Journal of Civil Engineering and Environmental Technology
p-ISSN: 2349-8404; e-ISSN: 2349-879X; Volume 5, Issue 2; January-March, 2018, pp. 54-59

http://www.krishisanskriti.org/Publication.html

Status of Plastic Waste in India: A Review

Athar Hussain[1], Ayushman Bhattacharya[*2] and Arfat Ahmed[3]

[1,2]Ch. Brahm Prakash Govt. Engg College, New Delhi-73
[3]Chandigarh College of Engg &Technology
E-mail: [1]athariitr@gmail.com, [2]ayushmanbhattacharya76@gmail.com, [3]er_arfat@yahoo.com

Abstract—*The global plastic production increased over years due to the vast applications of plastics in many sectors. More than 50% of the plastic waste generated in the country is recycled and used in the manufacture of various plastic products. The remaining half is disposed of at landfill sites or simply burned in incinerators. Dioxin is a highly carcinogenic and toxic by-product of the manufacturing process and burning of plastics. Burning of plastics, especially PVC, releases this dioxin and also furan into the atmosphere. The waste plastics are subjected to depolymerisation, pyrolysis, catalytic cracking and fractional distillation to obtain different value added fuels such as petrol, kerosene, and diesel, lube oil, furnace oil traction and coke. Thus, the process of converting plastics to fuel has now turned the problems into an opportunity to make wealth from waste. The present paper focuses on the current status of plastic waste management in India and industries working under the extended producer responsibility. Therefore in present paper an attempt has been to review the current practices prevalent in India to deal with this plastic waste and problems associated with it.*

Keywords*: Plastic waste, Biodegradable plastics, Pyrolysis, Extended producers responsibility.*

1. INTRODUCTION

Plastic, with its exclusive qualities is now a serious worldwide environmental and health concern, essentially due to its non-biodegradable nature. More than 50% of the plastic waste generated in the country is recycled and used in the manufacture of various plastic products. Dioxin is a highly carcinogenic and toxic by-product of the manufacturing process of plastics. Burning of plastics, especially PVC, releases this dioxin and also furan into the atmosphere. Plastics are so versatile in use that their impact on the environment is extremely wide ranging. Careless disposal of plastic bags chokes drains, blocks the porosity of the soil and causes problems for groundwater recharge. Dioxin is the common name for a class of 75 chemicals. It is a toxic waste product formed when waste containing chlorine is burned or when products containing chlorine are manufactured. Dioxins are among the most potent synthetic chemicals ever tested, causing cancer and harming our immune and reproductive systems even at very low concentrations (Pavani and Rajeswari, 2014). Plastic is a relatively cheap, durable, and versatile material. These properties have led to its use in the creation of thousands of products, which have brought benefits to society in terms of economic activity, jobs, and quality of life. However, plastic waste can also impose negative externalities such as greenhouse gas emissions or ecological damage. It is usually non-biodegradable and, therefore, can remain as waste in the environment for a very long time; it may pose risks to human health and the environment; in some cases, it can be difficult to reuse and/or recycle (Toxic link, 2011). Plastic disturbs the soil microbial activity. Plastic bags can also contaminate foodstuffs due to leaching of toxic dyes and transfer of pathogens. Furthermore, flame-retardant materials such as polyvinyl chloride (PVC) are known to cause corrosion in incinerators during combustion due to their constituent halogen substances; these materials also produce halogen compounds such as dioxins.

Moreover, CO_2 discharged from the combustion of polymers causes environmental problems such as global warming and acid rain. In addition, suspected endocrine disrupting chemicals, typically Bisphenol A, can dissolve out of polycarbonate (Fatima, 2014). As per the government report more than 15,000 tonnes of plastic waste are generated in India everyday, of which 6,000 tonnes remain uncollected and littered. As per a report of a Task Force constituted by erstwhile Planning Commission in 2014 indicates that 62 million tonnes of municipal solid waste is generated in India annually in urban areas. However, as per the CPCB report of 2014-15, 51.4 million tonnes of solid waste were generated in the country, of which 91 per cent was collected, and 27 per cent was treated and remaining 73 per cent disposed of at dump sites. Central Pollution Control Board has estimated that the generation of 15,342 tonnes of plastic waste in the country, out of which, 9,205 tonnes were reported to be recycled and leaving 6,137 tonnes uncollected and littered (Business standard,2016). The growth of the Indian plastic industry has been phenomenal equal to17% is higher than for the plastic industry elsewhere in the world (Panda et tal, 2010). Petrochemical products permeate the entire spectrum of daily use items and cover almost every sphere of life like clothing, housing, construction, furniture, automobiles, household items, agriculture, horticulture, irrigation, packaging, medical appliances, electronics and electrical etc. These industries hence drive the demand growth of petrochemicals. Current low per capita consumption level of plastic products as compared to developed countries per capita consumption as shown in Fig 1 suggests that India offers a huge opportunity over long term (FICCI-2014).

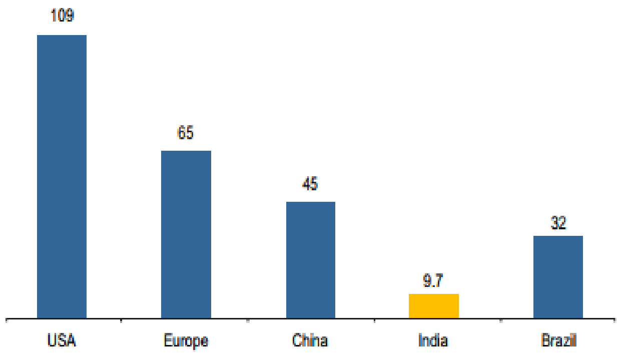

Fig. 1: Per capita plastic products consumption (Kg/person) (Source: A report on plastics industry, FICCI-2014)

To manufacture finished products, polymers are processed through various types of techniques namely extrusion, injection moulding, blow moulding and roto moulding. Various products manufactured through these processes are highlighted in the Table 1. In India, extrusion-based methods account for 75% of the total amount of plastics processed; this is very similar to the situation in Western Europe.

Over 27% of all extruders in the plastics processing industry are operated for the manufacture of blown films. Injection moulding is the second largest processing technique (19%) and is mainly used for the manufacture of household products, packaging, and in the electrical sector. Blow moulding and rotational moulding constitute a small share; these processes serve to manufacture products like bottles, drums, tanks etc. (Muth et tal, 2006).

Table 1: Manufacturing processes of plastics

Extrusion	Films and Sheets, Fibre and Filaments Pipe, Conduits and profiles, miscellaneous applications
Injection Moulding	Industrial Injection Moulding , Household Injection and Thermo-ware/ Moulded luggage
Blow Moulding	Bottles, Containers, Toys and Housewares
Roto Moulding	Large circular tanks such as water tanks

Source: A report on plastics industry - ficci

However plastics can be categorized as Recyclable Plastics (Thermoplastics) like PET, HDPE, LDPE, PP, PVC, PS etc. and Non-Recyclable Plastic (Thermoset & others) like Multilayer & Laminated plastics, PUF, Bakelite, Polycarbonate, Melamine, Nylon etc.

Technologies for plastics separation are Triboelectric separation, Froth flotation methods, Speed accelerators, Solvent-based, Hyperspectral imaging, Ultrasound technology, Laser-induced breakdown spectroscopy, X-ray fluorescence and infrared spectroscopy(Rahimi and Garcí, 2017). A triboelectric separator sorts materials on the basis of a surface charge transfer phenomenon. When materials are rubbed against each other, one material becomes positively charged, and the other becomes negatively charged or remains neutral.

Particles are mixed and contact one another in a rotating drum to allow charging. Materials with a particle size of approximately 2–4 mm is having the highest in both purity and recovery in the triboelectric process. Plastic waste can also be sorted by a speed accelerator technique, developed by Result Technology (Switzerland). This technique uses a high-speed accelerator to delaminate shredded waste, and the delaminated material is separated by air classification, sieves, and electrostatics. Using X-ray fluorescent (XRF) spectroscopy, different types of flame-retardants (FRs) can be identified. No matter how efficient the recycling scheme is, sorting is the most important step in the recycling loop. (Salem et tal, 2009).

2. ENVIRONMENTAL IMPACTS

The carbon footprint of plastic (Low density polythylene or Polyethylene terepthalate, polyethylene) is about 6 kg CO_2 per kg of plastic. The production of 1 kg of polyethylene (PET or LDPE), requires the equivalent of 2 kg of oil for energy and raw material .Polyethylene (PE) is the most commonly used plastic for plastic bags. Burning 1 kg of oil creates about 3 kg of carbon dioxide. In other words: Per kg of plastic, about 6 kg carbon dioxide is created during production and incineration (Times for Change, 2018). The combustion of plastics as presented in Table2 infers that several chemical compounds cause a serious risk to health and the environmental elements, among which, especially, the incineration of PVC poses the greatest threats. The use of poly (vinyl chloride) is highly restricted or banned in many countries of the European Union. During the incineration of PVC, up to 2 milligrams per gram of phosgene is generated, which is one of the most dangerous gases, and a serious risk to health. Phosgene ($COCl_2$) is an organic compound, colourless, its odour is reminiscent of musty hay, an asphyxiant gas it is a strong poison. It was used as a chemical weapon during World War I. It hydrolyses easily and is freely soluble in non-polar solvents. This also reacts with the condensing vapour during combustion, whereby hydrogen chloride is formed, which is also a toxic compound. The equation 1 presents the chemical reaction (NAGY and KUTI, 2016):

$$COCl_2 + H_2O \longrightarrow CO_2 + 2HCl \quad \text{Eq.1}$$

In terms of quantities, it can be said that every five grams of burned PVC derivatives pollute a cubic meter of air to such an extent that it will surely damage our health. The compounds generated by the incineration of PVC are acetone, toluene, xylene, acetaldehyde, benzaldehyde, phosgene etc.

Table 2: Combustion characteristics of plastics used in households

Name of Substance	Ignition temperature (^oC)	Heat of combustion (MJ/kg)
Polyethylene(PE)	350	46.3
Polyethylene terephthalate (PET)	500	22.7
Polystyrene(P5)	470	41.6
Polypropylene(PP)	410	46.6
Polyamide(PA)	500	31.4
Poly(vinyl chloride)(PVC)	760	19.26

Source:(NAGY and KUTI,2016)

Need of Biodegradable Plastics- Although traditional plastics can be reused or recycled, it take many decades and even more than two hundred years to decompose, leading to serious environmental problems. The solution for this problem is to produce oxo-biodegradable plastics (oxo-bio) by using the degradable to water (d2w) additive during the standard production process of plastics. The impact of the additive is therefore negligible and there is no special training required for workers. One of the common constituents of biodegradable plastics is polyhydroxyalkanonate (Pavani and Rajeswari, 2014).

3. PLASTIC WASTE MANAGEMENT: INDIAN SCENARIO

An attempt has been made to summarize the CPCB study on assessment and quantification of plastics waste generation in MSW in 60 major cities of India suggests that out of total plastics Waste, thermoplastics content is about 94% (Recyclable) and rest 6% belong to family of others including thermoset plastics (Non-Recyclable). The data mentioned in Table 3 indicates that the majority of the plastics waste (PW) obtained about 66% generated by HDPE/LPDE materials which is of mixed plastic wastes like Polybags, Multilayer pouches used for packing food items, Ghutkas etc. The households are the biggest source of plastics waste. The mechanical recycling requires extensive sorting is necessary to separate the packaging waste and the isolation of pure plastics was found to be too difficult.

Table 3: The consolidated details of classification of different constituents of plastics

S. No	Description	Total percentage obtained
1	PET	8.66
2	HDPE/LDPE	66.91
3	PVC	4.14
4	PP	9.9
5	PS	4.77
6	Others	6.43

(*Source*: CPCB, 2015)

The containers, films and other oversized items which consist of Polyethylene, Polypropylene and Polystyrene can undergo mechanical recycling. But the mixed plastics, any blended material or other multilayer films should be prepared for chemical or feedstock recycling. In the chemical recycling process, contamination and heterogeneity are not a problem. The multilayer components which consists of 2-3 layers of different plastics, will find difficult on the mechanical recycling. Hence the monomer recovery makes logistics and economic sense for the multilayer pouches which are littered in more quantity and keep piling up on garbage leads unhygienic condition. It is also observed that these multilayer/ Metalized pouched are not lifted by the rag pickers, because collecting them is not profitable and non-recyclable hence thrown/dumped in the dumpsite.

4. MANAGEMENT OF PLASTIC WASTE IN INDIA

House-to-house collection is system is adapted in few cities. In those cities that use house-to-house collection the waste that are collected from houses, offices, small shops and small markets. Here people are required to deposit their wastes in communal containers/ community bins (stationary or haul types), from which it is collected by municipal crews, handcarts and tricycles are used for waste collection from individual houses at a specific time in the morning, when residents deposit the stored waste into the handcarts. The waste in the handcarts is either transferred to community bins or directly transferred to vehicles going to the disposal site.Transportation of waste from collection point to disposal sites is carried out by using different types of vehicles depending on the distances to be covered by them. Larger vehicles carry the waste from the collection points to the disposal sites. Comparatively small vehicles discharge waste at transfer stations where the wastes are loaded into larger vehicles for transportation to the disposal sites. In metro cities transfer stations located at different places to support intermediate transfer of waste from the surrounding areas up to the dumping grounds.

5. TREATMENT AND DISPOSAL

There is no processing of waste being done in most of the Indian cities. The entire waste, which is collected, is taken for dumping to the disposal site. At present there is no sanitary landfill site in most of the cities. The disposal is carried out following the method of crude dumping where the waste is neither spread nor covered. In some areas the garbage waste is recklessly burnt in open dump yards placed on the main highway road. Land filling of mixed waste like non-biodegradable, inert waste and other waste that are not suitable either for recycling or for biological processing is dumped together with recyclable material. Waste processing facilities are not available with proper capacity except few cities (CPCB, 2015).

5.1 Incineration

The characteristics of plastic waste incinerated is shown in Table4.In India, incineration is not a common practice, since the garbage tends to be low in calorific value and volumes are generally low for a central facility. The technology for incineration is not available domestically and import options are highly capital intensive. An incinerator plant was established in Delhi during the 1980s and was expected to generate power for the local grid. However, the operational experience was not satisfactory (Tapan Narayana, 2009). The combustible percentage is found to be near in both the plastic waste and the liquid fuel but percentage of moisture content and ash content is found to be higher in PVC plastic waste and HDPE plastics waste (Chun-Teh Li, 2001).

Table 4: Components of three plastic waste and liquid fuel (Source: Chun-Teh Li, 2001)

Component	PVC plastics	PP plastics	HDPE plastics	Liquid diesel
Combustible (%)	97.3	99.4	98.4	99.9
Moisture (%)	1.67	0.27	0.05	0.05
Ash (%)	1.08	0.37	1.51	0.04

6. OPTIONS FOR PLASTIC WASTE MANAGEMENT

Recycling of plastics through environmentally sound manner is carried in order to minimize the pollution during the process and as a result to enhance the efficiency of the process and conserve the energy. Plastics recycling technologies have been historically divided into four general types -primary, secondary, tertiary and quaternary. Primary recycling involves processing of a waste/scrap into a product with characteristics similar to those of original product. Secondary recycling involves processing of waste/scrap plastics into materials that have characteristics different from those of original plastics product. Tertiary recycling involves the production of basic chemicals and fuels from plastics waste/scrap as part of the municipal waste stream or as a segregated waste. Quaternary recycling retrieves the energy content of waste/scrap plastics by burning / incineration. This process is not in use in India.

7. UTILIZATION OF PLASTICS WASTE IN DIFFERENT FIELD

7.1 Road construction

The plastic waste (Bags, Cups, Thermocloe) made out of PE, PP, & PS are separated, cleaned and shredded into small pieces by passing through 4.35mm sieve. The aggregate (granite) is heated to 170 C in the mini hot mix plant and shredded plastic waste is added, it’s get softened and coated over the aggregate. Immediately the hot bitumen of 160 C is added and mixed well. As the polymer and the bitumen are in the molten state they get mixed and the blend is formed at the surface of the aggregate. The mixture is transferred to the road for laying.

7.2 Cement kilns

The recycling of plastics waste for recovery of energy is the use of plastics waste as an alternative to fusible fuel in Cement Kilns. Any material having calorific value of at least 2,500 kcals are accepted as an alternative fuel in cement kilns, provided it is available at a cost less than the normal fossil fuel: plastics waste, which have quite high calorific values, offer a viable alternative fuel. In fact, Cement Kilns can be utilized for burning of some hazardous waste and for recovering precious energy out of it for production of cement. (CPCB, 2015).

7.3 Conversion of plastic waste into liquid Refuse derived fuel , RDF (oil)

The pyrolysis by direct heating was adopted to produce the paraffin and crude oil from the plastic wastes in the 1990s. The small-scaled process is featured by facilitation, convenience and low equipment investment However, the temperature caused by pyrolysis is higher and all the reactive time is longer than the other methods. The octane number of gasoline gained is relatively low and the pour point of diesel oil is high. More paraffin is produced in the process of pyrolysis. Although this process is simple and convenient, the converting rate and yield is still lower. Since the total yield of fuel oil with pyrolysis is still lower and the quality of oil is not satisfied as gasoline and diesel oil, the upgrade by catalytic cracking for the crude products gained with pyrolysis can be used. Having improved the quality of finished oil, this process has been widely used in many factories. The system consists of the knapper, extrusion machine, pyrolysis reactor, catalytic cracking reactor, fractionating tower, heating and temperature controller, separator of oil and water, and oilcan. The catalyst for the process is prepared by using Faujasite zeolite(05 - 35 wt%), Pseudoboehmite alumina(10 - 40 wt%), Polyammonium silicate (01 - 10 wt%),Kaolin clay(15 - 60 wt%).(Source: Raja and Murali, 2011).

8. INDIAN CITIES SCENARIO OF PLASTICS WASTE GENERATION

In almost all the cities the MSW generated from different sources like door to door, community bin at the street corners and from markets are collected by the municipal trucks or by the firms under contract to the government and dumped in the open dump yard. The plastic waste generation in Indian cities as per the survey done by CPCB are summarized below in Table 5.Perusal of data as summarized in Table 5 indicates that the average waste generation of PET plastics is higher in Faridabad city. Similarly the average waste generation of HDPE/LDPE plastics is found to be higher in Faridabad. Also the average waste generation of polyvinyl chloride plastics is higher in Varanasi. The average waste generation of polypropylene and polystyrene plastics is found to be higher in Amritsar and Delhi.

8.1 Study of Delhi City: PW (Kg/Mt)

In Delhi, the quantity of plastic waste has been assessed as 10.14%, which comprises of 76% of HDPE/LDPE, 6% of Polypropylene and 10% of Polystyrene material. The total MSW generated in this city was with an average of 6800 MT/ Day. During the survey on different weekdays, the minimum plastic waste generation was observed to be 87.23 Kg/MT and maximum was 118.74Kg/MT. It has been observed no post-treatment operation for MSW is carried out in the city and 100% of MSW is dumped as land-filling. Approximately, 200-250 rag pickers were voluntarily collecting the valuable plastics waste that was generated throughout the day. Further the compost fertilizer plant having the capacity of about 500MT was established in the city, but currently the plant produces with an output of about only 200 MT. Delhi, being the capital city requires urgent attention for efforts to recycle the recyclable plastic waste such as PET, PE & PP & PVC etc. since the quantum of waste would increase further in future. With over 10% of Plastics Waste in MSW, waste management authorities/civic bodies should set-up Plastics Waste Management Cell (PWMC) exclusively to deal with plastics waste by adopting prevailing technologies (CPCB, 2015).

Also the data obtained for Patna city reveals that the total MSW generated was about 220 MT/Day.The plastic waste was observed as 57.25 Kg/MT, out of which the majority of plastics waste found as carry bags and packaging pouches which is of 65.15% made up of HDPE/LDPE material. The field study reveals that the minimum plastic waste generation 35.98 Kg/MT and maximum of 76.57Kg/MT (CPCB, 2015).

9. WORKING OF INDUSTRIES UNDER EXTENDED PRODUCERS RESPONSIBILITY

9.1 Dabur India Limited

On 3rd January 2018 India's largest Science-based Ayurveda major Dabur India Limited has decided to form a consortium with other responsible organizations to collect and help Multilayer Plastic (MLP) Waste Collection and sending for co-processing as RDF (Refuse-Derived Fuel) in cement kilns for a Pilot Project in Gujarat state covering 11 major cities. This is also part of Gujrat first mega Environment Protection initiative called 'EPR Connect: Towards a Sustainable Future". Under Gujarat 1st Extended Producers Responsibility (EPR) consortium, Dabur is part of processing the first batch of collected waste of MLPs for recycling from 11 cities (Ahmedabad, Sanand, Chattral, Changodar, Mehsana, Kadi, Kalol, Hathijan, Gandhinagar, Rakanpur and Santej) in Gujarat State. This joint initiative is being implemented by Nepra Resource Management Private Limited, a waste management company, based in Ahmedabad duly guided and supported by Gujrat Pollution Control Board (GPCB), and Gujrat URBAN Development Department (Dabur Media).

9.2 Colgate-Palmolive Company

The Colgate-Palmolive Company is an American multinational consumer products company focused on household, health care, and personal hygiene products. Personal care products giant Colgate-Palmolive has committed to making 100% of its packaging for three of four product categories completely recyclable by 2020. In addition, Colgate has committed to work towards developing a fully recyclable toothpaste tube or package, which would bring its fourth product category close to the same sustainability standard. The company also agreed to increase the average recycled content of its packaging to 50%. Increasing the recycled content of key materials such as polyethylene (PE), polyethylene terephthalate (PET), high-density polyethylene (HDPE), polypropylene (PP), and paper pulp (fiber) is crucial to improving the sustainability of consumer packaging. Colgate's commitments includes that by 2020 achieve 100 percent recyclable portfolio of Home, Pet, and Personal Care packaging - three out of four of its product categories. Develop a fully recyclable toothpaste tube or other packaging in the fourth category, Oral Care. Increase recycled content of packaging from 40 percent to 50 percent. Reduce or eliminate use of PVC in packaging.

9.3 Coca-Cola Company

Coca-Cola, or Coke, is a carbonated soft drink produced by The Coca-Cola Company. As a responsible corporate citizen, coca-cola welcomes the introduction of 'Extended Producer Responsibility" as part of the new Plastic Waste Management Rules, 2016.As a system, coca-cola have always been a proponent of circular thinking and are committed to improving the recycling rates of PET waste in India. In the waste guzzling metropolis of Gurugram, coca-cola has launched a source segregation programme – "Alag Karo – Har Din Teen Bin" in partnership with Saahas, Tetra Pak and GIZ. Through this initiative, they are taking the practice of segregating waste at source to households, schools and commercial establishments across Gurugram. Coca-Cola's bottling partners continue to work together with consumers, collection agencies and authorised recycling partners to ensure that PET waste is collected and recycled to the extent possible.

10. CONCLUSION

The ill effects of Climate Change have already begun to be felt. Toxic substances are released via burning from plastics, open combustion, incineration, posing a threat to the surrounding areas including vegetation and health of individuals. Proper development of policy with respect to chemical exposure caused by plastic must be set in place with encouraging research in this direction. A sustainable step towards tomorrow's cleaner and healthier environment is the need of the hour. For this reason Extended Producer Responsibility (EPR) concept is introduced for all producers. The concept of Extended Producer Responsibility (EPR) is that the responsibility of the producer of a product is extended beyond conventional sales to its post-consumer or end-of-life (EOL) stage. This means that the producer is responsible for collection of the used products or packaging material and ensure its safe recycling or disposal. In line with the principle of ‘extended producer’s responsibility’ the new rules for the first time in India has underlined the role of municipal bodies in not only ensuring safe collection and disposal of plastic wastes but also in engaging agencies or groups working in waste management including waste pickers.

Table 5: Plastic waste generation of Indian cities (Source: CPCB, 2015)

City	PET	HDPE/LDPE	PVC	PP	PS	OTHERS
Lucknow	2.4-9.1	19.42-48.16	1.42-4.77	4.14-13.93	0.66-6.31	55.59-62.93
Allahabad	3.5-6.0	8.6-40.40	1.06-6.78	7.78-17.43	0.0-1.72	4.06-23.90
Chandigarh	0.0-0.8	8.0-21.60	0.2-5.6	0.32-9.6	0.8-3.2	4.0-13.6
Delhi	1.41-5.98	85.24-67.34	0.85-2.63	2.92-9.33	6.42-17.22	1.0-9.29
Faridabad	8.73-15.36	74.4-104.54	0.32-1.65	1.14-7.79	4.3-6.99	0.0-1.0
Jammu	0.32-2.56	16.32-36.88	0.64-14.16	12.16-28	4.48-8.16	7.2-34.08
Srinagar	2.32-10.4	16.68-25.06	4.0-5.68	9.11-10.56	2.32-5.76	1.52-9.04
Shimla	1.56-3.68	13.64-26.64	0.56-1.32	8.04-20.24	1.0-3.36	4.2-13.44
Amritsar	0.0-03.04	15.04-28.32	0.0-2.26	9.92-23.2	1.44-5.6	0.0-15.52
Dehradun	5.10-10.35	36.21-43.15	2.57-7.41	6.14-9.61	1.56-4.34	2.17-5.33
Agra	8.74-10.33	42.68-45.0	5.97-8.22	6.74-10.16	0.18-1.24	7.67-11.01
Meerut	1.55-6.49	41.10-42.26	3.022-6.92	4.77-7.11	0.62-2.48	3.40-7.24
Varanasi	2.84-12.37	13.03-42.89	2.58-15.27	3.98-10.05	0.54-2.21	3.53-10.2
Kanpur	3.36-8.36	40.19-53.15	4.26-8.17	2.08-7.02	0.34-0.95	1.03-3.44
Patna	1.0-1.67	33.25-46.56	0.42-6.93	1.70-9.63	1.68-6.8	2.12-10.76
Ranchi	0.65-1.02	35.64-42.54	0.36-1.19	5.71-7.0	3.36-5.89	6.02-9.31

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