MAT2001

STATISTICS FOR ENGINEERS

AIR QUALITY IN INDIA

A quick overview of India's air pollution levels over the years

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PROBLEM STATEMENT:

Using this dataset, one can explore India's air pollution levels at a more granular scale. This data is combined (across the years and states) and largely clean versions of the Historical Daily Ambient Air Quality Data released by the Ministry of Environment and Forests and Central Pollution Control Board of India under the National Data Sharing and Accessibility Policy (NDSAP).

Can we detect local trends? Can we relate the air quality changes to changes in Environmental policy in India?

ABSTRACT:

Air pollution occurs when harmful or excessive quantities of substances including gases, particles, and biological molecules are introduced into the Earth's atmosphere. Air pollution in India is a serious issue, ranking higher than smoking, high blood pressure, child and maternal malnutrition, and risk factors for diabetes. At least 140 million people breathe air 10 times or more over the WHO safe limit and 13 of the world's 20 cities with the highest annual levels of air pollution are in India. Air pollution contributes to the premature deaths of 2 million Indians every year. In urban areas, most emissions come from vehicles and industry, whereas in rural areas, much of the pollution stems from biomass burning for cooking and keeping warm. In autumn and winter months, large scale crop residue burning in agriculture fields – a low cost alternative to mechanical tilling – is a major source of smoke, smog and particulate pollution. India has a low per capita emissions of greenhouse gases but the country as a whole is the third largest after China and the United States. A 2013 study on non-smokers has found that Indians have 30% lower lung function compared to Europeans.

The major air pollutants are:
➢ Sulphur Dioxide (SO_2)
➢ Nitrogen Dioxide (NO_2)

INTERPRETATIONS:

```
#import data

mydata = read.csv ("C:\\Users\\Aravind\\Desktop\\data.csv")
summary (mydata)
```

```
> #import data
> mydata = read.csv ("C:\\Users\\Aravind\\Desktop\\data.csv")
> summary (mydata)
    stn_code        sampling_date           state               location
 193    :  1428   19-03-2015:   253   Maharashtra  : 60384   Guwahati  :  9984
 519    :  1280   12-02-2015:   237   Uttar Pradesh: 42816   Hyderabad :  9667
 708    :  1273   19-02-2015:   236   Andhra Pradesh: 26368  Delhi     :  8551
 541    :  1270   05-11-2015:   235   Punjab       : 25634   Chandigarh:  8520
 710    :  1269   11-11-2015:   234   Rajasthan    : 25589   Jaipur    :  7850
 (Other):285145   (Other)   :434544   Kerala       : 24728   (Other)   :391167
 NA's   :144077   NA's      :     3   (Other)      :230223   NA's      :     3
                                                             agency
 Maharashtra State Pollution Control Board                          : 27857
 Uttar Pradesh State Pollution Control Board                        : 22686
 Andhra Pradesh State Pollution Control Board                       : 19139
 Himachal Pradesh State Environment Proection & Pollution Control Board: 15287
 Punjab State Pollution Control Board                               : 15232
 (Other)                                                            :186060
 NA's                                                               :149481
                                  type            so2                no2                rspm               spm
 Residential, Rural and other Areas:179014  Min.   :  0.00   Min.   :  0.00   Min.   :   0.0   Min.   :   0.0
 Industrial Area                   : 96091  1st Qu.:  5.00   1st Qu.: 14.00   1st Qu.:  56.0   1st Qu.: 111.0
 Residential and others            : 86791  Median :  8.00   Median : 22.00   Median :  90.0   Median : 187.0
 Industrial Areas                  : 51747  Mean   : 10.83   Mean   : 25.81   Mean   : 108.8   Mean   : 220.8
 Sensitive Area                    :  8980  3rd Qu.: 13.70   3rd Qu.: 32.20   3rd Qu.: 142.0   3rd Qu.: 296.0
 (Other)                           :  7726  Max.   :909.00   Max.   :876.00   Max.   :6307.0   Max.   :3380.0
 NA's                              :  5393  NA's   :34646    NA's   :16233    NA's   :40222    NA's   :237387
                                          location_monitoring_station      pm2_5            date
 Regional Office                                           :  6261   Min.   :  3.0   19-03-2015:   253
 Paonta Sahib                                              :  1599   1st Qu.: 24.0   12-02-2015:   237
 Head Office, Bamunimaidan, Guwahati                       :  1327   Median : 32.0   19-02-2015:   236
 ITI Building, Gopinath Nagar, Guwahati                    :  1280   Mean   : 40.8   05-11-2015:   235
 Bank of Baroda Building, Near Pimpri-Chinchwad M.C. Building:  1273   3rd Qu.: 46.0   11-11-2015:   234
 (Other)                                                   :396511   Max.   :504.0   (Other)   :434540
 NA's                                                      : 27491   NA's   :426428   NA's      :     7
```

SULPHUR DIOXIDE (SO$_2$):

Sulphur dioxide is a gas. It is invisible and has a nasty, sharp smell. It reacts easily with other substances to form harmful compounds, such as sulphuric acid, sulphurous acid and sulphate particles.

- **STATE-WISE SO$_2$ ANALYSIS:**

```
#state-wise SO2 analysis

SO2 = aggregate (mydata $so2, list (state = mydata $state), mean, na.rm = TRUE)
SO2 = SO2    [order (-SO2 $x, decreasing = FALSE), ]
SO2 = na.omit (SO2)
SO2
```

```
> #state-wise SO2 analysis
>
> SO2 = aggregate (mydata $so2, list (state = mydata $state), mean, na.rm = TRUE)
> SO2 = SO2  [order (-SO2 $x, decreasing = FALSE), ]
> SO2 = na.omit (SO2)
> SO2
                       state          x
36              Uttaranchal 24.697736
35              Uttarakhand 24.372957
16                Jharkhand 23.485794
30                   Sikkim 19.800000
5                     Bihar 19.381476
21              Maharashtra 17.366863
12                  Gujarat 16.656343
13                  Haryana 14.064957
7               Chhattisgarh 12.846609
37              West Bengal 12.608766
34            Uttar Pradesh 12.528500
27               Puducherry 11.970639
20           Madhya Pradesh 11.587410
31               Tamil Nadu 11.315134
28                   Punjab 10.628598
17                Karnataka 10.223099
23                Meghalaya  8.955908
8      Dadra & Nagar Haveli  8.939587
10                    Delhi  8.737273
9               Daman & Diu  8.192958
29                Rajasthan  7.665725
2            Andhra Pradesh  7.284845
15          Jammu & Kashmir  7.180521
11                      Goa  6.827913
4                     Assam  6.723263
32               Telangana  5.418609
18                   Kerala  5.322350
26                   Odisha  5.275874
22                  Manipur  3.900000
3         Arunachal Pradesh  3.179104
6                Chandigarh  2.676986
14         Himachal Pradesh  2.667013
24                  Mizoram  2.085009
25                 Nagaland  2.059736
> |
```

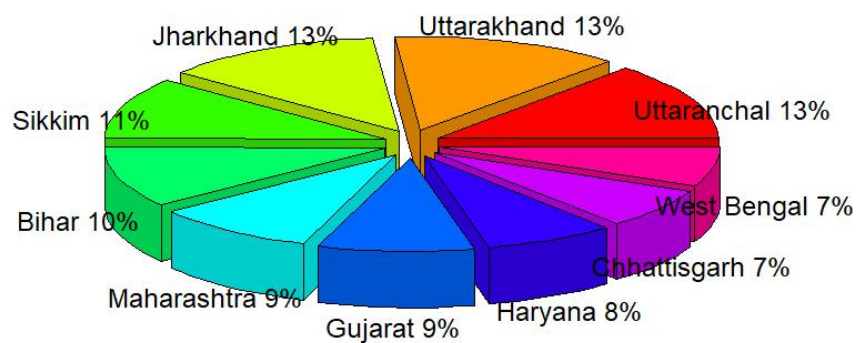- **TOP 10 SO$_2$ EMITTING STATES:**

```
#top 10 SO2 emitting states

top10 = head (SO2, 10)
top10
pct = round (top10 $x / sum (top10 $x) * 100)
top10pct = paste (top10 $state, pct)
top10pct = paste (top10pct, "%", sep="")
pie3D (top10 $x, labels = top10pct, explode = 0.1, col = rainbow (length (top10pct)),
main="Top 10 SO2 emitting states")
```

```
> #top 10 SO2 emitting states
>
> top10 = head (SO2, 10)
> top10
        state        x
36  Uttaranchal 24.69774
35  Uttarakhand 24.37296
16    Jharkhand 23.48579
30       Sikkim 19.80000
5         Bihar 19.38148
21  Maharashtra 17.36686
12      Gujarat 16.65634
13      Haryana 14.06496
7  Chhattisgarh 12.84661
37  West Bengal 12.60877
> pct = round (top10 $x / sum (top10 $x) * 100)
> top10pct = paste (top10 $state, pct)
> top10pct = paste (top10pct, "%", sep="")
> pie3D (top10 $x, labels = top10pct, explode = 0.1, col = rainbow (length (top10pct)), main="Top 10 SO2 emitting states")
>
```

Top 10 SO2 emitting states

- **BOTTOM 10 SO₂ EMITTING STATES:**

> *#bottom 10 SO2 emitting states*
>
> bot10 = tail (SO2, 10)
> bot10
> pct = round (bot10 $x / sum (bot10 $x) * 100)
> bot10pct = paste (bot10 $state, pct)
> bot10pct = paste (bot10pct, "%", sep="")
> pie3D (bot10 $x, labels = bot10pct, explode = 0.1, col = rainbow (length (bot10pct)), main="Bottom 10 SO2 emitting states")

```
> #bottom 10 SO2 emitting states
>
> bot10 = tail (SO2, 10)
> bot10
               state        x
4               Assam 6.723263
32          Telangana 5.418609
18             Kerala 5.322350
26             Odisha 5.275874
22            Manipur 3.900000
3   Arunachal Pradesh 3.179104
6           Chandigarh 2.676986
14   Himachal Pradesh 2.667013
24            Mizoram 2.085009
25           Nagaland 2.059736
> pct = round (bot10 $x / sum (bot10 $x) * 100)
> bot10pct = paste (bot10 $state, pct)
> bot10pct = paste (bot10pct, "%", sep="")
> pie3D (bot10 $x, labels = bot10pct, explode = 0.1, col = rainbow (length (bot10pct)), main="Bottom 10 SO2 emitting states")
> |
```


Bottom 10 SO2 emitting states
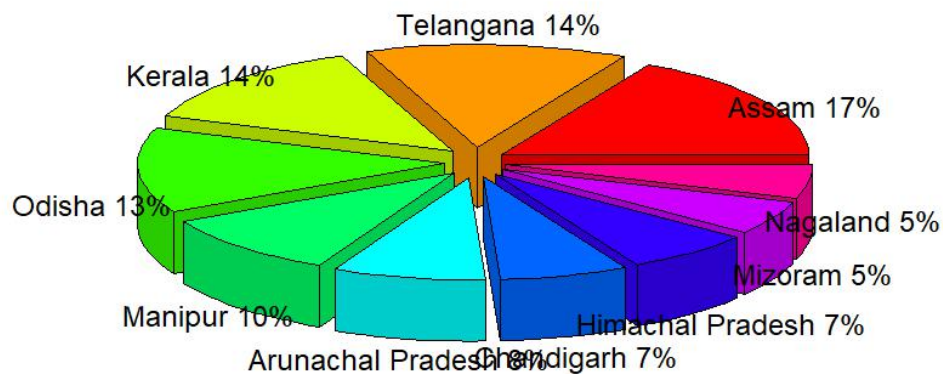
- ### HOW DOES SULPHUR DIOXIDE AFFECT HUMAN HEALTH?

Sulphur dioxide affects human health when it is breathed in. It irritates the nose, throat, and airways to cause coughing, wheezing, shortness of breath, or a tight feeling around the chest. The effects of sulphur dioxide are felt very quickly and most people would feel the worst symptoms in 10 or 15 minutes after breathing it in. Those most at risk of developing problems if they are exposed to sulphur dioxide are people with asthma or similar conditions.

- ### WHAT IS BEING DONE TO MANAGE SULPHUR DIOXIDE?

❖ Implementing national fuel quality standards.

❖ Supporting the implementation of tighter vehicle emission standards.

❖ Promoting alternative fuels.

NITROGEN DIOXIDE:

As for particulate matter and O_3, the evidence on NO_2 and health comes from different sources of information, including observational epidemiology, controlled

human exposures to pollutants and animal toxicology. The observational data are derived from studies outdoors where NO_2 is one component of the complex mixture of different pollutants found in ambient air and from studies of NO_2 exposure indoors where its sources include unvented combustion appliances. Interpretation of evidence on NO_2 exposures outdoors is complicated by the fact that in most urban locations, the nitrogen oxides that yield NO_2 are emitted primarily by motor vehicles, making it a strong indicator of vehicle emissions (including other unmeasured pollutants emitted by these sources). NO_2 (and other nitrogen oxides) is also a precursor for a number of harmful secondary air pollutants, including nitric acid, the nitrate part of secondary inorganic aerosols and photo oxidants (including ozone). The situation is also complicated by the fact that photochemical reactions take some time (depending on the composition of the atmosphere and meteorological parameters) and air can travel some distance before secondary pollutants are generated.

- **STATE-WISE NO_2 ANALYSIS:**

```
#state-wise NO2 analysis

NO2 = aggregate (mydata $no2, list (state = mydata $state), mean, na.rm = TRUE)
NO2 = NO2    [order (-NO2 $x, decreasing = FALSE), ]
NO2 = na.omit (NO2)
NO2
```

```
> #state-wise NO2 analysis
>
> NO2 = aggregate (mydata $no2, list (state = mydata $state), mean, na.rm = TRUE)
> NO2 = NO2  [order (-NO2 $x, decreasing = FALSE), ]
> NO2 = na.omit (NO2)
> NO2
                      state         x
37              West Bengal 59.075731
10                    Delhi 53.489147
16                Jharkhand 43.366341
5                     Bihar 36.575525
21              Maharashtra 32.115370
29                Rajasthan 30.441008
28                   Punjab 28.085846
34            Uttar Pradesh 27.610095
36               Uttaranchal 27.163019
35              Uttarakhand 26.938090
30                   Sikkim 26.800000
7              Chhattisgarh 24.815961
12                  Gujarat 24.065631
32                Telangana 23.864005
13                  Haryana 23.428311
17                Karnataka 22.702837
2            Andhra Pradesh 21.704451
31               Tamil Nadu 21.601202
22                  Manipur 20.173684
20           Madhya Pradesh 18.639596
6                Chandigarh 18.619404
8      Dadra & Nagar Haveli 18.293959
26                   Odisha 16.899568
9               Daman & Diu 16.168926
27               Puducherry 15.279496
4                     Assam 14.793691
18                   Kerala 14.421889
14         Himachal Pradesh 13.658688
11                      Goa 12.506337
15          Jammu & Kashmir 12.213181
23                Meghalaya 10.659706
25                 Nagaland  8.947265
24                  Mizoram  6.682171
3         Arunachal Pradesh  5.469697
>
```

- **TOP 10 NO_2 EMITTING STATES:**

```
#top 10 NO2 emitting states
```

```
top10 = head (NO2, 10)
top10
pct = round (top10 $x / sum (top10 $x) * 100)
top10pct = paste (top10 $state, pct)
top10pct = paste (top10pct, "%", sep="")
pie3D (top10 $x, labels = top10pct, explode = 0.1, col = rainbow (length
(top10pct)), main="Top 10 NO2 emitting states")
```

```
> #top 10 NO2 emitting states
>
> top10 = head (NO2, 10)
> top10
             state        x
37    West Bengal  59.07573
10          Delhi  53.48915
16       Jharkhand  43.36634
5            Bihar  36.57553
21     Maharashtra  32.11537
29       Rajasthan  30.44101
28          Punjab  28.08585
34   Uttar Pradesh  27.61010
36      Uttaranchal  27.16302
35      Uttarakhand  26.93809
> pct = round (top10 $x / sum (top10 $x) * 100)
> top10pct = paste (top10 $state, pct)
> top10pct = paste (top10pct, "%", sep="")
> pie3D (top10 $x, labels = top10pct, explode = 0.1, col = rainbow (length (top10pct)), main="Top 10 NO2 emitting states")
>
```

Top 10 NO2 emitting states
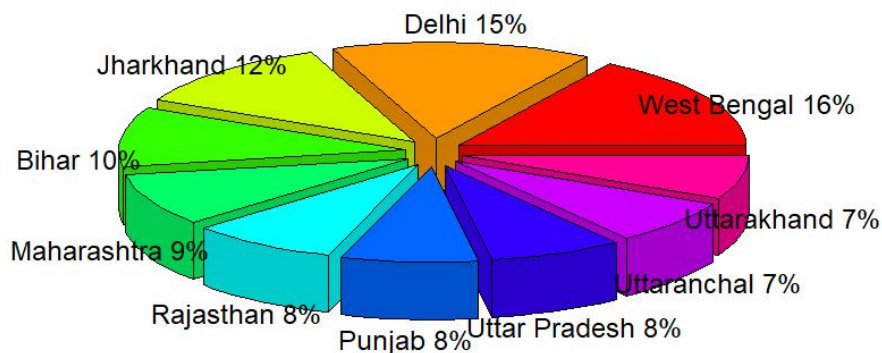
- **BOTTOM 10 NO₂ EMITTING STATES:**

```
#bottom 10 NO2 emitting states

bot10 = tail (NO2, 10)
bot10
pct = round (bot10 $x / sum (bot10 $x) * 100)
bot10pct = paste (bot10 $state, pct)
bot10pct = paste (bot10pct, "%", sep="")
pie3D (bot10 $x, labels = bot10pct, explode = 0.1, col = rainbow (length (bot10pct)),
main="Bottom 10 NO2 emitting states")
```

```
> #bottom 10 NO2 emitting states
>
> bot10 = tail (NO2, 10)
> bot10
            state        x
27      Puducherry 15.279496
4           Assam 14.793691
18          Kerala 14.421889
14 Himachal Pradesh 13.658688
11            Goa 12.506337
15 Jammu & Kashmir 12.213181
23      Meghalaya 10.659706
25        Nagaland  8.947265
24         Mizoram  6.682171
3  Arunachal Pradesh  5.469697
> pct = round (bot10 $x / sum (bot10 $x) * 100)
> bot10pct = paste (bot10 $state, pct)
> bot10pct = paste (bot10pct, "%", sep="")
> pie3D (bot10 $x, labels = bot10pct, explode = 0.1, col = rainbow (length (bot10pct)), main="Bottom 10 NO2 emitting states")
> |
```

Bottom 10 NO2 emitting states
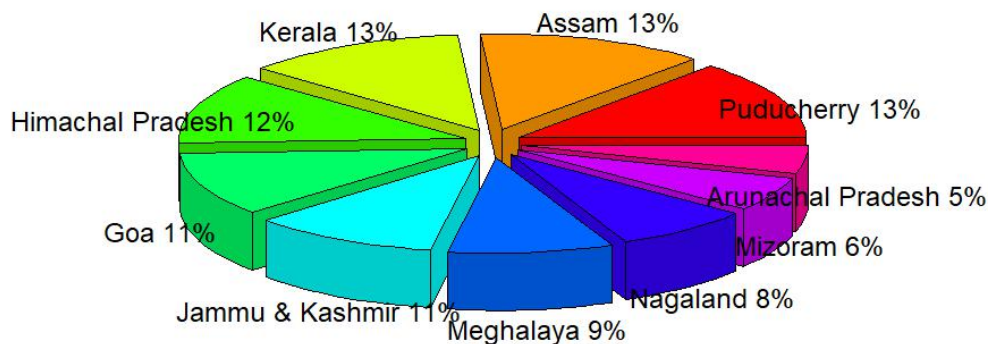
- **HOW DOES NITROGEN DIOXIDE AFFECT HUMAN HEALTH?**

The main effect of breathing in raised levels of nitrogen dioxide is the increased likelihood of respiratory problems. Nitrogen dioxide inflames the lining of the lungs, and it can reduce immunity to lung infections. This can cause problems such as wheezing, coughing, colds, flu and bronchitis. Increased levels of nitrogen dioxide can have significant impacts on people with asthma because it can cause more frequent and more intense attacks. Children with asthma and older people with heart disease are most at risk.

- **WHAT IS BEING DONE TO MANAGE NITROGEN DIOXIDE?**

  ❖ Implementing national fuel quality standards.

  ❖ Supporting the implementation of tighter vehicle emission standards.

  ❖ Developing a National Environment Protection Measure for diesel, to improve the in-service performance of diesel vehicles.

  ❖ Developing and promoting alternative fuels.

  ❖ Developing pollution forecasting systems for major cities.

  ❖ Promoting bicycle use for short journeys through *CycleConnect.*

❖ Working with the States and Territories through programs such as *TravelSmart* to influence passengers transport choices.

RESPIRABLE SUSPENDED PARTICULATE MATTER (RSPM):

RSPM is that fraction of TSPM which is readily inhaled by humans through their respiratory system and in general, considered as particulate matter with their diameter (aerodynamic) less than 2.5 micrometers. Larger particles would be filtered in the nasal duct.

● **STATE-WISE ANALYSIS OF RSPM CONCENTARTION:**

```
#state-wise analysis of rspm concentration

rspm = aggregate (mydata $rspm, list (state = mydata $state), mean, na.rm = TRUE)
rspm = rspm    [order (-rspm $x, decreasing = FALSE), ]
rspm = na.omit (rspm)
rspm
```

```
> #state-wise analysis of rspm concentration
>
> rspm = aggregate (mydata $rspm, list (state = mydata $state), mean, na.rm = TRUE)
> rspm = rspm  [order (-rspm $x, decreasing = FALSE), ]
> rspm = na.omit (rspm)
> rspm
                     state        x
10                   Delhi 196.63977
34           Uttar Pradesh 176.95231
28                  Punjab 173.49371
16               Jharkhand 168.51776
13                 Haryana 149.86054
35              Uttarakhand 148.97891
29               Rajasthan 142.01683
7             Chhattisgarh 126.47240
5                    Bihar 123.70518
36              Uttaranchal 121.69434
15         Jammu & Kashmir 117.44948
37             West Bengal 115.03991
20          Madhya Pradesh 114.71797
21             Maharashtra 101.47961
12                 Gujarat  98.24451
6               Chandigarh  96.58708
4                    Assam  93.72491
14        Himachal Pradesh  91.87020
32               Telangana  85.04301
26                  Odisha  83.61982
25                Nagaland  83.35703
17               Karnataka  79.37180
2           Andhra Pradesh  78.18282
3         Arunachal Pradesh 76.62921
8    Dadra & Nagar Haveli  76.53653
9             Daman & Diu   73.74943
22                 Manipur  69.81579
23               Meghalaya  68.98844
31              Tamil Nadu  66.58564
11                     Goa  61.21277
18                  Kerala  50.63606
27              Puducherry  43.41822
24                 Mizoram  42.71647
30                  Sikkim  32.00000
> |
```


● **TOP 10 RSPM CONCENTRATED STATES:**

```
#top 10 RSPM concentrated states
```

```
top10 = head (rspm, 10)
top10
pct = round (top10 $x / sum (top10 $x) * 100)
top10pct = paste (top10 $state, pct)
top10pct = paste (top10pct, "%", sep="")
pie3D (top10 $x, labels = top10pct, explode = 0.1, col = rainbow (length (top10pct)),
main="Top 10 rspm concentrated states")
```

```
> #top 10 RSPM concentrated states
>
> top10 = head (rspm, 10)
> top10
              state        x
10            Delhi 196.6398
34    Uttar Pradesh 176.9523
28           Punjab 173.4937
16        Jharkhand 168.5178
13          Haryana 149.8605
35       Uttarakhand 148.9789
29        Rajasthan 142.0168
7       Chhattisgarh 126.4724
5             Bihar 123.7052
36       Uttaranchal 121.6943
> pct = round (top10 $x / sum (top10 $x) * 100)
> top10pct = paste (top10 $state, pct)
> top10pct = paste (top10pct, "%", sep="")
> pie3D (top10 $x, labels = top10pct, explode = 0.1, col = rainbow (length (top10pct)), main="Top 10 rspm concentrated states")
>
```


Top 10 rspm concentrated states
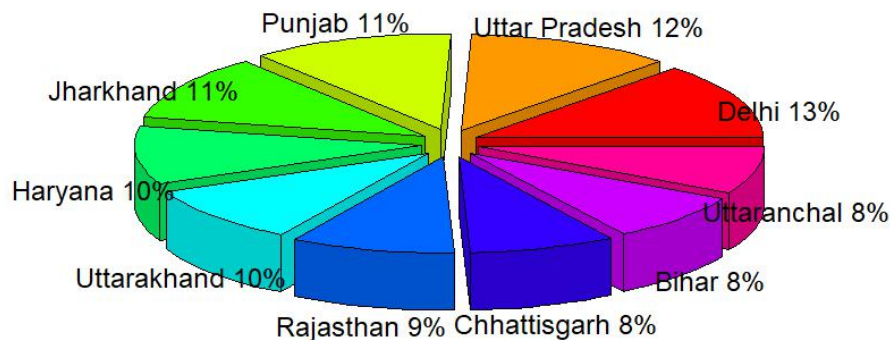
• **BOTTOM 10 RSPM CONCENTRATED STATES:**

#bottom 10 RSPM concentrated states

bot10 = tail (rspm, 10)
bot10
pct = round (bot10 $x / sum (bot10 $x) * 100)
bot10pct = paste (bot10 $state, pct)
bot10pct = paste (bot10pct, "%", sep="")
pie3D (bot10 $x, labels = bot10pct, explode = 0.1, col = rainbow (length (bot10pct)),
main="Bottom 10 rspm concentrated states")

```
> #bottom 10 RSPM concentrated states
>
> bot10 = tail (rspm, 10)
> bot10
                 state        x
8   Dadra & Nagar Haveli 76.53653
9           Daman & Diu 73.74943
22               Manipur 69.81579
23             Meghalaya 68.98844
31            Tamil Nadu 66.58564
11                   Goa 61.21277
18                Kerala 50.63606
27            Puducherry 43.41822
24               Mizoram 42.71647
30                Sikkim 32.00000
> pct = round (bot10 $x / sum (bot10 $x) * 100)
> bot10pct = paste (bot10 $state, pct)
> bot10pct = paste (bot10pct, "%", sep="")
> pie3D (bot10 $x, labels = bot10pct, explode = 0.1, col = rainbow (length (bot10pct)), main="Bottom 10 rspm concentrated states")
>
```

Bottom 10 rspm concentrated states
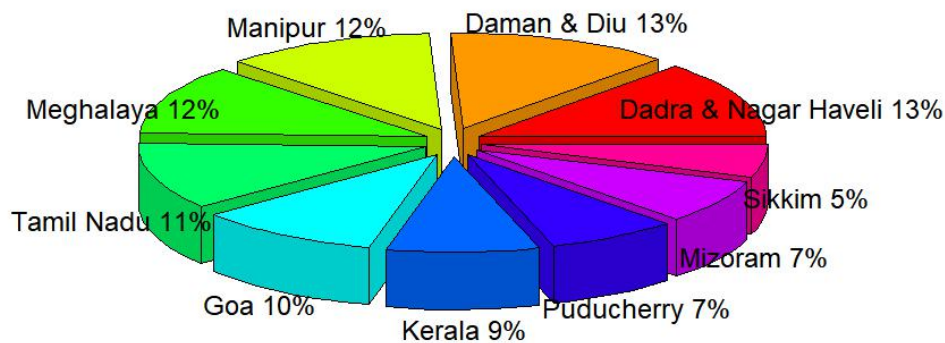
EFFECT OF RSPM ON HUMAN HEALTH:

The effects of RSPM are far reaching on human health and principally affect the body's respiratory and cardiovascular system, which to a large extent depends upon the degree of exposure and the individual's health status and genetics. Around 99% of the inhaled large and medium sized particles by the human body are generally filtered out through nostrils. The rest of the particles may either pass through the windpipe or lungs where some inhalable particulates cling to protective mucous and are removed. The remaining smallest particles, popularly known as respirable particulates may tend to be deposited in the tiny air sacs in the lungs. In the lungs, particulates leads to slow down the exchange of oxygen with carbon dioxide in the blood, causing acute shortness of breath. The heart gets affected as it has to function harder to compensate for oxygen loss. Usually, human beings who are more sensitive are likely to have respiratory diseases like asthma, bronchitis, emphysema or heart problems, etc. Particles themselves may be poisonous if inhaled, damaging remote organs like the kidneys or liver. Swallowed mucous that is laden with hazardous particulate matter may damage the stomach.

SUSPENDED PARTICULATE MATTER (SPM):

Suspended Particulate Matter (SPM) are microscopic solid or liquid matter suspended in Earth's atmosphere. The term aerosol commonly refers to the particulate/air mixture, as opposed to the particulate matter alone. Sources of particulate matter can be natural or anthropogenic. They have impacts on climate and precipitation that adversely affect human health.

- **STATE WISE ANALYSIS OF SPM CONCENTRATION:**

```
#state-wise analysis of spm concentration

spm = aggregate (mydata $spm, list (state = mydata $state), mean, na.rm = TRUE)
spm = spm [order (-spm $x, decreasing = FALSE), ]
spm = na.omit (spm)
spm
```

```
> #state-wise analysis of spm concentration
>
> spm = aggregate (mydata $spm, list (state = mydata $state), mean, na.rm = TRUE)
> spm = spm [order (-spm $x, decreasing = FALSE), ]
> spm = na.omit (spm)
> spm
                       state          x
10                     Delhi  399.40209
34             Uttar Pradesh  372.66369
35                Uttarakhand  306.75892
29                  Rajasthan  300.73540
36                Uttaranchal  283.33571
16                  Jharkhand  277.94075
5                       Bihar  276.91742
13                    Haryana  268.26480
28                     Punjab  244.91893
37               West Bengal  233.50652
7                Chhattisgarh  231.29097
20             Madhya Pradesh  210.06755
14           Himachal Pradesh  208.57563
6                  Chandigarh  206.05615
21                Maharashtra  205.25582
2              Andhra Pradesh  200.26038
15            Jammu & Kashmir  196.22105
12                    Gujarat  191.56793
8        Dadra & Nagar Haveli  170.54502
17                  Karnataka  168.00174
26                     Odisha  167.60984
22                    Manipur  158.65789
4                       Assam  153.35539
9                Daman & Diu  145.68142
25                   Nagaland  133.31145
31                 Tamil Nadu  126.72906
27                 Puducherry   95.59819
24                    Mizoram   87.83333
18                     Kerala   84.41979
23                  Meghalaya   78.00244
30                     Sikkim   75.00000
11                        Goa   67.25419
>
```

- **TOP 10 SPM CONCENTRATED STATES:**

```
#top 10 spm concentrated states

top10 = head (spm, 10)
top10
pct = round (top10 $x / sum (top10 $x) * 100)
top10pct = paste (top10 $state, pct)
top10pct = paste (top10pct, "%", sep="")
pie3D (top10 $x, labels = top10pct, explode = 0.1, col = rainbow (length (top10pct)),
main="Top 10 spm concentrated states")
```

```
> #top 10 spm concentrated states
>
> top10 = head (spm, 10)
> top10
                state          x
10              Delhi   399.4021
34      Uttar Pradesh   372.6637
35        Uttarakhand   306.7589
29          Rajasthan   300.7354
36        Uttaranchal   283.3357
16          Jharkhand   277.9407
5                Bihar  276.9174
13            Haryana   268.2648
28             Punjab   244.9189
37        West Bengal   233.5065
> pct = round (top10 $x / sum (top10 $x) * 100)
> top10pct = paste (top10 $state, pct)
> top10pct = paste (top10pct, "%", sep="")
> pie3D (top10 $x, labels = top10pct, explode = 0.1, col = rainbow (length (top10pct)), main="Top 10 spm concentrated states")
>
```

Top 10 spm concentrated states
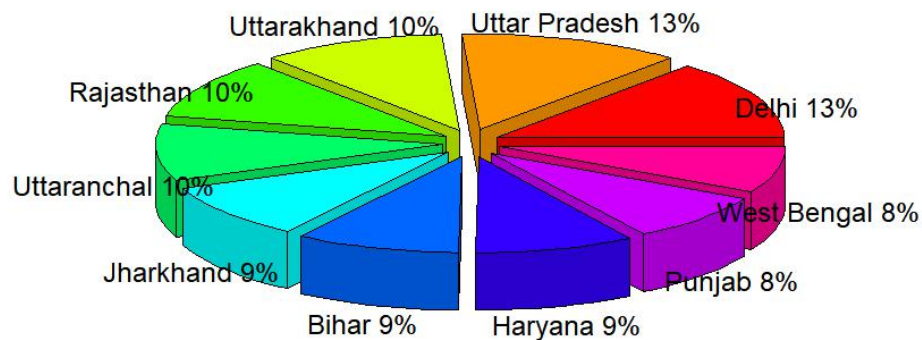
- ## BOTTOM 10 SPM CONCENTRATED STATES:

#bottom 10 spm concentrated states

bot10 = tail (spm, 10)
bot10
pct = round (bot10 $x / sum (bot10 $x) * 100)
bot10pct = paste (bot10 $state, pct)
bot10pct = paste (bot10pct, "%", sep="")
pie3D (bot10 $x, labels = bot10pct, explode = 0.1, col = rainbow (length (bot10pct)), main="Bottom 10 spm concentrated states")

```
> #bottom 10 spm concentrated states
>
> bot10 = tail (spm, 10)
> bot10
                state          x
4                Assam  153.35539
9       Daman & Diu     145.68142
25           Nagaland   133.31145
31         Tamil Nadu   126.72906
27         Puducherry    95.59819
24             Mizoram    87.83333
18              Kerala    84.41979
23          Meghalaya    78.00244
30              Sikkim    75.00000
11                 Goa    67.25419
> pct = round (bot10 $x / sum (bot10 $x) * 100)
> bot10pct = paste (bot10 $state, pct)
> bot10pct = paste (bot10pct, "%", sep="")
> pie3D (bot10 $x, labels = bot10pct, explode = 0.1, col = rainbow (length (bot10pct)), main="Bottom 10 spm concentrated states")
>
```

Bottom 10 spm concentrated states