the polluted soils compared to control soil. Cd concentration in polluted and control soils were below detectable level. Whereas significant increase in the Al and Cr observed in the polluted soils compared to control soils (Table.4). Cr occurred in appreciable concentrations and Cd in very low concentrations in four different brands of cement manufactured by prominent factories in India. (Tandon etal., 1984).
## Table - 4

Heavy metals in Cement dust polluted and unpolluted soils

<table>
<thead>
<tr>
<th>Heavy metal</th>
<th>Distance (Approx) from factory</th>
<th>0km</th>
<th>2km</th>
<th>4km</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(Polluted soil)</td>
<td>(Control soil)</td>
<td></td>
</tr>
<tr>
<td>Al</td>
<td></td>
<td>2753.000</td>
<td>2197.000</td>
<td>2129.000</td>
</tr>
<tr>
<td>Cr</td>
<td></td>
<td>5.631</td>
<td>6.763</td>
<td>5.121</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>2.47</td>
<td>2.446</td>
<td>2.507</td>
</tr>
<tr>
<td>Cd</td>
<td></td>
<td>&lt;0.982</td>
<td>&lt;0.98</td>
<td>&lt;0.98</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(BDL)</td>
<td>(BDL)</td>
<td>(BDL)</td>
</tr>
</tbody>
</table>

Each value is an average of triplicate.
BDL means Below detectable level.
The factors affecting plant availability, uptake and phytotoxicity of heavy metals are related to number of soil, plant and metal characteristics. Generally toxic metals are available to plants when the soil pH goes below 6.5. To suppress heavy metal toxicity to plants in acid soils liming is a common practice. (Duncan, 1981).

One of the major effects of Al on plants is to restrict root growth, nodulation (Caravaltho, 1981) and reduces the uptake of nutrients and water. There is a close relationship between soil pH and aluminium status. Decrease in soil pH is associated with the significant increase in exchangeable Al (Blamey and Asher Edwards, 1987). The toxic effects of Al may be modified by interaction between Al and other ions in the soil exchange complex and by the effect of pH perticularly with respect to Al solubility. Al taken up by most plants tend to accumulate in the roots and not easily translocated to tops. The toxic levels of Al in roots further inhibits the translocation of phosphorus from roots by precipitating as an aluminium phosphate. (Gormick and Borden, 1974).

Liming acid soils is a general practice to improve the yield of many crops (Pearson, 1975), the
The principle function of lime being to eliminate Al toxicity (Evans and Kamprath, 1970; Reeve and Summer, 1970) and to provide Ca and increase availability of P. There are reports that high Al saturation in sub soil caused poor root growth even in limed plots thereby reducing the use of sub soil water nutrients by plants (Blamey and Asher Edwards, 1987). There is an increase in Al content of polluted soils (Table.4). The alkalinity and high concentrations of exchangeable Ca, in polluted soils may decrease the severity of Al toxicity.

Al is reported to have inhibitory effect on N-mineralization (Liang and Tabatabai, 1977) and also considered as one of the most effective inhibitors of nitrification (Liang and Tabatabai, 1978). Gomes et al., (1985) reported that Al has profound effect on assimilation and acquisition of nitrogen.

A significant increase in Cr concentration in polluted soils is depicted in Table.4. as compared to unpolluted soil. Cr can exist in soils normally as trivalent Cr$^{3+}$ cation and the CrO$_2^-$ anion, and the hexavalent cations CrO$_4^{2-}$, Cr$_2$O$_7^{2-}$. However the Cr trivalent form is essential for human nutrition (Underwood, 1971) whereas the hexavalent form of Cr is toxic to humans (Sullivan, 1969).
The cement dust has hexavalent Cr, which is considered to cause cement eczema and dermatitis hazards.

Pirila (1954) reported that European cement contain Ni, Co, Cr in quantities sufficient to produce cutaneous reactions. Cr is known to cause skin irritation and dermatitis. (Langard and Norseth, 1979). Geiser (1968) concluded that Cr and Co were the important factors in producing cement dermatitis. However dermal itching and breathing difficulty may be attributed to Cr toxicity or to the alkaline and abrasive nature of the cement.

For plants hexavalent Cr is the available form and the trivalent Cr is the unavailable form. The polluted soils show an increase in content compared to control soil (Table.4) thus it is available to plant and can accumulate. But in soils after prolonged period hexavalent Cr will be reduced to trivalent Cr from. (Khasim et al., 1988 a,b). and also the presence of organic matter which acts as an electron donor, the reduction of hexavalent Cr takes place in the soil. But in polluted soils, the organic matter is less because of less vegetation and also decreased microbial activity. Which may also inhibits the reduction of hexavalent Cr to trivalent form. Thus increased hexavalent Cr from may act as toxic agent in the polluted soils.
Cr causes decrease in chlorophyll content (Arvind Bharathi et al., 1979) and Hewit (1854) showed inhibition of chlorophyll synthesis in sugar beet and decrease in weight of cabbage leaves. Cr at high concentrations also completely inhibited germination. (Guruprasad Rao and Nanda Kumar, 1981). Thus the increased Cr content in the polluted soils may be one of the factors for decreased vegetation and growth of plants.

Cr generally appears to accumulate in plant roots and is poorly translocated to the top when compared to accumulation in roots. Seeds show less accumulation than other parts. Thus, it is a sort of natural protection seem to operate in plants for the benefit of consumers of food chain.

Chromium caused inhibition of nitrifying bacteria (Fargo and Fleming, 1977) inhibited nitrification, causing accumulations of ammonium-N in soils. (Liang and Tabatabai, 1978). Cr is also one of the most effective inhibitor of N-mineralization (Liang and Tabatabai, 1977).

Nitrogen is one of the major nutrients for all living organisms. The maintenance of soil fertility is
EFFECT OF CEMENT DUST
ON % TOTAL NITROZEN

Fig. 4
dependent on adequate nitrogen resources for plant and the nitrogen is one of the most important factor limiting crop yield. The total nitrogen content of cement dust polluted soils and control soil are represented in Fig.4. The percentage of soil total nitrogen is 0.027 km, 0.046 at 2km and 0.057 at 4km from the factory. A significant decrease in total nitrogen was observed in polluted soils compared to that of the control. The decrease is further more in the soil samples collected at the base of the factory.

In soil, nitrogen occurs in both inorganic and organic forms with the later form predominant. These two forms are interconnected. Organic nitrogen is contributed by the dead organic matter includes compounds like amino acids, amines, proteins, polypeptides, urea, hippuric compounds originating from the flora and fauna communities. As organic nitrogen is unavailable from of nitrogen is mineralized to available inorganic forms. Studies of Sai and Mishra (1987) revealed that the cement dust contain some plant nutrients except for nitrogen which is supporting the results of present study. Singh and Rao, (1988) also reports low total nitrogen contents of polluted soils. The decrease in the total nitrogen in cement dust polluted
soils may be due to the decreased vegetation and microbial population, which contributes to the majority of the organic nitrogen.

The inorganic forms of nitrogen in soil are ammonia, nitrite and nitrate. Since the nitrogen availability is a major factor having profound influence on plant production, it is considered worth while to examine the influence of cement dust pollution on soil inorganic nitrogen fractions and the biochemical activities like ammonification and nitrification. The inorganic nitrogen fractions of the cement dust polluted soils and control soil are represented in Fig.5,6,7 which depicts an increase in ammonium content and decrease in nitrite and nitrite contents in both polluted soils compared to that of the unpolluted control soil. Further this change over control is more significant in the soil collected in the immediate vicinity of the cement factory.

The increase in accumulation of ammonia in polluted soils can be explained due to uninterrupted activities of ammonifier population and impairment of the activities of nitrifier population. In ammonification the diverse and heterogenous groups of microbes capable of proteolytic degradation of protein and other nitrogenous substrates, included are various genera of bacteria, fungi and actinomycetes which respire both aerobically and
EFFECT OF CEMENT DUST ON AMMONIA

Fig. 5
EFFECT OF CEMENT DUST ON NITRITE

![Graph showing the effect of cement dust on nitrite with distance from the factory.](Fig. 6)
EFFECT OF CEMENT DUST
ON NITRATE

\[ \text{\( \mu g \) No}_3^-/g \text{ soil} \]

Distance (Km) from factory

Fig.
anaerobically. Because of this diversity of organisms, the conversion of organic nitrogen into inorganic nitrogen via ammonification is a process which can occur in a variety of environments. The net accumulation of ammonium in the soil milieu is dependent on the nutritional requirements of the microbial community and various environmental factors including the presence of chemical toxicants.

The increase (or) accumulation of ammonia in polluted soils may be due to less utilisation of ammonia compared to that of ammonia production. This increased ammonia content in polluted soils might also be responsible for decreased nitrogen fixation, since nitrogen fixing microbes preferentially utilize $\text{NH}_4^+ - \text{N}$ as a nitrogen substrate instead of transforming $\text{N}_2$. Therefore, in an environment high in ammonia, nitrogenase activity is severely restricted. Solutions of Al. Concentrations of 75-125 Molar reduces nodulation and growth of all six stylo santhes species. (Carvalho, 1981). The increased concentrations of Al, Fe and P in cement dust polluted soils may favour to formation of Ammonium aluminium phosphates which immobilize ammonia for nitrification, this might have contributed to the increased concentrations of Ammonia in polluted soils. (Pereira, 1982). Thus their may be less contribution of
total Nitrogen from the nitrogen fixation process to the total Nitrogen content in the polluted soils. The high alkalinity of the polluted soils might have caused decreased microbial population. Which further causes less utilisation of ammonia. As the NH$_4^+$ is positively charged it is frequently bound to clay fractions in soil and therefore inaccessible for plant assimilation, whereas nitrate ion is readily mobile, percolating rapidly to the root zone plants with sufficient water movement. The two nitrogen constituents providing nitrogenous input for plants are NH$_4^+$ and NO$_3^-$.

In order to understand the effect of cement dust on the variations in the inorganic nitrogen constituents of the soil further work is extended to study the process of mineralizing organic nitrogen by ammonification and Nitrification and protease activity.

**Soil Biochemical process**

As a consequence of N- mineralization ammonium and nitrate are generated and organic nitrogen disappears, and these products delineate two distinct microbiological processes, Ammonification and nitrification.
Table 5

Changes in Ammonification* during incubation in Cement dust polluted and unpolluted soils.

<table>
<thead>
<tr>
<th>Weeks incubation</th>
<th>Distance (approx) from factory</th>
<th>8km</th>
<th>2km</th>
<th>4km</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NH⁺</td>
<td>No₂⁻</td>
<td>No₃⁻</td>
<td>NH⁺</td>
</tr>
<tr>
<td>1st Week</td>
<td>257.55</td>
<td>8.34b</td>
<td>2.04b</td>
<td>248.18c</td>
</tr>
<tr>
<td></td>
<td>(21.7)</td>
<td>(88.3)</td>
<td>(51.6)</td>
<td>(78.2)</td>
</tr>
<tr>
<td>2nd Week</td>
<td>567.55</td>
<td>8.06b</td>
<td>0.387b</td>
<td>569.046d</td>
</tr>
<tr>
<td></td>
<td>(74.3)</td>
<td>(-15.3)</td>
<td>(62.2)</td>
<td>(74.3)</td>
</tr>
<tr>
<td>3rd Week</td>
<td>172.66</td>
<td>1.995d</td>
<td>1.276c</td>
<td>174.157b</td>
</tr>
<tr>
<td></td>
<td>(51.4)</td>
<td>(-337.7)</td>
<td>(85.9)</td>
<td>(33.4)</td>
</tr>
<tr>
<td>4th Week</td>
<td>39.46a</td>
<td>0.195b</td>
<td>0.811b</td>
<td>48.686a</td>
</tr>
<tr>
<td></td>
<td>(63.3)</td>
<td>(95.3)</td>
<td>(82.6)</td>
<td>(61.9)</td>
</tr>
</tbody>
</table>

* (NH⁺ + No₂ + No₃) - N μg g⁻¹ soil.

Values in parenthesis indicate percentage change over control.

Means, in a column for each soil followed by the same letter are not significantly different (P<0.05) from each other according to Duncan multiple range (DMR) test.
Ammonification

Ammonification is the first step in the nitrogen mineralization involving degradation of protein and other complex nitrogenous components of organic matter into NH$_4^+$. Because of the diversity of organisms, the conversion of organic nitrogen into inorganic nitrogen via ammonification is a process which can occur in a variety of environments. In ammonification NH$_4^+$, NO$_2^-$, NO$_3^-$ are formed from organic forms of nitrogen.

Ammonification is assayed by measuring the amount of NH$_4^+$, NO$_2^-$ and NO$_3^-$ in the soils formed after the incubation with 1000 ppm N as Analar grade peptone for 1, 2, 3 and 4 weeks. The rate of Ammonification process was represented in table.5 and Fig.8. There is a significant decrease in the ammonification throughout the incubation period in polluted soils compared to that of the control soil and the percentage change is more in the soil collected from the base of the factory, (Table.5). Thus the Ammonification process is not responsible for increased concentration of NH$_4^+$ in the polluted soils. The decrease in the ammonification process may be due to decreased population of ammonifiers due to cement dust pollution and also by the decreased activity of proteases (Table.9) which
EFFECT OF CEMENT DUST
ON AMMONIFICATION

\[ (NH_4^+ + NO_2^- + NO_3^-) - N \]

Fig. 8
actually supply aminoacids for ammonification process. In soils of higher pH, the microbial activity is reduced, by which the decomposition rate of organic matter is lowered and resulted on decreased rates of N- mineralization. As ammonium ions are less accessible to plant assimilation than $\text{NO}_3^-$, ammonia content may be increased in polluted soils.

**Nitrification**

Nitrification refers to the biological formation of nitrite or nitrate from compounds containing reduced nitrogen. The process of nitrification is mainly brought about by two important species of chemosynthetic bacteria i.e. *nitrosomonas* species oxidising $\text{NH}_4^+$ to $\text{NO}_2^-$ and *nitrobacter* oxidising $\text{NO}_2^-$ to $\text{NO}_3^-$ and also by heterotrophic bacteria such as *Clostridium butyricum*, *Aspergillus flavus*, *Aspergillus niger* and others. The nitrifiers derive energy from the oxidation of $\text{NH}_4^+$ and $\text{NO}_2^-$. These organisms also require sufficient supplies of $\text{O}_2$ and carbon as well as suitable conditions with respect to moisture and temperature.

Soil nitrification is a important microbiological process and since the ultimate product of the process is $\text{NO}_3^-$, which is the major nitrogen source assimilated by plants, it is considered to be a good indicator of soil
Table-6
Changes in Nitrification* during incubation in Cement dust polluted soils

<table>
<thead>
<tr>
<th>Weeks incubation</th>
<th>Distance (Approx) from factory</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8km (Polluted soil-1)</td>
</tr>
<tr>
<td></td>
<td>No2</td>
</tr>
<tr>
<td>1st week</td>
<td>2.268c</td>
</tr>
<tr>
<td></td>
<td>(94.3)</td>
</tr>
<tr>
<td>2nd week</td>
<td>16.413d</td>
</tr>
<tr>
<td></td>
<td>(65.6)</td>
</tr>
<tr>
<td>3rd week</td>
<td>1.378b</td>
</tr>
<tr>
<td></td>
<td>(86.9)</td>
</tr>
<tr>
<td>4th week</td>
<td>8.715a</td>
</tr>
<tr>
<td></td>
<td>(79.1)</td>
</tr>
</tbody>
</table>

* (No2 + No3) - N in µg g-1 soil.

Values in parenthesis indicate percent change over control.

Means in a column, for each soil followed by the same letter are not significantly different P(<0.05) from each other according to Duncan multiple range (DMR) test.
fertility. Because of the high sensitivity of the process to various chemical pollutants in soil sub-system, it has been used extensively in various ecotoxicological studies in soil. (Dosmch et al., 1983). Therefore, in the present study the soil nitrification is investigated to examine the toxicological effect of cement dust on soil fertility.

The data on nitrification process in the polluted and control soils was represented in the table-6 and Fig.9. The rate of Nitrification process in soil was measured by measuring the amount of $NO_2^-$ and $NO_3^-$ in the soils after 1, 2, 3, 4 weeks intervals incubation with 200ppm N in form of analar grade ammonium sulphate. The rate of nitrification is significantly decreased in polluted soils compared to control and the percentage change over control is further more in soil collected to immediate vicinity of the factory.

As in the present study reduction in nitrification activity in polluted soils was also reported by Cerevelli et al., (1986), who showed the reduction in nitrification when an alkaline fly ash (pH 12.0) was added to a sandy loam soil. The adverse effects of alkaline flyash on microbial respiration and nitrification activity were attributed to high alkalinity by Wong and Wong (1986) and Cerevelli et al., (1986).
EFFECT OF CEMENT DUST
ON NITRIFICATION

Fig. 9

\[
\text{N} = \left( \text{NO}_2^- + \text{NO}_3^- \right) \text{ mg/L}
\]

Distance (Km) from factory

- 1st week
- 2nd week
- 3rd week
- 4th week

**Fig. 9**
The cement dust contains elevated levels of metals such as Cr, Al, Fe (Table 4) which affect the nitrification process to occur. Adverse effects on the free living nitrogen-fixing populations caused by heavy metal contamination from past mining activities have been found. Brookes et al. (1986) reported retardation of growth and a reduction in nitrogen-fixation activity by blue-green algae as a result of elevated metal concentrations was reported (Brookes et al., 1986).

In nitrification the concentration of $\text{NO}_2^-$ is less than $\text{NO}_3^-$. This indicates the impairment of $\text{NH}_4^+$ oxidation which to the subsequent blockage in $\text{NO}_3^-$ formation. Of the two genera, nitrosomonas species, the $\text{NH}_4^+$ oxidiser is reported to be more sensitive to various chemical pollutants. (Domsch et al., 1983). The addition of $\text{NO}_2^-$ (Nitrite) by nitrobacter is markedly inhibited because of the toxicity of free ammonia to nitrobacter (Focht and Verstreete 1977). Thus accumulation of ammonia and sensitive nature of nitrifiers in polluted soils cause retardation of nitrification.

Cement dust polluted soils are more alkaline, further accumulation of $\text{NH}_4^+\text{-N}$ results in gaseous loss of
ammonia. This might also result in inhibition of nitrification, which leads to several problems, such as damage to seedlings, nitrite toxicity and gaseous loss of organic nitrogen as ammonia.

**Soil enzyme activities**

The study of enzyme activities in soil has been a field of interest for some eighty years but it is only since the early 1950's that it has developed into a major research topic in soil microbiology and biochemistry (Skujins, 1978).

Soil enzymes are involved in the various decompositions and chemical transformations in the soil. Measurement of enzyme activities give an indication of the extent of specific biochemical processes in soil and in many cases used as an indicator of soil fertility (Hoffman, 1955; Mishra et al, 1979).

Enzymatic activity in natural soil seems to be closely correlated with the activities of microorganisms. Changes in environmental factors, agronomic and climatic, which would be expected to influence the activities of microorganisms also influence the magnitude of many enzymatic relation. (Block et al, 1970). In addition to the fundamental properties of enzymes in soil the data from
enzyme assays have been interpreted periodically as a guide to soil productivity (Kiss et al, 1978) an indirect measure of microbial biomass, e.g. dehydrogenase assay (Ladd, 1978), a consequence of rhizosphere effect (Boero and thein, 1979; Speir et al, 1980) and xenobiotic compounds (Burns and edwards, 1980) and a pointer to wards any harmful side effects of metal containing waste (Tyler, 1974; Doelman and Haanstra, 1979) and pesticides (Lethbridge et al 1981) an the microbiota. Thus the most substantial index of biological activity in soil is the enzymatic activity.

Soil enzymes are mostly secreted by the soil microorganisms. Amylase, invertase, cellulase and proteases are the extracellular enzymes secreted mostly by soil microorganisms. Thus, the factors responsible for regulating the activity of microflora indirectly affect the activities of these enzymes. Thus, a close relationship exists between enzyme activities and activity of microflora which again depend upon the supply of organic matter and nitrogen.

Dehydrogenase

The soil dehydrogenase activity is often used as an measure of metabolic activity of microorganisms of soil.
### Table 9

Dehydrogenase, protease, urease activities in Cement dust polluted and unpolluted soils.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Distance (approx) from factory</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0km</td>
</tr>
<tr>
<td></td>
<td>(Polluted soils)</td>
</tr>
<tr>
<td>Dehydrogenase (μg formazion g⁻¹ soil/24hrs)</td>
<td>10.463 (51.6)</td>
</tr>
<tr>
<td>Protease (μg tyrosine g⁻¹ soil/2hrs)</td>
<td>276.560 (48.8)</td>
</tr>
<tr>
<td>Urease (μg ammonia g⁻¹ soil/4 hrs)</td>
<td>23.093 (41.2)</td>
</tr>
</tbody>
</table>

Values in parenthesis indicate percent change over control.

Value is an mean for each soil followed by the same letter are not significantly different (P<0.05) from each other according to Duncan multiple range (DMR) test.
Lenhard (1956) introduced a concept of determining the metabolic activity of microorganisms in soil and other habitats by measuring dehydrogenase activity. The soil dehydrogenase system is due to rather wide group of soil enzymes which transfer electrons to available acceptors (e.g. $O_2$). Thus has a role in the initial stage of oxidation of soil organic matter and dehydrogenase activity appears to be more dependent on the metabolic state of microbial population of the soil than upon the activity of the specific free enzymes acting on particular substrate. Dehydrogenase activities therefore likely to be affected appreciably by many environmental factors.

As depicted in the table 9, the dehydrogenase activity was significantly decreased in polluted soils compared to control soil. Percent decrease in dehydrogenase activity in the soil collected at base of the cement factory is more (51.6%) than the polluted soil collected at 2km distance from the factory (32.3%) over the unpolluted soil.

The decrease in dehydrogenase activity in polluted soils may be due to the decrease in the population of anaerobic microorganisms, since most dehydrogenases are of anaerobic origin (Orten and Neuhans, 1970). Ross (1970) stated that dehydrogenase activity appear to be more
dependent on the microbial activity of soil than on the anaerobic activity. Thus the decrease in the total microbial population in polluted soils might have contributed to the decrease in the dehydrogenase activity. Further, as there is a higher percent decrease in enzyme activity in the soil collected near the base of the factory also indicated that the cement dust pollution is more near the factory than at 2 km from the factory.

Weimberg (1967), Flowers (1972), reported that increased salt concentrations were inhibitory to the dehydrogenase activity. As the polluted soils are more alkaline having high exchangeable salts are Na, K, Mg, Ca which may be responsible for the decrease in the microbial population as reflected by the decreased dehydrogenase activity.

**Amylase and Invertase**

Measurements of amylase and invertase activities in soil indicate the extent of hydrolysis of starch and its related polysaccharides, and sucrose respectively. The activities of these enzymes are important in soil in releasing simple carbon for growth and multiplication of soil microorganisms. The activity of the enzyme hydrolysing
sucrose was always greater than that hydrolysing starch. Amylase and invertase are extracellular enzymes secreted mostly by soil microorganisms mostly thus the factors responsible for regulating the activity of microflora indirectly affect the activity of these enzymes.

Amylase and invertase activities of soils are measured by the content of glucose formed during incubation with starch and sucrose respectively. Soil amylase probably consists of different enzymes or enzyme systems which have a role in hydrolysis of starch. As shown in Table 7, there is a significant decrease in the amylase activity in polluted soils compared to control soil. The percent decrease of amylase activity is more in the soil collected from the base of the factory (31.7, 59.6) than the polluted soil collected 2 km from the factory (21.8, 14.2) in both 24, 72 hours incubation periods.

Drobnik (1955) revealed that starch hydrolysing enzymes are extracellular and activities are inducible in soil. As amylase is inducible enzyme in unpolluted control soil there is a 54.74 per cent increase in the activity as observed at 72 hrs incubation with substrate compared to 24 hrs incubation period, whereas in polluted soil at 0 km from the factory only showed 17.07 percent increase in the
Table - 7

Amylase activity* in cement dust polluted and unpolluted soils.

<table>
<thead>
<tr>
<th>Distance (approx) from factory</th>
<th>24a</th>
<th>72a</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 km (Polluted soil-1)</td>
<td>52.120 A (+31.7) A</td>
<td>62.853 A (+59.6) A</td>
</tr>
<tr>
<td>2 km (Polluted soil-2)</td>
<td>59.650 B (+21.8) B</td>
<td>143.897 B (+14.2) B</td>
</tr>
<tr>
<td>4 km (Control soil)</td>
<td>76.303c</td>
<td>167.853c</td>
</tr>
</tbody>
</table>

* From glucose g⁻¹ soil

a incubation, in hours, of soil with starch (2% w/w).

Values in parenthesis indicate percent charge over control.

Means, in a column, for each soil followed by the same letter are not significantly different P(<0.05) from each other according to Duncan multiple range (DMR test).
amylase activity at 72 hrs incubation with substrate compared to 24 hrs incubation period. Whereas the polluted soil collected at 2 km from the factory showed 58.57 percent increase at 72 hrs incubation compared to 24 hrs incubation period. Thus there is significant decrease in the amylase induction in polluted soil at the base of the factory, whereas second polluted soil (2 km) shows no significant difference in percent induction of enzyme activity compared to the control soil.

Sucrose hydrolysing enzyme, invertase activity in cement dust polluted and unpolluted soils are represented in Table. 8. A significant decrease in enzyme activity is observed in polluted soils compared to control soil. Invertase activity of soil collected at the base of the factory showed 41.9 % and 36.9 % decrease in 24 hrs and 48 hrs incubation periods respectively. Whereas, the soil collected at 2 km from the factory showed 15.3 % decrease in 24 hrs incubation and 11.7 % decrease in 48 hrs incubation compared to the control soil.

The decrease in amylase and invertase activities in the polluted soils are probably due to decrease in population of different groups of enzyme producing microorganisms.
Table - 8
Invertase activity* in cement dust polluted and unpolluted soils.

<table>
<thead>
<tr>
<th>Distance (approx) from factory</th>
<th>24a</th>
<th>48a</th>
</tr>
</thead>
<tbody>
<tr>
<td>0km (Polluted soil-1)</td>
<td>283.920 (41.9)A</td>
<td>626.963 (36.9)A</td>
</tr>
<tr>
<td>2km (Polluted soil-2)</td>
<td>428.787 (15.3)B</td>
<td>877.743 (11.7)B</td>
</tr>
<tr>
<td>4km (Control soil)</td>
<td>506.247c</td>
<td>894.053c</td>
</tr>
</tbody>
</table>

* μg of glucose g⁻¹ soil formed from sucrose.

Incubation, in hours, of soil with sucrose.

Values in parenthesis indicate percent charge over control.

Means, in a column, for each soil followed by the same letter letter are not significantly different P(< 0.05) from each other according to Duncan multiple range (DMR) test.
organisms in soil. Balasubramanian et al., (1970) showed a highly positive correlations between enzymes hydrolysing sucrose, starch and bacterial, fungal populations in soil. Higher salt concentrations in polluted soils may inhibit the amylase and invertase activities. (Fouly and Jung, 1970; Dzhonibekova, 1972).

**Protease**

Proteases are involved in the initial hydrolysis of the protein and peptides. In the decomposition of proteins, the proteolytic enzymes cleave the protein molecule to polypeptides, simple peptides and finally to the free amino acids, the end products of protease action. It has been shown that proteases in soil can hydrolyse not only added proteins (Kiss et al., 1975) but also native soil proteins and peptides (Dedeken and Voets, 1985).

The activity of proteolytic enzymes in soil is assayed by incubating soils with proteins and measuring the aminoacid formation in short periods of incubation. The protease activity of the cement dust polluted and unpolluted control soils are depicted in Table 9, which reveals a high protease activity in unpolluted soil, than the polluted soils. The percent decrease in the protease activity in polluted soil collected at 0 km and 2 km from the factory...
are 49.8% and 33.5%, respectively, compared to control soil. Decreased proteolytic activity in polluted soils may be due to less availability of appropriate substrate or/and decreased population of proteolytic microorganisms in soil.

Many microorganisms utilize polypeptides, simple peptides and aminoacids in contrast to few genera degrading native proteins. Innumerable heterotrops utilize the aminoacids liberated by proteases as carbon and nitrogen sources. Thus the decreased protease activity in polluted soils may be responsible for decreased microbial population.

The protease activity is enhanced by addition not only of proteins but also of sugars, that bring about extensive microbial proliferation. Thus decrease in the amylase and invertase activities in polluted soils are also responsible for decreased proteolytic activity.

**Urease**

Urease is also another soil enzyme which has received greater attention because in soil it mediates the conversion of organic nitrogen to inorganic nitrogen by the hydrolysis of urea to ammonia. Urea in soil is pooled from decomposition of animal excreta and certain nitrogenous
compounds in plant residues or added as fertilizer. Soil urease activity is measured by estimating ammonia released from urea.

The activity of urease in polluted and unpolluted soils is represented in Table 9. Cement dust pollution causes significant decrease in urease activity as compared to unpolluted control soil. Further the decrease in the activity is more in polluted soil collected at 0 km distance than the soil collected at 2 km from the cement factory (Table 9).

The work with soil urease has shown that this enzyme is strongly inhibited by metal ions (Getoch and Pathrick, 1974; Tabatabai, 1977; Franskenberger and Tabatabai, 1980; Pulford and Tabatabai, 1988). Thus the decreased activity of urease in polluted soils may be due to increased concentrations of metals like Al, Cr.

Urea hydrolysis occurs at optimal rate in neutral or near neutral pH's. (Wickremasinghe et al., 1981). The high alkaline pH of the polluted soil (pH 9.3) collected at the base of the cement factory probably responsible for significant decrease of 66.6% in urease activity compared to control soil.
Mishra et al., (1979) showed a significant positive correlations among enzymes like amylase with invertase, protease with urease etc.

Thus in the present study, the enzyme activities of dehydrogenase, amylase, invertase, protease and urease are decreased in the cement dust polluted soils compared the control soil.

The decrease in the dehydrogenase activity in polluted soils infers that there is a decrease in microbial population in polluted soils compared to control soil. Amylase, invertase, protease and urease are the broad enzymes responsible for degradation of organic matter of plant and animal origin in soil. The decrease in activities of these enzymes in polluted soils infers the decreased rate of decomposition of organic matter. Although the organic carbon is more in polluted soils compared to unpolluted soils the enzymatic activities are decreased. This is attributed to the fact that the enzymatic activity is influenced not only by the amount but also by the type of organic matter (Burns, 1978). In polluted soils the unburnt carbon content of cement dust causes an increase in organic carbon content but it is not used as substrate for
microorganisms. In addition lesser nitrogen content of polluted soils contributes for poor fertility of these polluted soils, unfavourable for growth and multiplication of microorganisms and other vegetation.

The reasons attributed to the decreased activities of enzymes in polluted soils are alkaline pH due to Ca salts, high salinity due to increased salt concentrations, decreased pore space of soil due to occupation of cement dust in the voids of the soil, increased temperature (as cement dust is better conductor of heat than air) along with increased metal concentrations. Thus changes in all these physical and chemical properties of the polluted soils cause changes in biochemical processes of microorganisms and perhaps arrest the microbial activity resulting in decreased microbial population and fertility.