Health Risk Assessment and Value of Statistical Life for Emissions Effects for Surat City

1.1. INTRODUCTION

Ambient fine particulate matter ($PM_{2.5}$) is a major risk factor for ill health and death. As indicated in the literature review , there were many national and international case studies included in assessment which have established robust causal associations between long-term exposure to $PM_{2.5}$ and premature mortality from endpoints such as heart disease, stroke, respiratory diseases, and lung cancer, thereby substantially reducing life expectancy. In the Global Burden of Disease (GBD) 2019 comparative risk assessment, 5.5 million deaths were attributed to ambient air pollution[1], ranking it even higher risk factor for mortalities than global epidemic such as HIV-AIDS[2]. Following section explains the approach used for carrying out Health Risk Assessment related to exposure to $PM_{2.5}$ under SCAP and subsequent economic costs which have been evaluated based on GBD 2019 data.

1.2. METHODOLOGY

1.2.1. Dispersion Modelling

TERI could conduct dispersion modelling by conducting primary assessment of 10 different locations in the city of Surat. The modelled summer and winter concentrations specifically in the months of December and January were averaged to estimate winter seasons concentration. Similarly, ambient $PM_{2.5}$ concentration in May and June were averaged for Summer seasons spatial $PM_{2.5}$ concentration map. It is evident that $PM_{2.5}$ concentrations are much higher during winter due to meteorological adversity-low wind speeds and shallow inversion heights. In summers with higher amount of dispersive character in the atmosphere we see a dip in the ambient $PM_{2.5}$ concertation when compared with winter season.

Thereafter, the modelled results were validated against the observed measurements collected by TERI at multiple locations around the city. **Figure 1** shows the comparison of observed and modelled values of $PM_{2.5}$. The average ratio of simulated to observed values is found to be ~ 1.08, which can be considered quite satisfactory. The validation of model established that the model could reproduce physical and chemical processes which define pollutant concentrations, and it can be further utilized for running sensitivities of different sources.

[1] *State of Global Air 2020*
[2] *Addressing Global Mortality from Ambient $PM_{2.5}$ 2019 – part of GBD Study*

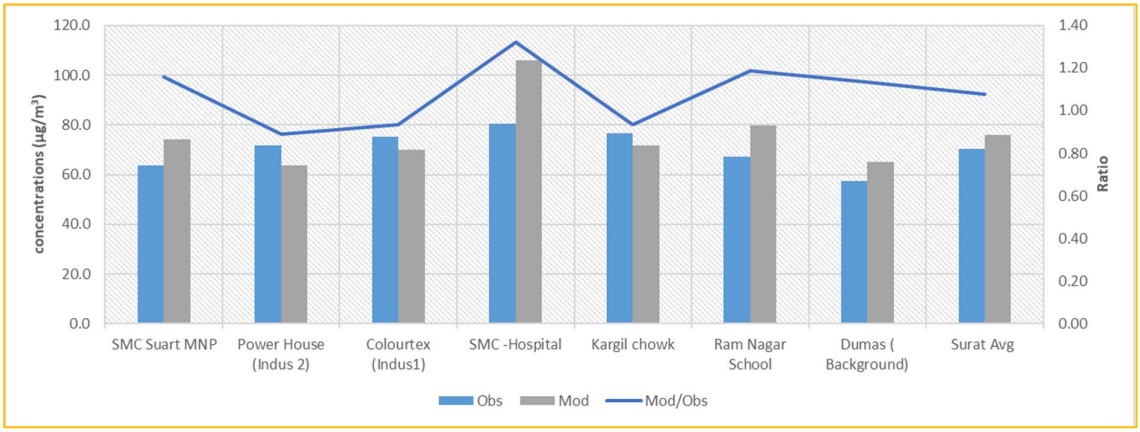

Figure 1: Simulated Results for Different Primary Stations and Average Concentrations for the city of Surat - µg/m3

1.2.2. Source Apportionment – Part of Emissions Inventories

The source sensitivity analysis was performed to estimate the contributions from different sources impacting the air quality in Surat district using dispersion model. The simulation has been performed for the same period in which monitoring was performed in Surat by TERI's team. The results are charted in **Figure 2**. The winter season in table is averaged from Dec 2019 and Jan 2020, while summer is averaged from May 2019 and Jun 2019 as explained in above section. The total emissions for the city

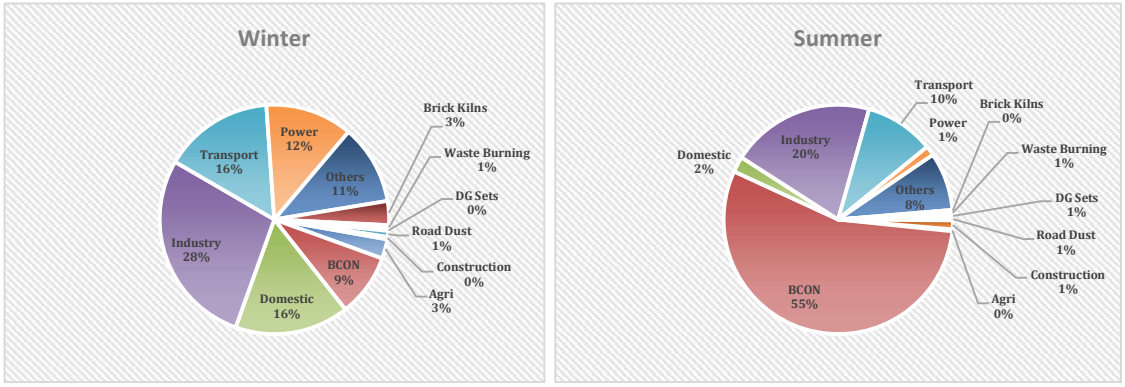

Figure 2: Seasonal averaged contribution averaged from 6 monitoring locations on the dates of monitoring

of Surat has been estimated to be 8.68 KT/Year for the base year 2019 in the emissions inventory prepared by TERI taking basis from the dispersion modelling.

1.2.3. Mortalities Assessment – Part of Health Risk Assessment

To understand the consequences of exposure and subsequent economic costs, the World Health Organization has used tools such as Health Risk Assessment. Health Risk Assessment helps to evaluate risks associated with toxic pollutants and helps the government to set regulatory policies to govern the causes and effects of these toxic pollutants. This may vary for different countries but as a thumb rule public health agency evaluate risk to determine what damage ambient air pollutants can have over normal functioning of body systems of adults and young adults in the urban agglomerations worldwide. The earlier understanding to severity can give sufficient time for the authorities to take mitigation

actions for curbing ambient air pollution. In addition to this, the HRA tool can give statistical associations with health effects due to prolonged exposure to different pollutants, making the interventions quite target specific with respect to locations, concentrations, and age-sex group of exposed personnel.

The inferences of the HRA tool could give away premature mortalities due to prolonged exposure to certain harmful pollutants which is life threatening and disabling diseases. One must note that these diseases formed basis for mortalities attribution to $PM_{2.5}$ concentrations in Surat city. However, in further cause-effect assessment, other ailments and combined effects of listed ailments can be performed. Having mentioned that, following diseases have been considered as standalone developmental issues leading to death or permanent disability in SCAP project.

- Chronic obstructive pulmonary disease (COPD)
- Ischemic heart disease (IHD)
- Acute respiratory lung infection (ALRI)
- Cerebrovascular disease (stroke) and
- Lung cancer (LC)

Table 1 gives fractional contribution of different sectors' attribution to mortality / due to their $PM_{2.5}$ generating capacity in the present mitigation options and desired implementation of programmes which have been explained separately for each chapter in the latter section of the report.

Table 1: Sector's Contribution and Associated Mortalities

Sector	**% Contribution** *($PM_{2.5}$ – Average for Summers and Winters)*	**Mortality caused**
HH Cooking	11	321
Industries	38	1096
Transportation	20	580
Power Plants	8	225
Brick Kilns	2	48
Waste burning	2	48
Road Dust	2	48
Agriculture	2	48
Construction	1	32
DG Sets	1	32
Other *(*)*	15	435
Total	100	2914

1. *(*) - Others include - Crematoria, Surat Port, Eateries, Landfills, Biogenic Gases*
2. *For the '**Eateries'** sector which has been considered as part of '**Others'** in the dispersion modelling results, separate assessment has been done for taking out emissions, mitigation interventions and*

techno-economic analysis-based project identification. However, the dispersion modelling includes only large restaurants and hotels but small eateries which is not being attributed to separate mortality count and have been estimated with other sectors as per above point no.1.

1.2.4. Associated Economic Costs – VSL Method[3]

Any mortality would generate some kind of economic impact irrespective of its contribution towards the cause creating the situation, here the cause would be air pollution and effect would be healthy people's exposure to $PM_{2.5}$ which are coming out from different sectors as mentioned in above sections as well as in **Chapter 2,** in details. After thorough assessments, two approaches to valuing the costs of premature mortality were taken out,

- A **welfare-based approach** that monetizes the increased fatality risk from air pollution according to individuals' willingness to pay (WTP); and
- A **labor share-based approach**[4] that equates the financial cost of premature mortality with the present value of forgone lifetime earnings in direct correlation of working population to regional (state) and national earning capacities.

As indicated in **Table 2** were the reference criteria considered for the assessment of above two approaches for the base year 2019.

Table 2: Reference Criteria for Calculations - VSL and LSO

Sr. No.	Criteria	Response	Source
1	GDP PC – USA (USD)	65297.52	WBG
2	GDP PC – INDIA (USD)	2099.599	WBG
3	GDP PC – GUJARAT (USD)	2788.732	CAG Gujarat Report
4	GDP PC – Surat (USD)	2610	Smart city Cell, SMC
5	VSL Base Value for USA (USD)	9815791	IHME VSL database
6	Labour Share – 'α'	0.456	Penn World Table 10.0
7	Working Population of Surat – No	6604514	Smart city Cell, SMC
8	GDP Share of Surat – Total (USD)	5.98E+10	Smart city Cell, SMC
9	Attributed Total Mortalities for the city of Surat – No	2978	WRI's Assessment – HRA
10	Total Affected Population due to air pollution in India - No	5.5 Mn	State of Global Air report 2020
11	Total Mortalities due to ambient air pollution in India - No	980000	State GBD Study 2020
12	Income Elasticity – 'e'	1.2	GBD2019 database

[3] *The Cost of Air Pollution – Strengthening Economic Case for Actions, IHME*
[4] *Value of Statistical Life in India: A Hedonic Wage Approach, A Majumder*

1.2.5. Welfare Based Approach – Part of VSL Assessments

In the welfare-based approach Value of Statistical Life forms an important factor for reference. From the assessment provided by the IHME reports (2019) considering GBD 2019 numbers, following can be the formula to take out VSL for India,

VSL for India in 2019 = VSL for USA * (GDP PC of India in 2019/GDP PC of USA in 2019) ^1.2

Similarly, for creating reference points to avail VSLs for the state of Gujarat and for the city of Surat at constant PPP and depreciation adjusted for the assessment year, following two formulas were plotted.

VSL for Gujarat in 2019 = VSL for India in 2019 * (GDP PC of Gujarat in 2019/GDP PC of India in 2019) ^1.2

VSL for Surat in 2019 = VSL for Gujarat in 2019 * (GDP PC of Surat in 2019/GDP PC of Gujarat in 2019) ^1.2

The similar assessment can be done for any other state or the city within the state since it is for creating a reference point in VSL value and transferring the risk attribution of losing economic gain due to mortality from a higher constant value of VSL.[5]

Considering above assessment factors and taking reference from a national level policy brief on cleaner fuel subsidy assessment, following formula was used to take out 'affected population group's willingness to pay' for the ill effects of air pollution ($PM_{2.5}$) in the city of Surat,

Affected Population Group's WTP = Mortalities Accounted in Emissions Inventory * VSL for Surat (USD) * Exchange Rate (USD to INR) in assessment year (2019) / Total Population of Surat in assessment year (2019)

From above formula, the average WTP for Surat city is coming to **Rs. 6500** which can be considered as per person's cost (without medical expenses) per capita annual income as the value of one DALY, to determine the upper bound of the amount for the government to spend on health interventions.[6]

[5] *IHME assessment for different departmental parameters attributed for VSL in an assessment year*
[6] *Smith et al, WHO CHOICE Method 2014*

1.2.6. Labour Share Based Approach – Part of VSL Assessments

Labor's share of GDP (α) was computed for the country, based on the Penn World Tables 10.0.1. The labor's share of GDP at market prices measured in 2019 was multiplied by an adjustment factor that reflects the ratio of GDP at basic prices to GDP at market prices. This adjustment factor[7] was computed to be α = 0.456 for India.[8]

Based on above assessment, the Labor Share factor then computed against total GDP of urban dwelling (here Surat city) and total working population of the unit, which is 99.5 as per the SMC reports for the year 2019.[9] Following formula was used to take out 'Output Losses Associated with Air Pollution Mortalities' in the city of Surat for the year 2019 for a single attributed death.

Output Losses Associated with Air Pollution Mortalities = (Labor Share of GDP – α (constant) * Total GDP Share of Surat city towards state for the year 2019) / Working Population of Surat city for the year 2019

While multiplying the result with exchange rate in assessment year, the approx. value came out to be **Rs. 290000** for a single death including medical expenses since medical services to do contribute towards the city's GDP and it can't not be excluded in calculations. However, an average person pays **Rs. 70000** exclusively for illnesses mentioned above in the city of Surat[10]. Also, the age factor must be accounted for the mortalities to take out more precise numbers.

1.2.7. Comparative Assessment of WTP and Output Losses

Considering the results of above two methods, the per capita 'Willingness to Pay' in the city of Surat is Rs. 6500 in the base year of 2019 while their actual cost considering labor share in the city's GDP towards state is coming to be Rs. 290000 for a single mortality attributed by the exposure to $PM_{2.5.}$

1.3. CHALLENGES

One of the major challenges in assessing the VSL and LSO is the age and gender factors of mortalities reported or assessed. There are studies available for India level[11], which accounts these factors along

[7] *Robert Inklaar et al, 2018*
[8] *State GBD Study 2020*
[9] *Reports suggested 100% employment, in the assessment 0.5% has been left to include the gender – age depreciation for economic contributions.*
[10] *SMIMER Study, 2017*
[11] *Health and economic impact of air pollution in the states of India: the Global Burden of Disease Study 2019*

with associated morbidities (risk factors), but these require further specific approach in calculating city specific information on different diseases.

1.4. IMPROVEMENT WORTHY INFERENCES

1.4.1. For Industries Sector

- Majority of the city's workforce is related to industrial production directly or indirectly. Thus, with significant attribution to industries' contribution to city's production and economy, having a healthy workforce can be boon to the city's future.
- The labor laws and rules pertaining to the workers in Gujarat state are quite elaborated and can be effective if implemented properly. Yet, the monitoring for the industrial workers' health is not being done properly. This leads to not only ambient air pollution exposure to these workers but also, they get exposed to occupational air borne hazards. However, no attribution has been made to occupational exposure to certain air borne hazards against ambient air pollutants.
- Usage of industrial fuel is the major criteria for the generation of different pollutants from the industrial agglomerations in Surat city. As we have seen in above points, fuel options such as wood, coal, furnace oil, High Speed Diesel Oil and Natural Gas are still in common usage for generating more calorific value heat for processes, abatements of emissions from industries will not be an easy task.

1.4.2. For Transportation Sector

- Tail Pipe and Road Dust Resuspension has the highest emissions contributions in above assessment[12]. In addition to this, there was no considerations given to tail pipe till the year of 2016 wherein the EVs were started to internalize in the city's development process along with other non-motorized transport options. With respect to the road dust resuspension issues, the SMC has been able to procure more than 16 mechanical sweepers in the first lot which are operational since 2013.
- The city of Surat also houses highest per capita two wheelers in the state, which are responsible for daily movements of large number of workers of the city. Policies for the capping of two wheelers can be a difficult task for the city. However, this can be achieved through robust interventions in EVs introduction in public utility vehicles and other government sponsored vehicular movements.
- To curb the issue of road dust resuspension, wet processing, and maintenance of the busiest roads along with green paving of sideways and green path development in collaboration with local forest department can prove to be boon for the city.

[12] Source Apportionment Assessment – SCAP project - TERI

1.4.3. Household Cooking

- Though the government has been promoting cleaner fuel options traditional fuel users are still there who are using coal and wood for cooking and heating purposes.
- The above point does not define ill outreach of interventions related to LPG since it has been observed in the studies[13] that though the lower economic status population pockets have access to LPG cylinders, they prefer coal and wood for partial cooking and heating purpose to conserve financial resources.
- In above point, to free the 'deserving' population groups from the worry of saving their financial resources, the government has introduced interventions such as Ujjawala Yojana, which has already been discussed in existing capacities to abate ill effects of emissions related with household cooking.
- Knowledge impartment is utmost necessary for the promotion of cleaner fuel and eventual replacement of traditional fuel for cooking with the same.
- In addition to above all, protection from indoor air pollution is not as generalized as protection from outdoor air pollution.

1.4.4. Construction

- For construction practices improvement in Surat, the Clean Construction Practices Guidelines (2020) are available to curb the emissions from the construction sites. However, this cannot be ensured unless the two major authorities[14] in the city take up these SOPs in their regular implementations.

1.4.5. Open MSW burning

- At times, these units are seen burning waste and also found that it's attitude behavioral problem. This cannot be considered as a good practice since these waste articles would only add up to co-morbidities of the exposed population as well as it is contributing to ambient air pollution significantly.

[13] *UCRA Study by WRI I, Rangwala et al. 2017*
[14] *Surat Municipal Corporation and Gujarat Pollution Control Board Regional Office*