

Dry deposited fluxes of inorganic constituents after a fire in Delhi—A case study

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Dry deposition samples, after a fire in a plastic scrap market in Delhi, were collected and analysed for pH, electrical conductance, Cl, NO₃, SO₄, Na, K, Mg and Ca. The fluxes of Na, Ca, Cl and NO₃ were observed to be 16, 7, 4 and 4 times higher than those under normal conditions. The higher fluxes of Cl may be attributed to the pyrolysis of PVC, while the higher fluxes of other components may be due to their presence in PVC or other materials burnt in the fire. Assuming that the fire influenced 1/4 part of Delhi, the total deposition of Ca, Cl, Na, NO₃, SO₄, K and Mg was estimated to be 61, 21, 16, 16, 11, 11 and 5 tones, respectively, due to this fire incident.

1 Introduction

Dry deposition is an important removal mechanism, because it operates throughout the travel path of a given emission in the mixing layer. The immediate and long term effects of dry deposition are of interest because of their potential influences on materials¹, forest canopies^{2,3}, plant health, plant biomass production and nutrient balance. A number of studies have been carried out on dry deposition to estimate the input of acidity, deposition of trace metals, cause for plant disease and throughfall chemistry in forests⁴⁻¹².

The deposition of particles are contributed by soil suspension, volcanic eruption and combustion of wood and other biomaterials. The combustion proceeds in three stages—(a) the pyrolysis of the material and its partial volatilization, (b) the organic vapours produced undergo combustion of organic matter in the flame zone and (c) the char produced in the first stage is subjected to a slower oxidation, provided the temperature stays high enough. This state is referred to as smoldering combustion. The formation of particulates occurs during all the three stages by the mechanical release of charcoal particles and by the escape and condensation of organic vapours. The analysis of particulate matter from open fires indicates that about 50% by weight is benzene

soluble organic compounds, 40% is elemental carbon and 10% is mineral^{13,14}.

The results of a study carried out after a fire which occurred at Jwalapuri PVC scrap market located in the west of Delhi city are presented in this paper. The fire was so severe that the whole market went up in the flames on 6 June 1995 causing a big loss to the plastic industry. Over 2500 shops stacked with PVC scrap were gutted by fire that engulfed almost everything in one square kilometre area. The thick smoke billowing from the tones of burning PVC material enveloped the neighbouring colonies and a good part of the capital was affected. The blaze which ravaged the biggest market of its kind in Asia, apparently started and ran through the sprawling complex, turning everything into a smoldering rubble within an hour or so. The smoke cover was mistaken for clouds at long distance till its source was seen.

In this paper, an effort has been made to estimate fluxes of Cl, SO₄, NO₃, Na, K, Mg and Ca and to compare with the fluxes obtained earlier during normal conditions. An estimation of total deposition of these components over Delhi has also been made.

2 Experimental observations

2.1 Site description

Delhi is a continental, urban site and one amongst

the twenty most polluted cities in the world. It lies in north-central India ($28^{\circ}12'N$ - $28^{\circ}53'N$; $76^{\circ}50'E$ - $77^{\circ}50'E$) and has an area of 1483 km^2 . The industrial activities include various types of manufacturing units like chemicals, plastics, cloth dyeing, potteries, steel rolling, engineering, pharmaceutical, rubber pulverization, and ferrous and non-ferrous castings. The vehicular density has also grown nearly 2.4 times from 0.93 million in 1985 to 2.23 million in 1994 (Ref. 15). Samples were collected at the terrace of the National Physical Laboratory (NPL) which is located at a distance of about 15 km in the S-E of Jwalapuri where the fire incident took place. The locations of fire incidents and collection site have been shown in Fig. 1.

2.2 Sample collection

The dry deposition samples were collected from 8 June to 30 June 1995 at the roof of NPL terrace at a height of 13 m above the ground using a collector and a stand raised at 1.5 m above the roof. The collector consisted of a polypropylene funnel (dia = 20 cm) fitted on a polypropylene bottle. The collector was exposed for a period of 24 h (10 a.m.-10 a.m.) and the deposited material was dissolved in 60 ml of double distilled deionized water. The samples were filtered through pre-washed whatman-41 filters to avoid any contamination. The filtrate was stored in cleaned polypropylene bottles in which a small amount of thymol was added as a preservative^{16,17}.

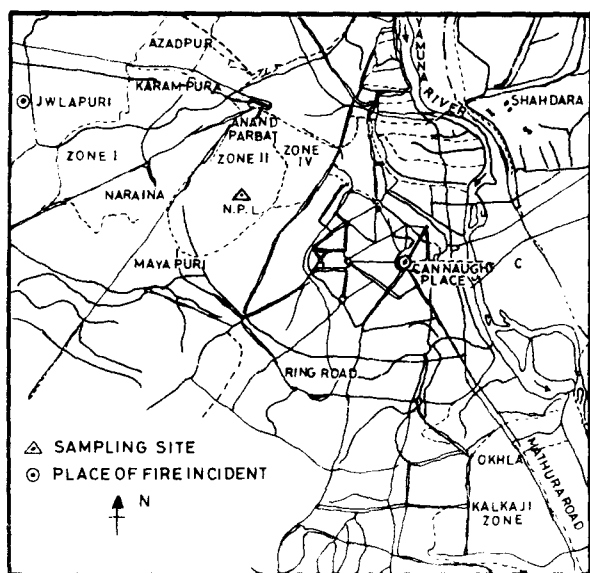


Fig. 1—Map showing the location of sampling site and fire incidents

2.3 Analysis

The pH and electrical conductance (EC) of dry deposition samples were measured just after their collection. The anions, i.e. Cl , NO_3 and SO_4 were analysed by ion chromatography (Dionex 2000i/SP) using AS4A separation column and AMMS-II suppressor column with eluent of 1.8 mM $\text{Na}_2\text{CO}_3/1.7 \text{ mM NaHCO}_3$ and 25 mN H_2SO_4 as regenerant. The cations Na, K, Mg and Ca were analysed by atomic absorption spectrophotometer (Varion Spectra AA-10).

3 Results and discussion

The pH of samples varied from 6.6 to 8.4 with an average of 7.7. Electrical conductance varied between $18.3 \mu\text{S cm}^{-1}$ and $79.3 \mu\text{S cm}^{-1}$ with an average of $47 \mu\text{S cm}^{-1}$. The pH of each sample of dry deposition was higher than our previous observations under normal conditions when no such incident occurred¹⁸. During normal conditions, the pH ranged from 5.7 to 7.3 for the same season. The reason for very high pH may be due the contribution of Na, K, Mg and Ca in large amount during the fire as the compounds of these elements are used as thermal stabilizers in PVC formation. These cations contribute to the alkalinity of dry deposition to a large extent.

The data of present study from 8 June to 27 June 1995 show a decreasing trend of deposition for anions and cations. Figure 2 shows the variation of fluxes of Cl and Ca in the samples. The variation of one anion (Cl) and one cation (Ca) have been shown just to understand the effect of PVC burning. All other anions and cations had almost similar

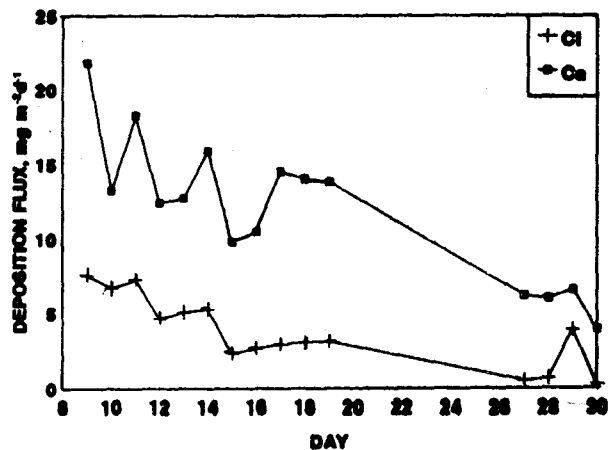


Fig. 2—Curves showing the variation of Cl and Ca on different days in June 1995

variations. It shows that fluxes of both are decreasing to the background level up to 28 June. A slight increase on 29 June 1995 seems to be due to another fire incident which occurred on midnight of 26 June 1995 in central part of New Delhi at Cannaught Place (at a distance around 5 km from NPL). Though this fire incident was not so severe, but seems to have influence on the dry deposition fluxes reported in this study. In addition, during the period of Jwalapuri fire incident, the prevailing wind direction was N-W and W and during the small fire at Cannaught Place, the prevailing wind direction was S-E and E which influenced the observations, as collection site is located in downwind Jwalapuri as well as Cannaught Place where the fire incidents took place [Fig. 3(a) and (b)]. On the second day after the incident, i.e. on 8 June 1995, the pH, EC and the fluxes of other ions were in the same range as reported earlier. It may be due to the fact that any particle emitted into the atmosphere requires certain residence time to get settled. Deposition velocities might not be sufficient to make these particles settled at the surface on the first two days.

Figure 4 shows a comparison of fluxes of Cl, NO₃, SO₄, Na, K, Mg, Ca (as observed in the present study) with the earlier observations¹⁸ (the prevailing wind directions were same during both studies which were done in the same season of different years). It

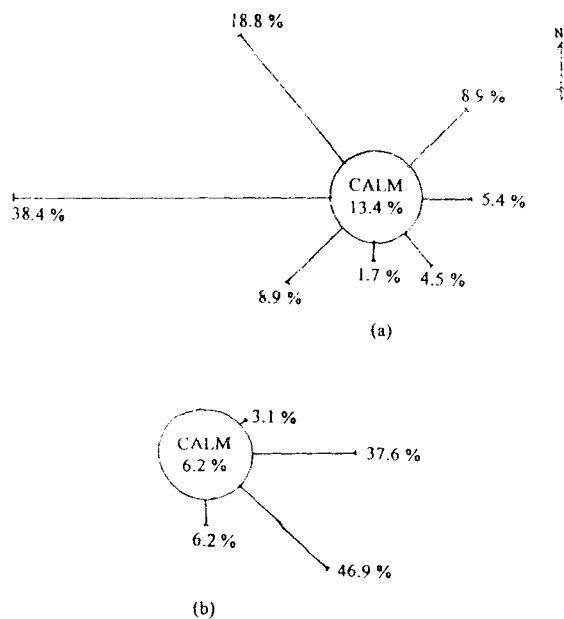


Fig. 3— (a) Wind rose for the period 8-27 June 1995 showing N-W and N as prevailing wind directions and (b) Wind rose for the period 28-30 June 1995 showing S-E and E as prevailing wind directions

shows that the deposition fluxes of all the components are enhanced. The fluxes of Na, Ca, Cl and NO₃, have increased by a factor of about 16, 7, 4 and 4, respectively, and those of K, Mg and SO₄ have increased by a factor of 2. The reason for the large increase of fluxes of Na, Ca and Cl may be due to the pyrolysis of PVC and release of these compounds at high temperature¹⁹. Many materials are used in the production of PVC appliances to avoid degradation, discoloration and for economic production. Degradation is checked by effective thermal stabilizers consisting of organometallic and inorganic salts which are especially effective. Metal soaps of Na and Ca are also used as stabilizers to prevent discoloration. Magnesium silicate, potassium aluminium silicate, hydrous magnesium silicate and calcium carbonate are used as fillers and are effective in reduction in cost. Calcium stearate is used as a lubricator in toys products and also for food appliances²⁰. Sodium and potassium phosphates/phosphites are used as excellent light stabilizers. A barium sodium derivative is excellent for stability of transparent products. Sulphates and thiosulphates of sodium and potassium, pyrophosphate of sodium, hydroxides, oxides and silicates of calcium, sodium carbonate and nitrates of sodium, potassium, magnesium and calcium are also used as general stabilizers²¹. In addition, these components might have been contributed by the burning of materials other than PVC kept together as scrap.

The concentration of these materials may vary in different PVC products but would contribute to dry deposition calculations of the total dry deposition (in tones) of Cl, NO₃, SO₄, Na, K, Mg and Ca. These

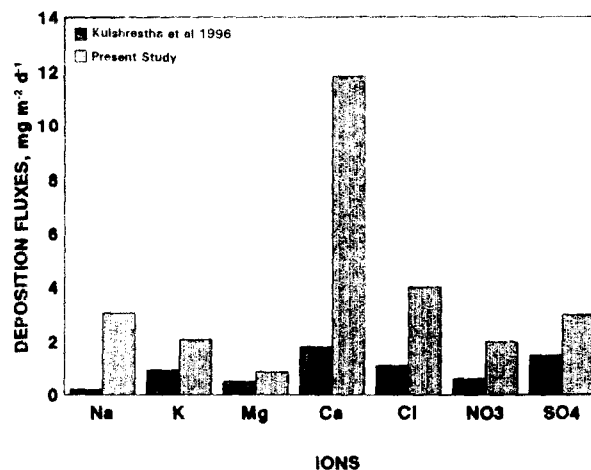


Fig. 4- Histogram showing the fluxes of major ions

calculations are based on the assumption that this fire incident affected 1/4th part of Delhi and deposition continued for about 14 days till almost all the particles contributed by fire got dry deposited. After 14 days, the concentration of different species was observed to be normal as reported under normal conditions. Among the anions, deposition of Cl was maximum followed by NO₃ and SO₄ and found to be 21, 16 and 11 tones, respectively. Among the cations, deposition of Ca was found to be maximum followed by Na, K and Mg and estimated to be 61, 16, 11 and 5 tones, respectively.

4 Conclusions

The results of this fire incident reveal that Cl, SO₄, NO₃, Na, K, Mg and Ca have greater dry deposition fluxes as compared to those reported under normal conditions. It indicates that these ions have been significantly contributed by this fire, Cl being the highest in anions and Ca being the highest in cations. The highest deposition of Cl may be ascribed to the pyrolysis of PVC, while the highest deposition of Ca may be due to the fact that Ca compounds are used as the thermal stabilizer for the upgradation of PVC. This is one of the first attempts to investigate the changes in atmospheric deposition due to the combustion of plastic scrap. More detailed studies in the laboratory under controlled conditions are being planned to understand the contribution of the organic and inorganic constituents from burning of PVC appliances from such accidental or refuse incineration fires.

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