Factal analysis of the contribution of aerosols from two different major sources

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Indian coals have high percentage of ash content. Bigger sizes are crushed into smaller ones and fed for washing. The main air pollution problem due to washeries project is the dust, which is more acute than any other coal processing industry. It is, therefore, essential to pay attention to assess the impact on air environment due to washeries activities. Air pollution problem in the washery in question was due to the superimposition of pollutants from the washery and a thermal power plant (TPP). To evaluate the actual contribution of air pollutants by washery and thermal power plant factal analysis techniques were adopted. Approach to the selection of air monitoring stations for factal analysis and methods adopted for air quality survey have been described. Three season data were generated and the status of air pollution has been evaluated. The data were critically analysed on the basis of changes in wind directions at different seasons, the proportion of ash and volatile matter in washery dust and TPP fly ash, and microscopic examination of the SPM by identification of black dust from the coal washery and whitish gray dust from power plant. From the data results the actual contribution of pollutants by the washery and thermal power plant were evaluated. The results obtained by different techniques were found to be comparable.

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The Indian reserve of coking coal is mainly located in the Jharia Coalfield. But these coals are believed to be of drift origin and have huge percentage of mineral matter embedded in them. The coking coal used in the blast furnace should have the ash content 14-20%, whereas Indian coals have much higher ash content. Thus, the demand of coal with an ash content that falls below the specified limits has led to the planning for up gradation of coal. To do so bigger sizes as mined are crushed into smaller sizes and fed for washing in coal washeries. In this process gravity separations eliminate the loose mineral materials. Some non-coking coals are also washed for thermal power plants to make it more efficient and higher heat evaluation per unit weight of coal burnt. The main source of air pollution in washeries areas is the dust generated during crushing, screening, loading and unloading of the cleans, middlings and reject coal. The movement of vehicles on dusty roads emits dust. Also burning of coal and vehicular movement in the areas generates large quantities of gaseous pollutants. These are not only causing pollution in washery premises but also in the surrounding areas. It is believed that air pollution caused by washeries is more acute than any other coal processing industry.

At present, there are 23 washeries located in the Jharia Coalfield region with an annual rated input of 45 Mt. The number of washeries is not sufficient to fulfill the demand of washed coal in the country. Thus, there are plans for more number of washeries to be installed in the area, which will create more serious air pollution problems. Therefore, attention must be paid towards evaluating the impacts on the air environment due to the washeries activities to check the air pollution problem. As the study area is being polluted by the surrounding industries like a thermal power plant, the objective of the present study is to evaluate the contribution of fly ash in increasing the concentration of SPM in the washery premises. To understand the contribution of air pollutants by the washery and thermal power plant, attempt has been made to develop a factal analysis technique to assess the actual contribution of fly ash from the thermal power plant to the coal washery premises.

Study area

The washery project under study is 40 km from Dhanbad City and is situated on the bank of the river Damodar with an installation capacity of 0.24 Mt/month and it is having latitude 23° 44’ to 23° 45’ N and longitude 86° 10’ to 86° 11’ E. It was installed in two phases. The washery takes feed coal from Angrapartha, Bansjora, and Mudidih, and Fulwaritand for phase 1; and from Block II for phase II. The feed coal of the washery has ash content in the range of 32 to 35 percent and the clean coal produced by washery has 20-21 percent ash. Phase one has three types of products; clean coal, middlings and rejects, which mostly contain coal fines contaminated with other

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minerals, organic components and some metal ions and anions.

The main sources of dust pollution in the area are various washery operations especially due to crushing, screening, etc. The dust produced by washery operations in the form of fines is blown to the surrounding areas. When the wind blows the loose materials from the dumped rejects, cleans and middlings are carried away to the surrounding areas. The other sources are heavy vehicular movement along the dusty road, and uncovered transportation by trucks and rails. The sources of gaseous pollutants within the project are vehicular emissions and coal burning.

Approach to the selection of air monitoring stations

As the project is surrounded by a number of coal mines and their allied activities, it is essential to know the background air pollution level to assess the actual contribution of pollutants by this project. In the present context, attempts had been made by monitoring air pollution at upwind and downwind sampling locations within the washery complex. The upwind sampler measures the background concentration of the pollutant of interest. Simultaneously, an identical sampler located down wind of the project measures the total concentration of pollutant emanating from the project and background. The difference in concentration of pollutant between the central and upwind measurements has been considered as impact due to the project activities in question.

Ambient air monitoring stations were selected keeping in view of the dominant wind directions prevailing in the area. The dominant wind directions were reported to be W and NW as observed from 30 years average data of Dhanbad meteorological station. One ambient air monitoring station DA1 was selected at the centre of the washery project. Thus, one ambient air monitoring station DA3 was located in the NW direction, and station DA4 in the SE direction. So the concentration value at DA4 represents downwind concentration and at DA3 it shows upwind concentration with respect to DA1 for most of the time period. Two other stations DA5 and DA2 were selected on W and E directions for upwind and down wind concentration of pollutants respectively with respect to DA1. By virtue of the relative positions of the ambient air monitoring stations, the stations DA1, DA4 and DA5 come under industrial zone, DA2 comes under residential zone and DA3 comes under sensitive zone. The approach was to place the stations in industrial, residential and sensitive area like hospital to discover the impact on air environment in various areas, because different standards have been fixed for different areas by Central Pollution Control Board (CPCB), Govt. of India. The details of the monitoring stations are given in Table 1.

Experimental Procedure

An air quality survey was carried out twice in a week covering the summer (April), monsoon (August) and winter (December) periods for four weeks in each season. Ambient air samples were collected each day for 24 h in three 8 h shifts, corresponding to day time (8-16 h), evening (16-24 h) and nighttime (0-8 h). Several high volume air samplers (HVS) were operated simultaneously at different sampling sites at the same time. Micrometeorological conditions were recorded on the sampling days with respect to wind direction, wind velocity, humidity and temperature. For the collection of SPM, glass fibre ambient (GF/A) filter was used in HVS. Air samples were drawn at a flow rate 1.0-1.5 m³/min that allows the SPM to deposit on the filter paper. Particulate with size range of 0.1 to 100 μ diameter was collected by HVS manufactured by M/s Envirotech Ltd., New Delhi. HVS having impingers (bubbler trains) in series with sodium tetrachloromercurate as absorbing reagent for collection of SO₂, and were operated at an average flow rate of 0.5 L/min for 24 h. In case of collection of NOₓ, sodium hydroxide was used as the absorbing solution and collected at an average flow rate of 0.2 L/min for 24 h.

<table>
<thead>
<tr>
<th>Station No</th>
<th>Direction from plant building</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>DA1</td>
<td>Centre</td>
<td>On the rooftop of the manager's office which is about 5 m above the ground</td>
</tr>
<tr>
<td>DA2</td>
<td>E</td>
<td>On the top of filter plant which is about 10 m from the ground</td>
</tr>
<tr>
<td>DA3</td>
<td>NW</td>
<td>On the rooftop of hospital which is 7 m above the ground level</td>
</tr>
<tr>
<td>DA4</td>
<td>W</td>
<td>On the roof top of slurry pump house which is only 5 m above the ground level</td>
</tr>
<tr>
<td>DA5</td>
<td>SE</td>
<td>On the top of the building near the dumped middlings and rejects which is 6 m above ground level.</td>
</tr>
</tbody>
</table>
The impinger samples were put into ice boxes immediately after sampling and transferred to a refrigerator until analysed. They were analysed spectrophotometrically using spectrophotometer (Simatzu, Model UV-265). West-Gacke method and Jackob and Hocheiser modified methods were used for analysis of SO$_2$ and NOx respectively. SPM was computed after weighing the filter paper before and after sampling. The filter papers were conditioned in a dry atmosphere before weighing. Data were collected from a monostatic and Doppler SODAR (Make M/s Ramtech, France) installed at CMRI, Dhanbad. The parameters studied were wind speed and direction, mixing height, ventilation coefficient, etc. To know the concentration of CO, the instrument used was an automatic CO-monitoring instrument (Make Environment S/A, CO/IIM, France), which is based on the principle of non-dispersive infrared absorption gas analysis.

**Results and Discussion**

**Status of air pollution**

Three season data were collected and analyses data are given in Table 2. Figure 1 shows the analytical data for SPM, SO$_2$, NOx and CO concentrations, which ultimately provide the status of air pollution observed during the year. The data for 3 seasons revealed that SPM concentrations for almost all the monitoring stations exceeded the limit specified by CPCB. At the industrial location DA1, the average SPM concentration was found to be 721, 543 and 905 µg/m$^3$ during summer, monsoon and winter respectively. All the values exceeded the permissible limit (500 µg/m$^3$) specified by CPCB. In case of industrial location DA4 the average concentration of SPM were found to be 563, 612 and 1342 µg/m$^3$ during summer, monsoon and winter respectively. Similarly in case of industrial location DA5 the average concentration of SPM was 808, 709 and 1428 µg/m$^3$ during summer, monsoon and winter periods respectively. Maximum SPM concentration of 2167 µg/m$^3$ was observed at DA4 during winter season. The station DA2 located at residential zone SPM concentration exceeded the CPCB limit (100 µg/m$^3$) for this zone (hospital is concerned) SPM concentration exceeded the CPCB limit (100 µg/m$^3$) for this zone.
for all the seasons namely summer (282 µg/m³), monsoon (278 µg/m³) and winter (393 µg/m³). The high concentrations are attributed to the fact that the hospital is situated very near to the washery project.

The average concentration of SO₂ was found to be within the CPCB limit (120 µg/m³) for industrial locations. The average concentration at DA1 during summer 62, monsoon 47, and winter 65 µg/m³ were observed. At industrial location DA4 average concentration of SO₂ during summer 70 µg/m³, monsoon 66 µg/m³ and winter 83 µg/m³. At the other industrial location DA5 these were 58, 42 and 64 µg/m³ for summer, monsoon and winter respectively. Maximum SO₂ concentration was found to be 92 µg/m³ at DA4 location in post-monsoon. This may be attributed to heavy vehicular movements. At the residential station DA2, SO₂ concentrations were 42, 28 and 37 µg/m³ for respective 3 seasons as against CPCB standard of 80 µg/m³ (for residential zone). At the hospital location DA3, SO₂ concentrations were 31, 23 and 35 µg/m³ for respective 3 seasons as against 30 µg/m³ for sensitive zone.

The average concentration of NOx at DA1 was found to be 110, 102 and 120 µg/m³ during the respective three seasons as against CPCB standards of 120 µg/m³ (for industrial zone). At other two industrial locations average NOx concentrations were found to be 137, 99 and 149 µg/m³ at DA4 and at DA5 105, 104 and 127 µg/m³ for the respective 3 seasons. At the residential location DA2, NOx concentrations were 107, 87 and 99 µg/m³ for the respective 3 seasons as against CPCB standard of 80 µg/m³ (for residential zone). At the hospital location DA3 these were 92, 80 and 96 µg/m³ respectively as against 30 µg/m³ (for sensitive zone). Maximum NOx concentration was found to be 158 µg/m³ at DA4 location in post monsoon. CO concentration at all the locations were found to be within the CPCB standards being 5000 µg/m³ for industrial, 2000 µg/m³ for residential and 1000 µg/m³ for sensitive zone. The annual rainfall during that year was found to be 1540 mm. The variation of the maximum mixing height was ranging from 1200-1600 m and minimum mixing height from 200-400 m. The maximum ventilation
coefficient (V.C.) was observed to be $9000\, \text{m}^2/\text{s}$ and the minimum was $1000\, \text{m}^2/\text{s}$.

**Factal analysis of SPM contribution**

Factal analysis is the technique to evaluate the actual contribution of air pollutants due to a particular project activity to the ambient air excluding the background concentration of pollutants\(^\text{17}\). It also gives the contribution of air pollutants by some other major polluting industries near the project in question. The ambient SPM in the washer complexes was attributable to the superimposition of the SPM from washer project and the flyash from thermal power plant (TPP), which is situated 1.5 km western side of the project. For determining the contribution of flyash due to thermal power plant, three different approaches were adopted to establish the factal analysis. These were: (a) Dominant wind directions; (b) Ash analysis by removing volatile matter; and (c) Particle analysis under the microscope.

During different seasons the wind tends to change its direction. So contribution of thermal power plant flyash varies in different seasons depending on dominant wind direction. SPM samples of different seasons were analysed by heating at $650^\circ\text{C}$. After the removal of volatile matter the increment of ash was found to be different as the contribution of flyash in SPM at different seasons were different. Moreover, it is a fact that in SPM contributed by washer, coal constituents dominate and so volatile matter will be high. On the other hand, thermal power plant flyash contains very less amount of volatile matter.

As coal washer SPM is mostly coaly matter their shape and colour are significantly different from thermal power plant flyash. Analyzing under microscope, coal washer SPM and thermal power plant flyash were identified, counted and quantified. The number of coal dust and flyash found in unit area were multiplied by their respective specific gravities and the results are expressed in $\mu\text{g/m}^3$ of air. All these three approaches were correlated to establish the factal analysis of probable contribution of SPM due to coal washer and thermal power plant.

To know the actual contribution of the TPP and washer to the air environment the volatile matter content and ash content of the SPM obtained at station DA1 were analysed. It has been observed that the proportion of ash and volatile matter was different due to the different composition of the dust particle from the washer and from TPP at different seasons. This idea has also been supported by the microscopic examination of the SPM by identification of black dust from the coal washer and whitish gray dust from power plant.

The wind rose diagrams at different seasons are shown in Fig. 2. During summer dominant wind direction with respect to W station DA4 may be considered as upwind location and DA2 as downwind locations with respect to DA1. From Fig. 2(a) it will be seen that at downwind location DA4 the average concentration of SPM was found to be $763\, \mu\text{g/m}^3$. This SPM was mainly the flyash emitted by the power plant. Along with western wind the flyash was dispersed and diluted and while passing over the washer project it mixed with the SPM emitted by the washer activities. The SW wind was found to be most dominant during summer season. The lower concentration at DA1 ($721\, \mu\text{g/m}^3$) with respect to upwind monitor may be attributable due to the dispersion and dilution of very high concentration of flyash emission by the power plant. At further downwind location DA2 the SPM concentration was
found to be more decreased. In summer the eastern wind was found to be negligible. The TPP is situated in the W and the dominant wind was blowing from W and SW. In this case the contribution of TPP fly ash increased the SPM concentration at DA1 upto 18 percent. By microscopic examination, probable contribution of flyash by the TPP has been computed to be as 131 μg/m\(^3\) and by washery as 590 μg/m\(^3\) and the ratio in SPM as 0.22.

During the monsoon, with respect to the dominant wind direction E, station DA2 may be considered as upwind monitor and DA4 as downwind monitor with respect to DA1. In this season at DA1 the concentration of SPM was found to be increased by 59 μg/m\(^3\) and at DA4 by 128 μg/m\(^3\). From Fig. 2(b) it will be seen that the dominant wind directions were just opposite to the thermal power plant and western wind was found to be negligible. As the TPP is located in the west, the contribution of flyash from the TPP can be taken as negligible. So the monsoon season may be considered as the ideal season when the superimposition of flyash to ambient SPM at DA1 was negligible. Ash determination and microscopic examination of SPM have also supported this fact. The results are shown in Table 3.

During winter, with respect to dominant wind direction W, station DA4 may be considered as upwind monitor and DA2 as downwind monitor with respect to DA1. During this season the concentration of SPM at DA1 was found to be decreased by 337 μg/m\(^3\) and at DA2 by 811 μg/m\(^3\) with respect to the upwind monitor. From Fig. 2 (c) it can be seen that W and SW winds were found to be most dominant in winter in comparison to other two seasons. The increment in ash content in SPM was found to be maximum and the probable contamination of flyash from TPP was also found to be maximum. Statistical parameters like number individual values used in calculating averages, accuracy, precision, strategy for removal of outliers etc. are duly considered in the evaluation procedure of factal analysis.

**Conclusion**

Main air pollution problem around the coal washery is due to the dust. Ambient air quality data also revealed the high pollution potential in the project area as well as in the surrounding areas. Factal analysis for the contribution of flyash from TPP to the washery premises can be made on the basis of composition of ash and volatile matter in SPM, microscopic examination and also on the basis of the change of wind directions at different seasons and the results obtained are comparable. The methodology adopted may have formed a guideline for factal analysis to resolve the conflicts of contribution of air pollutants by such industries and it may work on industrial scale at various sites.

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**References**

1. Anon, Dust Problem due to Washery, Central Mining Research Station, Dhanbad, (1961).