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**ORIGINAL ARTICLE**

# The optimization of detrimental effects of air pollution on buildings

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**ABSTRACT**

*Air pollution is a threat for the architecture as it accelerates depreciation in buildings. It is imperative to monitor air pollution as it escalates the burden on the economy of a country. In the present work, thetinplates were mounted in three different environmental regions (moderately polluted, heavily polluted, and relatively pristine environment). Site 1isEast Delhi (28.6276° N, 77.2784° E), Site 2 is South West (28°36'39.0"N, 77°02'16.0"E) and Site 3 is West Delhi (28°39'10.1"n, 77°09'27.2"E). Site 3 is heavily polluted majorly with vehicular pollution; Site 2 is enriched with vegetation/greenery while Site 1 exhibits moderate pollution. The plates were mounted on the concrete walls (height from the ground ~ 40m-50m) over the aforementioned sites for 90 days. The plates were analyzed for the morphological, physical, and chemical properties of the particles deposited on the wallsvia SEM-EDX (Scanning Electron Microscope- Energy Dispersive X-Ray).The contaminantsposses at East Delhi is Si, Al, N,Fe, C, Ca, Mg, K while at South West Delhi Si,Al,Fe,Ca, and at West, Delhi is Si, N Fe, C, Cd.*

*Keywords: Particulate pollution, Anthropogenic, Vehicular pollution, Concrete walls, Urban environment.*

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## INTRODUCTION

In a typical urban region, particulate pollution is contributing to the degradation of the outermost layer of walls by discoloring the paint or whitewash which gives rise to a huge economic burden on individuals and the governments[1].In recent years, the level of VOCs (Volatile Organic Compounds) and toxic gases have been rapidly increasing in urban areas. It is mainly in the cities of the countries which are developing or underdeveloped[2].The report of 2018 by WHO (World Health Organization)revealed that out of50 most polluted cities from all over the world are mainly from India and China i.e. 15 and 21 respectively. The main sources of air pollution are traffic blockage, unconstrained emission from vehicles and factories [3], building construction sites [4], burning of biomass and fuel wood [5], adulteration of fuel, and burning of crops residue on large scale[6]. The sources of pollutants that affect the atmosphere are smog, airborne particulate matter i.e. $PM_{2.5}$ and $PM_{10}$, SOx, NOx, CO, VOCs, and $NH_3$that are rapidly increased in the air [7]. These all pollutants are crossing the permissible limit in Delhi as it is the sixth most polluted city in the WHO list [8].

The increase in pollution may also cause some serious health problems such as lung damage, heart disease, etc. In 2010, the data from government environment regulatory like CPCB (Central Pollution Control Board) revealed that 77% of Indian urban clusters exceed NAAQS (National Ambient Air Quality Standard) for respirable suspended $PM_{10}$ (Particulate Matter) (CPCB 2012) [9]. The projections from WHO suggest that 13 out of 20 cities having the worst rate of fine $PM_{2.5}$of air pollution in India, in which Delhi is included in the worst rank city [10].The facade and beauty of the building are depreciated by the enhancement of the concentration of pollutants. According to the censor and Delhi had a population of around 16.7 million and 18.1 million in 2011 and 2016 [11]. From the last few years, there was an increment of developing industries in Delhi and NCR region as compared to a village which leads to the deterioration of buildings. Carvo *et al* have investigated how the pollutants and relative humidity can affect the building and the pollutants responsible for the blackening of buildings in 2008 [12].Orga2011 *et al* reported that the impact of anthropogenic pollutants is available in two different environments one is in Italy while the other is in Poland. The studies revealed the identification and computation of pollutants

that are responsible for surface deterioration [13]. Florentino *et al* reported that the metals are deciphering black crust on historic buildings[14].
This paper focuses on the investigation of the contaminates that are depositing on the surface of buildings and the effects of these pollutants on the facade of the building. We have collected particulate samples on the plate which are deposited on the building's concrete walls from assorted locations in a typical urban environment like Delhi. These contaminants were analyzed with the help of SEM- EDX and give a brief description of the pollutants which are accumulating on the surface which are responsible for the façade to lose its charm. These pollutants may provide some serious problems on the wall of building like cracks, degradation of outer painting if not controlled.

## MATERIAL AND METHODS

### Sampling sites

There are three different locations were chosen for sampling in the region of Delhi. The ambiance of all three locations was different so that the comparison can be made between the type of pollutants that are degrading the buildings. The tin plates were mounted on the surface of the concrete wall at the height of ~50 to 60 m so that the exposure to the environment is favorable and the deposition of pollutants is impeccable.

### East Delhi

It is situated in the east of Delhi and the geographical position of a site I is 28.6276° N, 77.2784° E. it is a residential area and the sample is mounted on the top floor in the building which is of height around 40-50m. location is around 500 m from the metro station and the connectivity to the main road is 130.70 m.

**Figure 1:** Sampling site for East Delhi

### South West Delhi

The location of site IIis in the Southwest of Delhi having a geographical positionof 28°36'39.0" N, 77°02'16.0" E. It is an educational institute with having a green atmosphere. The sample is mounted at the height of around40-50m. Location is around 2.3 k from metro i.e. Dwarka mor and distance of the road and the sampling site is 348 m apart only and this road is connected to the main road which is 1000 m awayfrom the building area.

**Figure 2:** Sampling site for southwest Delhi

 

## West Delhi

The location of site IIIis west of Delhi having a geographical position of 28°39’10.1”n, 77°09’27.2” E. This is a heavily polluted area as vehicular emission is higher in this area. The sample is mounted at the height of around 40-50m. Location is around 1 k from metro i.e. Shadipur and distance of the road and the sampling site is 69 m apart only.

**Figure 3:** Sampling site for West Delhi

## Materials and methods

### Tin Foil

The atomic number of tin is 50 and the chemical symbol is Sn. Tin is a metal having a silvery-white appearance, which is a soft metal and can be cut *via a* knife. The main advantage of tin is that it is easily accessible. Tinfoil (Alfa Alser) of thickness 0.01 mm and the purity is 99.99% has been used for the collection of air pollutants.

### Methods for sampling

Tinfoil (size 1 × 1 $mm^2$; ~0.1mm) were marked for the exposure side and then mounted on the grid of the concrete wall for three months i.e. February to April 2018 [15]. The tin is preserved till it is characterized. It is stored safely in small micro-biological specimen tubes so that the moisture is not absorbed by the plate. These samples were characterized by SEM-EDX (BRUKER). The chemical composition of selected particles as well as rare scans were performed by the SEM(Zeiss) equipped with an EDX spectrometer.

## RESULT AND DISCUSSION

The result has been conferred in two sub-sections i.e. bulk characterization of SEM-EDX followed by an individual single particle which was characterized by SEM-EDX.

*Bulk Characterization of SEM-EDX*

Here the boxed surface is scanned for elemental analysis with SEM equipped with EDX for the qualitative and quantitative analyses of foil. At site I the concentration of elements as shown in table 1 Si, Al, N, Fe, C, Ca, K, Mg while at site II the main elements that are found are Si, Al, Fe, and Ca, and the elements are investigated at site III are Si, N, Fe, C, and Cd.

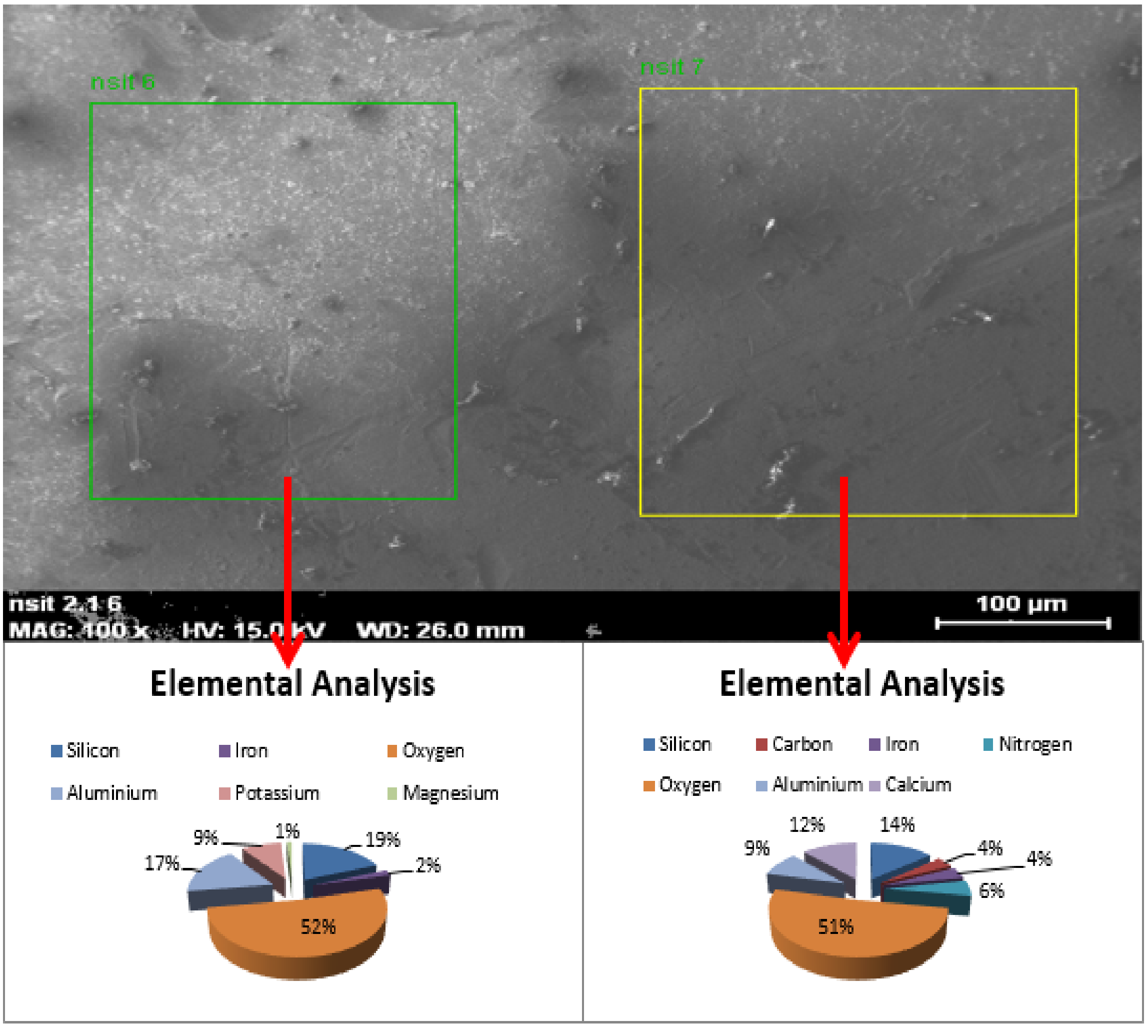


**Figure 4.** SEM-EDX of tinfoil of East Delhi

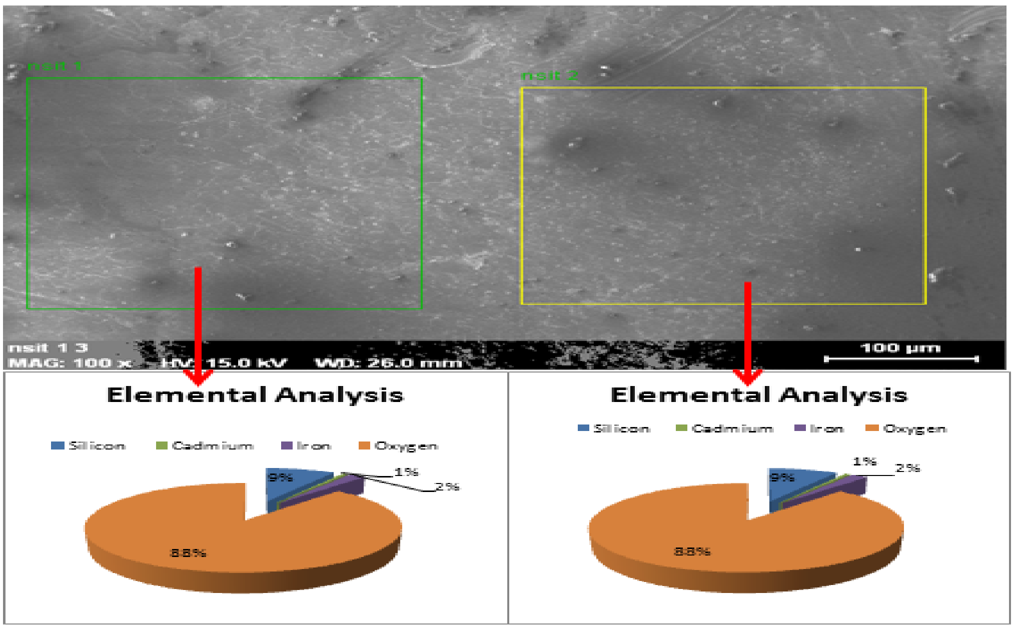


**Figure 5.** SEM-EDX of tinfoilof South West Delhi

 

Figure 4 indicates the presence of a concentration of elements like silicon, aluminum, calcium, potassium, nitrogen, carbon, iron, magnesium. The percent of elements present at site 1 are Si-0.688833274, Al-0.1116304 are typical dust signatures, and the presence of oxygen, Alumino-silicate and quartz particles are one of the major components of dust [16,17].The indication of Ca0.109553244concentration has been detected. The source may be the soil and it is an ore of dolomite and calcite[18,19].The various anthropogenic polluted elements like K, N, C, Fe, Mg having concentrations 0.5993333330,330669883,0.253279059, 0.079736, 0.078 are also detected on the sites. The source of emission of pollutants is biomass burning, vehicular emission, coal combustion, fly ash[20,21].As the site is residential, it may be biomass burning or particles of carbon that can form a matrix of neo-mineral due to the synergic interaction between material and environmental assistance. As nitrogen, itself is an inert element but it can form oxides of nitrogen which is acidic and result in degrading and white patches on the building were observed. This can be justified as Corvo*et al* has also said that oxides of nitrogen is responsible for the degradation and formation of white patches and the dust which accumulate on the surface not only dim the façade[12].

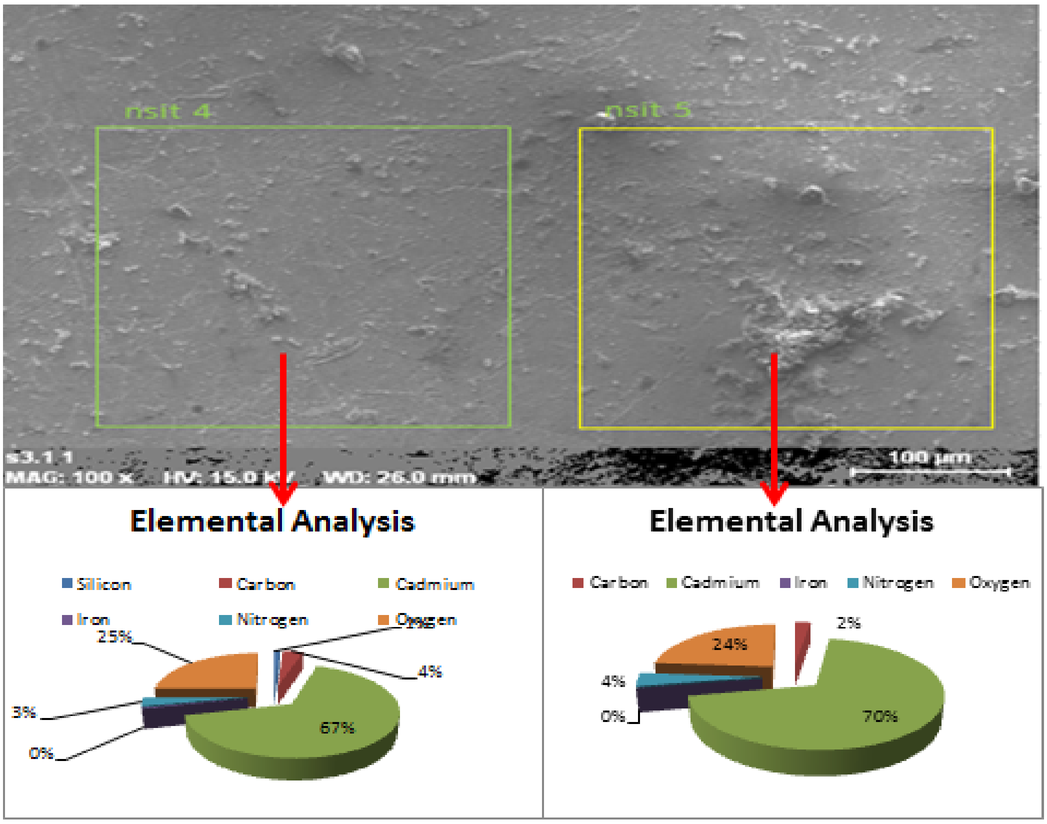


**Figure 6:**Figure SEM-EDX of tinfoil of West Delhi

At site II Si and Al are pollutants found in major parts. The main source of pollutants is dust. The concentration of Ca is 2.61351448 and the source may be soil or as it is a residential site in construction work is going on in which Ca is one of the components of cement [22]. Fe is mainly found in fly ash and vehicular emission. The deposition of dust is responsible for the black crust on the surface of the buildings [23].

The bulk characterization indicating that cadmium has only been found in the region of site III i.e. west Delhi and the concentration of other elements i.e. Si-0.068666667, N-0.499333333, Fe-0.03, C-0.412, Cd-9.07. The traces of carbon has also been found in the very same region and the main source of emission of carbon in the air is vehicular emission which differs on numerous factors including operating conditions, fuel composition, exhaust after-treatment technology, engine technology [24]. Diesel vehicles are one of the important sources of BC (Black Carbon), ultrafine particles, NOx in Urban and near roadside areas [25,26] and gasoline vehicles are the major source of CO (Carbon Monoxide) and VOCs [27]. Modern exhaust after-treatment techniques like diesel oxidation catalyst and PDF (diesel particulate filter) are considered to be effective in reducing the emission from diesel vehicles [28]. While cadmium is a heavy

 

metal emitted from the smoking of cigarettes and food [29]. Cadmium metal is mainly used in industrial processes like in the manufacturing of batteries nickel-cadmium. Cadmium is also associated with brake dust as it is used in the plating for the prevention of break pad corrosion [30,31]. As this site is heavily polluted with vehicular emission so they may be the source of emission at site 3. Oxides of nitrogen is an anthropogenic source of pollution which are responsible for the blackening of building and forming patches [32]. Carbon is responsible for the black crust on the buildings. Ghedini*et al* have analyzed that carbon is responsible for the blackening of the outermost layer of a building [32,33].
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**Table 1:**elemental analysis of tinfoil evaluated from SEM-EDX

| Elements | Site 1 | Site 2 | Site 3 |
|---|---|---|---|
| Silicon | 0.688833274 | 0.085716 | 0.068666667 |
| Aluminum | 0.1116304 | 0.020259802 | - |
| Nitrogen | 0.330669883 | - | 0.499333333 |
| Iron | 0.079736 | 0.526754856 | 0.03 |
| Carbon | 0.253279059 | - | 0.412 |
| Calcium | 0.109553244 | 2.61351448 | - |
| Potassium | 0.599333333 | - | - |
| Cadmium | - | - | 9.07 |
| Magnesium | 0.078 | - | - |
| Oxygen | 2.199787 | 3.169333 | 3.33733333 |

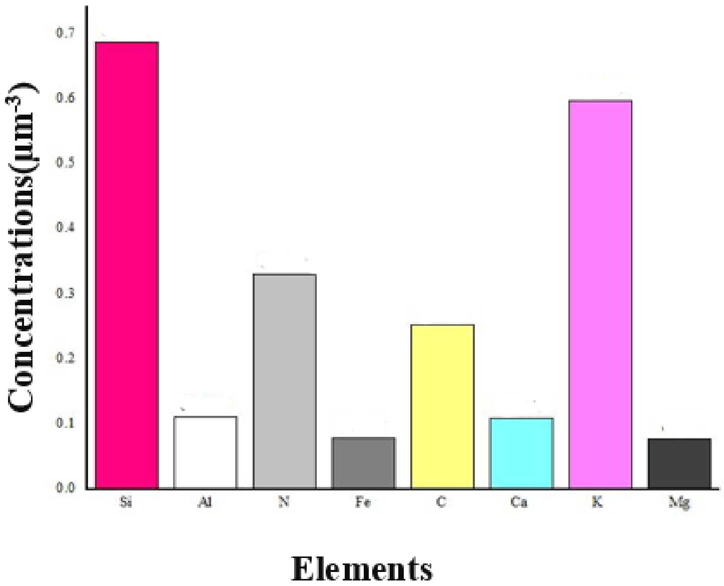


**Figure7:** Concentrations of elements present at East Delhi

In the region of East Delhi concentration in decreasing form are silicon, potassium, nitrogen, carbon, aluminum, calcium, magnesium, and iron. Si and Al is a dust signature and the reasoning of this can be dust storm as there was a dust storm during the time of sampling. C, Ca, K, and iron is anthropogenic sources. The Source of emission of carbon in the environment can be biomass burning and it is justified as it is a residential area [34]. Ca and Fe can be released from cement in the atmosphere as the construction is going on in a nearby place.

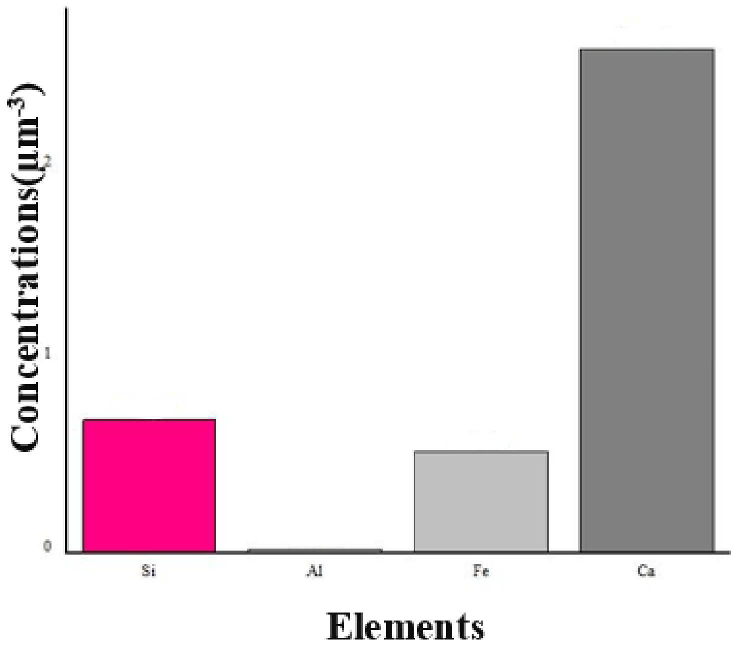


**Figure8:** Concentrations of elements present at South West Delhi

Calcium is investigated higher in the southwest region of Delhi followed by silicon, iron, and aluminum. Si and Al is a typical dust signature and the location site is enriched with greenery and it is acceptable from the composition. Although Ca and Fe may be transported from the different regions due to sand storms in Delhi during the sampling time.

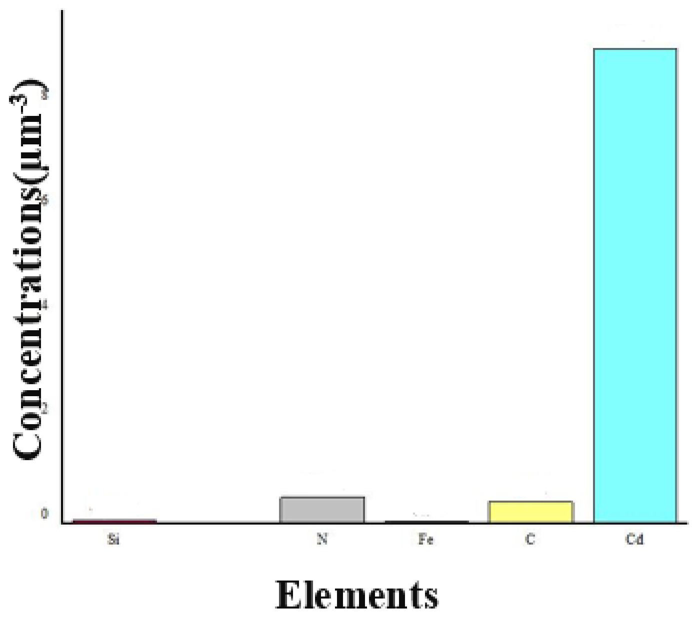


**Fig 9:** Concentrations of elements present at West Delhi

The graph interprets that the concentration of cadmium is higher in West Delhi which is a particular anthropogenic pollutant followed by nitrogen, carbon, and silica. Cd is a heavy metal released in the atmosphere through industries, vehicles and the location is highly prone to vehicles and industries [35]. C is also emitted by vehicles, burning of coal, etc.

*Individual Single Particle*

This section focusesonthe individual particle. As seen in fig10 the particle is like the dust is shown at site 3 as it is a greener site. At site II elemental analyses reveals that there are elements that are found dust as well as anthropogenic although the concentration is quite low they are also present. Which may cause dullness to the exterior surface[36].

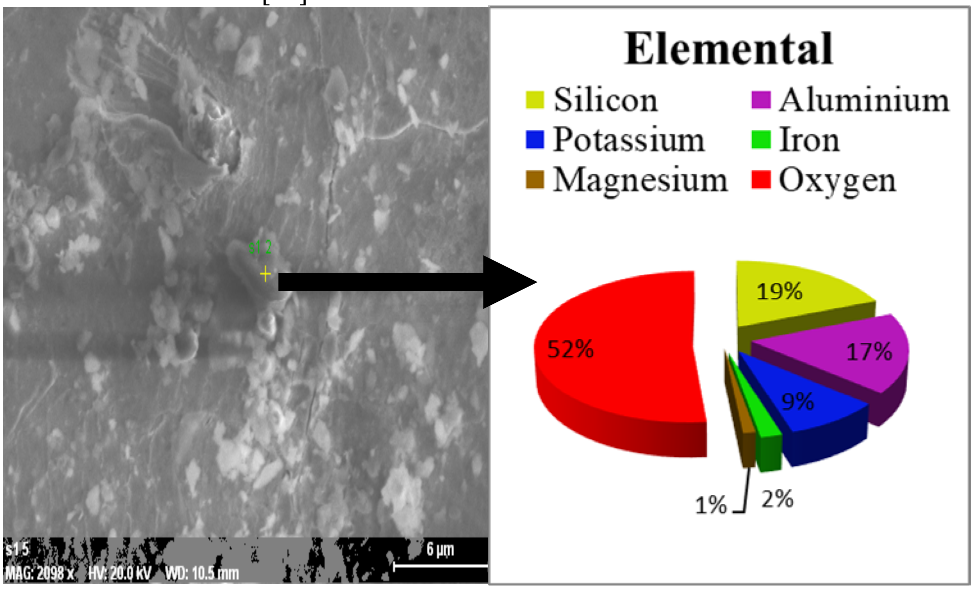


**Figure 10:** investigation of single particle using SEM-EDX of East Delhi

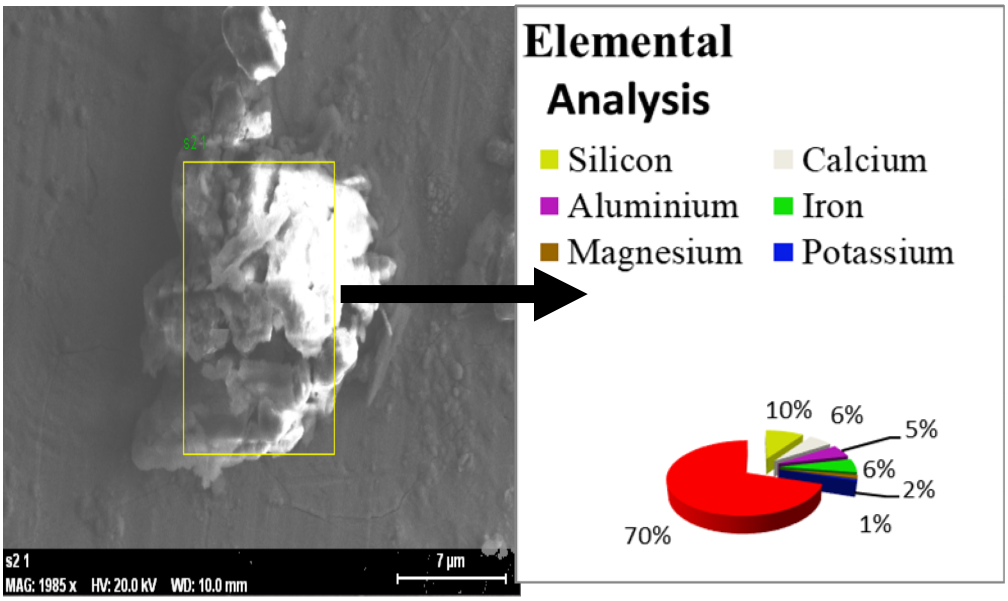


**Fig 11**: an investigation of a single particle using SEM-EDX of South West Delhi

 

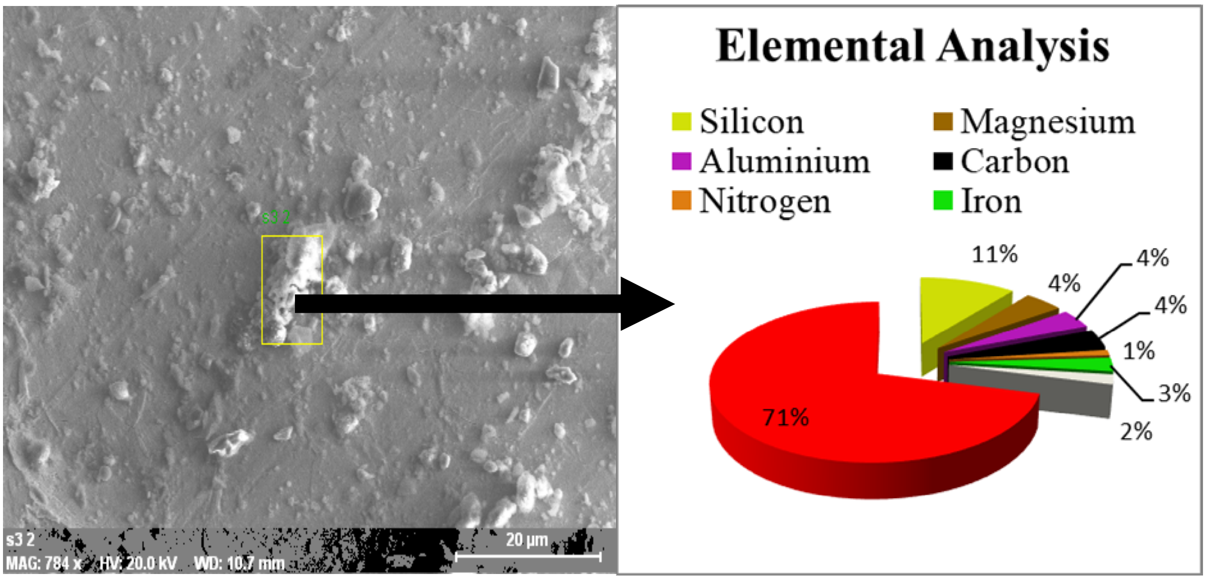


**Fig 12**: an investigation of a single particle using SEM-EDX of West Delhi

From figure 12 it can be predicted that pollutants are different from both sites like particular anthropogenic i.e. carbon and hydrocarbons which are emitted from vehicles or coal-burning as there are restaurants nearby site III as the hotels use coal for tandoors for making chapattis and from elemental analysis also it is shown that there are anthropogenic pollutants like carbon, potassium iron.

## CONCLUSION

The studies reveal the elements investigated indifferent locations. The pollutants examined at East Delhi are Si, Al, N, Fe, C, Ca, Mg, K while at South West Delhi Si, Al, Fe, Ca and at West Delhi are Si, N Fe, C, Cd. The pollutants found at residential sites are responsible for the formation of the black crust while at a greener area i.e. site II the particles form white patches on the outer surface and dust sticks on the surface makes the façade's appearance dull. While at site III heavily polluted and the particles found due to road dust, vehicular emission, and coal-burning from nearby hotels cause black crust, white patches, and cracking on the outer surface. Recently researchers are also employing to the smart building ( in developed countries) in use which can monitor the permissible limit of the pollutants like VOC's along with the humidity and also restricts the excess limit by proper detection and ventilation. To reduce the effect on the surface of buildings the nanomaterials of titanium dioxide and zinc oxide with paints can be employed. These materials can create a repulsion for the pollutants to interact with the material buildings and will reduce the damage to the buildings.

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