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Preparing Municipal Solid Waste Emission Inventory and Spatial Distribution of Prayagraj City Using GIS

Ashish Shankar Singh[1], Dr. A. K. Shukla[2]
[1]*M. Tech Environmental Engineering, Department of Civil Engineering, Institute of Engineering and Technology, Lucknow*
[2]*Professor Civil Engineering Department, Institute of Engineering and Technology, Lucknow*

Abstract: ***Pollutants in the air are emitted from a variety of sources in metropolitan areas, causing poor air quality. Using a Geographic Information System (GIS), this project attempts to assess municipal solid waste (MSW) burning emissions and prepare a spatial distribution grid for Prayagraj city. PM10, PM2.5, NOx, SO2, and CO emissions were computed using activity data and emission factors using a bottom-up approach. The result from this study shows that emissions for all 5 pollutants*** PM_{10}***,*** $PM_{2.5}$***,*** NO_x***,*** SO_2***, CO are 718, 488, 269, and 3771kg/day respectively, where CO is the highest emitted pollutant. The Prayagraj municipal area was divided into grids of 3 km*** ^{2} ***area. The spatial distribution plotted for Prayagraj city shows the hotspot grid areas for all 5 air pollutants emission. The hotspot grids for PM10 are P9, P10, P17, P29 and for*** $PM_{2.5}$***,*** NO_x***,*** SO_2***, are P9, P10, P17 and for CO are P9, P10, P14, P17, P29.***

Keywords: PM10, PM2.5, NOX, SO2, CO, Emission Inventory, Spatial distribution, Hotspot grids

I. INTRODUCTION

Air pollution is the main problem in the city which has adverse impacts on climatic change and human health. Prayagraj city. The emission inventory is a document that details the amount of air pollutants released over a given period of time as well as the location of the emission source. A powerful instrument used by environmental government agencies to observe and manage emission sources is an emission inventory.

The emission factors are the crucial parameters for evaluating emission inventory. The Municipal solid waste is one of the major problems in urban areas whose proper collection and disposal management plan is not being implemented on ground level in present scenario.

The reason for increase in MSW is growth in living style, socio-economic expansion, population increment, industrial growth and increase in per-capita demand of packed and man-made things. The uncollected solid waste is thrown in an unorganised way which can be seen at road side, colonies corners, bank of river, etc.

This improper disposal of uncollected solid waste causes serious spread of diseases, soil quality is also affected and burning of this waste also results in air pollution. In India this scenario becomes more critical in festival times as India is multicultural country. Prayagraj city is considered to be holiest pilgrimage centres of India situated at confluence of three rivers- Ganga, Yamuna, Sarswati, so the MSW issue becomes an important consideration for the city. Through this study Prayagraj city emission inventory through MSW source is evaluated and spatial distribution for 3km^2 grid area are digitised using ARC-GIS.

II. STUDY AREA

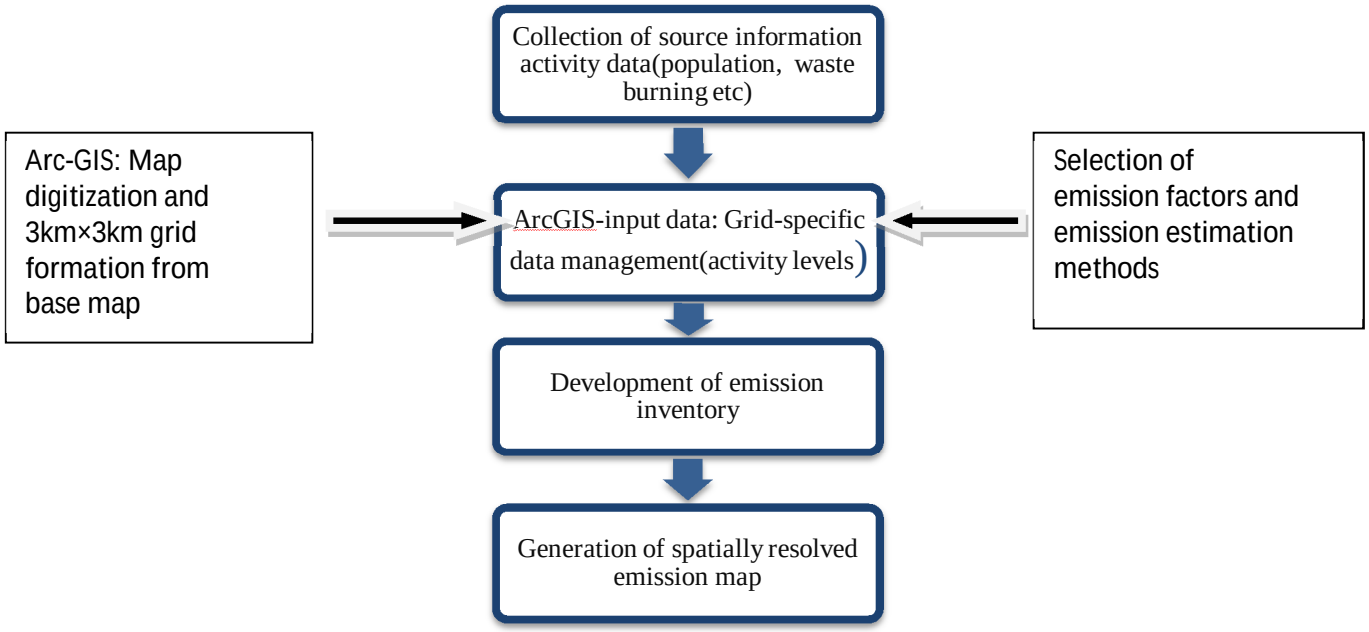
Prayaraj, Uttar Pradesh, India is in the Cities location category and is located at 25° 28' 22.9224" N and 81° 52' 42.0852" E in the India country. The city is 365 km2 in size and is located in southern Uttar Pradesh.With a population of 1.53 million people, Allahabad is the seventh most populated city in the state, thirteenth in Northern India, and thirty-sixth in India as of 2011. Allahabad is over 90 metres (295 feet) above sea level. Pratapgarh and Jaunpur are to the north, Mirzapur and Varanasi are to the east, and Banda and Fatehpur are to the west of Prayagraj city. City is separated from Madhya Pradesh by its southern border. Prayagraj city consists of 80 wards and the Prayagraj municipal boundary is divided into grids of 3km×3km area using ARC-GIS software for digitising spatial distribution map.

III. METHODOLOGY

A. *Data Collection*

The population data of Prayagraj city ward wise was taken from the government of India census data. This total population data for the year 1991, 2001, 2011 was also taken from government of India census data and the new population was forecasted for the year 2021 using incremental increase method. The uncollected MSW efficiency data was taken from planning commission report of India 2014 and the dry waste and wet waste was also taken from literatures. The emission factors for calculating MSW emission were taken from UPPCB report and USEPA AP42

B. *Steps Involved*



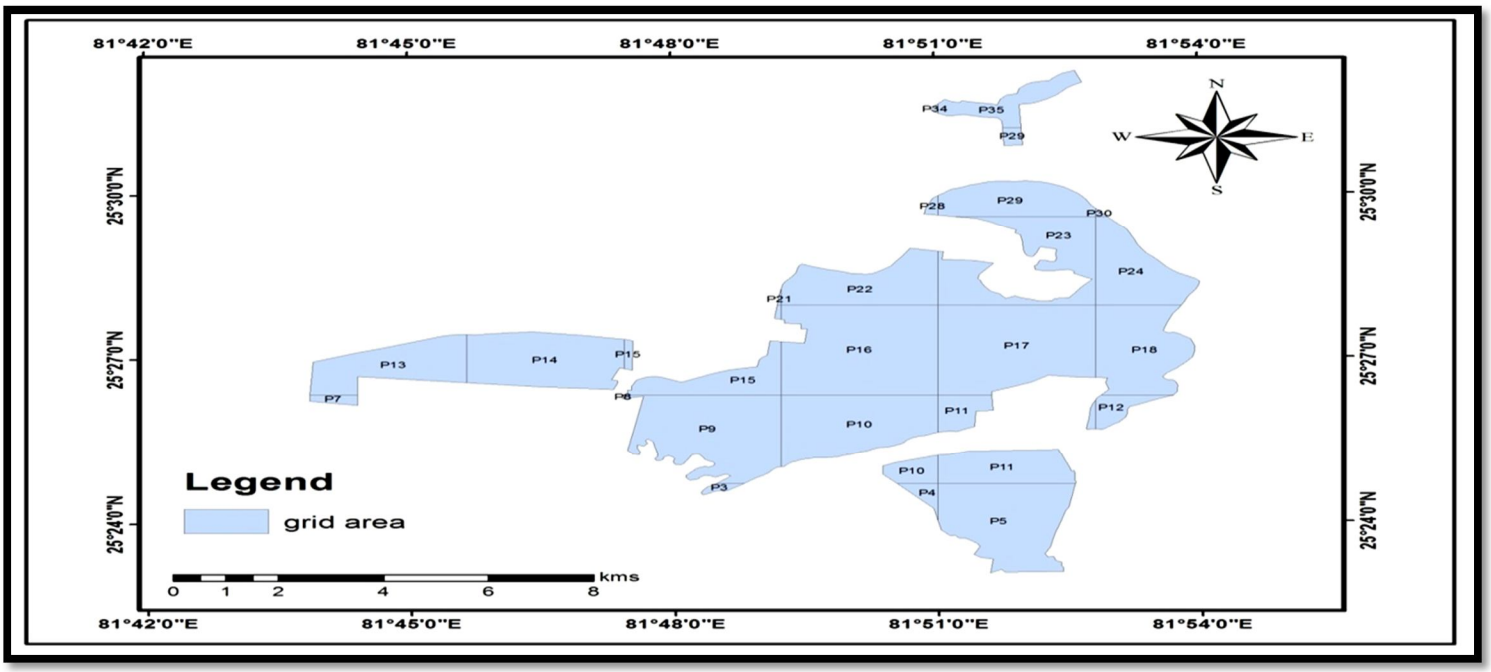


Fig:1- Digitised grid map using ARC-GIS

C. Formula and Emission Factors used

1) The emission factors table given below which are used calculating emission for pollutants PM_{10}, $PM_{2.5}$, NO_X, SO_2, CO

Pollutants	PM_{10}	$PM_{2.5}$	NO_X	SO_2	CO
Emission Factors	8	5.44	3	0.5	42

2) Emission (kg/day) = Activity data × E.F

3) Population forecasting using incremental increase method –

$$Pn = P + n.x + \left(\frac{n(n+1)}{2}\right).y$$

Pn= population after n^{th} decade
X=average increase
Y= incremental increase
P= actual population

D. Preparation of MSW Emission Inventory and Spatial Distribution

The emission of pollutants were calculated using the above formula ward wise of Prayagraj city. As the new population for the year 2021 was calculated using the incremental increase method considering the population from government of India census for the year 1991, 2001, 2011. The collection efficiency is 68%, so uncollected efficiency is 32 % of Prayagraj is taken into account, of which dry waste 20% is calculated and this dry waste is burned and emit air pollutants PM_{10}, $PM_{2.5}$, NO_X, SO_2, CO whose emissions are finally calculated. These pollutant values sheet is then join and related with the Prayagraj ward boundary and area is calculated in attribute table using ARC-GIS . Then grid boundary is opened which is intersected with ward boundary and values are distributed grid-wise. This change of ward emission to grid wise emission is done by calculating area and emission density for each pollutant in attribute table using field calculator. Then after the changed grid wise emission sheet is again join and related with grid boundary and finally emission values of each pollutant are spatially distributed and this spatial distribution is helpful in identifying most affected grids for each pollutant.

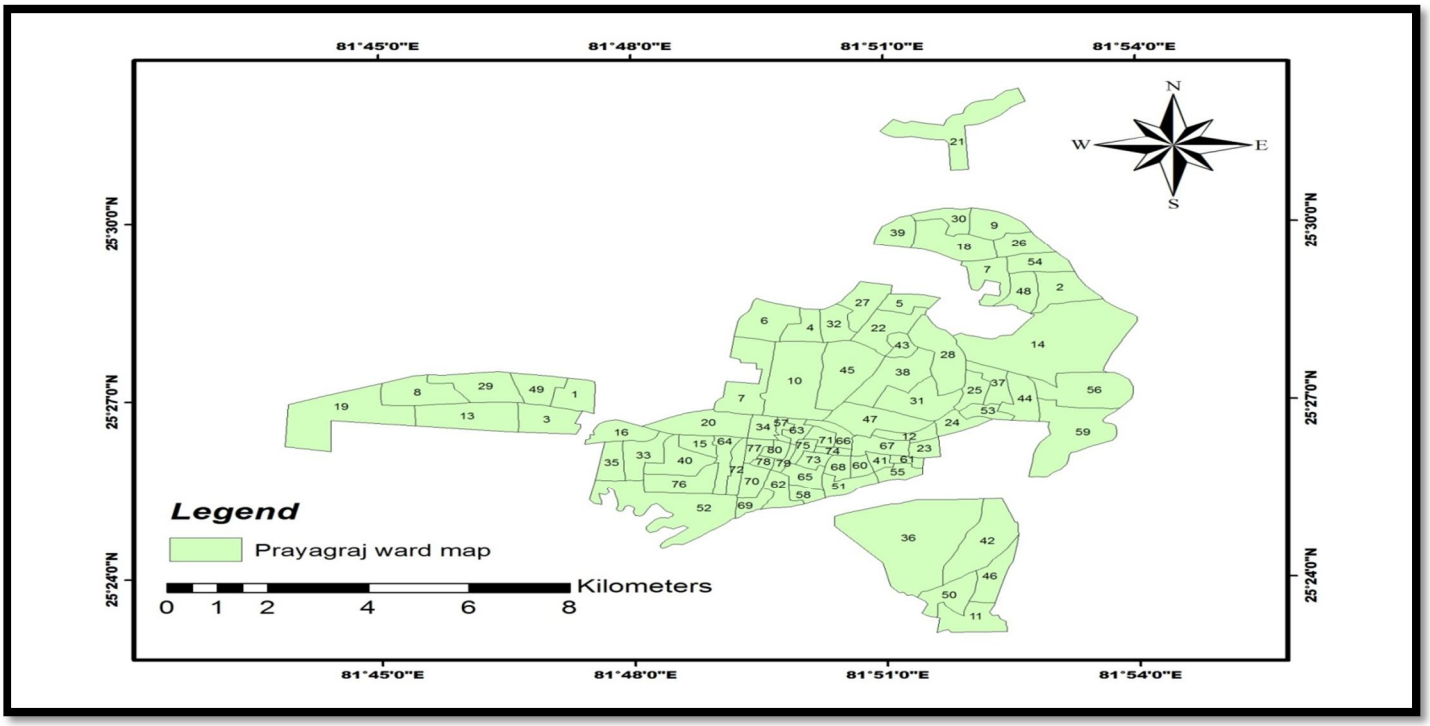


Fig:2- Digitised Prayagraj ward map using ARC-GIS

IV. RESULTS AND DISCUSSION

The collection efficiency of Prayagraj is 68% (taken from planning commission report 2014of India) and the dry waste which is burned found to be 20% of total uncollected solid waste which results in emission of air pollutants. As from Nagar Nigam report of Prayagraj city 540MT of solid waste is generated every day and so the average generation of solid waste per capita is 0.4kg/day taken from Uttar Pradesh Pollution Control Board (UPPCB) report.

Table: 1-Emissions Result

Ward No	Population	new population	Waste Generation (kg/day)	Waste collection	UNCOLLETCTED	DRY WASTE	PM10	PM2.5	SO2	NOx	CO
							8	5.44	0.5	3	42
		2017980.259									
Allahabad (M Corp.) WARD NO.-0001	17654	32022	12809	8710	4099	820	6.5580208	4.45945417	0.409876302	2.459258	34.42961
Allahabad (M Corp.) WARD NO.-0002	12125	21993	8797	5982	2815	985	7.8822366	5.35992087	0.492639786	2.955839	41.38174
Allahabad (M Corp.) WARD NO.-0003	15211	27590	11036	7505	3532	1236	9.8883877	6.72410362	0.61802423	3.708145	51.91404
Allahabad (M Corp.) WARD NO.-0004	14056	25495	10198	6935	3263	1142	9.1375437	6.21352972	0.571096481	3.426579	47.9721
Allahabad (M Corp.) WARD NO.-0005	15436	27998	11199	7616	3584	1254	10.034656	6.82356607	0.627165999	3.762996	52.68194
Allahabad (M Corp.) WARD NO.-0006	11532	20917	8367	5689	2677	937	7.4967383	5.09778206	0.468546145	2.811277	39.35788
Allahabad (M Corp.) WARD NO.-0007	6750	12243	4897	3330	1567	549	4.3880492	2.98387348	0.274253077	1.645518	23.03726
Allahabad (M Corp.) WARD NO.-0008	20360	36930	14772	10045	4727	1654	13.235657	9.00024651	0.827202854	4.963371	69.4872
Allahabad (M Corp.) WARD NO.-0009	12206	22140	8856	6022	2834	992	7.9348932	5.39572736	0.495930823	2.975585	41.65819
Allahabad (M Corp.) WARD NO.-0010	16600	30110	12044	8190	3854	1349	10.791351	7.33811847	0.674459419	4.046757	56.65459
Allahabad (M Corp.) WARD NO.-0011	13654	24766	9906	6736	3170	1110	8.876211	6.03582347	0.554763187	3.328579	46.60011
Allahabad (M Corp.) WARD NO.-0012	12196	22122	8849	6017	2832	991	7.9283924	5.39113068	0.495524522	2.973147	41.62406
Allahabad (M Corp.) WARD NO.-0013	13375	24260	9704	6599	3105	1087	8.6948383	5.91249004	0.543427393	3.260564	45.6479
Allahabad (M Corp.) WARD NO.-0014	14163	25689	10276	6988	3288	1151	9.2071024	6.26082964	0.57543439	3.452663	48.33729
Allahabad (M Corp.) WARD NO.-0015	8681	15746	6298	4283	2015	705	5.6433563	3.83748232	0.352709772	2.116259	29.62762
Allahabad (M Corp.) WARD NO.-0016	9540	17304	6922	4707	2215	775	6.2017762	4.21720785	0.387611015	2.325666	32.55933
Allahabad (M Corp.) WARD NO.-0017	16631	30166	12066	8205	3861	1351	10.811503	7.35182219	0.675718951	4.054314	56.76039
Allahabad (M Corp.) WARD NO.-0018	15593	28283	11313	7693	3620	1267	10.136719	6.89296876	0.633544923	3.80127	53.21777
Allahabad (M Corp.) WARD NO.-0019	16069	29147	11659	7928	3731	1306	10.446157	7.10338709	0.652884843	3.917309	54.84233
Allahabad (M Corp.) WARD NO.-0020	11574	20993	8397	5710	2687	941	7.5240417	5.11634839	0.470252609	2.821516	39.50122
Allahabad (M Corp.)	1976	35847	14339	9750	4588	1606	12.84	8.736	0.8029	4.81	67.4

WARD NO.-0021	3						7558	33948	72379	7834	4968
Allahabad (M Corp.) WARD NO.-0022	11921	21623	8649	5881	2768	969	7.74962	5.269 74159	0.4843 51249	2.90 6107	40.6 855
Allahabad (M Corp.) WARD NO.-0023	13581	24634	9854	6700	3153	1104	8.828 755	6.003 55343	0.5517 97191	3.31 0783	46.3 5096
Allahabad (M Corp.) WARD NO.-0024	14126	25622	10249	6969	3280	1148	9.183 0494	6.244 47359	0.5739 40587	3.44 3644	48.2 1101
Allahabad (M Corp.) WARD NO.-0025	19960	36204	14482	9848	4634	1622	12.97 5624	8.823 42438	0.8109 76506	4.86 5859	68.1 2203
Allahabad (M Corp.) WARD NO.-0026	10671	19356	7742	5265	2478	867	6.937 0183	4.717 17242	0.4335 63642	2.60 1382	36.4 1935
Allahabad (M Corp.) WARD NO.-0027	16122	29243	11697	7954	3743	1310	10.48 0612	7.126 81603	0.6550 38238	3.93 0229	55.0 2321
Allahabad (M Corp.) WARD NO.-0028	9937	18024	7210	4903	2307	807	6.459 8585	4.392 70381	0.4037 41159	2.42 2447	33.9 1426
Allahabad (M Corp.) WARD NO.-0029	12983	23549	9420	6405	3014	1055	8.440 0064	5.739 20435	0.5275 00399	3.16 5002	44.3 1003
Allahabad (M Corp.) WARD NO.-0030	15799	28657	11463	7795	3668	1284	10.27 0636	6.984 03216	0.6419 1472	3.85 1488	53.9 2084
Allahabad (M Corp.) WARD NO.-0031	9361	16979	6792	4618	2173	761	6.085 4117	4.138 07994	0.3803 3823	2.28 2029	31.9 4841
Allahabad (M Corp.) WARD NO.-0032	20955	38009	15204	10338	4865	1703	13.62 2455	9.263 26944	0.8514 03441	5.10 8421	71.5 1789
Allahabad (M Corp.) WARD NO.-0033	19527	35419	14168	9634	4534	1587	12.69 4139	8.632 01442	0.7933 83679	4.76 0302	66.6 4423
Allahabad (M Corp.) WARD NO.-0034	15380	27897	11159	7588	3571	1250	9.998 2514	6.798 81097	0.6248 90714	3.74 9344	52.4 9082

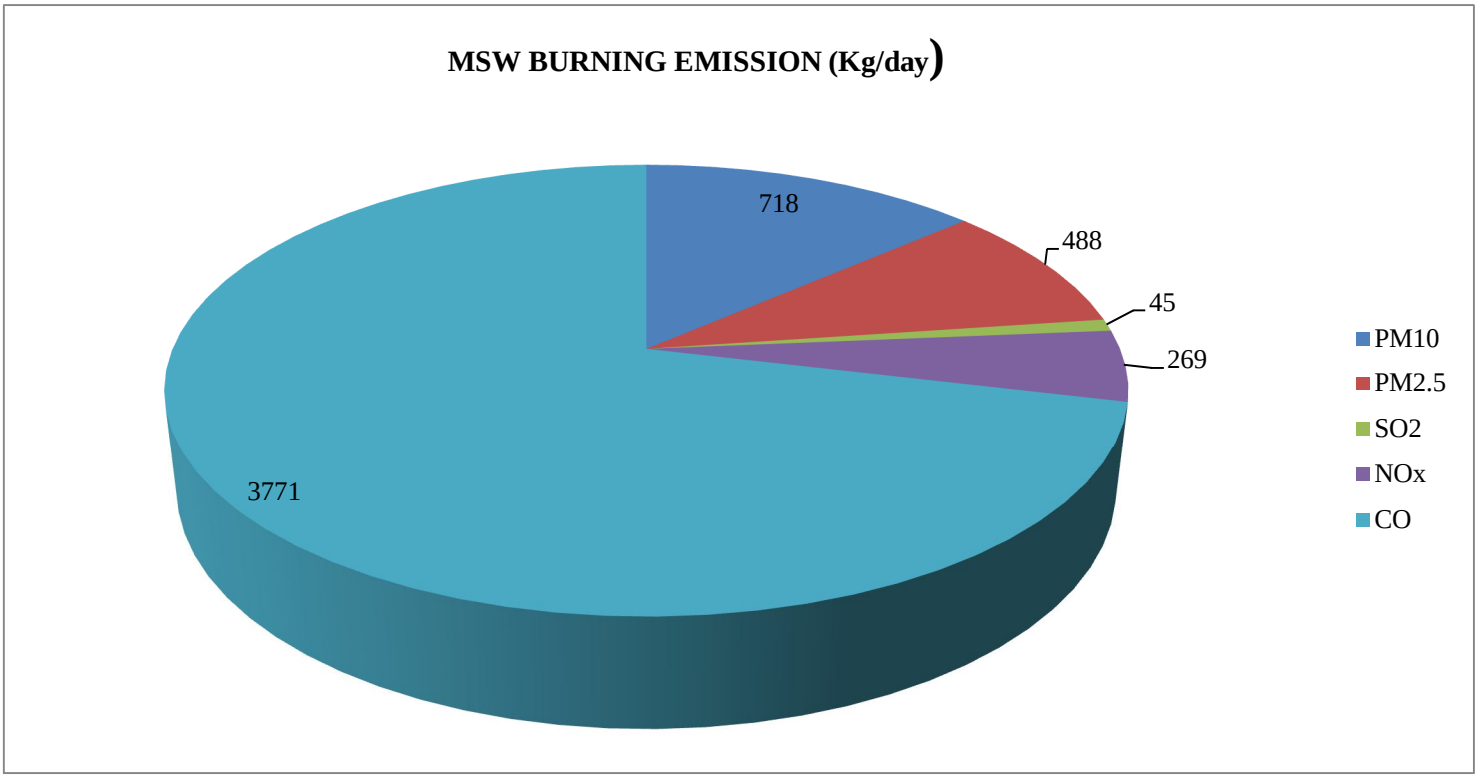


Fig:3- Pie chart shows emissions result

Table:2- Grid-wise emissions (kg/day) of air pollutants

Grid	Imoprtant Location	PM10	PM2.5	SO2	NOx	CO
P3		0.848194	0.576772	0.053012	0.318073	4.45302
P4	Mirakhpur kachhar	1.087302	0.739366	0.067956	0.407738	5.708337
P5	Naini Railway Station	39.57262	26.90938	2.473289	14.83973	207.7563
P7		0.996688	0.677748	0.062293	0.373758	5.232613
P8		0.024214	0.016466	0.001513	0.00908	0.127124
P9	Daiwghat	88.61592	60.25883	5.538495	33.23097	465.2336
P10	Rani Mandi	139.9353	95.15602	8.745957	52.47574	734.6604
P11	Bai Ka Bagh	32.8471	22.33603	2.052944	12.31766	172.4473
P12		3.214236	2.185681	0.20089	1.205339	16.87474
P13	Bamrauli	20.91206	14.2202	1.307004	7.842024	109.7883
P14	Transport nagar	43.99292	29.91518	2.749557	16.49734	230.9628
P15	Lukarganj	18.08347	12.29676	1.130217	6.781302	94.93823
P16	Johnstonganj	69.87489	47.51492	4.367181	26.20308	366.8432
P17	Tagore Town	80.98399	55.06911	5.061499	30.369	425.166
P18	Daraganj	21.42509	14.56906	1.339068	8.03441	112.4817
P21		0.099215	0.067467	0.006201	0.037206	0.520881
P22	Muinabad	45.81996	31.15758	2.863748	17.18249	240.5548
P23	Teliarganj	36.62585	24.90558	2.289116	13.73469	192.2857
P24		15.07797	10.25302	0.942373	5.654238	79.15933
P28		2.101602	1.429089	0.13135	0.788101	11.03341
P29	Rasulabad	37.98103	25.8271	2.373815	14.24289	199.4004
P30		0.384593	0.261523	0.024037	0.144222	2.019113
P34		0.170662	0.11605	0.010666	0.063998	0.895976
P35	Phaphaman	11.22725	7.634527	0.701703	4.210217	58.94304

The spatial distribution map will show the most affected grids due to air pollutants emission. The following maps will represent the emission value for each pollutant.

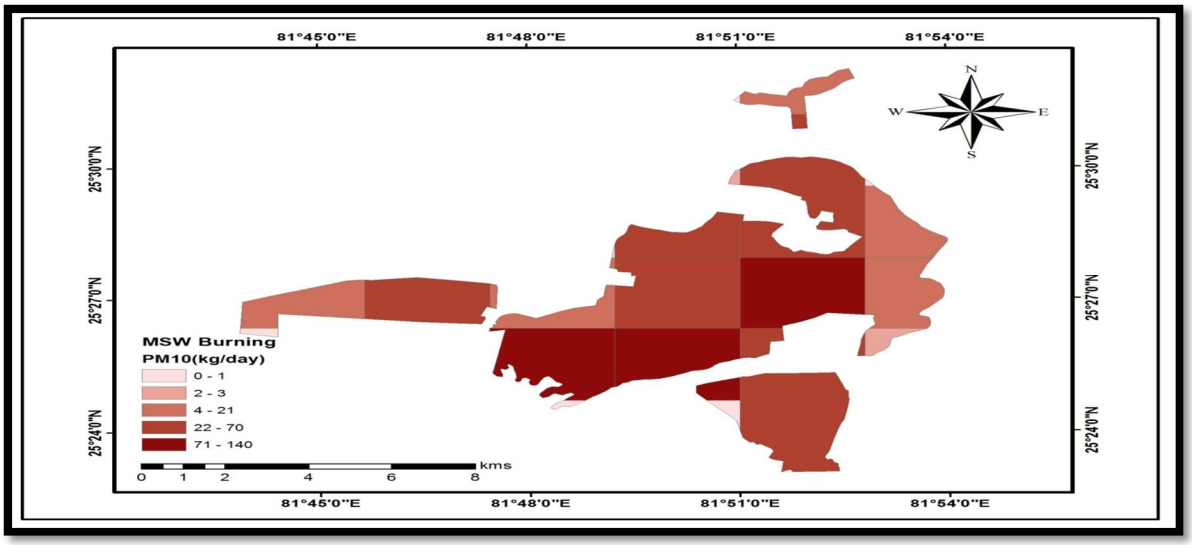


Fig:4- MSW spatial map for PM10 emission

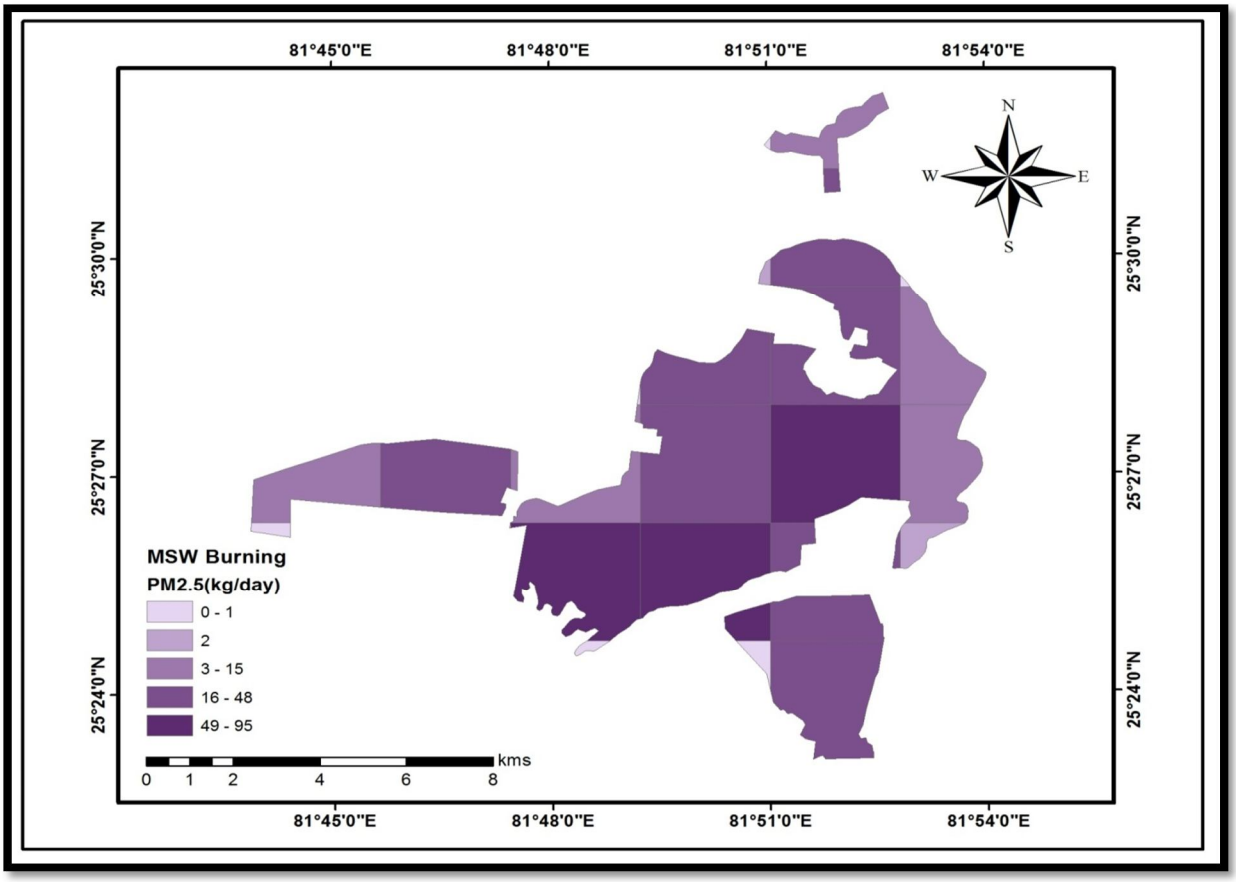


Fig:5- MSW spatial map for PM2.5 emission

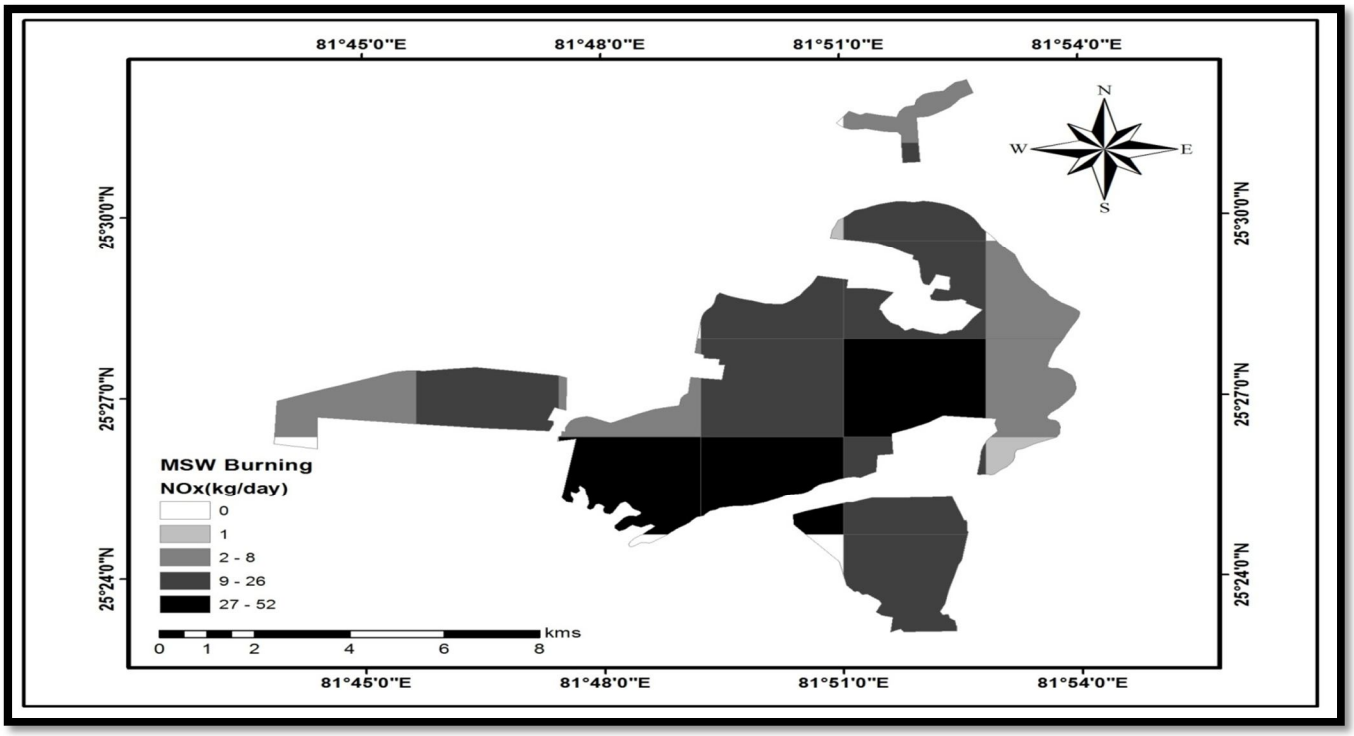


Fig:6- MSW spatial map for NO_X emission

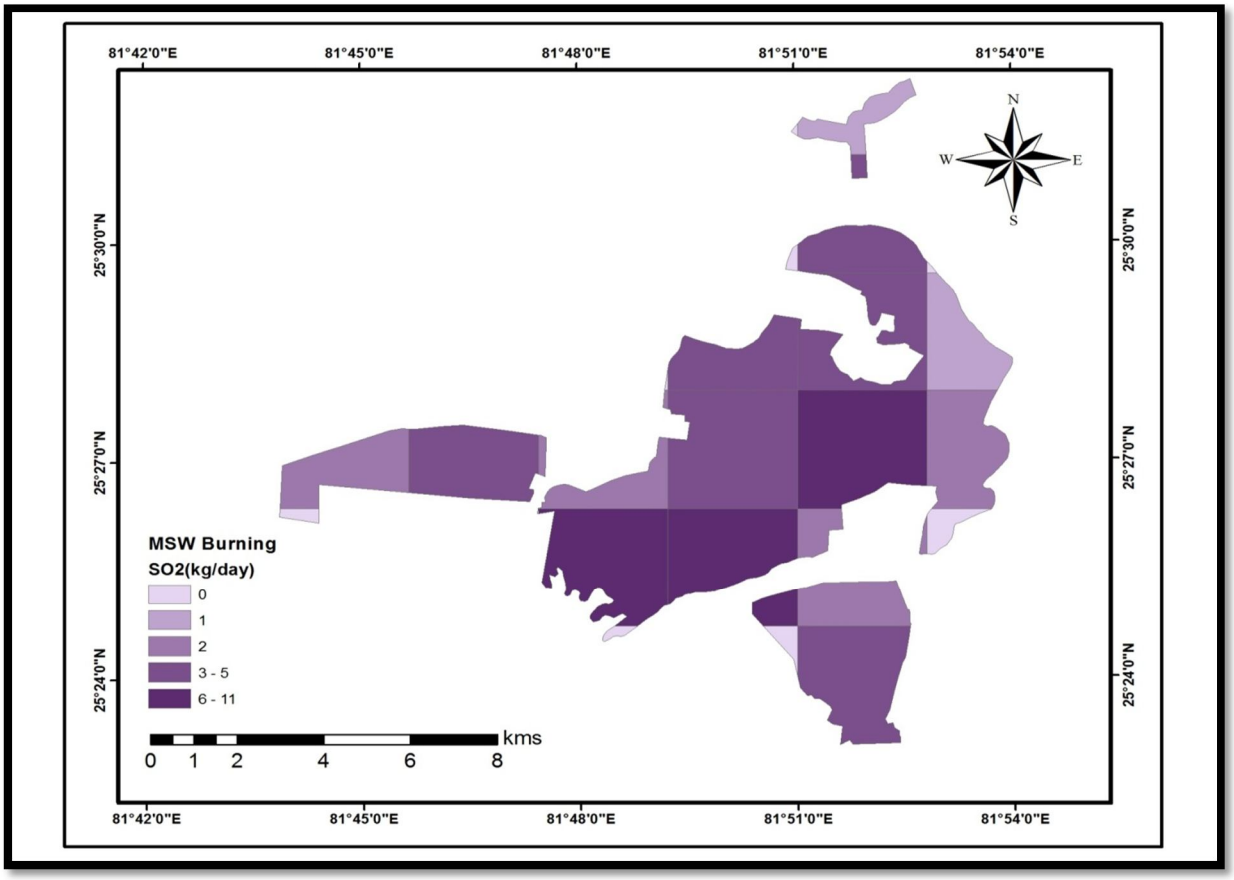


Fig:7- MSW spatial map for SO_2emission

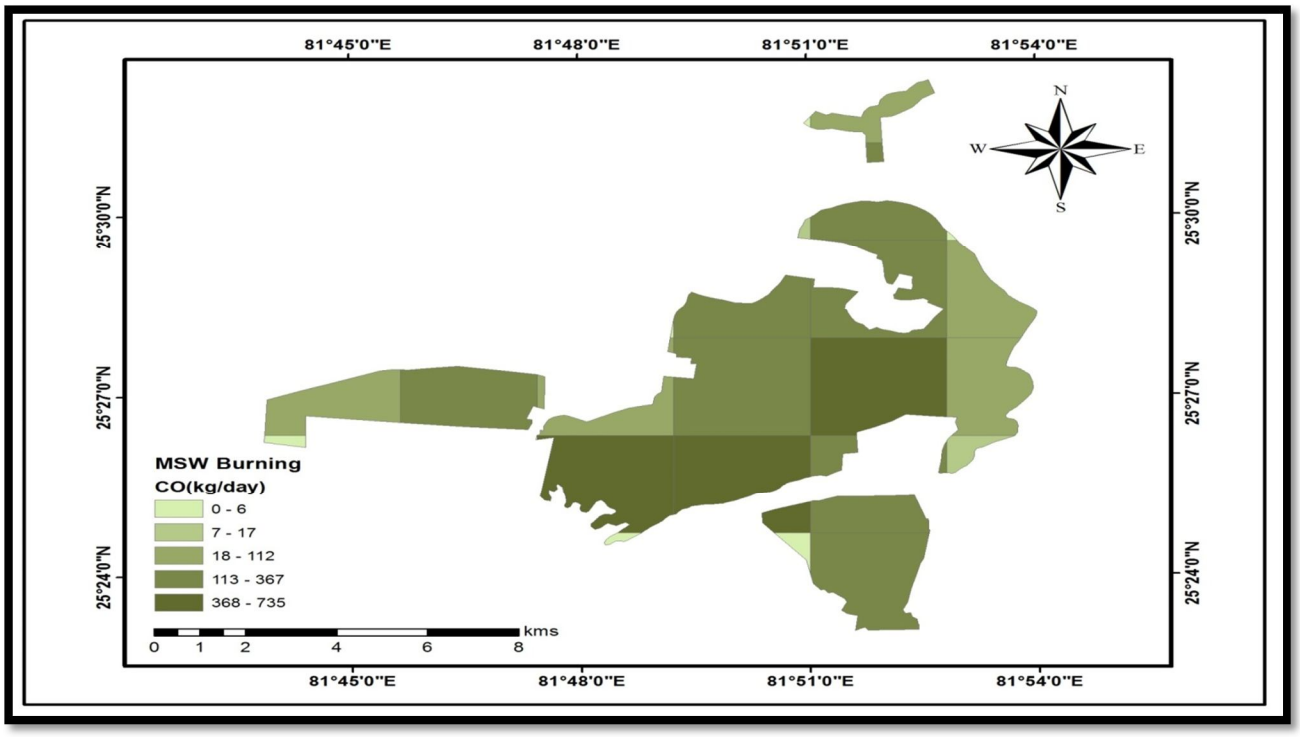


Fig:8- MSW spatial map for CO emission

V. CONCLUSION

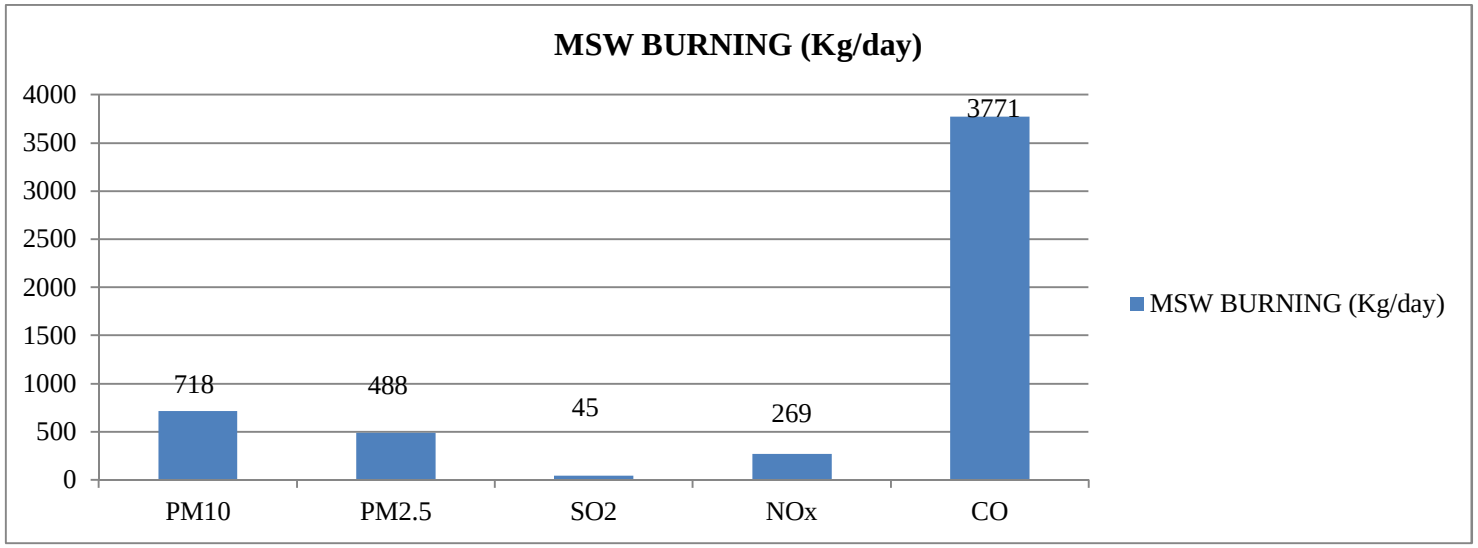


Fig:9- Final emissions (kg/day) from burning solid waste

(Domestic)PM10		
High Emission Grid	LOCATION	EMISSIONS(Kg/day)
P5	Naini railway station	142
P9	Daiwghat	164
P10	Ranimandi	292
(Domestic)PM2.5		
High Emission Grid	LOCATION	EMISSIONS(Kg/day)
P5	Naini railway station	99
P9	Daiwghat	115
P10	Ranimandi	204
P14	SukmSarai	117
P17	Tagore Town	101
P29	Rasulabad	62

Table:3- Grids with high emission value of PM_{10} and $PM_{2.5}$

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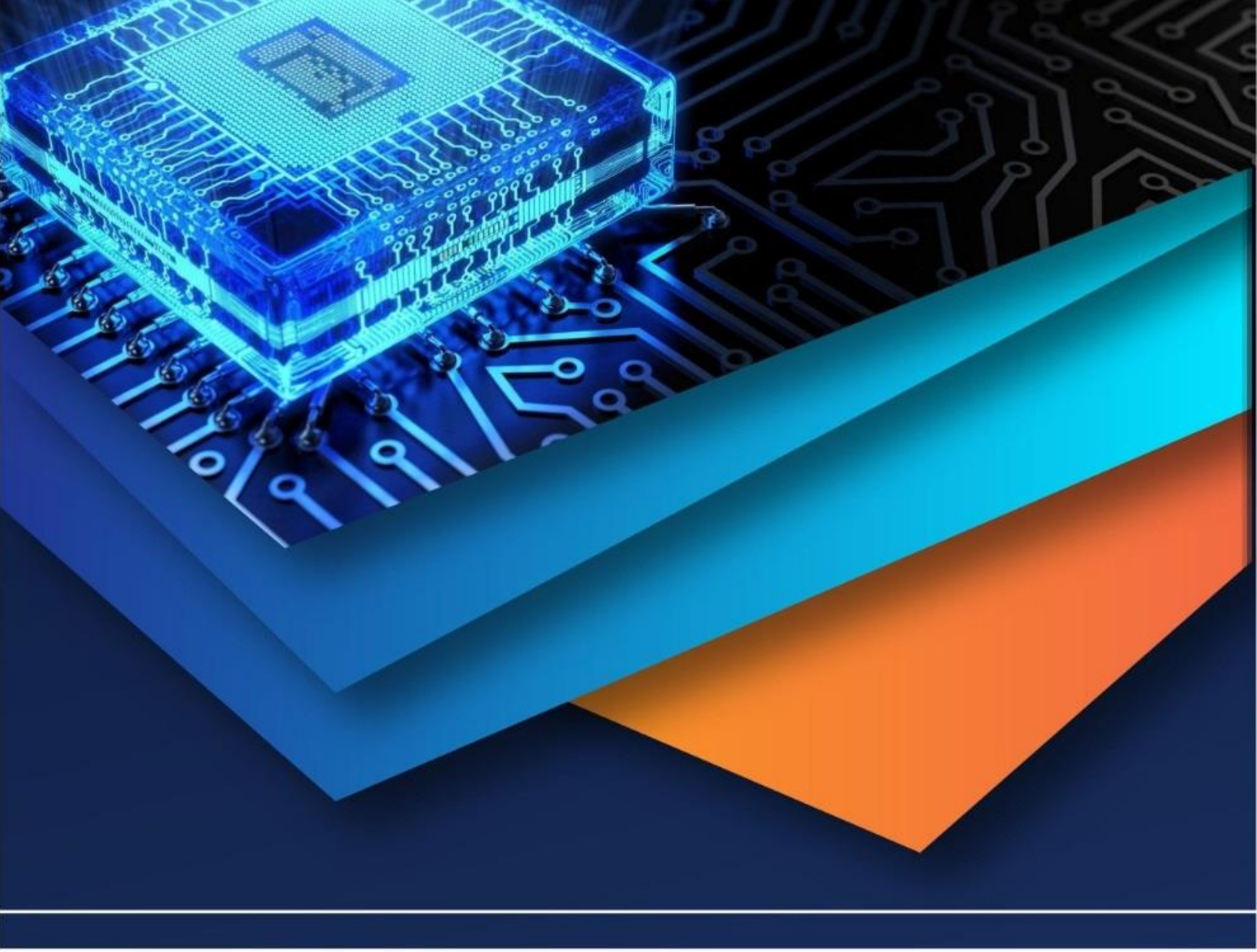

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