CHAPTER - III

AMBIENT AIR QUALITY AROUND THE CEMENT INDUSTRY AND PHYSICOCHEMICAL NATURE OF CEMENT DUST.
Summary

Concentration of fugitive dust in air varies greatly from one area to another depending upon nature, intensity of source, meteorological conditions.

Four sampling sites in four directions around the cement industry were selected as air quality monitoring point. By following standard method concentration of RSPM, SPM particulate matters were analyzed.

Results showed that, the air quality in the vicinity of the cement plant was deteriorated due to factory emissions and the concentration of particulates was higher than the permissible limits; prescribed by Indian air quality standard. Higher concentrations of SPM, RSPM were observed in winter season than the other seasons. Also settle-able dust were collected and analyzed. Dust analysis showed elevated basic pH, high salinity, and was rich in metal oxides of Ca and Si, whereas, the dust was poorer in the oxides of Al, Fe, K and Mg. The Atomic Absorption spectroscopic analysis of trace metals showed settle-able dust from cement industry were rich in Pb, Cr, Cd heavy metal content with little amount of Zn, Cu, and K metals.
CHAPTER -3

AMBIENT AIR QUALITY AROUND THE CEMENT INDUSTRY AND 
PHYSICOCHEMICAL NATURE OF CEMENT DUST

3.1 Introduction - Air is a significant natural resource for the sustenance of life and other activities in the biosphere. As atmosphere plays a crucial role in the survival of life, but different factors such as population boom, rapid industrialization and urbanization have resulted in the deterioration of the air quality, Naeem et al. (2009)\(^2\).

Air pollution may be defined as "any atmospheric situation in which substances are present in concentrations high enough above their normal ambient levels to generate a measurable consequence on man, animals, vegetation or materials"; substances mean any natural or manmade chemical element or compound capable of being air-borne. They may exist in the atmosphere as gases, liquid drops or solid particles forms, Seinfeld (2012)\(^1\).

The sources of air pollutants are both natural and anthropogenic. Natural sources consist of those substances which would be present even in the absence of human activities. These are forest fires, volcanoes, dust storms, sea-salt spray, pollen and spores released by plants and biological activities in the soil, while anthropogenic sources, the pollutants are emitted due to the human activities. It consists of gases and waste smoke formed by thermal power plants, cement kiln, house-holds, automobiles, rocket combustion processes etc. However the emissions from natural sources are comparatively higher in amount than the anthropogenic emissions globally. But the latter does more dangerous because the emissions are released into the atmosphere in a particular region in higher concentration (Henderson-Sellers, 1984)\(^3\).

Apart from direct effects a group of new problems have also emerged due to air pollution over the past two decades are acidic depositions, stratospheric ozone
Ambient Air Quality Around the Cement Industry and Physicochemical Nature of Cement Dust.

hole, global warming due to increased CO₂, indoor pollution, lead deposition, radioactivity, long range transport of pollutants and non-ionizing radiations.

The common air pollutants are suspended particulate matter (SPM), oxides of Nitrogen (NOₓ), sulphur dioxide (SO₂), oxides of carbon, complex organic compounds, hydrocarbons and various metallic dusts etc, Levy (2011)⁴.

Particulate Matter is the solid and liquid aerosols suspended in the atmosphere. It results both from direct emissions of particulates and from secondary formations. These are emitted into the atmosphere from power plants, cement, nuclear, steel industries, motor vehicles, construction activities, natural windblown dusts, volcanic action, sea-salt spray and forest fires etc. Smoke, soot, dust, ash, pollen, spores and many other materials are included in particulates, Cambra et al., (2010)⁵ and Nowak (2013)⁶.

Particulates are frequently the most obvious form of air pollution because they reduce visibility. The visual range is inversely proportional to the concentration of particulate matter. The main source of suspended particulate matter (SPM) is the open cast mining (Sushmitha, 2007)⁷. Subtypes of atmospheric particulate matter includes non-respirable suspended particulate matter (NSPM), respirable suspended particle (RSPM; particles with diameter of 10 micrometres or less), fine particles (diameter of 2.5 micrometres or less), ultrafine particles, and soot.

SO₂ and NOₓ, hydrocarbons, CO₂ and H₂S are major gaseous air pollutants. SO₂ is poisonous, smog forming and the worst "problem" gas in the atmosphere. It is colourless but corrosive gas which originates from the combustion of sulphur-containing fuels, primarily coal and oil. It is also emitted by industrial processes that consume sulphur containing raw materials. Very tiny particles act as a medium on which acidic sulphate ion is carried over long distances in the atmosphere. When it is
"washed" out by rain, it contributes to a serious environmental problem known as acid rain. It damages materials and adversely affects plants. It damages lung tissues, effects breathing and respiratory system causes premature death as it is highly irritating to mucous tissues.

The major sources of NO\textsubscript{x} include fossil fuel burning, lightning, emissions from the biosphere, stratospheric injections and biomass burning. The sum of both NO and NO\textsubscript{2} is designated as NO\textsubscript{x}. Both are formed by combustion at high temperatures, Kanakidou (2005)\textsuperscript{8}.

Hydrocarbons are solid, liquid and gaseous compounds that are composed only of hydrogen and carbon. In cities, the incomplete combustion of gasoline in motor vehicles is the principal source of hydrocarbons, although some hydrocarbons from other sources are carcinogenic. Gasoline is a complex mixture of various hydrocarbons. When hydrocarbons react with certain other pollutants (oxides of gases) poisonous products result, this produces photochemical smog.

Carbon monoxide is a colourless, odourless and poisonous gas produced by incomplete burning of carbon in fuels. CO is the most abundant primary pollutant and that about two-thirds of the nationwide emissions are from vehicular sources, mainly highway vehicles. Because it cannot be seen, smelt or tasted, CO can have an effect on people without realizing it. In small amounts it causes wispiness, slows reflexes and impairs judgement. At high concentrations, CO can cause death by not allowing the blood to transport adequate oxygen.

The ambient air quality is a composite and dynamic environmental phenomenon, which shows temporal and spatial variations in air atmosphere, due to the changes in the rate of emissions from anthropogenic and natural sources, as well as due to changes in meteorological and topographic conditions. The monitoring of ambient air quality in an area is imminent to provide data to allow a resolution of the
dynamic nature of air quality in terms of temporal and spatial variations. The monitoring data so generated may be compared with the prescribed permissible air quality standards and their violations may suggest the bias and gravity of air pollution problems prevailing in an area. The basic components of biosphere are affected by atmospheric deposition of various pollutants. Atmospheric particles, depending on a size, can settle by gravity close to the source of pollution, or can be carried by wind to various distances from the source. The most direct consequences of atmospheric deposition both dry and wet are acidification of soil and water and accumulation of heavy metals in the biosphere (Soriano et al., 2012).

Air Pollution is a growing problem in both developing and developed countries. Constantly increasing urbanization and industrialization have led to enormous emissions of an array of pollutant e.g. SO$_2$, NO$_x$, hydrocarbons, SPM etc. into the atmosphere. The adverse-effects of these pollutants are well known. In addition to their adverse effects on human health and vegetation, they cause the acidification of the environment and also play a key role in global warming, Hansen et al., (2009).

Cement manufacturing plants are the third largest industrial source of air pollution, according to Environmental Protection Agency (EPA, 1993). Cement industries are emitting more than 500,000 tons per year of SO$_2$, NO$_2$ and CO. The pollution can contribute to respiratory illness, heart disease; formation of acid rain reduces visibility, which can be transported over long distances before falling on land and water. Cement production releases large amounts of CO$_2$ by both fuel combustion and chemical processes. According to the National Greenhouse Gas Inventory of China, cement production contributed 57% of CO$_2$ process emissions, Canpolat et al., (2002) and Yatkin and Bayram (2010). Dust consists of tiny solid particles carried by air currents, these particles are formed by disintegration or fracture process
Particles that are too large to remain airborne settle, while others remain in the air indefinitely, (Ade-Ademilua, 2008). The damaging effect of these pollutants on both fauna and flora can be very considerable (Rovera et al., 2011). According to Baby et al. (2008) cement industries is one of the 17 most polluting industries listed by the Central Pollution Control Board (CPCB) and a major source of particulate matters, SO$_x$, NO$_x$ and CO$_2$ emissions. Cement plants also are one of the biggest sources of mercury emission second only to coal-fired power plants in their output. Mercury is an extraordinarily toxic metal that damages the ability of babies and young children to think and learn. The United state environmental protection agency has estimated that more than 300,000 newborns every year may face increased risk of learning disabilities because of in exposure to toxic forms of mercury through the energy process of cement manufacturing, Akpan et al. (2011) and Zdravko (2014).

3.1.1 Cement Production and Cement Kiln Dust generation

“A typical Portland cement is manufactured by feeding materials containing appropriate proportions of lime, silica, alumina and iron into the upper end of a kiln. The mix passes through the kiln at a rate controlled by the slope of the kiln and the speed at which the kiln rotates. Burning fuel is forced into the lower end of the kiln where it produces temperatures of 1400-1500°C, changing the raw mix to a cement clinker. During this operation a large percentage of the material in the form of dust (CKD) depending on raw materials used and producing the same cement type will typically have relatively consistent composition” (Carlson et al., 2011).

Fugitive emissions during process - Emissions released to air other than those from stacks or vents (fig 3.1.1). Potential fugitive emission sources from the cement process include:
- **Mining** - Opencast mine in which limestone is blasted and transported on haul roads.

- **Crushing** - Limestone is crushed and screened in primary and secondary crushers. Crushed limestone is transported and blended on material stockpiles.

- **Raw material handling** - Raw materials received by road are stockpiled with limestone.

- **Raw material grinding** - All raw materials are proportionally extracted and mixed. Mixed raw materials are ground and stored in silos.

- **Burning** - Ground raw material is burned in kilns (thermal) to produce clinker.

- **Clinker grinding** - Clinker is ground in finish mills (cement mills) to produce different types of cements.

- **Packaging and dispatch** - Final products are transported, packed, stored and loaded for dispatch. (US EPA, 2004)\textsuperscript{21}. 

\textsuperscript{21} US Environmental Protection Agency.
Figure 3.1.1- Points of emission during cement manufacturing process

(1) PARTICULATE EMISSION (FUGITIVE)
(2) PARTICULATE EMISSION (STACK)
(3) GASEOUS EMISSION
3.1.2 Nature of cement kiln dust - The principal constituents of cement kiln dust are compounds of lime, silica, and alumina, and iron. The physical and chemical characteristics of cement kiln dust depend on the raw materials used and the method of its collection employed at a particular cement plant. Free lime is found in cement kiln dust, the concentration of free lime is generally highest in the particles of cement kiln dust captured closest to the kiln, (Sariosseiri, 2008)\(^{22}\).

Trace elements enter the cement from the burning process or via underground additives, the trace elements barium, chromium, copper, zinc, nickel, cadmium, lead, zirconium, molybdenum, arsenic, mercury fractions originating from burning process incorporated mainly in the clinker phases generally found in concentrations of percent by weight and are typically expressed as milligrams per kilogram (mg/kg), or parts per million. These constituents include certain organic chemicals, metals such as cadmium, lead, and selenium, and radio nuclides. Trace constituents are important to an analysis of the chemical characteristics of cement kiln dust because some of these elements and compounds are toxic or otherwise harmful at low concentrations, cement kiln dust has been managed in a way that may release these trace constituents to the environment, (Sreekrishnavilasam et al., 2006)\(^{23}\).

Variation in mass and elemental concentration of particulate matter with local climatic conditions, process mechanism in factories and adverse effect on soil fertility showed the need for air quality assessment of surrounding environment of single point source and was the objective of this study, carried out in the vicinity of selected cement plant.

3.2 Study area- Present work was done in surrounding area of a cement plant, which is situated about 50 km away from the state capital Raipur and is in Simga Tehsil of Bhatapara district (Baloda Bazar) in Chhattisgarh.
Plate- 2 Internal Map of Cement Industry
3.3 Materials and methods –

3.3.1 Ambient Air quality around the cement industry - Ambient air concentration around the industry was determined by the cooperation with pollution control board Raipur, following Indian Standard Methods for Measurement of Air Pollution (1974)\(^{24}\).

**Sampling station** - Air quality was determined during the study period April 2011 to December 2011 around the study site in the radius of 1km meter (plate-2).

Four sampling sites in four directions were selected as determination point. Concentration of fugitive dust in air vary greatly from one area to another depending upon nature, intensity of source, meteorological conditions like weather condition, rain fall, humidity, wind velocity, temperature inversion. Meteorological data during the sampling period was collected from local metrological station.

1) Determination of concentration of particulate matter in ambient air-

Determination of concentration of particulate matter in ambient air was done by Indian standard method for particulate concentration measurement by the formula given by Watson (1998)\(^{25}\) following pollution control board Raipur.

- Collection of samples - Samples for respirable suspended particulate matter (RSPM), suspended particulate matter (SPM) and gaseous concentration collected with the help of respirable dust sampler (RDS) sampler (Envirotech, Model APM 460) provided by pollution control board Raipur. Suspended particulates were trapped on a glass fibre filter paper attached to the hopper of RDS. The particulates deposited on filter papers were computed as the net mass divided by the volume of sampled air. Two sets of RDS sampler were used in the interval of three days for multiple sampling in each site. The samplers were operated at the
height of five meters for 24 hours sampling with average flow rate 1.0 L/min. Total five to six samples in each direction in each month were collected during the overall sampling period.

- **Sample preparation and mass measurement** - All particulate samples were collected in glass microfiber filter sheets (size 8”x10”, Whatman), because of low resistance to air flow, a low affinity for moisture and maximum collection efficiency. The filters were attached with a respirable dust sampler. Pre and post sampling treatment of filter papers was carried out in moisture-free desiccators followed by drying in an oven for 24 hours. All pre and post-sampling treated filters were weighed using a 5-digit balance (Sartorius Model R 200D). Meteorological parameters during the sampling period were collected from a local meteorological station.

- **Formula** - **Calculation of concentration of ambient particulate matter (PM)**

\[
\text{RSPM} = \frac{(W_2 - W_1) \times 10^6}{V}
\]

\[
W_1 = \text{initial weight of filter paper}, \quad W_2 = \text{final weight of filter paper}
\]

\[
\text{SPM} = \text{RSPM} + \text{weight of collector}
\]

b) **Determination of Sulphur dioxide (SO}_2\) – determination of SO\(_2\) was done by following, West and Gaeke method (IS 5182 Part 2 Method of Measurement of Air Pollution: Sulphur dioxide\(^{26}\). Sulphur dioxide from air was absorbed in a solution of potassium tetrachloromercurate (TCM). A dichlorosulphitomercurate complex, which resists oxidation by the oxygen in the air, was formed, the complex was made to react with para-rosaniline and formaldehyde to form the intensely coloured pararosaniline methylsulphonic acid. The absorbance of the solution was measured by spectrophotometer at 560nm.
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- **Sampling** - 30 ml of absorbing solution, potassium tetrachloro-mercurate (TCM) placed in an impinger and sampled for 24 hours at the flow rate of 1 L/min. After sampling the volume of sample were measured and transferred to a sample storage bottle.

- **Analysis** - Distilled water was added up to the calibration mark on the absorber to replace water lost by evaporation during sampling and was mixed thoroughly. 10 ml of the collected sample was pipette out into a 25 ml volumetric flask. 1 ml 0.6% sulphamic acid was added and allowed reacting for 10 minutes to destroy the nitrite resulting from oxides of nitrogen. 2 ml of 0.2% formaldehyde solution and 2 ml para-rosaniline solution were added and diluted to 25 ml with distilled water. A blank was prepared in the same manner using 10 ml of unexposed absorbing reagent and allowed to stand for 30 min to colour development and absorbance of samples and blank was taken at 560 nm. The SO\(_2\) concentration was calculated by the formula described by the West and Gacke (1966)\(^{26}\).

  - **Formula** - \(C (SO_2 \mu g/m^3) = (As - Ab) \times CF \times Vs / Va \times Vt\)

Where, \(C (SO_2) = \) Concentration of Sulphur dioxide, \(\mu g/m^3\)

\(As = \) Absorbance of sample, \(Ab = \) Absorbance of blank,

\(CF = \) Calibration factor, \(Va = \) Volume of air sampled in \(m^3\),

\(Vs = \) Volume of sample, \(Vt = \) Volume of aliquot,

C) **Determination of nitrogen dioxide (NO\(_2\))**

Determination of nitrogen dioxide was done by Modified Jacobs & Hochheiser Method\(^{27}\). Ambient nitrogen dioxide (NO\(_2\)) was collected by bubbling air through a solution of sodium hydroxide and sodium arsenate. The concentration of nitrite ion (NO\(_2\)) produced during sampling was determined colorimetrically by reacting the nitrite ion with phosphoric acid, Sulfanil-amide and N-(1-naphthyl)-
ethylene-diamine-di-hydrochloride (NEDA) and measuring the absorbance of the highly colored azo-dye at 540 nm.

**Analysis** - Distilled water was added up to the calibration mark on the absorber to replace water lost by evaporation during sampling and was mixed thoroughly, 10 ml of the collected sample was pipette out into a 50ml volumetric flask and 1ml of hydrogen peroxide solution, 10ml of sulphanilamide solution, and 1.4ml of NEDA (N-(1-naphthyl) – ethylene – di-amine – di - hydrochloride) solution, were added with thorough mixing after the addition of each reagent and volume was made to 50ml with distilled water. A blank was prepared in same manner using 10ml of unexposed absorbing reagent, after a 10min colour development interval, the absorbance of samples and reagent blank was measured at 540nm.

- **Formula** – \( C (NO_2) \mu g/m^3 = (As - Ab) \times CF \times Vs \times Va \times Vt \)

Where \( C (NO_2) \) = Concentration of Nitrogen dioxide, \( \mu g/m^3 \)

\( As = \) Absorbance of sample, \( Ab = \) Absorbance of blank

\( CF= \) Calibration factor, \( Va = \) Volume of air sampled, (ml)

\( Vs = \) Volume of sample, \( Vt = \) Volume of aliquot, (ml)

**3.3.2 Physico-chemical nature of cement dust** - To determine the nature of cement dust and its trace constituents the samples of settable dust were collected around the cement industry then processed and characterized for constituents.

**a) Collection of settable dust**- Settable dust was collected at four sampling sites within a distance of 500m from the cement plant in each direction following the standard methods for dust fall survey using deposition gauges as describe by Adams, 1997\(^{28}\); Soriano, *et al.* 2012\(^{50}\). Each comprised a cylindrical jar 15cm height, 20cm in diameter half filled with distilled water and mounted on 1m height iron tripod with a concrete slab base to avoid being blown away by wind. 1%
CuSO$_4$ solution was added to each of the jar as fungicide and algaecide. The collectors were placed in position 5-10 m above the ground. After the duration of 30 days the jars were brought to laboratory and the settled dust was analyzed for different constituents Hall (1988)$^{29}$ and Quraishi (1995)$^{30}$.

b) Analysis of Settle-able Dust -

1) Analysis of physical properties

Hydrogen ion concentration (pH):- pH is negative log of hydrogen ion concentration.

$$\text{pH} = \log \frac{1}{\text{aH}^+} = \log_{10} \text{aH},$$

aH$^+$ activity of hydrogen ion in soil water suspension expressed as g ions / L.

Procedure - 20 g of dust was taken in 100 ml beaker and added 40 ml of distilled water to it. The suspension was stirred at a regular interval of 30 minutes. After calibration of instrument with standard buffer solutions, pH of sample suspension was determined by pH meter following Jackson, (1973)$^{31}$.

Categories of pH - < 5.0 = strongly acidic, 5.1 - 6.5 = acidic, 6.6 - 7.0 = neutral, 7.1 - 8.1 = alkaline and > 8.2 = strongly alkaline.

2. Electrical conductivity (EC):- Electrical ions are the carrier of electricity. The electrical conductivity of the system rises according to the content or soluble salts giving rise to more of ion pairs on dissection as in case of dilution thus the measurement of EC is directly related to quantity or concentration of soluble salts.

The Electrical conductivity was determined by following the method of Jackson, (1973)$^{31}$.

Procedure - Saturation extract or dust water extract 1:2.5 (dust: water) was taken in a 25ml beaker. 0.01 M KCl solution was used to calibrate the instrument. Conductivity
cell was connected to meter and dipped-in the sample and conductivity value in μSm-1 was noted.

2) Analysis of trace metals

- **Digestion of dust** - Digestion of dust was done by following the method of Jackson (1973)31. Samples were ground and homogenized with mortar and pestle. 0.5g dust samples were taken in platinum crucible treated with mixture of con. HF and con.HClO4 (3:1) and water then the samples were blasted to muffle furnace at 1500-2000°C for 40 minutes then, H3BO3 was added and heated in a microwave at 160°C for six minutes again and residue was dissolved in 20% HCl and diluted with distilled water and filtered in100 ml volumetric flask volume was raised and stored in air tight container.

**Principle** - In atomic absorption method of chemical analysis, a portion of sample is converted to the atomic vapors by flame and irradiated by the light from source whose emission light by the atoms of the element in the vaporized sample is related to the concentration of the desired metal in it and is measured at a specific wavelength which is characteristic of the element. Concentration of the metal in the solution was measured by comparing with absorbance measurements on standards of known composition.

**Procedure** - The instrument (AAS-GF240) was calibrated with standards, prior to the measurements, blank samples were also taken, and the average blank value was then deducted from the measured sample concentrations. Standard solution of different metals were prepared by using foil or wire (AR sigma) and diluted to one liter with distilled water as stock solution, from this, working standard solution was prepared and read on atomic absorption spectrophotometer for calculating factor
following Lindsay and Norvell (1978)\textsuperscript{32}. Samples were analyzed for metals Zn, Cu, Mn, Cr, Pd, Cd and Ni in Jawahar Lal Agriculture University Jabalpur.

**Formula:** - metal (mg/kg) = 100 X concentration

3) **Analysis for metal oxides**

a) **Determination of silica (SiO\textsubscript{2})**

Silica was determined by following the method of Hillbrand (1980)\textsuperscript{33}.

**Procedure** - 10 gm of the finely powdered substance was weighed out and ignited in a covered platinum crucible over a strong blast for fifteen minutes, then transferred to evaporating dish of platinum and moistened with enough water to prevent lumping. 5 to 10 drops of strong HCl was added and digested with the gentle heat and agitation until complete evaporation on the water bath. The solution then evaporated to dryness, the residue without further heating was treated with 5 to 10 drops of strong HCl and allowed for ten minutes on the water bath, after which the solution was filtered and the separated silica was washed thoroughly with water. The filtrate was again evaporated to dryness. The small amount of silica it contains was separated on another filter paper. The papers containing the residue transferred to a weighed platinum crucible, dried, ignited, first over burner until the carbon of the filter was completely consumed and finally over the blast for fifteen minutes to constant weight. The silica, was treated in the crucible with 10ml of HF and 4 drops of H\textsubscript{2}SO\textsubscript{4}, and evaporated over a low flame to complete dryness. The small residue finally blasted, for a minute then cooled and weighed. The difference between weights obtained given the amount of silica.

**Formula** - Silica (%) = 200 (W\textsubscript{2}-W\textsubscript{1})

W\textsubscript{2}= weight of crucible with silica  \quad W\textsubscript{1}= empty crucible weight
b) **Determination of ferric-oxide (Fe$_2$O$_3$)**

Ferric-oxide was determined by EDTA method following Kitson and Milton, 1944.$^{34}$

**Procedure** - Filtrate of silica determination was made to the volume 250 ml in a volumetric flask with distilled water. 25 ml of above solution was added with NH$_4$OH solution till the turbidity appeared. The turbidity was cleared with a minimum amount of HCl and pH was adjusted to approximately 3, then 100 mg of sulphi-salicylic acid was added and titrated with 0.01N EDTA to a colorless solution as end point.

**Formula** - Fe$_2$O$_3$ % = (0.799 X V)/W

V = volume of EDTA used in ml,  W = weight of sample in gm

c) **Determination of Alumina (Al$_2$O$_3$)**

Alumina was determined by following the method of Olsen (1990)$^{35}$. 

**Procedure** - To the 25ml colorless solution after determination of Fe$_2$O$_3$ , 1ml of phosphoric acid, 5ml of sulphuric acid was added. Later excess ammonium acetate solution was added by stirring to adjust the pH 6. The solution was heated then cooled and 50mg of solid xylenol orange indicator was added by stirring until the color of solution was changed colorless to red, then solution was titrated against 0.01N EDTA and end point was indicated by sharp yellow color change.

**Formula** -  Al$_2$O$_3$ % = (0.5098 X V)/W

V = volume of EDTA used in ml,  W = weight of sample in gm

d) **Determination of calcium oxide (CaO)**

Calcium oxide was determined by following the method of Jugovic, 1988.$^{36}$

**Procedure** - Neutralized filtrates (after filtration of silica) with HCl, few drops of methyl red indicator and 30ml NH$_4$OH was drop wise added by stirring until the color changed from red to yellow. Solution was allowed to stand without further heating for 60minute), with occasional stirring during the first 30min it was filtered by
using retentive paper and the precipitate was washed 8 to 10 times with hot water. Later it was diluted with distilled water and 10ml of dilute H₂SO₄ and brought up to volume 250ml with distilled water. 25ml of aliquot of above solution was taken, heated and titrated immediately with 0.1N KMnO₄ solution, slowly until the pink color persisted for at least 10 seconds; the same procedure was used for blank.

**Formula** - CaO % = F (V - B)

\[
F = \text{Normality of KMnO}_4 \text{ solution} \times 0.02804 \times 100/10 \\
V = \text{ml of KMnO}_4 \text{ solution required by the sample,} \\
B = \text{ml of KMnO}_4 \text{ solution required by the blank.}
\]

e) **Determination of Magnesium Oxide (MgO)**

Magnesium oxide was determined by following the method of Olsen (1990).³⁵

**Procedure** - The filtrate was after removal of silica acidified with HCl and boiled. The solution was cooled and was added with 10 ml of ammonium hydrogen phosphate (NH₄)₂HPO₄ solution and 30 ml of NH₄OH then it was stirred vigorously for 10 to 15 minutes. The solution was allowed to stand for at least 1 hour in a cool atmosphere and filtered; the residue was washed for five to six times with NH₄OH and ignited in a weighed platinum crucible, in flame for 30 to 45 minutes. Then the residue was weighed as magnesium pyrophosphate (Mg₂P₂O₇).

**Formula** - MgO % = W X 72.4

\[
W = \text{grams of Mg}_2\text{P}_2\text{O}_7
\]

f) **Determination of Sulphur Trioxide (SO₃)**

Sulphur Trioxide was determined by following the method of Kirk (1979).³⁷

Sulphate is precipitated from an acid solution of the cement with barium chloride (BaCl₂). The SO₃ is equivalent to the precipitate ignited and weighed as barium sulfate (BaSO₄).

**Procedure** - 1 g of the sample was added with 25 ml of cold water and stirred vigorously, 5 ml of HCl was added and the solution was heated and grinded the
material with the flattened end of a glass rod. The solution was then diluted with 50ml of water and digested for 15 minutes at a temperature about 200°C. The solution was filtered through a filter paper. To the filtrate 10 ml of hot BaCl₂ was added slowly and the boiling was continued until the precipitate was well formed. The solution was digested for 12 to 24 hours at temperature just below boiling; the precipitate was washed thoroughly with hot water. The paper was placed in a weighed platinum crucible, and was slowly charred and the paper was consumed without flaming and ignited at 800 to 900°C and cooled in desiccators and again was weighed.

**Formula** - $\text{SO}_3 \% = W \times 34.3$

$W = \text{grams of BaSO}_4$,

### 3.4 Results and discussion

#### 3.4.1 Meteorological data during the sampling period -

Meteorological data was collected from meteorological department of Indira Gandhi Agriculture University, Raipur. Data exhibited a comparative seasonal variability.

**Table-3.4.1: Average meteorological parameters of sampling period April to December 2011.**

<table>
<thead>
<tr>
<th>Month</th>
<th>Temperature (°C)</th>
<th>Rainfall (mm)</th>
<th>Rainy days</th>
<th>Relative Humidity (%)</th>
<th>Vapour Pressure (mm Hg)</th>
<th>Wind Velocity (Km/h)</th>
<th>Wind Direction</th>
<th>Evaporation (mm)</th>
<th>Sunshine (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr</td>
<td>39.8</td>
<td>24.6</td>
<td>3.2</td>
<td>1</td>
<td>57.8</td>
<td>15.5</td>
<td>10.0</td>
<td>5.4</td>
<td>SW,W</td>
</tr>
<tr>
<td>May</td>
<td>43.7</td>
<td>28.0</td>
<td>0.6</td>
<td>1</td>
<td>37.3</td>
<td>13.0</td>
<td>8.8</td>
<td>4.5</td>
<td>W,SW</td>
</tr>
<tr>
<td>Jun</td>
<td>37.4</td>
<td>27.0</td>
<td>62.4</td>
<td>9</td>
<td>71.0</td>
<td>20.1</td>
<td>18.8</td>
<td>8.9</td>
<td>W,NW</td>
</tr>
<tr>
<td>July</td>
<td>29.1</td>
<td>24.5</td>
<td>163.9</td>
<td>12</td>
<td>92.4</td>
<td>22.3</td>
<td>23.6</td>
<td>8.0</td>
<td>NW,SE,SW</td>
</tr>
<tr>
<td>Aug</td>
<td>29.9</td>
<td>25.1</td>
<td>80.8</td>
<td>12</td>
<td>92.0</td>
<td>23.0</td>
<td>23.1</td>
<td>5.9</td>
<td>NW,SE,SW</td>
</tr>
<tr>
<td>Sep</td>
<td>31.1</td>
<td>24.7</td>
<td>51.1</td>
<td>4</td>
<td>92.8</td>
<td>23.0</td>
<td>22.1</td>
<td>3.9</td>
<td>SW,NW</td>
</tr>
<tr>
<td>Oct</td>
<td>31.1</td>
<td>20.1</td>
<td>7.3</td>
<td>1</td>
<td>89.0</td>
<td>17.6</td>
<td>14.9</td>
<td>1.9</td>
<td>SE,SW</td>
</tr>
<tr>
<td>Nov</td>
<td>29.2</td>
<td>15.2</td>
<td>1.4</td>
<td>0</td>
<td>89.5</td>
<td>12.8</td>
<td>13.6</td>
<td>1.2</td>
<td>SW,SE</td>
</tr>
<tr>
<td>Dec</td>
<td>28.6</td>
<td>12.8</td>
<td>0.1</td>
<td>0</td>
<td>89.3</td>
<td>11.0</td>
<td>10.1</td>
<td>1.6</td>
<td>SE,E</td>
</tr>
</tbody>
</table>
(a) **Temperature and rate of evaporation** - Mean Minimum temperature during summer (March to May) was varied from 24.6 - 28.6 °C and mean maximum temperature was noted 43.7 - 39.8 °C (fig-1). Weather was dry and hot. In the monsoon season (late June to October) variation of minimum temperature was 24.5 to 28 °C and maximum temperature was 29.1 to 37.4 °C. Weather conditions was frequent rainy, high moisture and cloud covered and in winter season (late November to February) the minimum temperature variation was 12.8 to 15.2 °C and maximum temperature was 28.6 to 29.2 °C. Weather was clear, cloudless and sunny. The hottest month was May when maximum temperature was 43.7 °C. The maximum evaporation rate 85.1 mm was recorded in the month of May. The Climate of the study area was humid with hot to semi hot temperature. Wind velocity was high during mid of the year throughout the study area resembled as tropical to subtropical region weather.

(b) **Rainfall and rainy days** - The rain fall in the area varied between 0.1 mm to 163.9 mm during different month. Maximum rain falls was recorded in the month of July (163.9 mm) and minimum in December (0.1mm). 85% of rainfall was received in monsoon season from June to September. Maximum rainy days were observed in the month of July and August.
Figure – 1 Average temperature variations during the study period April to December 2011

Figure – 2: Average vapour pressure variations during the study period April to December 2011
(c) Relative humidity and vapour pressure - Relative Humidity varied 37.3% to 92.8% was recorded in the month of April to December 2011. Maximum humidity was 92.8% in September and minimum of 37.3 in the month of May. Vapour pressure was varied from 8.8 to 23.1 mm Hg (Tab-3.4.1, Fig-2), maximum vapor pressure 23 mm Hg was recorded in the month of September.

(d) Wind speed and wind direction - Wind speed in the area varied from 1.2 to 8.9 Km / h. Maximum wind velocity was recorded during the month of June in monsoon season and minimum wind velocity was recorded during the month of November in winter season (fig-3). According to meteorological data week wind poor carrying capacity of atmosphere bellowed in post monsoon and winter season. During summer the prominent wind directions were W, SW and NW during winter E and SE and during rainy season were NE, SE and SW.
Figure – 3: Average wind velocity variations during the study period April to December 2011.
3.4.2. Ambient air concentration around the cement industry –

According to meteorological data table (3.4.1), the westerly wind blow and prevailed wind direction from south west to north east, so there was maximum emissions found in the north east direction in every season. The results of mean concentration of ambient air particulates matters around the cement industry are presented in the table (3.4.6).

In the above study, it was found that the air quality in the vicinity of the cement plant is deteriorated due to factory emission and the concentration of particulates was higher than the permissible limits prescribed by Indian air quality standards. The mean particulate concentration in winter (October to December) was higher. Respirable suspended particulate matter (RSPM) was 164.214µg/m$^3$ and suspended particulate matter (SPM) was 463.305µg/m$^3$, while in the monsoon season (July to September) RSPM was 149.172µg/m$^3$ and SPM was 369.180µg/m$^3$. The reason of relatively low content of SPM and RSPM during the rainy season July to September may be assigned to the high rains, relative humidity, more wind velocity during these months as compared to the summer (April to June) and winter (October to December). Statistical analysis (Tab: 3.4.2 and 3.4.3, fig: 4) showed significant seasonal variation in particulate matter concentrations. It is apparent from the results that the SPM and RSPM concentration is in compliance with central pollution control board (CPCB) standard for ambient air quality (RSPM 100-150µg/m$^3$ and SPM 200-260 µg/m$^3$). Higher concentrations were measured for SPM and RSPM in winter season than the other season, similar results were noted by Cetin, 2008$^{38}$ and Nadal et al., 2009$^{39}$. The emissions of gases from industry was recorded, sulphur di oxide (SO$_2$) 50.665 µg/m$^3$, NO$_2$ 61.672 µg/m$^3$ in winter and SO$_2$ 40.707 µg/m$^3$, NO$_2$ was 52.375 µg/m$^3$ for the monsoon season (July to Sep), (Tab-3.4.4, Fig-5) were below the
allowable limits 80µg/m³ for human exposure. Statistical analysis (Table: 3.4.4 and 3.4.5) showed significant seasonal variations (p < 0.01) in the concentrations of the gaseous pollutants. Higher concentrations were obtained in the winter season than monsoon. Results obtained have agreements with Oguntoke, 2012. Thermal NOx forms at temperature above 1200°C and involves the reaction of nitrogen and oxygen molecules in the combustion air. Thermal NO₂ is produced mainly in the burning zone of kiln where it is hot enough to achieve this reaction. The amount of thermal NO₂ produced in the burning zone is related to both burning zone temperature and oxygen content (air excess factor).

The rate of reaction for thermal NO₂ increases with temperature; therefore, hard-to-burn mixes which require hotter burning zones will tend to generate more thermal NO₂ than kilns with easier-burning mixes. SO₂ emissions from cement plants are primarily determined by the content of the volatile sulphur in the raw materials. Kilns that use raw materials with little or no volatile sulphur have little problems with SO₂ emissions. In the scientific literature, it is largely stated that the concentrations of particulate matter are higher at colder temperatures in ambient air of some industrial sites probably because of the effect of additional emission sources, such as heating (Lee et al., 1999; Mari et al., 2008 and Venier et al., 2009).

The SO₂ and NO₂ content in the ambient air around the industry were maximum during the winter as compared to the summer and monsoon seasons because of low vapour pressure, wind velocity and decrease in the relative humidity of the atmosphere (Fig - 6 and 7).

b) Physico-chemical nature of cement dust – Dust samples was collected at four sampling sites within a distance of one km from the cement plant in each direction. The settled dust was subjected to digestion with standard digestion method and
analyzed for different metal oxides and trace metal constituents. Results of the present study (Table - 3.4.7), indicated an elevated basic pH 12.3, high salinity 1912 (µS) and rich metal oxides of Ca and Si, while the dusts were poorer in the oxides of Al, Fe, K and Mg as comparison the values recorded by American Concrete Institute (1990)\textsuperscript{44}, Polat (2004)\textsuperscript{45}, Akpan (2011)\textsuperscript{18} and Kakooei (2012)\textsuperscript{46}.

The atomic absorption spectrophotometer (AAS) analysis of trace metals showed settle-able dust from cement industry were rich in Pd, Cr, Cd, and Ni heavy metal content with trace amount of Zn, Cu, Mn metals, similar findings were obtained by Zargari (2008)\textsuperscript{47}, Zerrouqi (2008)\textsuperscript{14}, Mackie (2010)\textsuperscript{48} and Witt \textit{et al.} (2014)\textsuperscript{49}.  

Figure – 4 ambient air particulate matters (RSPM and SPM) concentration in one Km radius around the cement industry during April to December 2011.

Figure – 5 Gaseous concentration in ambient air in one Km radius around the cement industry during April to December 2011.
Figure 6: Correlations between wind velocity and ambient air SO$_2$ concentrations around the cement industry during April to December 2011

Figure 7: Correlations between wind velocity and ambient air NO$_2$ concentrations around the cement industry during April to December 2011
Table: 3.4.2. Suspended particulate matter (SPM) concentration (µg/m³) in ambient air around the cement industry during the month of April to December 2011

<table>
<thead>
<tr>
<th>Month</th>
<th>East</th>
<th>West</th>
<th>North</th>
<th>South</th>
<th>Total</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>427.048</td>
<td>425.824</td>
<td>439.744</td>
<td>439.722</td>
<td>1732.34</td>
<td>433.084</td>
</tr>
<tr>
<td>May</td>
<td>450.518</td>
<td>444.518</td>
<td>454.385</td>
<td>444.518</td>
<td>1793.94</td>
<td>448.485</td>
</tr>
<tr>
<td>June</td>
<td>420.518</td>
<td>417.864</td>
<td>426.652</td>
<td>420.264</td>
<td>1685.30</td>
<td>421.325</td>
</tr>
<tr>
<td>July</td>
<td>374.918</td>
<td>369.984</td>
<td>390.410</td>
<td>372.410</td>
<td>1507.72</td>
<td>376.931</td>
</tr>
<tr>
<td>August</td>
<td>378.672</td>
<td>363.240</td>
<td>381.384</td>
<td>372.264</td>
<td>1495.56</td>
<td>373.890</td>
</tr>
<tr>
<td>September</td>
<td>357.624</td>
<td>355.610</td>
<td>360.409</td>
<td>353.237</td>
<td>1426.88</td>
<td>356.720</td>
</tr>
<tr>
<td>October</td>
<td>434.944</td>
<td>432.277</td>
<td>454.144</td>
<td>439.722</td>
<td>1761.09</td>
<td>440.272</td>
</tr>
<tr>
<td>November</td>
<td>466.385</td>
<td>468.505</td>
<td>479.582</td>
<td>471.480</td>
<td>1885.95</td>
<td>471.488</td>
</tr>
<tr>
<td>December</td>
<td>479.305</td>
<td>478.144</td>
<td>480.517</td>
<td>474.652</td>
<td>1912.62</td>
<td>478.154</td>
</tr>
<tr>
<td>Average</td>
<td>421.104</td>
<td>417.330</td>
<td>429.692</td>
<td>420.919</td>
<td>SEM 1.102</td>
<td>CD5 % 3.218</td>
</tr>
</tbody>
</table>

Table: 3.4.3 Respirable suspended particulate matter (RSPM) concentration (µg/m³) in ambient air around the cement industry during the month of April to December 2011

<table>
<thead>
<tr>
<th>Month</th>
<th>East</th>
<th>West</th>
<th>North</th>
<th>South</th>
<th>Total</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>160.548</td>
<td>156.257</td>
<td>165.504</td>
<td>154.944</td>
<td>637.253</td>
<td>159.313</td>
</tr>
<tr>
<td>May</td>
<td>158.152</td>
<td>156.257</td>
<td>165.504</td>
<td>159.317</td>
<td>639.229</td>
<td>159.807</td>
</tr>
<tr>
<td>June</td>
<td>161.851</td>
<td>155.448</td>
<td>162.600</td>
<td>154.022</td>
<td>633.922</td>
<td>158.480</td>
</tr>
<tr>
<td>August</td>
<td>146.810</td>
<td>148.252</td>
<td>151.056</td>
<td>150.648</td>
<td>596.766</td>
<td>149.192</td>
</tr>
<tr>
<td>September</td>
<td>149.233</td>
<td>147.342</td>
<td>152.784</td>
<td>149.832</td>
<td>599.191</td>
<td>149.798</td>
</tr>
<tr>
<td>October</td>
<td>167.477</td>
<td>162.268</td>
<td>168.864</td>
<td>161.160</td>
<td>659.768</td>
<td>164.942</td>
</tr>
<tr>
<td>November</td>
<td>163.574</td>
<td>162.768</td>
<td>170.256</td>
<td>159.318</td>
<td>655.916</td>
<td>163.979</td>
</tr>
<tr>
<td>December</td>
<td>166.014</td>
<td>159.487</td>
<td>168.864</td>
<td>160.518</td>
<td>654.883</td>
<td>163.721</td>
</tr>
<tr>
<td>Average</td>
<td>158.005</td>
<td>155.059</td>
<td>161.669</td>
<td>155.382</td>
<td>SEM 1.102</td>
<td>CD5 % 3.218</td>
</tr>
</tbody>
</table>
Table: 3.4.4 Sulphur dioxide (SO$_2$) concentration (µg/m$^3$) in ambient air around the cement industry during the month of April to December 2011

<table>
<thead>
<tr>
<th>Month</th>
<th>East</th>
<th>West</th>
<th>North</th>
<th>South</th>
<th>Total</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>41.218</td>
<td>36.528</td>
<td>47.352</td>
<td>37.896</td>
<td>162.994</td>
<td>40.748</td>
</tr>
<tr>
<td>May</td>
<td>39.077</td>
<td>40.080</td>
<td>45.648</td>
<td>42.785</td>
<td>167.590</td>
<td>41.897</td>
</tr>
<tr>
<td>June</td>
<td>36.677</td>
<td>34.144</td>
<td>44.952</td>
<td>36.277</td>
<td>152.050</td>
<td>38.012</td>
</tr>
<tr>
<td>July</td>
<td>39.052</td>
<td>36.785</td>
<td>44.952</td>
<td>39.444</td>
<td>160.232</td>
<td>40.058</td>
</tr>
<tr>
<td>August</td>
<td>39.250</td>
<td>38.808</td>
<td>43.728</td>
<td>36.276</td>
<td>158.062</td>
<td>39.515</td>
</tr>
<tr>
<td>September</td>
<td>40.512</td>
<td>44.136</td>
<td>44.952</td>
<td>40.584</td>
<td>170.184</td>
<td>42.546</td>
</tr>
<tr>
<td>October</td>
<td>48.888</td>
<td>46.140</td>
<td>49.848</td>
<td>44.448</td>
<td>189.324</td>
<td>47.331</td>
</tr>
<tr>
<td>November</td>
<td>51.048</td>
<td>49.584</td>
<td>51.816</td>
<td>49.440</td>
<td>201.888</td>
<td>50.472</td>
</tr>
<tr>
<td>December</td>
<td>55.416</td>
<td>52.632</td>
<td>58.008</td>
<td>50.712</td>
<td>216.768</td>
<td>54.192</td>
</tr>
<tr>
<td>Average</td>
<td>43.460</td>
<td>42.093</td>
<td>47.917</td>
<td>41.985</td>
<td>SEM 0.961</td>
<td>CD5% 2.805</td>
</tr>
</tbody>
</table>

Table: 3.4.5 Nitrogen dioxide (NO$_2$) concentration (µg/m$^3$) in ambient air around the cement industry during the month of April to December 2011

<table>
<thead>
<tr>
<th>Month</th>
<th>East</th>
<th>West</th>
<th>North</th>
<th>South</th>
<th>Total</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>55.178</td>
<td>54.497</td>
<td>55.608</td>
<td>52.092</td>
<td>217.375</td>
<td>54.344</td>
</tr>
<tr>
<td>May</td>
<td>55.718</td>
<td>55.380</td>
<td>58.272</td>
<td>56.748</td>
<td>226.118</td>
<td>56.530</td>
</tr>
<tr>
<td>June</td>
<td>52.322</td>
<td>52.068</td>
<td>52.512</td>
<td>52.092</td>
<td>208.994</td>
<td>52.249</td>
</tr>
<tr>
<td>July</td>
<td>43.130</td>
<td>46.039</td>
<td>51.420</td>
<td>50.887</td>
<td>191.477</td>
<td>47.869</td>
</tr>
<tr>
<td>August</td>
<td>50.820</td>
<td>52.782</td>
<td>52.092</td>
<td>50.706</td>
<td>206.400</td>
<td>51.600</td>
</tr>
<tr>
<td>September</td>
<td>57.871</td>
<td>54.497</td>
<td>60.804</td>
<td>59.674</td>
<td>232.846</td>
<td>58.211</td>
</tr>
<tr>
<td>October</td>
<td>60.941</td>
<td>59.186</td>
<td>63.180</td>
<td>54.271</td>
<td>237.578</td>
<td>59.395</td>
</tr>
<tr>
<td>November</td>
<td>64.272</td>
<td>61.058</td>
<td>69.048</td>
<td>65.352</td>
<td>259.730</td>
<td>64.933</td>
</tr>
<tr>
<td>December</td>
<td>60.247</td>
<td>58.248</td>
<td>62.940</td>
<td>61.325</td>
<td>242.760</td>
<td>60.690</td>
</tr>
<tr>
<td>Average</td>
<td>55.611</td>
<td>54.862</td>
<td>58.431</td>
<td>55.905</td>
<td>SEM 1.0622</td>
<td>CD 5%3.100</td>
</tr>
</tbody>
</table>
Table 3.4.6: Ambient air quality around the cement industry in Hirmi village Baloda bazaar district during the month of April to December 2011

<table>
<thead>
<tr>
<th>Month</th>
<th>Direction from industry</th>
<th>RSPM (µg/m³)</th>
<th>SPM (µg/m³)</th>
<th>SO₂ (µg/m³)</th>
<th>NO₂ (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>April to June</td>
<td>East</td>
<td>160.184</td>
<td>432.695</td>
<td>38.990</td>
<td>54.406</td>
</tr>
<tr>
<td></td>
<td>West</td>
<td>155.987</td>
<td>429.402</td>
<td>36.917</td>
<td>53.982</td>
</tr>
<tr>
<td></td>
<td>North</td>
<td>164.536</td>
<td>440.260</td>
<td>45.984</td>
<td>55.464</td>
</tr>
<tr>
<td></td>
<td>South</td>
<td>156.094</td>
<td>434.835</td>
<td>38.986</td>
<td>53.644</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>159.200</td>
<td>434.298</td>
<td>40.219</td>
<td>54.374</td>
</tr>
<tr>
<td>July to Sep 2011</td>
<td>East</td>
<td>148.143</td>
<td>370.405</td>
<td>39.604</td>
<td>50.607</td>
</tr>
<tr>
<td></td>
<td>West</td>
<td>147.682</td>
<td>362.945</td>
<td>39.910</td>
<td>51.106</td>
</tr>
<tr>
<td></td>
<td>North</td>
<td>151.142</td>
<td>377.401</td>
<td>44.544</td>
<td>54.772</td>
</tr>
<tr>
<td></td>
<td>South</td>
<td>149.720</td>
<td>365.970</td>
<td>38.768</td>
<td>53.756</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>149.172</td>
<td>369.180</td>
<td>40.707</td>
<td>52.560</td>
</tr>
<tr>
<td>Oct to Des. 2011</td>
<td>East</td>
<td>165.688</td>
<td>460.211</td>
<td>51.784</td>
<td>61.820</td>
</tr>
<tr>
<td></td>
<td>West</td>
<td>161.508</td>
<td>459.642</td>
<td>49.452</td>
<td>59.498</td>
</tr>
<tr>
<td></td>
<td>North</td>
<td>169.328</td>
<td>471.414</td>
<td>53.224</td>
<td>65.056</td>
</tr>
<tr>
<td></td>
<td>South</td>
<td>160.332</td>
<td>461.951</td>
<td>48.200</td>
<td>60.316</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>164.214</td>
<td>463.305</td>
<td>50.665</td>
<td>61.672</td>
</tr>
</tbody>
</table>

Table -3.4.7: Physico-chemical characteristics of Settle-able dust collected 1 km distance from cement industry during the month of April to December 2011

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Recorded value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>11.80</td>
</tr>
<tr>
<td>EC</td>
<td>1912 (µS)</td>
</tr>
<tr>
<td>CaO</td>
<td>44.0 %</td>
</tr>
<tr>
<td>MgO</td>
<td>2.99 %</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>3.90 %</td>
</tr>
<tr>
<td>SiO₂</td>
<td>10.70%</td>
</tr>
<tr>
<td>SO₃</td>
<td>1.23%</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>2.22%</td>
</tr>
<tr>
<td>Mn</td>
<td>31.02 ppm</td>
</tr>
<tr>
<td>Cu</td>
<td>71.00 ppm</td>
</tr>
<tr>
<td>Zn</td>
<td>60.02 ppm</td>
</tr>
<tr>
<td>Ni</td>
<td>78.00 ppm</td>
</tr>
<tr>
<td>Pb</td>
<td>99.00 ppm</td>
</tr>
<tr>
<td>Cd</td>
<td>7.45 ppm</td>
</tr>
<tr>
<td>Cr</td>
<td>175.0 ppm</td>
</tr>
</tbody>
</table>
3.5 Conclusion- The study elucidates that air pollution emitted from cement industries adversely affecting the ambient air. Emissions of NOx from cement plant can mainly be attributed to large quantity of excess air exceeding the optimum values; however, raw materials from another source of NOx. Sulphur dioxide emissions are largely attributed to the raw materials adsorbed by the cold feed in the pre-heater and the remainder is released with the fuel gases in presence of large quantities of excess air.

Feeding rate and type of incinerator may inhibit or minimize the formation of pollutants. The manufacture of Portland cement is an energy intensive process. It produces significant pollution and uses large amounts on non-renewable resources. With increasing pressures to reduce greenhouse gas emissions due to cement manufacturing, research and development of fuel alternatives and their effect on the manufacturing process has become an industry focus. The inherent properties of sintering cement in a rotary kiln allows for a large number of fuels to be burnt which are normally prohibited for use as fuel in other processes. To examine the suitability of a fuel, process modelling and simulation can be undertaken to predict the final impact of that fuel on kiln performance and greenhouse gas emission. With an accurate model and sufficient data, it is possible to conduct simulations for a wider range of alternative fuels. More research is, however, necessary to evaluate the contribution of individual and in combination of air pollutant on crop production and its losses.
3.6 References-


