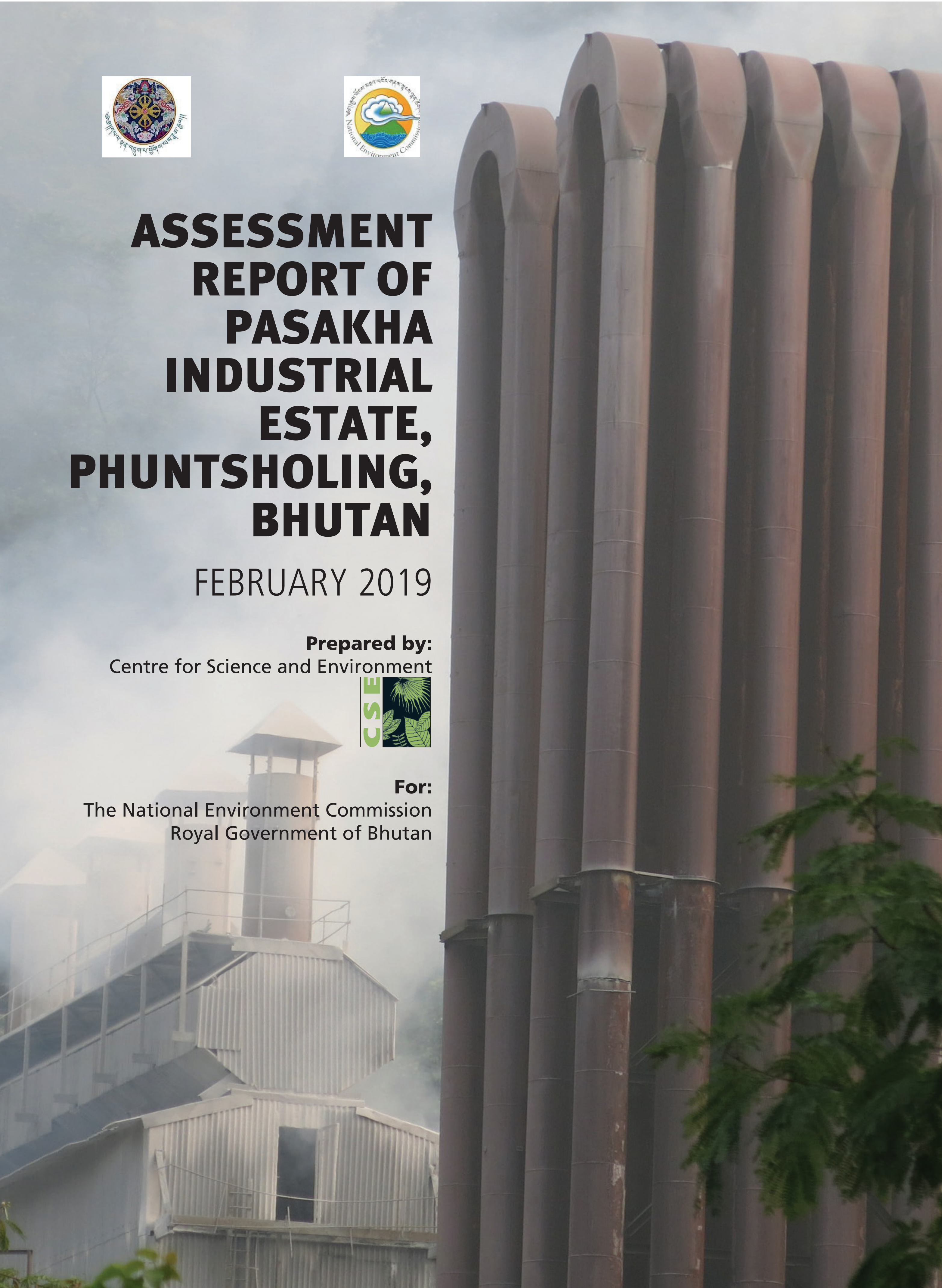

ASSESSMENT REPORT OF PASAKHA INDUSTRIAL ESTATE, PHUNTSHOLING, BHUTAN

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Prepared by:
Centre for Science and Environment

For:
The National Environment Commission
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1. Introduction

Pursuant to the request received vide NECS/EACD/CSE/2018/884, dated 8 November 2018, from the National Environment Commission (NEC), Bhutan, experts from the Centre for Science and Environment (CSE), New Delhi, India conducted an assessment of the Pasakha Industrial Estate during the period 15 November 2018 to 19 November 2018.

The composition of the team of officials who carried out monitoring of compliance is given below:

1.1 Officials from National Environment Commission (NEC)

S. no.	Name	Agency
1.	Tshering Dorji	NECS
2.	Kunzang Rinzin	NECS
3.	Wangdi Phuntsho	NECS
4.	Choki Wangmo	NECS
5.	Drodhel Zangpo	NECS
6.	Rinchen Dorji	NECS
7.	Kezang Choden	NECS
8.	Ugyen Tshomo	NECS
9.	Kunzang DemaRinchen	NECS
10.	Jangchu Dema	NECS
11.	Dechen Lham	NECS
12.	Kezang Lhaden (intern)	NECS
13.	Sonam Zangmo (intern)	NECS

1.2 Ministry of Economic Affairs

- Ugyen Sonam, Department of Industry

1.3 Centre for Science and Environment, India

- Sujit Kumar Singh (Senior Programme Manager, CSE)
- Rahul Kumar (CSE)
- Mohan Patil (Air Pollution Control Expert))
- Bhavik Patel (Independent consultant)

1.4 Peer Review

- DD Basu, Former Additional Director, Central Pollution Control Board (CPCB), India
- JS Kamyotra, Former Member Secretary, CPCB, India

1.5 Objectives of Assessment

- Carrying cumulative impact assessment study of Pasakha Industrial Estate (PIE);
- Efficiency of pollution abatement equipments installed by the industries in PIE;

- Point source and fugitive emissions from the concerned industries;
- Train officials from NECS and department of industry to carry out compliance.

1.6 Methodology

The following methodologies were adopted for the inspection of Saint-Gobain:

- Literature review and review of documents and information available with NEC
- Site inspection
- Interaction with industrial representatives.

The methodology adopted for carrying out assessment was first to have literature review of the different kind of industries situated in the industrial estate. The literature review was followed by site inspection and interaction with the industrial representatives. The site visit and interaction provide clear picture of the ground realities. The last step was to monitor the air quality, which included both ambient and point source, and comparing the same with the Ambient Air Quality Standards prescribed in the Emission Standards, 2010 of Bhutan.

2. About Pasakha Industrial Estate

Pasakha Industrial Estate is located 18 kilometres from Phuentsholing and is Bhutan's first major industrial town (*see Figure 1*); the site is located in a valley surrounded by hills from three sides. Pasakha is a small village situated close to the border with India, on the bank of rivers Sigye and Barsa.

Presently, there are 39 industries present within the Pasakha Industrial Estate ***(see: Box list of industries)***. Due to locational advantage and availability of cheap electricity, Pasakha Industrial Estate is an attractive destination for mineral-based industries. Further, proximity to the Indian border enables swift and easy import of raw materials, labour and provides a market to sell finished products. Besides this, many minerals such as quartz, dolomite and limestone are also available locally from villages such as Pachina, Kamji, Tintali, Gomtu, which are less than 100 kilometers away from Pasakha Industrial Estate. Another added advantage is the double lane road between Phuentsholing and Pasakha, making it convenient for large trucks to ferry finished products and raw materials. The industries located within Pasakha Industrial Estate are as provided below and a thematic diagram is provided in ***Figure 2***.

NEC put expansion of air polluting industries on hold

Of total industries in Pasakha, around 46% of industries are air polluting, among them are - a Silicon Carbide Plant, nine Ferro-silicon factories, five steel industry, an alloy, a cement and coke industry.

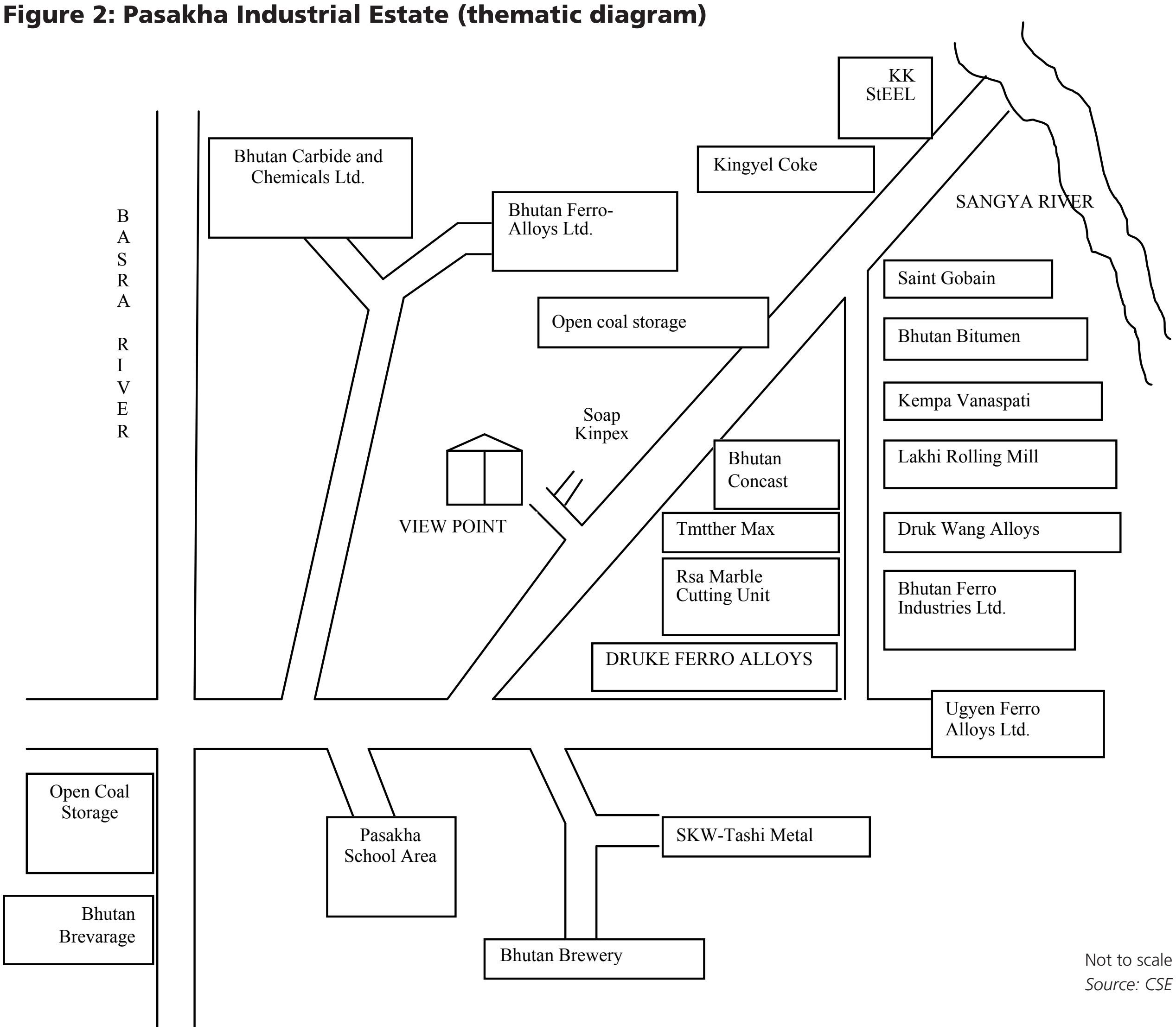
Currently, National Environment Commission (NEC) kept all application of such industries on hold because of high air pollution level in Pasakha Industrial Estate.

Figure 1: Pasakha Industrial Estate (Screen grab from google earth)

List of Industries in Pasakha Industrial Estate

- One Silicon Carbide Plant (Saint Gobain)
- Nine Ferro silicon industries
- Five Steel industries including one rolling mill
- One Alloy industry
- One Cement (Druk cement)
- Two Beverage and 2 breweries
- Two Food industry
- Two Gas industry
- One Bitumen and 1 coke
- Two Plastic industry
- One Wire industry
- One Marble industry
- One Oil vanaspati and 1pharmaceutical
- One Detergent and 1 brick industry
- One Feed production
- One Wall putty and 1 furniture
- One Beetle nut processing plant

Figure 2: Pasakha Industrial Estate (thematic diagram)



Not to scale

Source: CSE

3. Ambient Air Quality of Pasakha

Pashaka industrial area is located in a valley (surrounded by mountain from three sides), this natural restriction leads to poor dilution and dispersion of the pollutants, and therefore, they remain confined in the valley for a long time.

The major source of air pollution in the region is the burning of fossil fuels without running pollution control devices, tapping (120 to 140 tapping per day), heavy vehicle movement, poor road condition, and poor raw material handling and storage mechanism. Majority of the industries in the region are air polluting industries. All together, the cumulative impact of the industries due to the above mentioned reasons, is contributing in deteriorating the ambient air quality of the region.

The permissible limits for ambient air quality of most of the pollutants in Bhutan are already relaxed for the industrial area when compared with India. Further some of the key parameters which are important for assessing the ambient air quality are found to be missing, such as PM2.5, ozone, etc. A comparison of ambient air quality standards for Bhutan and India is provided in Table 1 below.

Figure 3: Poor dispersion of pollutants in Pasakha Industrial Estate

Table 1: Ambient Air Quality Standards (Maximum Permissible Limits in µg/m^3)

Parameters		Standards in Bhutan for Industrial Area	Standard in India
Total Suspended Particulate Matter (TSP)	24 hours average	500	No standard—earlier it was there but in 2009 it was removed and instead of that PM 2.5 have been added
	Yearly average	360	No standard—earlier it was there but in 2009 it was removed and instead of that PM 2.5 have been added
Respirable Particulate Matter (PM10)	24 hours average	200	100
	Yearly average	120	60
PM 2.5	24 hours	No standards	60
	Yearly average	No standards	40
Carbon Monoxide (CO)	1 hour	10,000	4,000
	8 hours	5,000	2,000
Sulfur dioxide (SO2)	24 hours	120	80
	Yearly average	80	50
Oxides of Nitrogen (NOx)	24 hours	120	80
	Yearly average	80	40

4. Monitoring

In order to assess the ambient air quality of Pasakha Industrial Estate, monitoring of parameters such as CO, NO2, PM 10, PM 2.5, SO2 and Ozone were done at three places for 24 hours within the estate. The locations chosen for monitoring were such that it represents the ambient air around the area and the locations were 120 degrees apart from each other, and covered the entire industrial estate, except the Bhalujhora village (near Bhutan Silicon Metals Pvt Ltd), where the monitoring was carried with the help of instantaneous monitoring. This monitoring was done through a continuous ambient air quality monitor so that the actual variation during the monitoring period could be captured.

Apart from this 24 hour monitoring, instantaneous readings of particulate concentrations were also taken at different locations within the industrial estate to access the ambient air quality. The instantaneous monitoring was only to capture the concentration of PM10, PM2.5 and Total Suspended Particles (TSP) to have a basic understanding of the air quality at the particular location.

It is pertinent to mention that the Ambient Air Quality Standards of the Environmental Standards, 2010 prescribed by NEC, Bhutan has only PM10 and TSP for industrial areas (*see Table 1*).

Particulate Matter (PM) is one such parameter based on which quality of ambient air can be measured. The particulate pollution includes PM10 and PM2.5, both are inhalable particles with diameters that are 10 micrometers or less and with diameters that are 2.5 micrometers or less, respectively. The concentrations of both these particulate pollutants along with the Total Suspended Particles (TSP) were monitored.

Figure 4: Monitoring locations where ambient air monitoring was done on the Pasakha map

Location 1: IIDD Office

Location 2: Near Saint Gobain Ceramic Materials Bhutan Pvt. Ltd.

Location 3: Near KK Steel Pvt. Ltd.

The 24 hour monitoring was carried out at Industrial Infrastructure Development Division (IIDD) office, Saint Gobain Ceramic Material Bhutan Pvt. Ltd. and K. K. Steel Pvt. Ltd.

Location 1: IIDD Office

First day, the monitoring was done at the IIDD office and the recorded readings are as presented in Table 2 below;

Table 2: Monitoring results and relevant standards (readings are in μg/m³)

Parameter	Maximum	Average	Prescribed Standards in Bhutan
CO	4,458.75	218.75	5,000 for 8 hrs average
NO2	206.33	116.24	120 for 24 hrs average
SO2	15.42	6.76	120 for 24 hrs average
PM 10	466.86	284.59	200 for 24 hrs average
PM 2.5	461.41	250.57	In Bhutan—no standard, in India the standard is 60 μg/m³

Here, the particulate concentration was found to be exceeding the permissible limits. Both PM10 and PM2.5 average values were very high, the average recorded value of PM10 was 284.59 μg/m³ and PM2.5 was 250.57 μg/m³. The values were found to be high for most of the time; approximately 75 per cent of the time the value exceeded the permissible limit of 200 μg/m³ prescribed by the Ambient Air Quality Standards of the Environmental Standards 2010 of Bhutan.

Other parameters CO and SO2 were within the limits. NO2 was within the limit as well, but was approaching the maximum prescribed limit. The average value

Figure 5: Installation of continuous ambient air quality monitoring equipment near IIDD office

recorded was 116.24 μg/m^3 whereas the maximum prescribed standard is 120 μg/m^3.

The instantaneous monitoring was also done near IIDD office and the results substantiated the higher values for PM10, PM2.5 and TSP. The recorded average value for 1 hour instantaneous monitoring done near the IIDD office was 141 μg/m^3 for PM2.5; for PM10, the value was 292 μg/m^3 and the TSP was recorded to be 359 μg/m^3.

Location 2: Near Saint Gobain Ceramic Material Bhutan Pvt. Ltd.

Second day, the monitoring was done near Saint Gobain Industry and the recorded readings are as presented in Table 3 below;

Table 3: Monitoring results and relevant standards (readings are in μg/m^3)

Parameter	Maximum	Average	Prescribed Standards in Bhutan
CO	1,8103.75	12,837	5,000 for 8 hrs average
NO2	119.15	62.32	120 for 24 hrs average
SO2	95.77	73.02	120 for 24 hrs average
PM 10	319.26	150.25	200 for 24 hrs average
PM 2.5	278.54	110.83	In Bhutan - no standard, in India the standard is 60 μg/m^3

Here, the CO concentration was found to be very high; this may be because of the incomplete burning of the fuels in Saint Gobain industry. Other parameters were found to be within limits, except particulate emission. Here also the PM2.5 value was exceeding the limits prescribed by most of the neighbouring countries; it is important to note here that there is no specified standard for PM2.5 in Bhutan. PM10 value was recorded to be 150 μg/m^3 which is within the limit but is approaching the maximum prescribed limit of 200 μg/m^3.

The other important thing to observe in the first reading at IIDD office and the second reading is the result of SO2. The SO2 level has increased significantly when compared to the readings at IIDD office, this is mainly due to the use of petcoke with high percentage of sulphur (5 to 6 per cent) by Saint Gobain.

The recorded average value of instantaneous monitoring carried out in the area was 352 μg/m^3 for PM2.5, for PM10 the value was 523 μg/m^3 and the TSP was recorded to be 558 μg/m^3.

Location 3: Near KK Steel Pvt. Ltd.

Third, 24 hour monitoring was done near K. K. Steels and the recorded readings are as presented in Table 4 below:

Table 4: Monitoring results and relevant standards (readings are in µg/m³)

Parameter	Maximum	Average	Prescribed Standards in Bhutan
CO	1622	212.5	5,000 for 8 hrs average
NO2	120.12	49.9	120 for 24 hrs average
PM 10	179.43	68.83	200 for 24 hrs average
PM 2.5	143.67	56.69	In Bhutan—no standard, in India the standard is 60 µg/m³

Here, all the readings were found to be within the prescribed limits. Due to some problem in the SO2 sensor, the SO2 value was not recorded.

The instantaneous monitoring which gives the real time particulate concentration at a place was carried out at several other places as well. The monitoring results of PM10, PM2.5 and TSP are presented in Table 5 below:

Table 5: Instantaneous monitoring results at various places

Location	PM 10 Average	PM 2.5 Average	TSP Average
IIDD office	292	141	359
Near Saint Gobain	523	352	558
Near Kinjore Beer (Road Side)	558	123	830
Tashi Metal Pvt Ltd	403	204	464
Druk Ferro Alloy Pvt Ltd	374	138	468
Bhutan Silicon Pvt Ltd	789	140	1,010
Druke Wagen	364	153	430
Bhalujhora village (near Bhutan Silicon Metal Pvt Ltd)	635	111	829

At all the places, it was noticed that the value of particulate concentration was very high. The amalgamation of pollutants from all the industries, fugitive emission due to the poor road condition, and inadequate raw material handling and storage facility have contributed in increasing the pollution load of the area. This is one of the main reasons that particulate concentration was found to be very high.

Point Source monitoring

In order to access the contribution by different industries, it was decided to conduct point source monitoring of a few selected air polluting industries. Six industries with proper ladder, platform and porthole considering the feasibility of monitoring and also human safety were monitored. These six industries were:

1. Tashi Metal and Ferro Alloys Pvt. Ltd.
2. Druk Ferro Alloys Ltd.
3. Bhutan Silicon Metal Pvt. Ltd.
4. Druk Waygen Alloys and Ferro Ltd.
5. Pelden Pvt. Ltd.
6. Ugyen Alloys and Ferro Ltd.

In addition to point source, the team also decided to monitor the gaseous emission during tapping. Thus, an analysis of the tapping fumes was done at Druk Waygen Alloys and Ferro Ltd, which had a separate line for extracting tapping fumes and it was passed through bag filters.

There are 9 ferrous silicon industries in the industrial estate and in all of them tapping takes place at an interval of 2 hours, so approximately 12 to 13 tapping occurs in each industry and altogether around 120–140 tapping takes place in the industrial estate, per day. During the tapping period, the NOx emission was recorded to be very high, the average NOx emission from the duct where the tapping fumes are channelized was 571 mg/Nm3, whereas the maximum prescribed standard for the industrial emission as per NEC is 100 mg/Nm3.

The monitoring result during tapping is presented in Table 6 below, and it is important to note here that in Emission Standards 2010 of Bhutan for industrial emission maximum permissible limits, no standard is prescribed for NOx and for SO2 emission, the emission standard is only prescription for SPM. However, for other places like arc furnace, induction furnace, stacks, etc. the maximum prescribed limit is 100 mg/Nm^3 for both SO2 and NOx.

Figure 6: Monitoring of point source emission at a stack

Figure 7: Emission during tapping process in ferro-silicon industries

Figure 8: Gaseous emission during tapping process

Figure 9: Cumulative impact during 3–4 tapping which occurs simultaneously

Table 6: Emission results during tapping period

Parameter	Maximum	Average	Prescribed Standards in Bhutan
NOx (in mg/Nm^3)	815.1	571.3	No prescribed standard in Bhutan
SO2 (in mg/Nm^3)	57	37	No prescribed standard in Bhutan

During tapping, it was noticed that the particulate concentration also shoots up significantly and affects the surrounding air quality.

The gas analysis results conducted at the stack of six industries are presented in Table 7 below.

Table 7: The table below shows the gas analysis results conducted at the stack of different industries (all values are in mg/Nm^3)

Name of the Industries	CO		Std in Bhutan	NOx		Std in Bhutan	SO2		Std in Bhutan
	Max	Avg		Max	Avg		Max	Avg	
Tashi Metal and Ferro Alloys Pvt. Ltd	26.25	16.25	Maximum Prescribed limit for CO is $50mg/Nm^3$	94.9	41.0	Maximum Prescribed limit for NOx is $100mg/Nm^3$	329	191	Maximum Prescribed limit for SO2 is $100mg/Nm^3$
Druk Ferro Alloys Ltd	843.75	538.75		30.3	21.5		117	66	
Bhutan Silicon Metal Pvt. Ltd	126.25	98.75		78.9	64.2		489	409	
Druk Waygen Alloys and Ferro Ltd	342.5	320		148.8	83.8		489	366	
Pelden Pvt. Ltd	783.75	645		53.1	41.4		451	323	
Ugyen Alloys and Ferro Ltd	365	215		283.7	57.0		131	29	

Carbon monoxide (CO), which is generated due to incomplete combustion of the fuel was found to be high in almost every industry, except Tashi Metal and Ferro Alloys Pvt. Ltd.

SO2 was recorded to be crossing the permissible limit of 100 mg/Nm^3 in all the stacks, except Druk Ferro Alloys Ltd., and Ugyen Alloys and Ferro Ltd.

NOx value was within the permissible limit of 100 mg/Nm^3 at all the stacks monitored, but it is important to note here that during tapping NOx value was recorded to be very high.

5. Observations

During the assessment, few industries were visited and existing air pollution control devices (APCDs) were observed. The observations and comments are discussed below:

5.1 Problems in Steel Industries:

The steel industry, which was visited was Lhaki Steel and Rolling Mills. The unit has installed the Air pollution control system, namely, 'Low canopy movable hood fume extraction cum bagfilter type control system'. But still substantial fugitive emissions from the furnace were visible. The main reasons why these emissions cannot be controlled in this case are explained below:

Figure 10: Inadequate Fume extraction system at Lhaki Steel and Rolling Mills

1. Zero/No extraction of fumes from the furnace by the hood:

If the fumes are to be extracted from the furnace by the hood, there has to be some suction power in the duct connecting to hood. The suction capacity is measured as Static Pressure in Millimeter of water column (mmWC) using a simple U-tube manometer. Typically, it should be at least or more than 20–30 mmWC.

A small hole of 10 mm diameter was made in the duct near the hood and static pressure was measured using a U tube Manometer, and it was found that there is 0 (zero) mmWC. Static pressure or suction power, which means, there is no suction at all. So, naturally, no gases/fumes are getting extracted into the hood. It could be said that the gas extraction efficiency of this system is 0 per cent. For technical reasons, it can be said that the furnace is operating without any fume extraction system.

The hood at a height above head level, i.e. approx. at 2 to 2.5 meter high from furnace platform, is improper and ineffective. Also, the hood was damaged and deformed, its bearing alignment was also damaged, which made the hood movement harder. The hood can only be moved by crane magnet and cannot be pulled manually. Therefore the present position, height, shape, and hood movement arrangement is improper and hence will not extract any emissions from the furnace.

Figure 11: Ineffective fume extraction at Lhaki Steel

(a) At what height the hood should be above the furnace?

The hood should be as close to the furnace as possible, typically less than 1 meter from the furnace platform. Higher the hood, less effective will be extraction of fumes and also the volume to be sucked will be higher and hence the fan motor power will be higher and as a result the operating power cost goes up. It is very much possible to have the hood at about 0.7 to 1.0 meter above the furnace and several such designs are in operation in various induction furnaces in India.

(b) Hood design constraints:

Due to requirement of charging scrap by crane and requirement of tilting the furnace during pouring, there cannot be a FIXED HOOD above the furnace, hence a movable hood needs to be provided to suck the furnace emissions.

(c) Frequent hood movements:

The hood needs to be pushed away several times, whenever the crane is charging the scrap by magnet. But it is equally important that the hood should be pulled back on furnace, immediately after the charging as the crane/magnet goes away. The actual time for the magnet to charge the scrap in furnace is less than 1 minute each time and such charging may happen 4 or 5 times per cycle of 60 to 90 minutes. The hood needs to pushed away and pulled back for about 4 to 5 times per hour or more number of times, every time for about 1 to 2 minutes each only. That means, in 1 hour (or 60 minutes), the hood should be away for about 5 to 10 minutes only, for the rest 50-55 minutes/hr, the hood can be held right on top of the furnace.

During pouring/tapping, which takes about 5 to 8 minutes, the hood needs to be pushed away, clearing the tapping ladle area. During tapping, the hood can be nearby the tapping area (about 1 or 2 meters away, instead of pushing it far away like 4–5 meter away). This way, the hood can still suck some emissions even during tapping time.

(d) How smooth the movement of hood should be?

For the effective extraction of fumes, the pulling and pushing movement of the hood should be smooth, such that only one workman should be able to push/pull easily, without much effort. It is wrong to use crane magnet to push/pull the hood, it can never work, only the hood will get damaged/deformed and its bearing alignment will be damaged, making the hood movement harder and harder, (which is the present case at Lhaki Steel). The smooth movement of the hood is a must for the success of this APCD, it needs to be designed accordingly. The hood should only be pushed and pulled manually or by using an electrically operated gear-pinion arrangement, but never by magnet crane.

(e) Percentage of time the emissions can be sucked by hood:

In all, the hood needs to be pushed away for a period of about 10 to 20 minutes during 4–5 magnet charging and 5–10 minutes during tapping during the tap to tap cycle time of about 70 to 90 minutes, i.e. for 75 to 85 per cent of the cycle time the hood can be held over the furnace and during this period almost all the emissions should be satisfactorily sucked by the hood, which should be of design requirement. The balance 15 to 25 per cent of the time, the hood should be pushed away, but should be kept as close to the area of emissions as possible such that the emissions can at least be partially sucked, if not fully.

2. Choked bag-filter and absence of proper operation & maintenance:

The static pressure at the fan/blower inlet should typically be more than 200 to 250 mmWC, and about 50 to 100 mmWC at Gas inlet duct entering the bag-filter to take care of pressure drop across the bag-filter and also to overcome friction resistance in the duct length and bends, etc.

Figure 12: Junk lying below the Bag-filter hoppers at Lhaki Steel

At the inlet duct of the bag-filter, the static pressure was found to be 0 (zero) mmWC, which means, there is no gas flow to the bag-filter, this may be because the bag-filter is completely choked. Also the pulse jet cleaning arrangement is not working at all.

The dust collected in the hoppers of the bag-filter should be removed from the bottom on a daily basis. The rotary air lock valve fixed at hopper bottom opening should continuously operate such that the collected dust falls down.

In Lhaki steel, these valves were not operating, some valves even the motors were removed and there was no evidence showing that the dust is removed if at all from the hoppers (see Figure 12), junk lying below the bag-filter hoppers, no dust collected at all, it shows the bag-filter is not in operation for many days/weeks, may be months.

In the present circumstances, unless the filter bags are changed and the compressor operated, air pulse jet cleaning arrangement is made functional, the bag-filter cannot work and no emissions could be extracted from the furnace by the hood. (This calls for major modification in the system).

Even if penalty or fine is levied on the unit, the fact remains that the APCD cannot be properly operated without a major overhaul and operationalizing of bag-filter system followed by its adequacy testing. **The present APCD system is grossly inadequate and cannot work, without major overhaul. Accordingly, the directions should be issued.**

3. The installed energy meter at Lhaki Steel and comments:

The unit has installed a separate energy meter on the fan motor, as in Figure 13. In this case, even if the fan is running and the energy meter is showing consumption of electricity in KWh, since the bag-filter is choked there cannot be any extraction of emissions from the furnace and hence the very purpose of its installation is defeated.

Also, this is an analog meter and the data cannot be transmitted through internet and hence hourly or daily energy consumption is not recorded, nor it can be captured in software. All industries therefore should be directed to install only smart meters such that the data can be captured by computer and analysed through software.

Figure 13: Analog energy meter at the fan motor of Lhaki Steel

5.2 Problems in ferro alloy industries

The required fume extraction systems along with bag filters are installed by almost all the ferro-silicon industries. But, there are still substantial emissions from the furnaces, especially during tapping.

Due to reasons like partial choking of filter bags or inappropriate functioning of the pulse jet cleaning system etc, there is high pressure drop at bag filter, thereby the gas quantity extracted from the furnaces is reduced substantially and therefore fugitive emissions start from the furnaces.

Some industries have proper door sealing system to close the furnace openings by hydraulically operated doors, thereby outside air does not enter the furnace and the extraction of emissions from furnaces is more effective (see Figure 16–17).

Figure 14: Fugitive emissions from open furnace—Ferro Alloy industry

Figure 15: Fugitive emission from open furnace due to inappropriate functioning of fume extraction system

Figure 16: Hydraulically operated furnace doors at a submerged arc furnace—Reduces fugitive emission

Figure 17: Hydraulically operated furnace doors to control fugitive emission—Reduces fugitive emission

To assess the problems, a diagnostic study is required by an expert to do various measurements on the installed systems, like static pressure, temperature, gas volumes extracted etc. After this study, appropriate modifications could be suggested and the industries could implement them.

For capturing emissions during tapping, some industries have installed a separate bag filter system, while some have not. There may be some shortfalls in terms of design faults or under sizing of fan and number of filter bags etc, which adversely affects the performance of the APCD systems.

6. Conclusion

The air pollution level at Pasakha industrial area is alarmingly high and ruining the environment of Bhutan. There are substantial un-sucked/un-controlled fugitive emissions of dust particles along with gases from the industries. Though almost all industries have installed some or other type of Air Pollution Control Devices (APCD), still there are substantial emissions.

These emissions are not localized to Pasakha industrial estate, but it spreads in all directions due to wind movement and the area over several kilometers is adversely affected. Any colour to the emissions is because of presence of fine particles/dust in the gases, which give a visual impression of air pollution, so it is nec to arrest these dust particles from the gases.

Ambient air quality of Pashaka industrial area is deteriorating due to the cumulative impact of industrial emissions. In the industrial zone there are many other industries which contribute to the pollution load of the area.

The monitoring result reveled that some of the pollutants at different monitoring locations had exceeded the national standard. It was observed that the PM value at most of the places where instantaneous monitoring was done was well above the permissible limits.

The road condition of the industrial zone is very poor and the truck movement is also a contributing factor to the pollution load. In most of the industries the material handling and storage is not adequate and most of the raw materials are stored in open area whereas it should have been in the covered area.

Figure 18: Cumulative impact industrial emission on air quality of Pasakha

Figure 19: Fugitive emission during loading and unloading of material—most industries store raw materials in open

Figure 21: Poor road condition in the area adds to the fugitive emission during transportation of raw material

Figure 20: Fugitive emission during loading and unloading of material

Other important observations during the assessment are provided below:

1. Housekeeping within the industry was very poor in all the six industries visited;
2. Access to stack was not safe in few industries;
3. Waste handling system was found to be poor, in most of the industries the ruined bag-filters were found thrown here and there, without any designated place for storage;
4. The visited steel plant was not operating its Gas Cleaning Plant (GCP);
5. Most of the industries in the estate have installed single ID fan for the GCP, hence during breakdown they vent air directly to atmosphere;
6. High emission were observed during tapping process, at a time 3 – 4 tapping occurs in the estate and this adds to the emission of the pollutants in the area;
7. Dust collection mechanism from the bottom of the bag-filter hoppers are very poor, further it is done manually at most of the places which is hazardous for the workers working in the area;
8. In adequate design and flaws were found in the pollution control equipments of the steel industries; and
9. Operating and maintenance knowledge of the workers operating the pollution control system as well as industrial officials were not found to be satisfactory.

Figure 22: Poor housekeeping in most of the industry

Figure 23: Poor housekeeping – storage of waste without any designated place

Figure 24: Bhutan Bitumen poor housekeeping —no designated place for storage

Figure 25: Storage of used oil drums near storm water drains — can lead to water contamination

Figure 26: Access to stack and gas cleaning plant blocked

Figure 27: Burning of rejected bag filters and other waste in the open

Figure 28: Discarded bag filters—no designated place for disposal

Figure 29: Raw material storage and handling not proper, it adds to the fugitive emission

Figure 30: HCL stored in the open without any liner—high risk of soil and ground water contamination

Figure 31: Raw material storage in open even though facility for storage is available

Figure 32: Poor dust handling mechanism from hoppers of gas cleaning plants

Figure 33: Emission from point source during non-operation of Gas Cleaning Plant

Figure 34: Emission from point source during non-operation of Gas Cleaning Plant

Figure 35: Workers working without any safety gears in most of the industries

7. Recommendations

In order to improve the ambient air quality of Pasakha, the assessing team proposes the following recommendations. The recommendations need to be implemented in two stages—one will be short-term measures which should be implemented on immediate basis and two is a long-term approach to ensure that the ambient air quality of the estate does not deteriorate.

Further, under the prevailing conditions all expansions to the air polluting industries should be put on hold until the ambient air quality of the Pasakha Industrial Estate improves. Meanwhile, the authority should allow only non air polluting industries in the estate.

7.1 Proposed short-term measures for immediate implementation:

1. Pasakha should not be left unattended by NEC and MOEA. In the absence of both the organizations, sincerity of the industries in controlling emission goes down like switching of the ID fan to save cost, etc.
2. Installation Continuous Ambient Air Quality Monitoring Stations (CAAQMS). At least 3 CAAQMS should be installed for monitoring PM10, PM 2.5, NOx, CO, SO2, etc. In addition to this one monitoring station near the human settlement along the bank of the river (BFAL and BCC colony) should also be installed.
3. Two ID fans, one operational and other on standby, for air pollution control or GCP system, and at least 1 ID fan should run all time.
4. Tapping fume should be collected and channelized through a duct connected with bag-filter with two ID fans, and it should not be vented out directly.
5. Raw material handling and storage facility to be converted from open storage area into closed/three sides closed with adequate suction device fitted with bag-filters.
6. Housekeeping in most of the industries needs to improved, including the access to the stack and waste-handling mechanism.
7. Industries in the estate should be asked to conduct continuous real-time monitoring and the monitoring results should be shared with NEC, Bhutan on a regular basis.
8. Introduce a system for submission of ADEQUACY REPORTS of GCP by third party, empanelled by NEC.
9. The NEC should conduct a pilot study in one of the industries for reducing NOx during tapping process, so that NEC can take strategy level decision.
10. Conduct a pilot study in one plant for improving efficiency of GCP, so that NEC can take strategy level decision.
11. Road condition of the estate needs to be improved so that the fugitive emission from it can be reduced.
12. Regular water sprinkling (3 times a day) is suggested during loading and unloading of the materials and on the roads to suppress fugitive emission.
13. In induction furnaces, hydraulically operated gate should be installed which closes completely, this will reduce emission to a great extend (only two FeSi plants were operating with closed gate).
14. Mechanized collection of FeSi dust from the bottom of the bag house, currently in most of the industries it is done manually (see Figures 36 and 37).

Figure 36: Manual dust collection in most of the industries

Figure 37: Mechanical dust collection system in one of the industries

15. NEC should not issue environmental clearance (EC) to first-of-its-kind projects without understanding the issues. The officials need to have detailed understanding of the environmental issues associated with such an industry by visiting similar existing industries in other countries.
16. NEC officials need to be trained on regular basis for effective compliance monitoring.

7.2 Proposed long-term strategy for ensuring overall improvements:

1. **Diagnostic study to know present health status of APCDs of all the industries in the estate:**
   An agency having expertise in the area of designing of air pollution control systems need to be involved to assess the present health of installed APCDs in all the industries. The agency will have to carry out assessment of the installed systems. Based on the assessment and upon detailed observations of the installed APCDs, the APCD health status report could be prepared. The report would include the present problems in design or operation of the systems and what modifications are required to make the APCDs function satisfactorily.

2. **Install a digital energy meter on each fan motor to capture operating hours and KWh consumption**
   The energy meters would capture the KWh consumption of the fan motors and operating hours during 24 hr day. The trends could be analysed for KWh/day, KWh/month, KWh/fan motor, etc. It could be cross-checked with a random reading of current amps to calculate actual power consumption of that fan motor.

3. **On-site display of 2 numbers of U-tube manometers, one at Bag-filter inlet side and one at Fan inlet:**
   Install Digital temperature meters with recorder at bag-filter inlet and outlet to display and record gas temperatures. This recorded values over the 24 hour cycle would tell us whether the gases really get extracted from the furnace or not. (Normally, if the gases are extracted from the furnace, the gas temperature would be in the range of 100 to 200 ^{o}C. If the Fan is stopped during nights, no gas will be extracted from furnace and hence the meter would record low temperature (close to ambient temperature). The period during which the temperature is close to ambient temperature, would mean no gases are extracted from the furnace. This would also act as a cross check for energy meter data.

4. **Industries to submit basic technical specifications of the installed APCD:**
   All the industries should be asked to submit in writing, the technical specifications of the installed/modified APCDs. (A suitable form/format can be designed for this).

5. **Adequacy testing by the agency and Adequacy Report:**
   The third party empanelled by NEC, will do the system adequacy testing. If some more adjustments, fine tuning etc is required, the same will be suggested and got done by industries. Finally, the agency will issue its Adequacy Report, certifying that the modified APCD system is adequate in terms of design.

6. **Training of industry officials, operators on operation and maintenance of APCDs:**
   Regular basic training to industry personnel on how to operate and maintain the APCDs and what checks should be followed and records to be periodically maintained should be provided by an expert agency.

7. **Categorization of industry**
   Based upon the environmental impact of the industry as high, medium and low, categorization of the industries should be done in order to suggest the extend of environmental impact study required. This will help in making the environmental clearance process much more effective.

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