A REVIEW ON THE EFFECTS OF CEMENT DUST ON VEGETATION

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ABSTRACT

Cement dust is a potentially phyto-toxic pollutant. Large amounts of toxic substances are emitted during its production viz. carbon dioxide, particulate matter (dust), oxides of nitrogen and sulfur dioxide. Cement dust also contains heavy metals like nickel, cobalt, lead, chromium and mercury. Its alkaline constituents such as oxides of calcium, potassium and sodium are responsible for the alkalization of ecosystem and soil. It is a common air pollutant affecting plants in various ways i.e. cement dust deposition on leaves plugs stomatal activitiy and interrupts light absorption and gaseous diffusion.

Keywords: *Cement dust, Particulate matter, Ecosystem, Air pollutant, Heavy metals.*

Introduction

Cement industry is one of the most boomed up industry in India which is now the second largest cement producer in the world after China. It plays a crucial role in the infrastructural development of the country as there is an interlinking relation between cement consumption and the economic growth. As India is on a high growth track and at present the focus is on the development of the infrastructure facilities such as highways, ports, canals, bridges etc. Infrastructural development obviously gives rise to increased demand for cement production. With the increase in demand for cement in India, the number of factories is increasing annually and both consumption and production of cement has increased greatly in recent years. It is listed as one of the 17^{th} most polluting industries by the Central Pollution Control Board. The emission of dust from cement factories has increased alarmingly due to expansion of more cement plants to meet the requirements of cement materials for construction of buildings. The pollution problem in the cement industry is dust of cement which is emitted from various parts of the production process such as the raw material crusher, rotary kiln, cranes, mills, storage silos and packing sections. Cement dust is potentially harmful to the environment and it affects plants either directly through dust deposition on plants or indirectly by interfering with the soil's chemical composition.

Composition of cement

The main raw material used for cement industry includes limestone ($CaCO_3$), clay, sandstone (SiO_2), bauxite (N_2O_3) and gypsum ($CaSO_4.2H_2O$) and involves the release of various particulates, dust, gases and heavy metals.

Table1: Main constituents of cement.

Compound	Formula
Calcium oxide (lime)	CaO
Silicon dioxide (silica)	SiO_2
Aluminum oxide (alumina)	Al_2O_3
Iron oxide	Fe_2O_3
Sulfate	SO_3

Manufacturing processes

The manufacturing of cement is carried out through these four basic processes- dry, semi-dry, semi-wet and wet processes. All these processes are followed by some sub-processes such as quarrying, raw materials preparation, fuels preparation, clinker burning, mineral additions preparations, cement grinding, and finally cement dispatch.

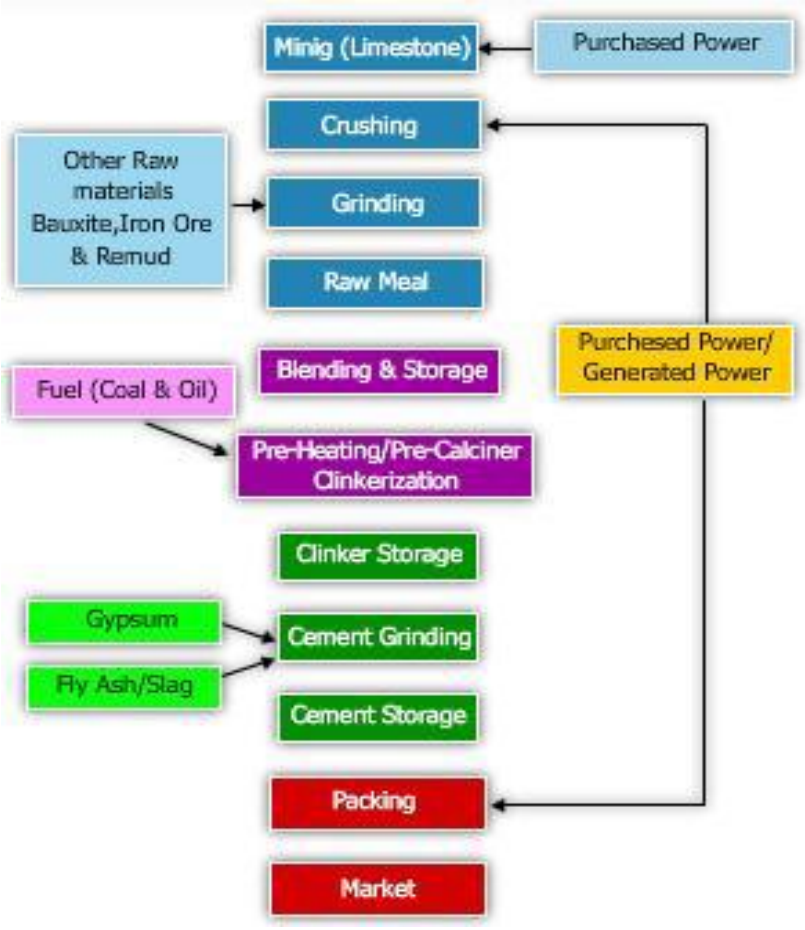

Fig.1. Source: JK Cements LTD

Impact of cement manufacturing

The main impacts of the cement activity on the environment are the broadcasts of dusts and gases. The industry releases huge amounts of cement dust into the atmosphere which settles on the surrounding areas forming a hard crust and causes various adverse impacts. The largest amount of

substances emitted during the production of cement is carbon dioxide, particulate matter (dust), oxides of nitrogen, and sulphur dioxide. Cement dust which contains nickel, cobalt, lead, chromium, mercury pollutants which are hazardous to the biotic environment, with adverse impacts on vegetation, human and animal health and ecosystems (Baby *et al*., 2008).

Plants: natural sink for air pollutants

Plants act as a sink for air pollutants as they reduce their concentration in the air. Dust interception capacity of plants depends on their phyllotaxy, and leaf external characteristics such as hairs, cuticle etc., it also depends on height, and canopy of trees. Pollutants can be removed by plants from atmosphere by three means- absorption by the leaves, deposition of particulates and aerosols over leaf surfaces and fallout of particulates on the leeward side of the vegetation (Rawat and Banerjee, 1996).

Pollutants Mechanism

Pollutants especially cement dust interact with the plants via two ways either it gets deposited on the leaf and plant surface or it settles down on soil surface. In first case it interrupts light availability to the plants which is one of the basic components of photosynthesis. Its deposition on leaf surface affects the gaseous exchange through stomata. In second case cement dust settled on soil interferes with its chemical composition and affects plants via root uptake which has prominent effects on plant growth and yield.

Effects of cement dust deposition on vegetation

Cement dust deposition on various plant parts severely affects the physiological activities of the plants. Photosynthesis is known to be one of the most stress-sensitive processes and it can be completely inhibited by stress before other symptoms are detected. Dust deposition on vegetation affects photosynthetic rate, stomatal functioning and productivity. Limestone present in cement dust severely damages the photosynthetic apparatus of plants. Continuous deposition of alkaline cement dust form a crust on leaves, twigs and flowers and when this dust comes in contact with water it forms a gelatinous calcium silicate hydrate which later crystallizes and solidifies to a hard crust. It ultimately plugs stomata and interrupts absorption of light and diffusion of gases.

Dust particulates absorbed through the outer surface of the plants shows some common effects such as chlorosis, necrosis and growth retardation. Cement dust deposition on the leaf surface reduces the chlorophyll content of the leaf and also acts as a barrier to photosynthetic processes. It shows a subsequent reduction in starch, carbohydrates, proteins and amino acids in comparison to normal leaves. The physiological and biochemical characteristics are severely affected which have direct impact on plant productivity.

Deposition of cement dust on soil

Cement dust deposition on soil surface changes the physico-chemical properties of soil as it causes a shift of pH towards alkaline range, which generally reduces the absorption of mineral substances from the soils. Interference of alkaline cement dust with soil may mediate both the synthesis and decomposition of soil organic matter and therefore influences ion exchange capacity, the soil N, S, and P and soil water-holding capacity. It also affects the microbial activity of the affected soil. Al–Khashman *et al.* (2006) reported that soils around cement factories showed high concentrations of heavy metals.

Morphological changes

Cement dust pollution severely affects the growth and morphology of plants. It might be in the form of

visible markings on the foliage such as chlorosis, necrosis, veinal deformities, mottling etc. Ade-Ademilua *et al*. (2008) reported a significant reduction in shoot length, total leaf area and dry weight of plants affected by cement dust pollution. A significant delay in germination of seeds which was followed by growth retardation in terms of plant height and leaf area, number of leaves, length of petiole, number of flowers and fruits, fresh and dry weight were also seen by Katiyar *et al.* (2015). Reduction in growth parameters are due to the cumulative effects of the causal factors on the physiological processes necessary for plant growth and its development (Schutzki and Cregg, 2007). Dust deposition reduces diffusive resistance and increases temperature of leaf making the tree more likely to be susceptible to drought (Farmer 1993). It also causes slight decrease in transpiration rate, stomatal conductance while leaf temperature increased.

Physiological changes

Air pollution has an adverse effect on many metabolic processes in plants such as photosynthetic activities, mitochondrial respiration and stomatal clogging, seed germination, protein content, soluble sugar contents etc.

Effects on seed germination: In case of cement dust pollution, gradual decrease in seed germination with increasing concentration of cement dust was reported which might be due to the toxic effects of metals present in cement dust which interfere with the normal synthesis of plant metabolites thus directly affecting the cell division and cell elongation (Singh and Srivastava, 2002, Katiyar *et al.,* 2015).

Effects on photosynthetic pigments: Photosynthetic pigments mainly- chlorophyll and carotenoid contents, are affected by a variety of stress factors. As these are the dominant photosynthetic pigments in green plants and assessment of their concentrations in foliage provide an estimate of potential photosynthetic capability (Gitelson and Merzlyak, 1996; Carter, 1998). Chlorophyll 'a' is being more severely affected than chlorophyll 'b'. Chlorophyll 'a' is degraded to phaeophytin through replacement of Mg^{+2} ions in chlorophyll molecules, while chlorophyll 'b' forms chlorophyllide 'b' through the removal of phytol group of the molecule (Rao and Le Blane, 1966). All the atmospheric pollutants retained by leaves are transformed inside the plant and affect its photosynthesis and respiration. This damage appears in the form of chlorotic and necrotic lesions at leaves level (Landis and Yu, 1995). Analysis of photosynthetic pigments may provide insight into the physiological status of vegetation (Moran *et al.,* 2000).

Effects on protein content: Effects of cement dust pollution on certain metabolites such as protein, starch and sugar content were also studied by several researchers and a considerable decrease was found in all. (Vijayawar and Pandey 1996, Murugesan *et al*. 2004). Decreased photosynthesis might be the first cause of decrease in protein content. Stressed conditions might enhance the rate of protein denaturation and breakdown of existing protein to amino acid which ultimately causes reduction in protein content (Constantinidou and Kozlowski, 1979, Singh and Joshi, 1999, Tripathi and Gautam, 2007).

Effects on soluble sugar content: Sugar plays an important role various developmental aspects of higher plants. This organic substance is synthesized during photosynthesis while its breakdown occurs during respiration. The soluble sugar concentration indicates the physiological activity and sensitivity of plants to air pollution. The sugar content was found to be reduced with the increase in the amount of cement dust. Reduction in soluble sugar content in polluted sites might be due to increased respiration and decreased CO_2 fixation because of chlorophyll deterioration (Tripathi and Gautam, 2007).

Effects of heavy metals on vegetation

As cement dust contains a remarkable amount of heavy metals, its amendment in soil causes severe damaging effects such as metal accumulation in various plant parts especially in leaves and roots. Accumulation of different metals has been observed in different plant parts as aluminium has been observed in leaves, however copper is found in the seeds.

In both cases, these metals could be hazardous to human health as leaves and seeds both are consumed by humans. Heavy metals become bio-accumulated in the body and remain in the body in an unchanged state and are continually accumulated during the life of an organism causing biomagnifications (Clark, 1995). In some cases, plant growth was also found to be reduced due to metal-metal interaction which reduces the availability of certain minerals to the plants. Alkalization and high amount of Ca^{++} content of the cement pollutes soil environment which inhibits the assimilation of Mg, Mn and Fe by plants (Mandre and Tuulmets, 1997).

Iron is essential for plant growth and its presence in cement dust could be of advantage; especially when cultivating legumes that are naturally sourced for their iron content. Heavy metals like zinc and copper which could be present in the soil due to synergistic effects (metal-metal attraction and association) as pointed out by Forstner (1995) can reduce the translocation of iron in plants. Heavy metal pollutants are stable in the environment but highly toxic to biological organisms (Zou *et al.,* 2006; Levent *et al.,* 2009). Among the heavy metals— mercury, lead, nickel and chromium are most dangerous heavy metals released by cement factories (Kumar *et al.,* 2008) and are responsible for causing various biochemical changes which also include cyto-toxic and mutagenic effects (Ritambhara *et al.,*2010 and Yahaya *et al.,* 2012)

Effect on soil physiology

Cement dust deposition on soil surface interferes with its physico-chemical properties which might be in terms of mineral disbalance. Cation exchange capacity was basically affected by pollutants. Studies revealed that cement dust affects the availability of exchangeable calcium, sodium, hydrogen, magnesium and soil organic matter. The concentration of metals such as Fe, Al, Zn, Cu, Pb, Cr and Cd were found relatively high in the soil nearby cement industries as compared to normal (Asadu *et al.*, 2008). Cement dust accumulation caused an increase in pH of soil solution, salinity, calcium carbonate, electrical conductivity, total alkalinity and sulphate contents beside the disturbance of soil texture (Abdel-Rahman and Ibrahim 2012)

Conclusion

The present study concludes that cement dust pollution is very hazardous for environment. This industry has a significant contribution to air and soil pollution. It has a deleterious effect on vegetation as it causes severe reduction in growth and physiological activity of plants. Presence of heavy metals in cement affects the mineral assimilation through roots. Bio-magnification of heavy metals in various plant parts is also a serious issue which could not be neglected as it might have serious consequences at each trophic level in the food chain. Such detrimental effects from cement industries are alarming which forces us to be more sensible and conscious about industrial settlement.

The byproducts and environmental hazards caused by such sources are thus alarming. Pollution control must be taken as a priority by the industrialists and such socially responsible industries should also be encouraged by the government for their technological advancement for minimizing waste and become eco-friendly. Development should be sustainable as we must have to create a secure

environment for the upcoming generations by keeping the following points into consideration:

- Cement industries should be installed on the outskirts of town or cities.
- Ethical guidelines should be approved by government.
- Workers should be trained in the light of hazardous consequences of cement dust.
- Regular health check up of workers should be done to reduce the occupational health issues.
- Green belt development should be encouraged in nearby areas for attenuation of industrial air pollution.

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