# 9 REFUSE BURNING

Scrape materials, garbage, biomass materials, etc., those are burnt anthropogenically in the open area are considered as refuse in the present study. The amount of waste generation depends on the population and livelihood of residents in a particular place. The basic equation (Eq. 26) followed to estimate the emissions of different pollutants from the burning of refuse materials is:

$$Epol = \sum_{S=1}^{35} \sum_{a=1}^{2} \sum_{i=1}^{n} fWb_{a,i} \times EF_{i,S} \quad (26)$$

where, E*pol* is the emission of a particular pollutant from the burning of the refuse material; $f$Wb is the fraction of waste materials burnt in an area (a); i is the type of waste material burnt; and EF is the state specific (S) emission factor of the particular pollutant (*pol*) from the burning of the waste material (i) (Table 29). The area (a) is classified as rural and urban.

**Table 29 Region-wise emission factors (g/kg) of different pollutants**

| Refuse type | $PM_{2.5}$ | $PM_{10}$ | $SO_2$ | CO | $NO_x$ | VOC |
|---|---|---|---|---|---|---|
| Rubber | 70.50 | 88.13 | 47.78 | 69.65 | 12.58 | 16.45 |
| Plastic | 5.11 | 6.26 | 1.94 | 39.61 | 2.62 | 15.00 |
| Paper | 2.28 | 3.13 | 0.47 | 44.29 | 4.76 | 3.79 |
| Biomass | 14.73 | 20.42 | 0.39 | 64.25 | 8.68 | 5.58 |

It is required to estimate the total waste generation to calculate the $f$Wb. The population of the year 2016 was estimated using the *eq. 3*. The CPCB (2000) has reported average waste generation in different urban areas based on the population of the area (*Table 30*). On the other side, Sharholy et al. (2008) have suggested average solid waste generation in the range of 0.21 to 0.50 kg/capita/day in India. Based on this, the average solid waste generation in the rural areas of India was taken as 0.21 kg/capita/day.

**Table 30 Waste generation in relation to population in urban areas of India**

| Population | Waste generation (kg/capita/day) |
|---|---|
| > 2,000,000 | 0.43 |
| 1,000,000 – 2,000,000 | 0.39 |
| 500,000 – 10,000,000 | 0.38 |
| 100,000 – 500,000 | 0.39 |
| <100,000 | 0.36 |

The composition of waste (biodegrable, plastic, paper and rubber) was segregated following Selvan and Palanivel et al. (2015) for different areas. The average value of different types of area was assumed as the composition of waste in the country (*Table 31*).

**Table 31 Average composition of refuse materials in India**

| Type of waste | Commercial area (%) | Residential area (%) | Dump yard (%) | Mean (%) |
|---|---|---|---|---|
| Biodegradable | 60.3 | 52.64 | 76.95 | 63.30 |
| Plastic | 12.3 | 17.56 | 5.5 | 11.79 |
| Paper | 10.5 | 3.36 | 0.6 | 4.82 |
| Rubber | 1.5 | 3.32 | 0.55 | 1.79 |

However, most of the cities and towns in India have a well-defined waste collection facility, which prevents the burning of entire waste generated in these areas. State-level waste collection efficiency data was collected from the MoSPI (2016) (Table 32). Conversely, there is no structured waste collection facility in rural areas of India.

**Table 32 Urban waste collection efficiencies of different states of India**

| States/UTs | Collection efficiency | States/UTs | Collection efficiency | States/UTs | Collection efficiency |
|---|---|---|---|---|---|
| Andaman and Nicobar Islands | 100% | Himachal Pradesh | 75% | Odisha | 89% |
| Andhra Pradesh | 98% | Jammu and Kashmir | 74% | Puducherry | 98% |
| Arunachal Pradesh | 85% | Jharkhand | 100% | Punjab | 100% |
| Assam | 54% | Karnataka | 84% | Rajasthan | 49% |
| Bihar | 0% | Kerala | 49% | Sikkim | 100% |
| Chandigarh | 97% | Lakshadweep | NA | Tamil Nadu | 98% |
| Chhattisgarh | 90% | Madhya Pradesh | 65% | Tripura | 89% |
| Daman and Diu, Dadra | 100% | Maharashtra | 100% | Telangana | 94% |
| Delhi | 99% | Manipur | 71% | Uttar Pradesh | 100% |
| Goa | 89% | Meghalaya | 84% | Uttarakhand | 100% |
| Gujarat | 100% | Mizoram | 50% | West Bengal | 85% |
| Haryana | 100% | Nagaland | 56% | **India** | 91% |

NA Not available

We assumed that 60% of total uncollected wastes in both rural and urban areas get burned to reduce the volume of the waste following IPCC (2006). Accordingly, the $fWb$ was calculated following Eq. 27.

$$fWb_{a,i} = \{P_a \times C_\omega \times Com_i \times (1 - \varphi)\} \times 0.6 \quad (27)$$

where, $P_a$ is the population of the area (rural or urban); $C_\omega$ is the per capita waste generation (Table 30); *Com* is the fraction of the waste (*i*) (*Table 31*); and φ is the waste collection efficiency (Table 32).

## 9.1 Emission inventory of different pollutants due to refuse burning

Estimated region-wise emissions of different pollutants due to the burning of different refuse materials are given in Figure 13.

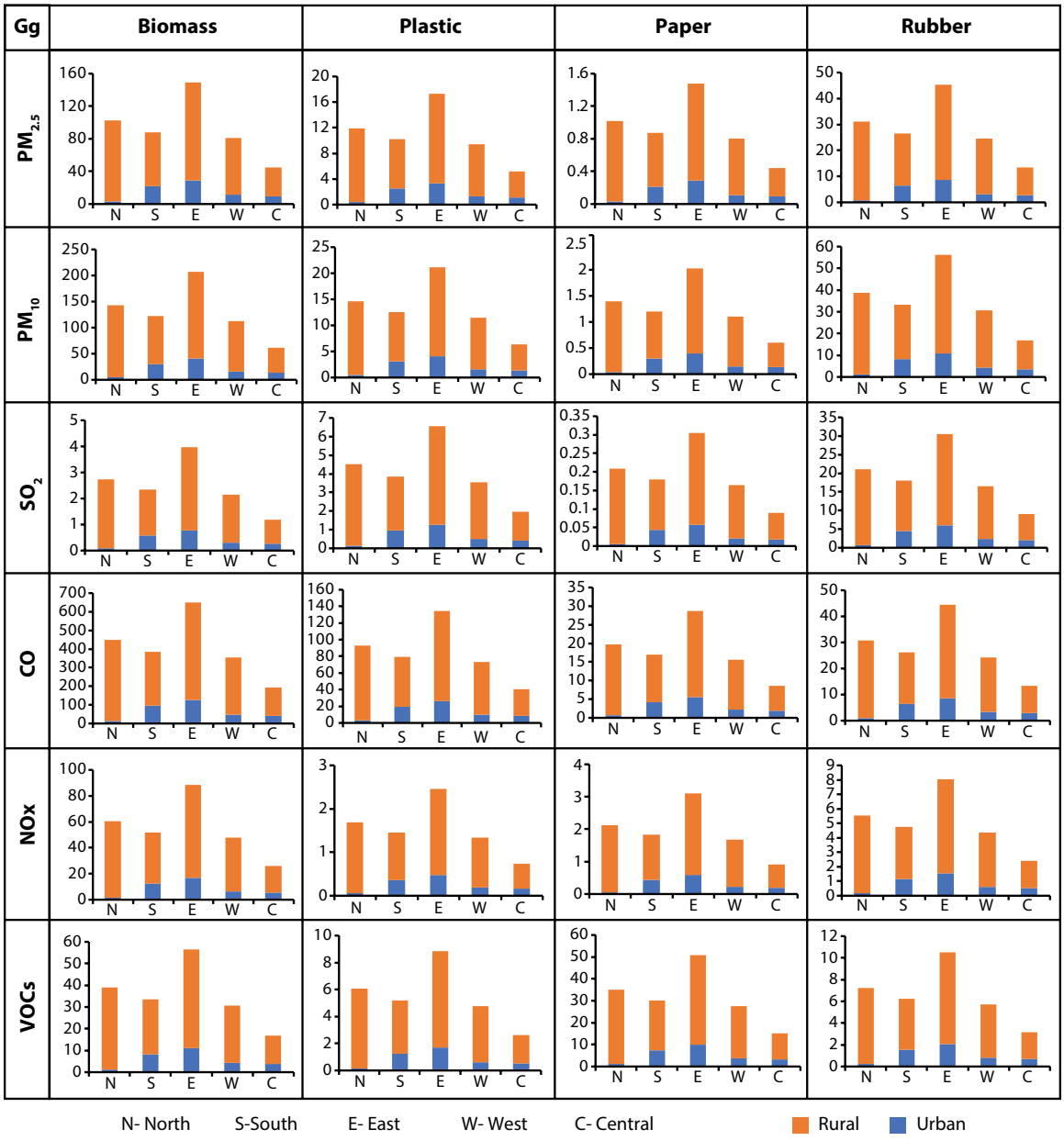


**Figure 13 Emissions of different pollutants in the rural and urban areas due to the burning of various refuse materials**

Total emissions of atmospheric $PM_{10}$ and $PM_{2.5}$ due to refuse burning were estimated as 862 and 632 Kt during 2016 respectively (*Table 33*). Burning of biomass waste material was the major source of almost all estimated pollutants emission.

**Table 33 Emissions of different pollutants (Gg) due to refuse burning during 2016**

| State | $PM_{10}$ | $PM_{2.5}$ | $SO_2$ | $NO_x$ | CO | VOC |
|---|---|---|---|---|---|---|
| Andhra Pradesh | 30.49 | 22.68 | 4.40 | 11.49 | 91.36 | 12.80 |
| Arunachal Pradesh | 1.06 | 0.79 | 0.15 | 0.40 | 3.19 | 0.45 |
| Assam | 30.33 | 22.56 | 4.38 | 11.43 | 90.89 | 12.74 |
| Bihar | 109.30 | 81.30 | 15.78 | 41.17 | 327.50 | 45.89 |
| Chhattisgarh | 19.81 | 14.74 | 2.86 | 7.46 | 59.36 | 8.32 |
| Goa | 0.67 | 0.50 | 0.10 | 0.25 | 2.00 | 0.28 |
| Gujarat | 31.11 | 23.14 | 4.49 | 11.72 | 93.22 | 13.06 |
| Haryana | 14.81 | 11.02 | 2.14 | 5.58 | 44.38 | 6.22 |
| Himachal Pradesh | 4.61 | 3.43 | 0.67 | 1.74 | 13.81 | 1.94 |
| Jammu and Kashmir | 11.06 | 8.22 | 1.60 | 4.16 | 33.13 | 4.64 |
| Jharkhand | 23.57 | 17.53 | 3.40 | 8.88 | 70.61 | 9.90 |
| Karnataka | 42.74 | 31.80 | 6.17 | 16.10 | 128.08 | 17.95 |
| Kerala | 39.96 | 29.72 | 5.77 | 15.05 | 119.73 | 16.78 |
| Madhya Pradesh | 65.39 | 48.64 | 9.44 | 24.63 | 195.95 | 27.46 |
| Maharashtra | 55.25 | 41.10 | 7.98 | 20.82 | 165.57 | 23.20 |
| Manipur | 2.32 | 1.73 | 0.34 | 0.87 | 6.96 | 0.98 |
| Meghalaya | 2.53 | 1.89 | 0.37 | 0.95 | 7.59 | 1.06 |
| Mizoram | 0.99 | 0.74 | 0.14 | 0.37 | 2.96 | 0.42 |
| Nagaland | 1.77 | 1.32 | 0.26 | 0.67 | 5.32 | 0.75 |
| Odisha | 34.16 | 25.41 | 4.93 | 12.87 | 102.35 | 14.34 |
| Punjab | 15.43 | 11.48 | 2.23 | 5.81 | 46.23 | 6.48 |
| Rajasthan | 68.45 | 50.92 | 9.88 | 25.79 | 205.10 | 28.74 |
| Sikkim | 0.38 | 0.28 | 0.05 | 0.14 | 1.14 | 0.16 |
| Tamil Nadu | 34.54 | 25.69 | 4.99 | 13.01 | 103.49 | 14.50 |
| Telangana | 20.95 | 15.58 | 3.02 | 7.89 | 62.77 | 8.80 |
| Tripura | 2.57 | 1.92 | 0.37 | 0.97 | 7.71 | 1.08 |
| Uttar Pradesh | 144.89 | 107.78 | 20.92 | 54.58 | 434.16 | 60.84 |
| Uttarakhand | 6.30 | 4.69 | 0.91 | 2.37 | 18.88 | 2.65 |

| State | $PM_{10}$ | $PM_{2.5}$ | $SO_2$ | $NO_x$ | CO | VOC |
|---|---|---|---|---|---|---|
| West Bengal | 63.91 | 47.54 | 9.23 | 24.07 | 191.49 | 26.83 |
| Andaman and Nicobar Islands | 0.20 | 0.15 | 0.03 | 0.08 | 0.60 | 0.08 |
| Lakshadweep | 0.14 | 0.10 | 0.02 | 0.05 | 0.41 | 0.06 |
| NCT of Delhi | 0.33 | 0.24 | 0.05 | 0.12 | 0.98 | 0.14 |
| Puducherry | 0.37 | 0.28 | 0.05 | 0.14 | 1.12 | 0.16 |
| National emission (Gg) | 880 | 655 | 127 | 332 | 2638 | 370 |
| Contribution of different type of refuse materials (%) | | | | | | |
| Biodegradable | 73.4 | 71.2 | 9.7 | 82.8 | 77.1 | 47.8 |
| Plastic | 7.5 | 8.2 | 16.1 | 8.3 | 15.8 | 42.8 |
| Paper | 0.7 | 0.7 | 0.7 | 2.9 | 3.4 | 2.1 |
| Rubber | 20 | 21.5 | 75 | 7.6 | 5.3 | 8.9 |

The state-level emissions of different pollutants due to burning of the refuse materials were spatially distributed following the weighted value of each polygon in a state. The weighted value of each polygon was derived based on the ratio of the polygon area and the area of the state (Figure 14).

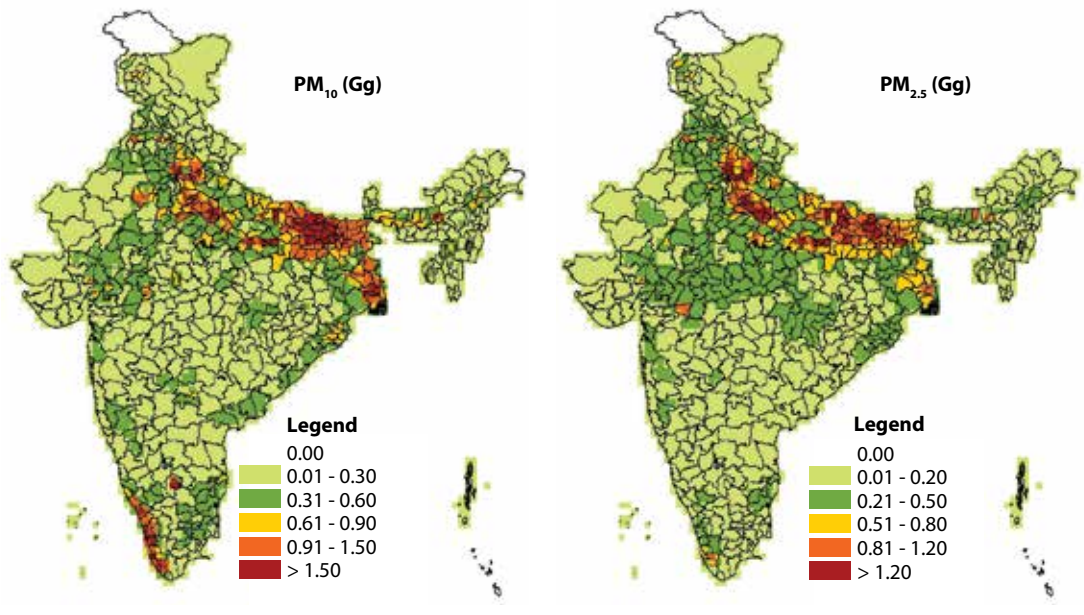


**Figure 14 Contd...**

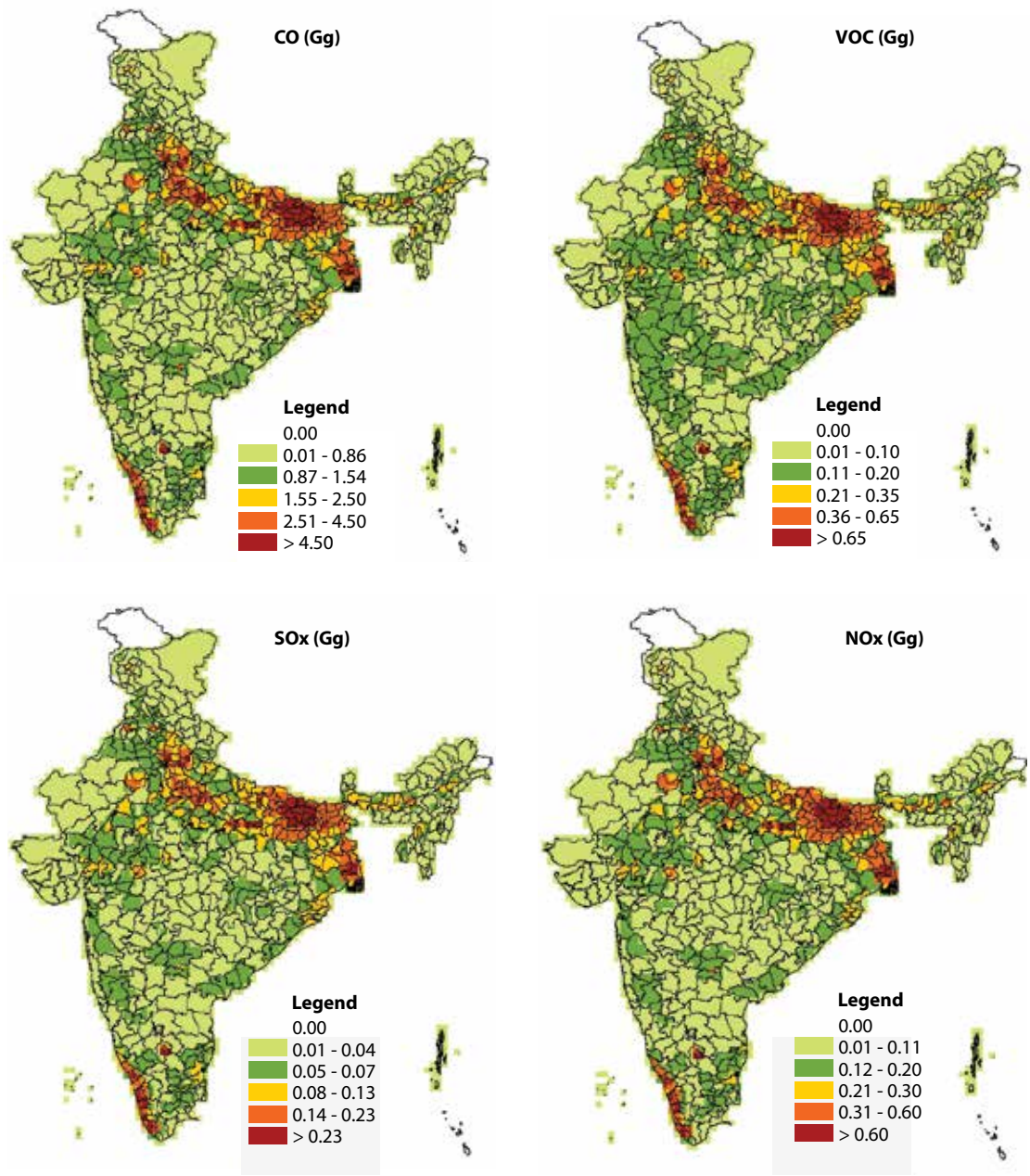


**Figure 14 Spatial distribution of emission of different pollutants due to the burning of the refuse materials**