Mineral Metal Energy Oil Gas Aggregate, *1(2): 148-157; 2024. DOI: 10.18311/2MEOGA/2024/v1i2/44973* *SCIENTIFIC TECHNICAL PAPER*

INFORMATICS JOURNALS

Print ISSN : Applied for

Mineral Metal Energy Oil Gas and Aggregate

Contents available at: *www.informaticsjournals.com/index.php/2MEOGA*

2MEOGA

Study to Ascertain the Efficacy of the Bag Filters Attached to Various Locations at a Calcining Plant

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Abstract

This study investigates the efficacy of bag filters installed at various locations within a calcining plant situated in Paradeep, Odisha, India. The plant processes raw petroleum coke into calcined petroleum coke, generating significant amounts of particulate matter and gaseous emissions. The research focuses on assessing ambient air quality inside the plant premises and evaluating the performance of the bag filters in reducing particulate and gaseous pollutants. Measurements of $PM_{2.5}$, PM_{10}, SO_x, and NO_x were taken using the EVM-7 equipment under operating and non-operating conditions of the bag filters. Results indicated substantial reductions in particulate concentrations when bag filters were in operation, although some levels remained above standard limits. The study highlights the importance of continuous operation and maintenance of pollution control equipment, proper handling of materials, and enhanced housekeeping practices to mitigate indoor air pollution and ensure workplace safety.

Keywords: *Bag Filters; Calcining Plant; Particulate Matter; Air Quality; Pollution Control; Industrial Emissions*

1.0 Introduction

Industrial activities, particularly those involving the processing of raw materials, contribute significantly to air pollution. Among these, calcining plants, which process raw petroleum coke into calcined petroleum coke, are notable for their emissions of particulate matter and gaseous pollutants. The calcining process involves high-temperature treatment, resulting in the release of fine particles ($PM_{2.5}$ and PM_{10}) and gases such as sulfur oxides (SO_x) and nitrogen oxides (NO_x). These pollutants pose serious environmental and health risks, necessitating the implementation of effective pollution control measures[1,2]. Since the 1990s, convincing evidence from large cohort studies has consistently demonstrated that long-term exposures to particulate air pollutants are associated with increased mortality[3].

One common and effective method for controlling particulate emissions in such industrial settings is the use of bag filters. Bag filters are designed to capture and remove particulate matter from exhaust gases, thereby improving air quality. However, the efficacy of these filters can vary depending on their design, maintenance, and operational conditions.

This study focuses on a calcining plant located in Paradeep, Odisha, India, to evaluate the effectiveness of bag filters installed at various locations within the facility. By measuring concentrations of $PM_{2.5}$, PM_{10}, SO_x, and NO_x under different operating conditions of the bag filters, this research aims to provide insights into their performance and identify areas for improvement. Understanding the effectiveness of these filters is crucial for ensuring compliance with environmental regulations,

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safeguarding worker health, and minimizing the plant's environmental footprint.

1.1 The Plant Description

A calcining plant (Figure 1) processes raw petroleum coke into calcined petroleum coke, which is used as carbon electrode paste and tamping paste. Located in the port town of Paradeep, Odisha, along the coastline of India, the plant preheats the raw petroleum coke to remove moisture. The preheated coke is then fed into a rotary kiln with a capacity of 200 TPD, equipped with a secondary fan and a shell-mounted tertiary air fan. Exhaust gases from the rotary kiln pass through an incinerator to ensure the complete combustion of unburnt hydrocarbons.

The plant features two spray towers and a venturi scrubber, followed by a cyclone, with one of each serving as a standby unit. These pollution control systems are designed to treat the exhaust gases before they exit through a 160 ft. stack. The nozzles within the equipment have a flow rate capacity of 38 l/min. An induced draft fan with a power capacity of 100,000 m^3/hr is installed at the end of the pollution control system to manage the exhaust flow. Additionally, water pumps with a capacity of 7,500 m^3/hr support the operation of the equipment, ensuring efficient removal of pollutants from the gas stream.

1.2 Bag Filter

A Bag filter/dust collector is a system used to enhance the quality of air released from industrial and commercial processes by collecting dust and other impurities from air or gas. A dust collector system is designed to handle high-volume dust loads, consisting of a blower, dust filter, a filter-cleaning system, and a dust receptacle or dust

Figure 1. The Calcining plant site.

removal system. It is distinguished from air purifiers, which use disposable filters to remove dust (Figure 2).

1.2.1 Working Principle

The dust-laden air enters the bag filter bustle. The air is uniformly distributed avoiding channelling. Initially a coat of material forms on the bags. Subsequently, the coat acts as the filtering medium. The dust accumulates on filter elements while the air passes through the filter bags from outside to inside. The accumulated powder is dislodged from the bags by using reverse pulse-jet air intermittently. The dislodged powder falls on the bottom cone and is discharged through powder discharge valves. The dust-free air is sucked by an induced draft fan and is exhausted into the atmosphere. Knockers are provided on the conical portion, especially for sticky/hygroscopic materials.

2.0 About the Study

One of the most prominent threats to urban environmental health is fine PM, which is also unqualifiedly called dust. Ambient PM in fine and ultrafine ranges (aerodynamic diameter <2.5μm, $PM_{2.5}$) is strongly associated with the pathogenesis, occurring because of long-term exposure to air pollution-associated systemic diseases[4]. Most recent studies suggest that long-term exposure to $PM_{2.5}$ above the current US EPA standards is associated with neurodegeneration and increased risk of Alzheimer's disease[5].

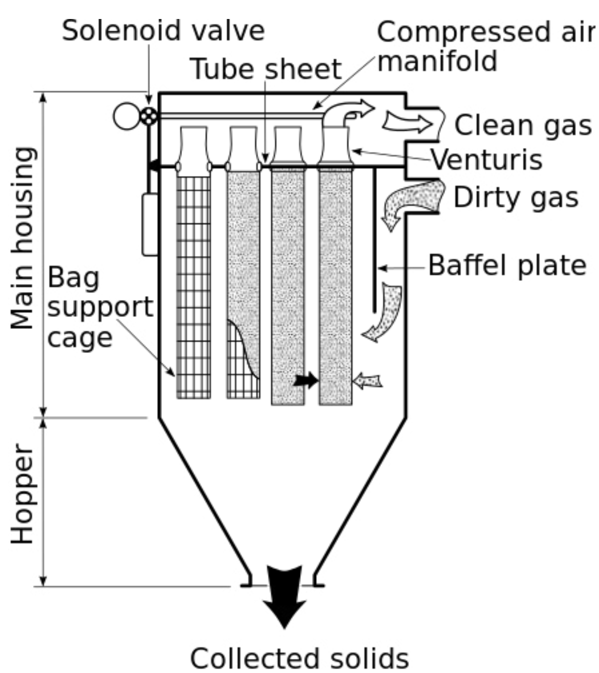

Figure 2. Bag filter

The team visited the plant on September 2018 and measured the ambient air quality inside the plant premises and the efficiency of bag filters installed to control indoor air pollution during the processes of preparation, cooling and handling of Calcined Petroleum Coke (CPC). The team used the equipment of EVM of 3M for measuring the concentrations of particulate matter (PM_{10}, $PM_{2.5}$) and Gaseous emissions (SO_x, NO_x, CO and CO_2) which are indicative of ambient air quality, near the vicinity of the bag filter and conveyer belt inside the plant when the bag filter was in operation and when not in operation at 66% capacity of plant operation. The team was apprised of the various operational parameters of the plant by the management.

3.0 Objective

To study the status of ambient conditions of PM and gases inside the plant before and after all the de-dusting systems (bag filters) were in operation.

4.0 Materials and Methods

4.1 About EVM 7 Equipment

The EVM-7 (Figure 3) monitors both particulates and air quality in one compact instrument. The EVM-7

Figure 3. EVM 7 (3M).

provides a lower cost of ownership by combining three instruments into one. This durable, easy-to-use model provides simultaneous worksite monitoring of particulate mass concentrations (0.1-10 μm), select volatile organic compounds, select toxic gases, carbon dioxide, relative humidity, and temperature.

4.2 Method of Measurement

Indoor air quality monitoring was done inside the plant during our visit to M/s Kalinga calciner in two phases both in operating and non-operating condition of the bag filter by forming a square grid at a distance of 2.5m near the vicinity of the bag filter and the conveyor belt. Stack monitoring of the bag filter was also done in the same condition (Figure 4).

4.3 Working Conditions Related to the Environment

The team was told that there are two bag filters one in the RPC area and another inside the plant. Connected to the stream of prepared CPC. The team could find only one working, i.e., the one near the CPC stream after preparation.

5.0 Leakages Inside the Plant

During the visit, the team observed dust and gas leakages inside the plant areas coming out from the conveyor sections, and transfer points (Figure 5). Many of these places were not covered. There are several leakage points for internal dust circulation inside the plant.

According to US EPA-453/R-95-01, such industrial plants have a lot of leakage points (Figure 5). In the CPC Plant at Paradeep, the team could see leakages of dust and gas, emanating through the roof, conveyor sections, transfers, connectors, flanges and lines that can be controlled and profitably recovered.

The dust and gas generated inside the plant must be efficiently arrested by the bag filters and cyclones, not to allow the dust and gases to go out to the external environment, as much as possible. The constituents of dust and gases coming out from Calcining RPC are represented in Table 1. This will not only help the external environment but also will protect the internal working environment and workplace safety. It is recommended that as much as airborne dust and gas be arrested inside the plant by improved housekeeping, overall leakage restrictions, regular de-dusting, and by employing an array of gas and dust collecting devices (Figure 6). All gas and dust-producing pints must be flexibly covered and cannot be kept open. All pollution control devices must be run at all operational and production times without fail. All such devices should be run before the start of operation. Exposure to pollutants such as airborne participate matter and ozone has been associated with increases in mortality and hospital admissions due to respiratory and cardiovascular disease[6].

Figure 4. Indoor air pollution measurement by EVM 7.

Figure 5. Open transfer points, open/temporarily covered belt conveyor, floor-laden dust and roof ventilating leakages as found during the visit.

Figure 6. **(a, b)** Un-separated stockpiles contribute to fugitive dust exposure to the workers, **(c)** Worker without face musk, the image showing dust settled on the face, **(d)** Dust getting suspended in the air through open sections. The whole section can be flexibly covered.

6.0 Emerging Environmental Challenges of Increasing Sulfur Levels in Imported RPC

All new calciners that have been built in the world in the last 20 years have been built with SO_2 scrubbers. Retrofitting scrubbers to existing calciners is also becoming more common as environmental regulations tighten. Using the United States as an example, a new National Ambient Air Quality Standard (NAAQS) was proposed in 2010 and will come into full effect in mid-2018. The current NAAQS has an allowable maximum concentration of SO_2 in the ambient air of 140 ppb (parts per billion) averaging over 24 hours. The new NAAQS allows a concentration of 75 ppb averaged over a 1-h period. All states in the United States are now working on compliance plans to meet the new NAAQS. Rain CII Carbon has recently added a fluidized-bed SO_2 scrubber to its Lake Charles calciner in Louisiana and is in the process of adding a similar scrubber to its Chalmette calciner in readiness for the new NAAQS.

7.0 Results and Discussions

The flue gas emanated from the rotary kiln consequent to the calcination of the coke process consists of volatile fractions, particulate matter and gaseous pollutants including Sulphur dioxide. The characteristics of Raw Petroleum Coke (RPC) and Calcined Petroleum Coke (CPC) as provided by the plant authorities are as follows:

Table 2 indicates the loss of moisture, volatile matter and release of Sulphur which can be in the form of Sulphur dioxide along with some other oxidized gaseous emissions like CO, CO_2 and NO_x released from volatiles. As per mass balance diagrams collected from the plant authorities during an inspection at 100% running

Table 1. Constituents of dust and gases coming out from Calcining RPC

	Anode grade		
	CPC A*	**CPC B***	**CPC C***
Sulphur, %	0.5	2.0	4.6
Vanadium, ppm	15	180	460
Nickel, ppm	65	170	190
Iron, ppm	190	190	110
Calcium, ppm	180	50	60
Silicon, ppm	185	50	90
Sodium, ppm	45	50	90
VM content, %	11.2	10.4	11.8

* CPC A, B and C are not the ones particularly being used in the plant Paradeep; these are only suggestive to say what to expect as constituents of CPC and what can come in the form of particulate dust and gases when RPC is calcined.

Table 2. Characteristics of Raw Petroleum Coke (RPC) and Calcined Petroleum Coke (CPC)

S. No	Characteristics	Unit	RPC	CPC
1	Moisture	%	6.79	0.29
2	Ash	%	0.22	0.34
3	Volatile Matter	%	11.25	0.25
4	Fixed Carbon	%	81.74	99.12
5	Vanadium	ppm	310	370
6	Silicon	ppm	420	478
7	Iron	ppm	220	270
8	Nickel	ppm	194	210
9	Sulphur	%	2.35	2.30

Table 3. Air quality in the vicinity of the bag filter

	When the bag filter was not in operation				When the bag filter was in operation				
Location	**$PM_{2.5}$ (μg/M^3)**	**PM_{10} (μg/M^3)**	**SO_x (μg/M^3)**	**NO_x (μg/M^3)**	**$PM_{2.5}$ (μg/M^3)**	**PM_{10} (μg/M^3)**	**SO_x (μg/M^3)**	**NO_x (μg/M^3)**	**Comments**
1 (close to the bag filter)	353	882.5	75	80	159	397.5	72	80	While operations of 2 bag filters were desirable at the time of the measurement, even the operation of one bag filter shows significant improvement in PM values but has no or minor influence on SO_2 and NO_2 values.
2	315	787.5	60	75	259	647.5	58	76	
3	383	957.5	55	64	172	430	54	63	
4	417	875	40	55	274	475.5	45	42	
5	729	1822.5	45	50	363	907.5	50	47	
6	637	1592.5	41	52	218	545	37	53	
7	197	492.5	40	57	109	272.5	37	45	
8	180	450	55	54	128	320	52	54	
9	204	481	55	65	174	385	53	62	
Average	*380*	*927*	52	61	*206*	*487*	51	58	
Standards (NAAQS)	**60**	**100**	**80**	**80**	**60**	**100**	**80**	**80**	

Table 4. Measurements near the vicinity of the conveyor belt in a similar arrangement as in Figure 7

	When the bag filter was not in operation				When the bag filter was in operation				
Location	**$PM_{2.5}$ (μg/M^3)**	**PM_{10} (μg/M^3)**	**SO_x (μg/M^3)**	**NO_x (μg/M^3)**	**$PM_{2.5}$ (μg/M^3)**	**PM_{10} (μg/M^3)**	**SO_x (μg/M^3)**	**NO_x (μg/M^3)**	**Comments**
1	29	72.5	55	65	25	62.5	54	66	While operations of 2 bag filters were desirable at the time of the measurement, even operation of one show remarkable improvement in PM values but has no or minor influence on SO_2 and NO_2 values. The storage of CPC may have some influence on the parameters.
2	34	85	40	55	28	70	41	57	
3	26	65	35	50	20	50	37	53	
4	30	75	20	45	22	55	18	51	
5	39	97.5	25	35	24	60	26	36	
6	25	62.5	23	32	21	52.5	24	38	
7	27	67.5	18	37	22	55	18	41	
8	21	64.2	35	34	20	54	37	33	
9	26	58	35	37	24	52	38	45	
Average	*28.56*	*71.91*	32	43	*22.89*	*56.78*	32	47	
Standards (NAAQS)	**60**	**100**	**80**	**80**	**60**	**100**	**80**	**80**	

capacity of the plant with RPC of 10.15 T/hr, flue gas generation from the kiln is 18665 Nm^3/hr at a dust load of 782 kg/hr. The gas combustion chamber after the rotary kiln facilitates the burning of incompletely combusted and residual carbon monoxide and other carbon particles aided by atmospheric air at 900°C, increasing the gas volume to 31590 NM^3/hr and a dust load of 38.5kg/hr at the outlet of the combustion chamber, at the inlet of the air pollution control equipment. The reduction in the dust mass is compensated with an increase in the gaseous emissions indicating complete combustion of the converted particulate matter.

The concentrations of Particulate matter ($PM_{2.5}$ and PM_{10}) were very high (almost 6 and 9 times greater than

Table 5. At the stack of the bag filter

	When the bag filter is not in operation				When the bag filter is in operation			
Location	**$PM_{2.5}$ (µg/M^3)**	**PM_{10} (µg/M^3)**	**SO_x (µg/M^3)**	**NO_x (µg/M^3)**	**$PM_{2.5}$ (µg/M^3)**	**PM_{10} (µg/M^3)**	**SO_x (µg/M^3)**	**NO_x (µg/M^3)**
Stack of bag filter (11.7m)	237	711	90	90	38.5	96.25	86	88
Standards (NAAQS)	**60**	**100**	**80**	**80**	**60**	**100**	**80**	**80**

Table 6. Summary of the air quality inside and vicinity of the plant with/without bag filter operation

		The bag filter is Not in operation				Bag filter in operation			
S. No	**Location**	**$PM_{2.5}$ (µg/M^3)**	**PM_{10} (µg/M^3)**	**SO_2 (µg/M^3)**	**NO_2 (µg/M^3)**	**$PM_{2.5}$ (µg/M^3)**	**PM_{10} (µg/M^3)**	**SO_2 (µg/M^3)**	**NO_2 (µg/M^3)**
1	Near bag filter housing	380	927	52	61	206	487	51	58
2	Near conveyor belt	28.56	71.91	32	43	22.89	56.78	32	47
3	Stack (above 11.7 m from the ground), attached to bag filter exhaust	237	711	90	90	38.5	96.25	86	88
	Standards (NAAQS)	**60**	**100**	**80**	**80**	**60**	**100**	**80**	**80**

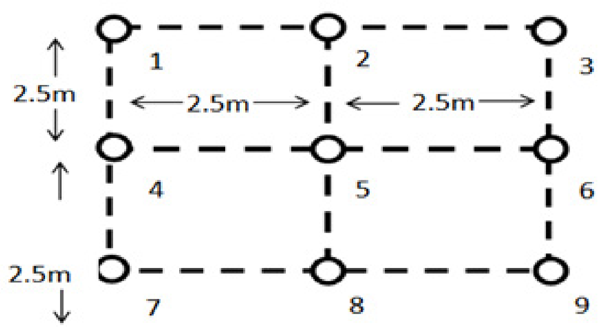

Figure 7. Points of measurement near the operating bag filter (Point 1 is the safe closest position near the bag filter).

Figure 8. Wind-driven ventilators.

the standard prescribed limits by CPCB)[7] inside the plant premises when the bag filter was not in operation (Table 3). Even with the bag filter running at full capacity the indoor air pollution, especially of particulate matter near the Bag filter was very high (Table 3). But with the operation of the bag filter the particulate matter concentrations drop significantly, but still higher than the AAQ standards, at the stack (Table 5) indicating the efficiency of the bag filter installed in reducing the pollution. The high particulate matter concentrations inside the plant may be attributed to improper handling of finished CPC being stacked inside without proper covering and fugitive dust. Even the conveyor belt and sections, which transfer the finished CPC after cooling also is not properly covered, contributing to indoor air pollution. Air pollution is associated with an increased risk for cardiovascular events. Many of the biological pathways involved could also promote diabetes mellitus[8,9].

The concentrations of SO_x and NO_x, though high and bordering the standards, are within prescribed limits by the CPCB.

8.0 Inferences and Recommendations

8.1 Inferences

- Near the vicinity of the Bag filter, the concentrations of $PM_{2.5}$ and PM_{10} were above the limit in both circumstances (operating and non-operating of the bag filter). One of the reasons that can be attributed to it is the non-functioning of one of the bag filters. Another reason could be worn and tear, an increase in the size of the pores and aging of the bag material.
- Bag filter has almost no influence on the concentrations of SO_x and NO_x inside and in the vicinity of the plant in operation (Table 4), as expected. High SO_x and NO_x point to leakages in the sections under CPC preparation. Some can also come from the volatilization of CPC/RPC inside the plant.
- The fugitive dust inside the plant was contributed by the operation, stockpile. The values inside the plant were more or less the same except near the accesses, because of some dilution effect but inside the plant, the airflow was stabilised, and the concentrations reached a steady state concentration all over the plant.
- Near the bag filter stack above 11.7m from the ground, the concentrations of $PM_{2.5}$ and PM_{10} were much reduced when the bag filter was operated. The details are presented in table 6.
- The particulate concentrations of $PM_{2.5}$ and PM_{10} were within limits some 4m away from the scrubber largely because of the dilution and crosscurrents of air.
- Concentrations of SO_x and NO_x were high but remained within the limits of AAQ.

8.2 Recommendations

1. All pollution control equipment in and outside the plant must be operated continuously and periodic maintenance of the equipment should be done. The cleaning of the bag filters, cyclone, etc needs to be done regularly with records being kept. In case, any of the pollution control equipment is under breakdown or repair the plant must not be run at any time.
2. The high-quality bag filter fabric should be appropriately selected with adequacy, suitability and quality in mind. Adequate fan pressure and flow must be maintained at all times to maintain suction. The fabric must be cleaned regularly.
3. Bag filter material should be maintained and replaced at regular intervals to prevent leakages with proper records. Further, the joints, flanges, and pipe sections are also sources of leakage inside the plant.
4. Dust gets collected in various parts of the scrubber and they solidify generally but, more particularly during the wet season. They need to be removed. The team was told that the fine CPC is sold at a higher price than normal-justifying investment in regular maintenance, cleaning and replacement.
5. With all the pollution control equipment running, the PM pollutants concentration during the visit was found to be within the permissible limit, when the plant was run at 100%, except near the bag filter. The bag material of the filter may require replacement. Till the time the problem is not rectified, workers cannot be allowed to remain within 4.0 m distance for more than ½ hour at any time. After every ½ hour of exposure, he or she should be given work outside for more than 2 hours before being brought back for ½ hour again. SO_x and NO_x were though under CPCB AAQ level is still very high. The plant must decide for recorded measurement of all noted pollutants, every month, particularly in summer and whenever there is a change in raw material.
6. Concrete floors must be cleaned regularly with mobile vacuum cleaners. Water sprinklers must be operated at regular intervals inside the plant premises to reduce the fugitive emission, in all dry times.
7. The RPC material is both fine and combustible. The handling process generates a lot of dust. Fugitive dust emissions can be managed by a range of strategies inclusive of chemical stabilization using surfactants, planting of vegetation cover, construction of windbreaks, and finally, watering. Chemical applications provide longer periods of dust suppression than watering but can be costly, adversely affect plant and animal life, and contaminate the treated material. Watering is the most common and, generally, least expensive method.

8. The loading area shed/warehouse should be covered from all sides at all ordinary times and be opened during the preparation of the stockpile in the loading area. This will reduce fugitive dust generation from the stockpile area a lot. After cover, it should be properly lighted and ventilated.
9. The rooftop ventilators like wind-driven ventilators should be used (Figure 8).
10. All CPC and RPC loading/transferring stationery equipment areas should be covered during material transfer at all times. All moving material handling equipment like motor, and belt section must be fenced. The workers in this area must be given training from time to time for safe operating practices.
11. All around the truck loading/waiting/queuing areas there should be a large tree plantation of a minimum 6 m width all along.
12. Floor dust cleaning and Water sprinkling should also be done in the truck bays.
13. Workers must be given Personal Protective Equipment (PPEs) wherever the dust is airborne and there is danger/hazard in the work.
14. The plant must have an emergency management plan for safety and a disaster management plan.
15. The plant must adopt a zero-effluent water discharge plan in every operational area. For its benefit, it must have an audit of the sources of water and their structural protection.
16. The persons working there should be given personal protective equipment and made to use them at all times. As a penal practice, attendance may be cut for non-adherence or a fine to be imposed. The fine collected will be used for workers' welfare. The piles of CPC ready for packaging inside the plant should the properly covered. The workers doing the loading and handling must wear PPEs.
17. Whether there is any fire hazard in the plant can only be confirmed after a study. As also pointed out elsewhere in the report, there could be fire hazards in the RPC stockpile and inside the plant and these should be managed by proper resource and manpower allocation and sound management practices.
18. The plant may be allowed to run at full capacity, but the above recommendations are to be followed, majorly all the bag filters and scrubbers including cyclone must run at all times of operation, CPC/RPC stock must be kept under cover, and fugitive dust must be controlled by all means like water spraying, and covering, etc.

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