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Measurement of Ambient Air Pollutants in the Vicinity of Gwalior, Madhya Pradesh, India: Sampling, Analysis and Suggestion

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Abstract: ***In the report of world health organization (WHO), May 2016 it is quoted that Gwalior is 2nd most polluted city of the world. To investigate the causes for poor air quality in Gwalior, the Sampling and analysis of ambient air in the vicinity of Gwalior City (M.P.) during May-June, 2018 is carried out in three shifts (i.e. Early morning shift (EMS), Day shift (DS) and Evening shift (ES)) at three sampling stations. Following parameters like SO_X, NO_X and PM_{10} are determined by using high volume sampler (HVS). Monitoring sites are selected on the criterion of prevailing wind direction, which is decided with the help of Wind Rose diagram. The sampling is done regularly for 24 hour and for three days. Parameters like SO_X, NO_X and PM_{10} at each sampling stations are measured as per guidelines of CPCB manual. Prevailing meteorological parameters such as wind velocity, wind direction, rainfall, etc. are also recorded for accessing their effect on existing air quality. The study reveals that the concentration of PM_{10} is greater than the permissible limit (100 µg/m^3) and the concentration of SO_X & NO_X is below the permissible limit (80 µg/m^3 each) at all sampling stations as mentioned in the national ambient air quality standards (NAAQS) (refer table 1). The causes of poor air quality are also correlated with the pollution causing activities, inventories and geographical parameters, etc. Suitable measures to impart significant improvement in the air quality are also suggested.***

Keywords: HVS; Wind Rose diagram; CPCB Manual; Ambient Air Quality; SO_X; NO_X; PM_{10}.

Abbreviations- PM_{10}: Particulate Matter; NAAQS: National ambient air quality standards; HVS: High Volume Sampler; EPA: Environmental Protection Agency; CPCB: Central Pollution Control Board; MPPCB: Madhya Pradesh Pollution Control Board; AAQM: Ambient Air Quality Monitoring, MP: Madhya Pradesh, WHO: World Health Organization; GKM: Gole Ka Mandir, GWL: Gwalior; EMS: Early Morning Shift; DS: Day Shift; ES: Evening Shift; S1: Rayaru chouraha; S2: Gole ka Mandir chouraha; S3: MPCT College Triangle.

I. INTRODUCTION

Gwalior is one of the Major City of Madhya Pradesh, India. It is titled by many names such as "The Gateway of Madhya Pradesh, "The city of Scindia", and City of kings. Gwalior is a tourism hub, surrounded by many historical monuments, including the Gwalior Fort (Gibraltar of India), "Jai Vilas Palace", Teli ka Mandir and "Tomb of Tansen" etc. A study carried out by World Health Organization (WHO) on urban pollution in May 2016 reveals that the Gwalior is the 2nd most air polluted city in the world after Iran's Zabol (Capital of Zabol country) (WHO report May, 2016). Air pollution has adverse impacts on human health as well as on the health of other living entities, man-made heritage structures and life support system. Air pollution is accessed by the concentration of various air pollutants like PM_{10}, SO_X, NO_X, $PM_{2.5}$, CO etc. It is very difficult for a common man to understand the quality of air on the basis of concentration of above referred pollutants. The air quality index provides the solution for above mentioned problem. The air quality index is a single index which is representing the sum total of adverse effect of all the pollutants on the air quality. Therefore air quality index is widely used all over the world to represent air quality. The concept of Air Quality Index was introduced by the Environmental protection agency (EPA) in USA to measure the air quality due to major air pollutants ($PM_{2.5}$, SO_X, NO_X and PM_{10}, RSPM, CO, etc.). Unplanned urbanization and industrialization is causing deterioration of the environment. It is observed that the population of Gwalior has increased rapidly from 0.71 million (census, 1991) to 1.336 million (in year 2018). Gwalior has witnessed intense industrial and construction activities during this period. Gwalior is also known for mines of best quality of stone aggregates. Stone mines are located in the fringe area of Gwalior city. The exponential growth of vehicles coupled with above mentioned reasons seems to be the main cause for the increased air pollution. Unsuitable geological and geographical conditions also resulted in to aggregation of the air pollution phenomenon. Results of monitoring stations set up by Madhya Pradesh Pollution Control Board (MPPCB) in the Gwalior city (i.e. Bada & Deen Dayal Nagar) also confirms the WHO

report. The data compiled by MPPCB for the year 2016-2017 at two AAQM stations reveals that the concentration of various pollutants in Gwalior is moderate except concentration of $PM_{2.5}$. All values of PM_{10} measured during study were much higher than National Ambient Air Quality Standards (100µg/m^3). Air quality directly affects the health of the residents and quality of life. For improving the Quality of life, it is necessary to analyze the air quality and investigate the impact of air pollutant on health of residence. The study in the paper also includes the identification of reasons for poor air quality and suitable measures for improvement of air quality. As things stand, air pollution in the Gwalior is largely due to vehicles because two national highways (NH3, NH75) crossing the city and various industrial processes like stone quarries, steel bar factories, rubber processing, dairy units, wine factory, railway spring karkhana, and Engineering works inside the city including open burning of garbage, etc. Apart from local sources Malanpur industrial area and Banmore industrial area are also situated within 10-15 km from municipal limit.

TABLE-1 National Ambient Air Quality Standards (2009)

S.N.	Pollutants	Time weighted average	Concentration in ambient air (in µg/m^3)			Method of measurement
			Sensitive area	Industrial area	Residential, rural and other areas	
1	Oxides of Sulphur (SO_X)	Annual average	20	50	50	Improved west and Geake method
		24 hour	80	80	80	
2	Oxides of nitrogen (NO_X)	Annual average	30	40	40	Jacob and Hochheiser modified (Na-Arsenite) method
		24 hour	80	80	80	
3	Suspended particulate matter PM_{10}	Annual average	60	60	60	Gravimetric method
		24 hour	100	100	100	

Source: Central Pollution Control Board, Ministry of Environment & Forests, Parivesh Bhawan, East Arjun Nagar, Delhi- 110032 (Website: http://www.cpcb.nic.in)

II. MATERIALS AND METHODS

Materials and methods (pl. refer table 2) which are used in this study are described in details. (Including chemicals, reagents, glassware's, instruments and filter papers etc.)

A. Instruments/Equipments

1) High volume sampler (Envirotech Pvt. Ltd., New Delhi)
2) Analytical Balance (Citizen, CY- 204), KEROY KM 2. (Least count 0.01 mg
3) Spectrophotometer (Elico
4) P^H meter (RI RS-232 µC P^H meter
5) Magnetic stirrer with Hot plate
6) Universal hot air Oven
7) Desiccators, etc.

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CHEMICALS/REAGENTS- For SO_X: Distilled water, Mercuric chloride, Potassium chloride/Sodium chloride, EDTA, 0.04 M Potassium Tetrachloro-mercurate (absorbing reagent), Sulphamic acid, formaldehyde, purified pararosaniline (PRA), Starch indicator solution, Sodium thio-sulphate, Potassium iodate, etc.
For NO_X: Distilled Water, Sodium hydroxide (absorbing reagent), Sodium Arsenite, Sulphanilamide, N- (1- Naphthyl)-ethylenediamene Di-hydrochloride (NEDA), Hydrogen Peroxide-30%, Phosphoric acid-85%, Sodium Nitrite, etc.
Glassware- Beaker, Measuring Cylinder, Volumetric flask, pipette, Amber color bottle, Glass bottles, Test tube, Burette, Funnel, Impingers, Wash bottle, etc.
Filter paper- Whatman GF/A filter papers of size (8'×10') for sampling of air pollutants, Whatman filter paper 40 NO.

TABLE-2 IS code & method used in the study

S.N.	Pollutants	Method	IS code	Manual
1.	SO_X	West and Geake Method	IS:5182 (Part II) – 2001	CPCB Manual, 2009
2.	NO_X	Jacob and Hoccheiser Method	IS:5182 (Part VI) – 2006	CPCB Manual, 2009
3.	PM_{10}	Gravimetric Method	IS:5182 (Part IV) – 1999	CPCB Manual, 2009

Source: Website: http://www.cpcb.nic.in

III. AIR POLLUTION STUDY AND SOURCES OF AIR POLLUTION

Central pollution control board (CPCB) and Madhya Pradesh pollution control board (MPPCB) deals with air pollution monitoring at a national level and State level respectively. Their tasks include determination and collection of requisite data/information from various air pollution sampling stations which are the integral part of National air quality monitoring network. CPCB is also responsible for creation of integrated database for analysis and information sharing. Gwalior city had two air quality monitoring stations (under the national air monitoring grid) the data of which used for regulatory purpose. These stations are mainly located in the internal parts of the city, out of which one is in prominent commercial area and another is in residential area (Maharaja Bada & Deen Dayal Nagar). Growing vehicular population is one of the primary causes for increased air pollutant levels. Vehicular pollution is considered as primary precursor for ground-level ozone pollution and secondary contributor for Particulate matters (PM_{10}). The air pollution sources in Gwalior include open burning, industrial boilers, dust emissions from construction, industrial establishment in the city, household heating systems, clay brick production, public and private transports, road re-suspension, insufficient road capacity, poor design of road elements and irresponsible public attitude. Most typical urban pollutants in Gwalior includes suspended particulate matters (SPM), oxides of sulfur (SO_X), volatile organic compounds (VOCs), lead (Pb), carbon monoxide (CO), carbon dioxide (CO_2), oxides of nitrogen (NO_X) and ozone (O_3). Out of these pollutants, the particulate matter (PM) is one of the most critical pollutant responsible for poor air quality in Gwalior.

IV. SITE DESCRIPTION

Gwalior is the home to the heritage magnificent Gwalior fort (Gibraltar of India). It occupies a strategic location in the central India, having co-ordinates as (26.22°N 78.18°E) and altitude 197 meters (646 feet) above Mean Sea Level. Gwalior is located in Madhya Pradesh 286 km away from Delhi. The sampling stations are selected for the sampling of air pollutant on the consideration of prevailing wind direction. Wind rose diagram of May-June months (IEM: Wind Rose) is used for selecting sampling stations. It has been found that the wind is blowing in the major part of the city from the direction of North-West to South-East during the period of study. According to prevailing wind direction three monitoring stations are selected for air pollutant monitoring of city, (i.e. Rayaru Chouraha, Gole Ka Mandir Chouraha, MPCT College Triangle) in Upwind N-W Direction, inside the city and downwind direction respectively (pl. refer table -3and figure - I).

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TABLE - 3 Locations of Air Monitoring Stations in the vicinity of Gwalior.

S.N.	Location	Station Name	Monitoring Position	Latitude & longitude
1.	Rayaru	S1	Rayaru Chouraha	26.300°N 78.119°E
2.	Gole Ka Mandir	S2	Gole Ka Mandir Chouraha	26.234°N 78.207°E
3.	MPCT College Triangle	S3	MPCT College Triangle	26.193°N 78.203°E

A. Sample Collection

Samples are collected from selected sites daily (24 hour) for three days in three shifts (first two hour shift and remaining shifts are of four hour). Sampling was conducted during 4:00 AM to 11:00 PM daily (i.e. early morning (4:00 AM–6:00 AM), Day shift (7:00 AM –11:00 AM) and Evening shift (07:00 PM–11:00 PM)) and meteorological parameters like wind direction, wind velocity, humidity, pressure, cloud cover and temperature are also recorded to correlate impact on air quality. Sampling was done at a height of 2-3 m from ground level. The collection of samples of particulate matter (PM_{10}), were carried out by high volume sampler (HVS) with constant flow rate and SO_X, NO_X samples are collected with the help of Gaseous attachment with HVS (Envirotech Pvt. Ltd., New Delhi). HVS is operated at an average flow rate of 1.0 litre/minute for collection of SO_X and NO_X. The impingers were kept in iceboxes immediately after sampling and transferred to a refrigerator prior to analysis in the institute laboratory.

B. Gravimetric And Chemical Analysis

GF/A Filter papers were dried in oven at 102˚C for half an hour and cooled in dessicator to room temperature before loading it on HVS. The weight of filter paper was recorded prior to loading in HVS. Simultaneously impingers filled with suitable absorbing solution (30ml each) are also attached with HVS. The gable roof of the equipment was reseated before sampling. Impingers were jacketed in icebox to maintain the required temperature. Initial sampling rate of air was recorded though flow meter and sampling rate was recorded regularly after completion of one hour sampling. So that average sampling rate can be worked out for analysis of PM_{10}. At the end of the work filter paper is taken out carefully from the filter holder gasket assembly and heated to 102˚C, to draw out the moisture if any. Subsequently filter paper was cooled to room temperature in dessicator and final weight is taken. For sampling of SO_X & NO_X as per CPCB guidelines the air flow rate was set at 1.0 lpm by adjusting gas manifold valve. At the end of the sampling the air flow rate was further recorded to find out the average rate of sampling. Final volume of each absorbent is also recorded for accurate calculation of volume of air passed through Gas manifold assembly. Impingers along with the icebox are immediately transferred to refrigerator before chemical analysis of sample. Chemical analysis of sample is conducted within 12-24 hrs in the laboratory. While calculating the volume of sampled air correction for Temperature and Pressure is also incorporated.

C. Meteorological Measurements

Besides anthropogenic sources, climate and natural sources too play an important role in the build-up of pollution levels WHO). Gwalior has a semi-arid climate, with an extremely hot summer, average rainfall and moderate cold winters (IMD). Meteorological data (such as Temperature, pressure, humidity, cloud cover, wind direction, wind speed), prevailing at the time of sampling is taken from website (www.accuweather.com). Periodic cleaning of the sampler was done to make the sampler dust free so that the reliability and reproducibility of the results can be ensured.

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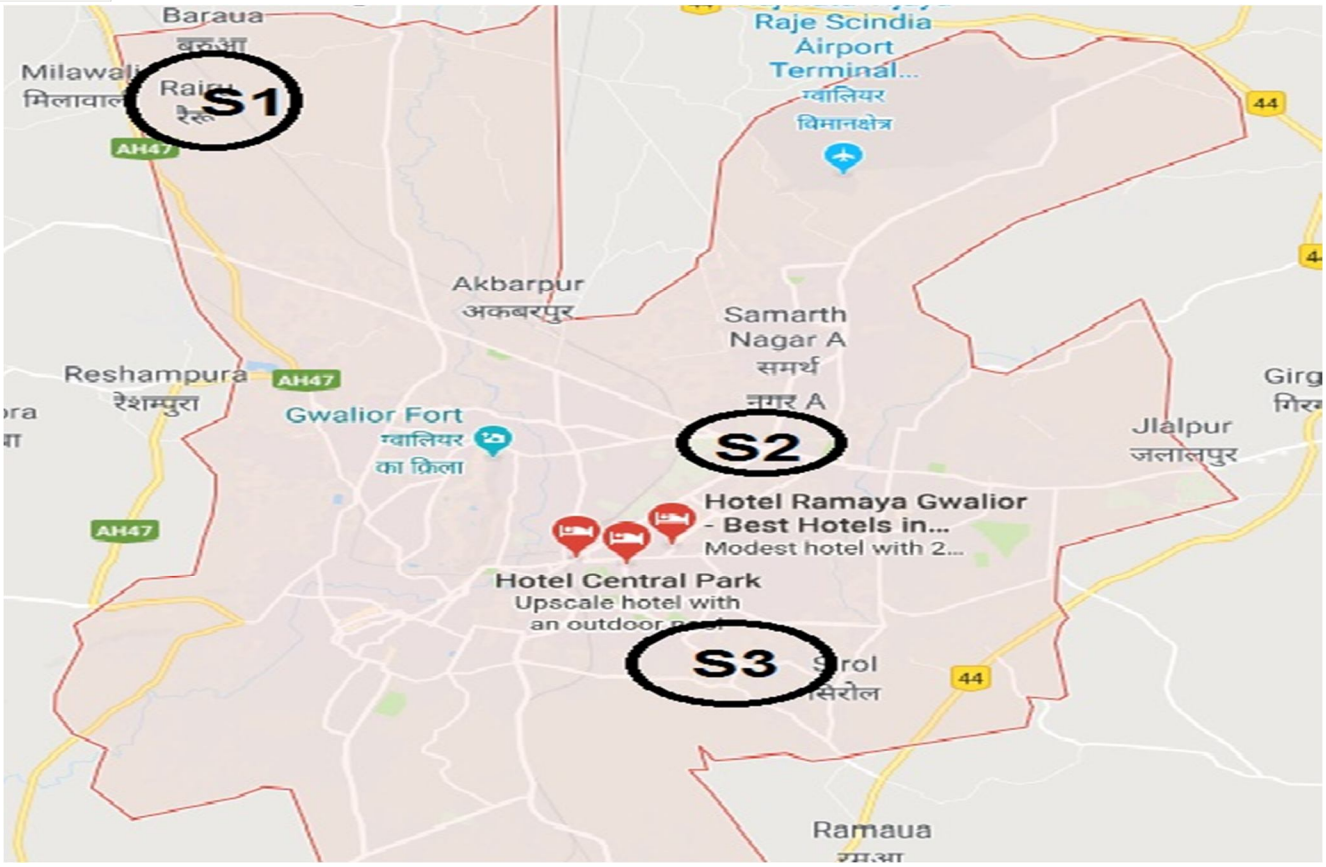

Figure I - Shows location of Monitoring Site on Map

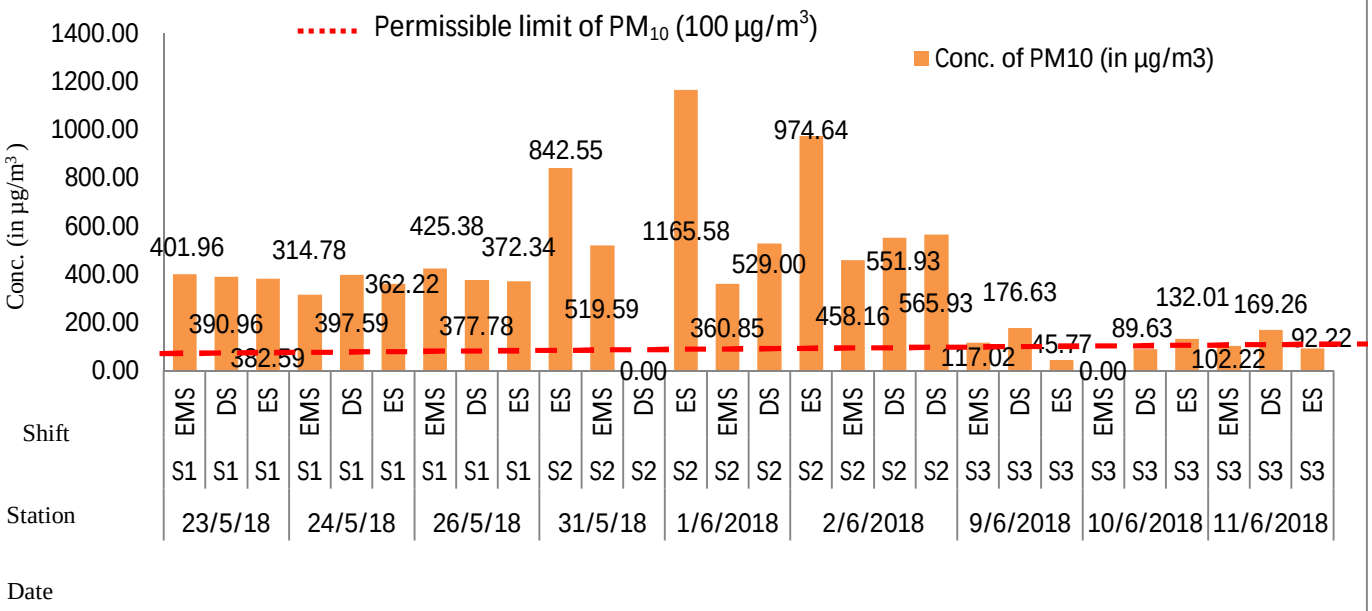

Figure 1: 24 Hour shift wise Concentration of PM10 daily in 3 shifts @3 days regularly at each station (S1-Rayaru Chouraha, S2-Gole ka Mandir Chouraha, MPCT college Triangle) (EMS=Early Moring Shift, DS=Day Shift, ES=Evening Shift).

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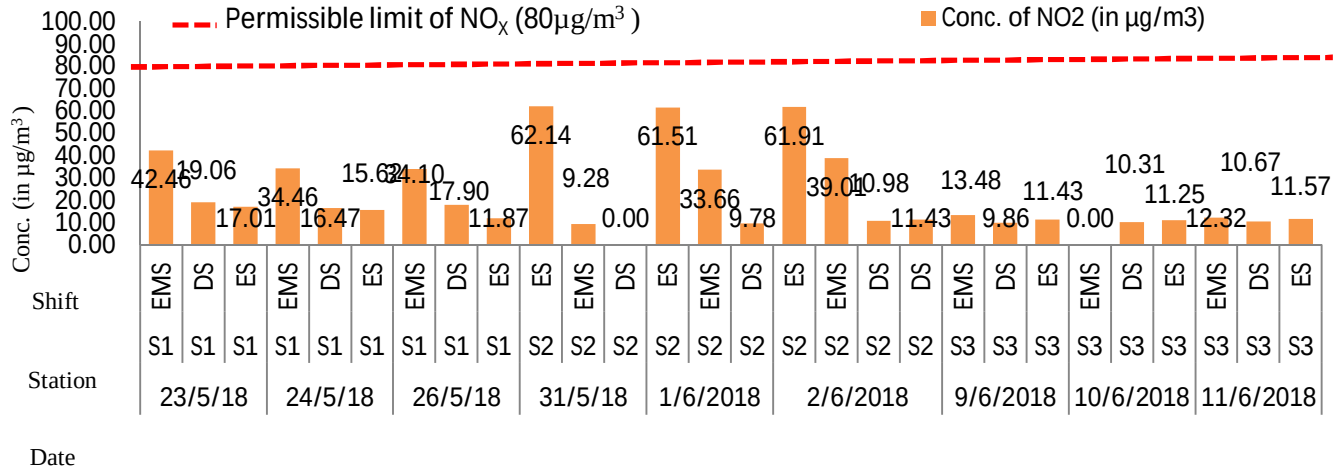

Figure 2: 24 Hour shift wise Concentration of Nitrogen Di Oxide daily in 3 shifts @3 days regularly at each station (S1-Rayaru Chouraha, S2-Gole ka Mandir Chouraha, MPCT college Triangle) (EMS=Early Moring Shift, DS=Day Shift, ES=Evening Shift).

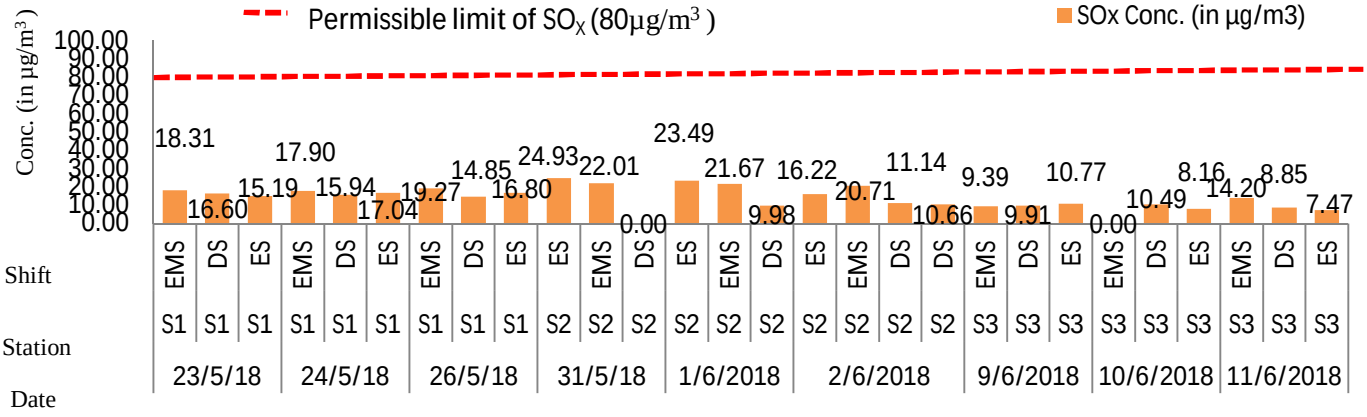

Figure 3: 24 Hour shift wise Concentration of Sulfur Di Oxide daily in three shifts @3 days regularly at each station (S1-Rayaru Chouraha, S2-Gole ka Mandir Chouraha, MPCT college Triangle) (EMS=Early Moring Shift, DS=Day Shift, ES=Evening Shift).

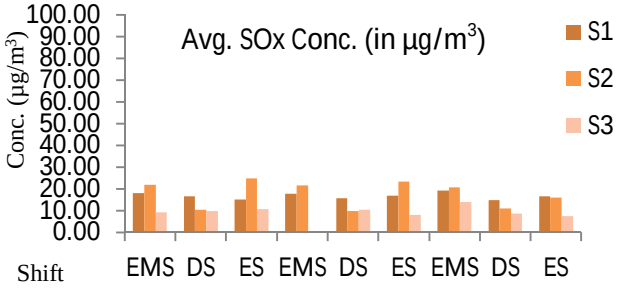

Figure 4: 24 Hour Concentration of sulphur Di Oxide (S1-Rayaru Chouraha, S2-Gole ka Mandir Chouraha, MPCT college Triangle) (EMS=Early Moring Shift, DS=Day Shift, ES=Evening Shift).

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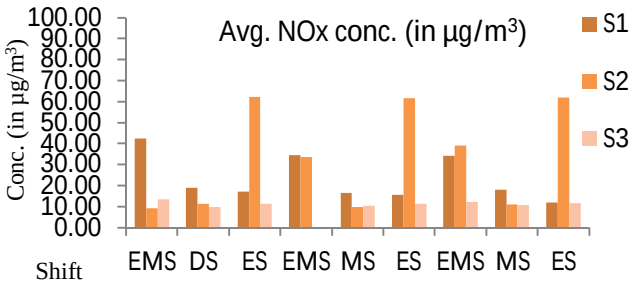

Figure 5: 24 Hour Concentration of NOx (S1-Rayaru Chouraha, S2-Gole ka Mandir Chouraha, MPCT college Triangle) (EMS=Early Moring Shift, DS=Day Shift, ES=Evening Shift).

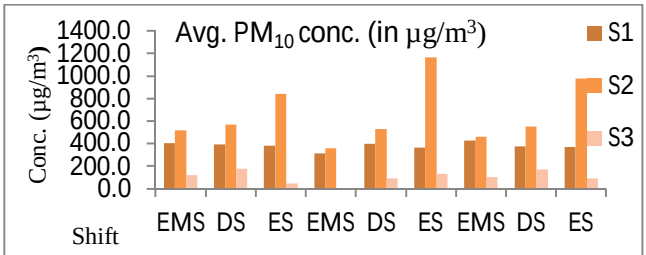

Figure 6: 24 Hourly Concentration of PM10 (S1-Rayaru Chouraha, S2-Gole ka Mandir Chouraha, MPCT college Triangle) (EMS=Early Moring Shft, DS=Day Shift, ES=Evening Shift).

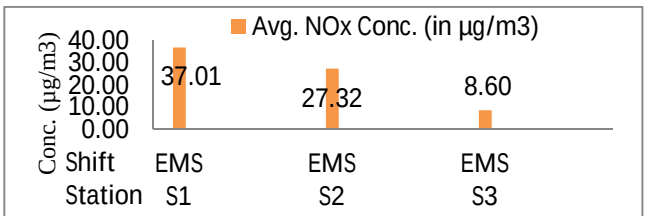

Figure 8: 24 Hourly Avg. Concentration of NOx (S1-Rayaru Chouraha, S2-Gole ka Mandir Chouraha, MPCT college Triangle) (EMS=Early Moring Shift).

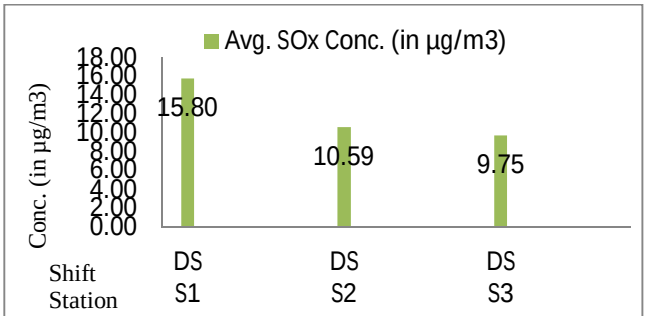

Figure 10: 24 Hourly Avg. Concentration of SOx (S1-Rayaru Chouraha, S2-Gole ka Mandir Chouraha, MPCT college Triangle) (DS= Day Shift).

	S1	S2	S3
SOx(in µg/m3)	16.88	17.87	9.56
Nox(in µg/m3)	23.22	33.30	11.30
PM10(in µg/m3)	380.62	663.14	115.10

Figure 12: 24 Hourly Average Concentration of SOx, NOx & PM10 (S1-Rayaru Chouraha, S2-Gole ka Mandir Chouraha, MPCT college Triangle)

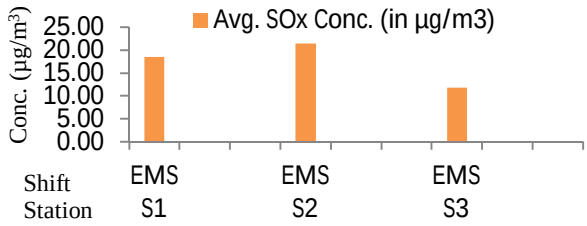

Figure 7: 24 Hourly Avg. Concentration of SOx (S1-Rayaru Chouraha, S2-Gole ka Mandir Chouraha, MPCT college Triangle) (ES=Evening Morning Shift).

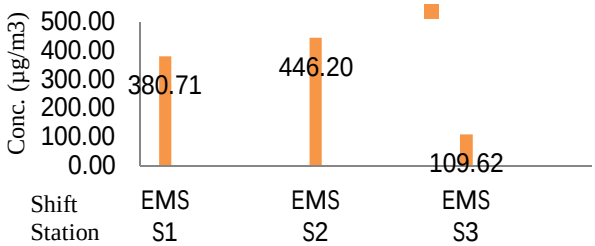

Figure 9: 24 Hourly Avg. Concentration of PM10 (S1-Rayaru Chouraha, S2-Gole ka Mandir Chouraha, MPCT college Triangle) (EMS=Early Moring Shift).

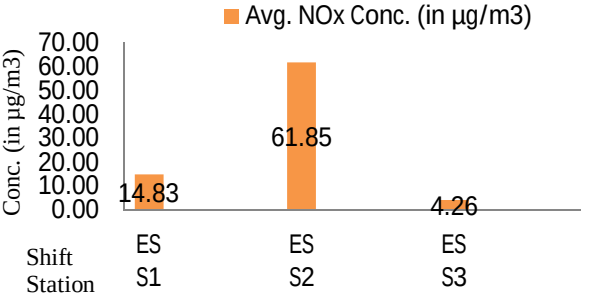

Figure 11: 24 Hourly Avg. Concentration of NOx (S1-Rayaru Chouraha, S2-Gole ka Mandir Chouraha, MPCT college Triangle) (ES= Evening Shift).

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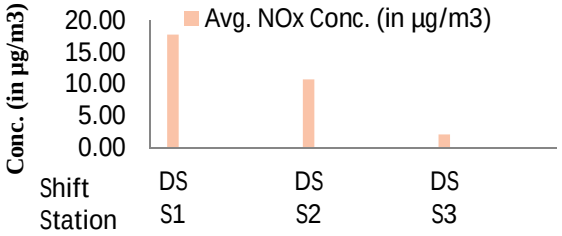


Figure 13: 24 Hourly Avg. Concentration of NOx (S1-Rayaru Chouraha, S2-Gole ka Mandir Chouraha, MPCT college Triangle) (DS= Day Shift).

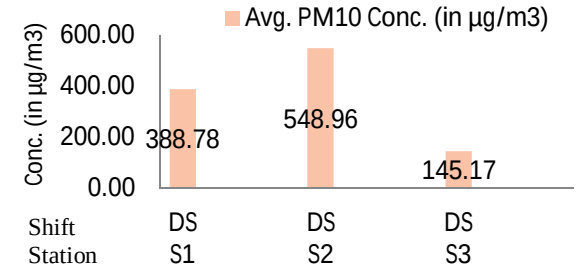


Figure14: 24 Hourly Avg. Concentration of PM10(S1-Rayaru Chouraha, S2-Gole ka Mandir Chouraha, MPCT college Triangle) (DS= Day Shift).

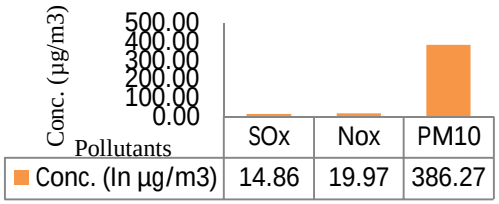
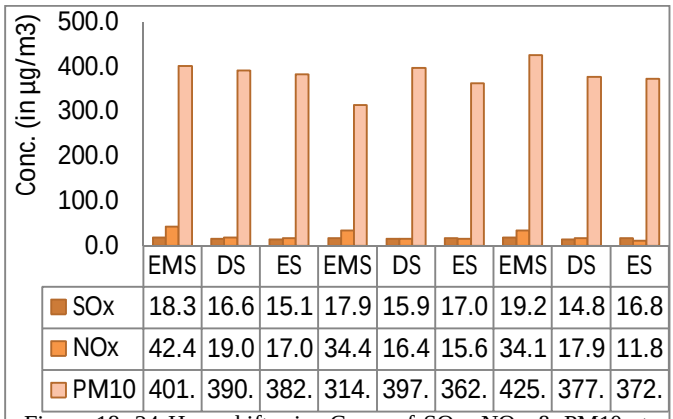


Figure 16: 24 Hourly Avg. Concentration of SOx, NOx & PM10 in Gwalior city.



	EMS	DS	ES	EMS	DS	ES	EMS	DS	ES
SOx	18.3	16.6	15.1	17.9	15.9	17.0	19.2	14.8	16.8
NOx	42.4	19.0	17.0	34.4	16.4	15.6	34.1	17.9	11.8
PM10	401.	390.	382.	314.	397.	362.	425.	377.	372.

Figure 18: 24 Hour shift wise Conc. of SOx. NOx & PM10 at Rayaru chouraha (EMS=Early Moring Shift, DS=Day Shift, ES=Evening Shift).

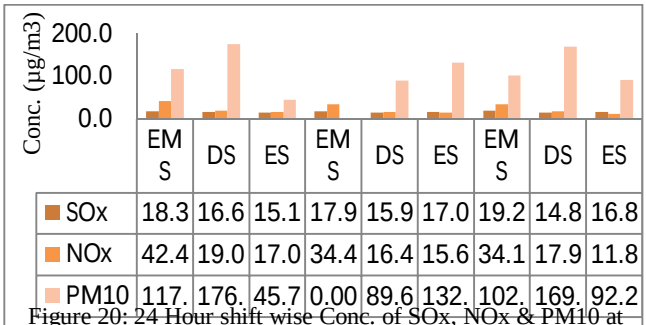


Figure 20: 24 Hour shift wise Conc. of SOx, NOx & PM10 at MPCT College Triangle (EMS=Early Moring Shift, DS=Day Shift, ES=Evening Shift).

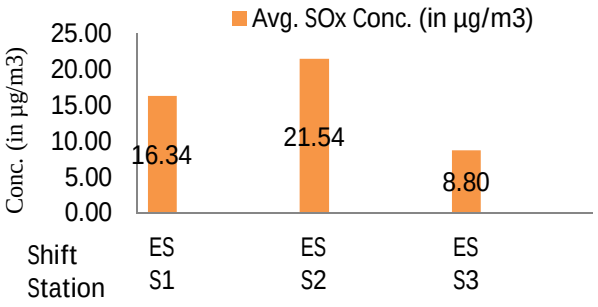


Figure15: 24 Hourly Avg. Concentration of SOx (S1-Rayaru Chouraha, S2-Gole ka Mandir Chouraha, MPCT college Triangle) (ES= Evening Shift).

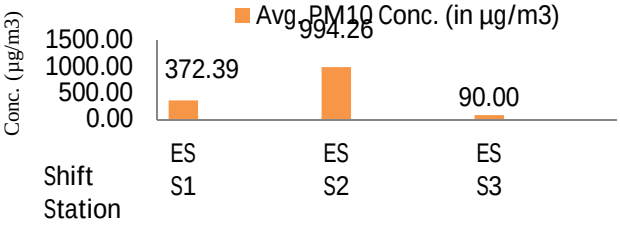


Figure 17: 24 Hourly Avg. Concentration of PM10 (S1-Rayaru Chouraha, S2-Gole ka Mandir Chouraha, MPCT college Triangle) (ES= Evening Shift).

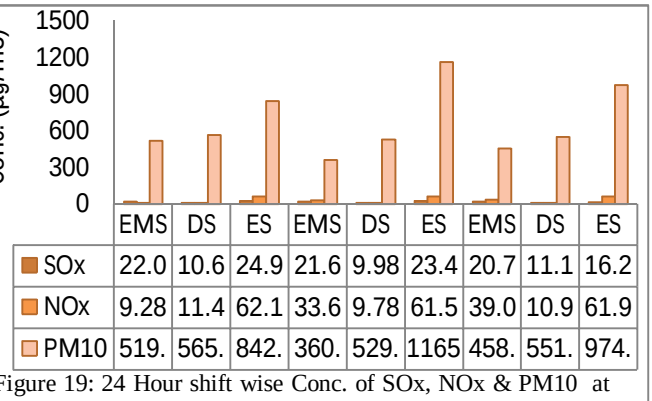


Figure 19: 24 Hour shift wise Conc. of SOx, NOx & PM10 at Gole ka Mandir (EMS=Early Moring Shift, DS=Day Shift, ES=Evening Shift).

TABLE 5: 24 Hour Average Concentration of Air Pollutants.

S.N.	STATION	SHIFT	POLLUTANTS		
			SO_X (µg/ m^3)	NO_X (µg/ m^3)	PM_{10} (µg/ m^3)
1	S1	EMS	18.49	37.01	380.71
2		DS	15.80	17.81	388.78
3		ES	16.34	14.83	372.39
4	S2	EMS	21.46	27.32	446.20
5		DS	10.59	10.73	548.96
6		ES	21.54	61.85	994.26
7	S3	EMS	11.79	8.60	109.62
8		DS	9.75	10.28	145.17
9		ES	8.80	11.42	90.00

V. RESULTS

A. *Particulate Matter (Pm_{10})*

The 24 hour average concentration of PM_{10} at Rayaru (outermost location within the municipal limit on windward side), Gole Ka Mandir (near centre location) and MPCT College Triangle (outermost location within municipal limit on leeward side) were observed to be 380.8µg/m^3, 663.1µg/m^3 and 115.1µg/m^3 respectively (see fig.13). On the basis of above, 24 hour average PM_{10} concentration in the Gwalior worked out to be 386.27µg/m^3 (see fig. 17). This value exceeds the permissible limit (100µg/m^3) laid down by central Pollution Control Board (CPCB) for residential area. Further, results shows that the measured value of PM_{10} at all three locations during all three shifts (24 Hour) is considerably more than the prescribed concentration of SPM. At Rayaru PM_{10} concentration was measured to be nearly same during all three shifts (380.7µg/m^3, 388.7µg/m^3, and 372.3µg/m^3). At Gole Ka Mandir maximum PM_{10} concentration (994.2µg/m^3) was observed during evening shift. However minimum concentration of PM_{10} at GKM was observed during day shift (446.2µg/m^3). The PM_{10} concentrations of MPCT College Triangle were observed to considerably less in comparison to other two monitoring points. Maximum and minimum concentration of PM_{10} at this location is measured to be 145.1µg/m^3 and 90.0µg/m^3 during day shift and evening shift respectively. On the basis of above results it is estimated that the average concentration of PM_{10} in city is maximum (485.5µg/m^3) during evening shift and minimum concentration of PM_{10} is (312.2µg/m^3) during early day shift. (Pl. refer figure 18, 19, 20)

B. *Oxides Of Sulphur And Nitrogen (So_x And No_x)*

The 24 average concentrations of SO_X / NO_X at Rayaru, Gole Ka Mandir and MPCT College Triangle were 16.8µg/m^3 / 23.2µg/m^3,17.8µg/m^3 / 33.3µg/m^3 and 9.5µg/m^3 / 3.39µg/m^3 respectively (see fig. 12). On the basis of above, 24 hour average SO_X and NO_X concentration in the Gwalior worked out to be 14.8µg/m^3 and 20.0µg/m^3 respectively (see fig. 16). These values are under the permissible limit (80µg/m^3 each) prescribed in the guidelines of CPCB manual for residential area. At Rayaru maximum SO_X and NO_X concentration (18.4µg/m^3 and 37.0µg/m^3) was observed during day shift. However, minimum concentration of SO_X and NO_X is observed to be (15.8µg/m^3 and 14.8µg/m^3) at Rayaru during day shift and evening shift respectively. At Gole Ka Mandir site maximum SO_X and NO_X concentration (21.5µg/m^3 and 61.8µg/m^3) was observed during evening shift. However, minimum concentration of SO_X and NO_X at GKM was observed during day shift (10.5µg/m^3 and 10.7µg/m^3). The SO_X and NO_X concentrations of MPCT College Triangle were observed to considerably less in comparison to other two sampling points. Maximum and minimum concentration of SO_X at this location is measured to be 11.7µg/m^3 and 8.8µg/m^3 during early morning shift and evening shift respectively. However, Maximum and minimum concentration of NO_X at this location is measured to be 11.42µg/m^3 and 8.60µg/m^3 during evening shift and early morning shift respectively. On the basis of above results it is estimated that the average concentration of SO_X and NO_X in city is maximum (17.2µg/m^3 and 29.37µg/m^3) during day shift and evening shift respectively. However, minimum 24 Hour average concentration of SO_X and NO_X is (12.0µg/m^3 and 10.9µg/m^3) during day shift. (Pl. refer figure 18, 19, 20)

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VI. DISCUSSION

Result shows that at all the three stations during all three shifts, the concentration of PM10 exceed the permissible limit (100µg/m^3) prescribed in guidelines of CPCB manual. At the Rayaru Chouraha, the higher concentration of PM_{10} may be attributes to the location of Banmore industrial area, Indian oil Depot, wine factory, agricultural process and open burning etc. Rayaru Chouraha is the junction of two major highways (NH75 & NH 3) because of which the traffic gets congested and long queue of heavy vehicles is observed in its vicinity. Stone mines are also located near this junction within reasonable distance. All the above mentioned factors may be jointly responsible for higher concentration of PM_{10} at this station.

In the centre location of city i.e. the Gole ka Mandir chouraha, the concentrations of PM_{10} is measured to be very high (446.2-994.2µg/m^3). Pollutants from the Birla Nagar industrial area and stone mines areas located behind the Deen Dayal Nagar area may be responsible for the higher value of PM10. Other factors such as heavy traffic, traffic congestion, improper signal timing, improper geometry of junction, mixed traffic, poor road marking, pedestrian crowding, lack of greenery near junction, use of adulterated fuel, etc. may also be responsible for the higher concentration of PM10. GKM chouraha is the junction of three satellite town of Gwalior i.e. Lashkar, Gwalior, Morar. Therefore density of public transport (Tempo, vikram, Buses) is also very high. Further, counting of agricultural vehicles like Tractors, Loading Vehicles is also considerably high. Gathering of vendors along the roads on either sides of road near Chouraha increases the traffic friction causing reduction in average speed of all vehicles. As per the registration data available with the regional transport office (RTO), approximately one lakh vehicles ply the city road, out of which more than 80% vehicles are two wheelers & three wheelers. Due to constricted road space, poor road surface quality and unplanned traffic, normal vehicular movement is restricted near GKM Chouraha which results in to increase in fuel consumption thereby increasing exhaust emissions. Approximately 60%-70% of the total pollution load at GKM may be contributed to the automobile exhaust pollution.

At the third station i.e. MPCT College Triangle, the concentration of PM10 is observed to be considerably less in comparison to other sampling stations. The nearby area contains adequate vegetation / plantation in Jiwaji University, MP high court, IITTM, collector office, District court, colleges and other institutes. These campuses having green area are located on wind-ward direction of the sampling point. This acts as buffer thereby reducing the contamination of particulate matter.

VII. SUGGESTION & CONCLUSION

Earlier referred Results & Discussion shows that the air quality in the Gwalior city is very poor especially with respect to concentration of PM10. There is an urgent need to take suitable measures to control the high concentration PM_{10} particles in the air. Following are the suggestion for the same.

A. Strict measures must be taken to control dust pollution from stone quarry and stone mining being practices in the vicinity of Gwalior. Water sprinkling or similar methods shall be used to control re-suspension of PM_{10}.
B. Adequate plantation (creation of buffer zone) may be done to prevent the dust pollution from stone mining's.
C. Open burning of agricultural waste, solid waste, shall be strictly banned.
D. Transportation/Traffic is another major cause of increased concentration of PM_{10}. It is suggested that vehicles older than 15 years shall be removed from the road and without no pollution certificate fuel like Diesel and petrol shall not be made available to the vehicles at fuel station. Further, strict checking shall be done regularly to avoid adulteration of fuel. Strict punitive measures shall be taken if adulteration of fuel is reported.
E. Traffic rotaries, traffic signals shall be re-designed for smooth movement of vehicles thereby reducing pollution.
F. Widening of road, removal of obstruction, improvement in riding quality of road surface, re-designing of curves etc. shall be done.
G. Facilities of public transport shall be improved to encourage use of it. Public transport vehicles shall run on CNG, Electric Batteries, and Bio-diesel etc.
H. Peripheral plantation of selective plants shall be done along the major roads to absorb air pollutants.
I. Open transportation of solid waste shall be completely banned.
J. Dust removal (Sweeping) of the roads shall be done regularly. To avoid re-suspension of dust fully mechanized machine shall be used for sweeping.
K. Industries emitting air pollutants located in the close proximity of Gwalior (Malanpur, Banmore, Ghirongi, Birla Nagar etc.) shall be regularly inspected to ensure that pollution control equipments are working satisfactorily in their premises.
L. More water sprinklers shall be provided in road intersection.

M. More parks, gardens and green areas shall be developed to help in prevention and control of PM_{10}.
N. NGO's shall be promoted to help in implementation of pollution control strategies and enhancing public awareness.
O. Timing of schools, offices, institutions etc. shall be staggered to relieve pressure on road. This will enable to reduce traffic born pollution.
P. Public shall be encouraged to carry out plantation in their own premises and public places.
Q. Air pollution control equipments such as scrubbers, separators, precipitators etc. may be used at proper location in the city.
R. The wind coming from state Rajasthan is reported to be heavily laden with dust particles. To prevent this dense plantation on the outskirts of the city shall be done.

Author expects that if above mentioned measures are implemented effectively in the Gwalior city. Air quality of Gwalior will certainly get improved and resident of Gwalior will breathe good quality of air.

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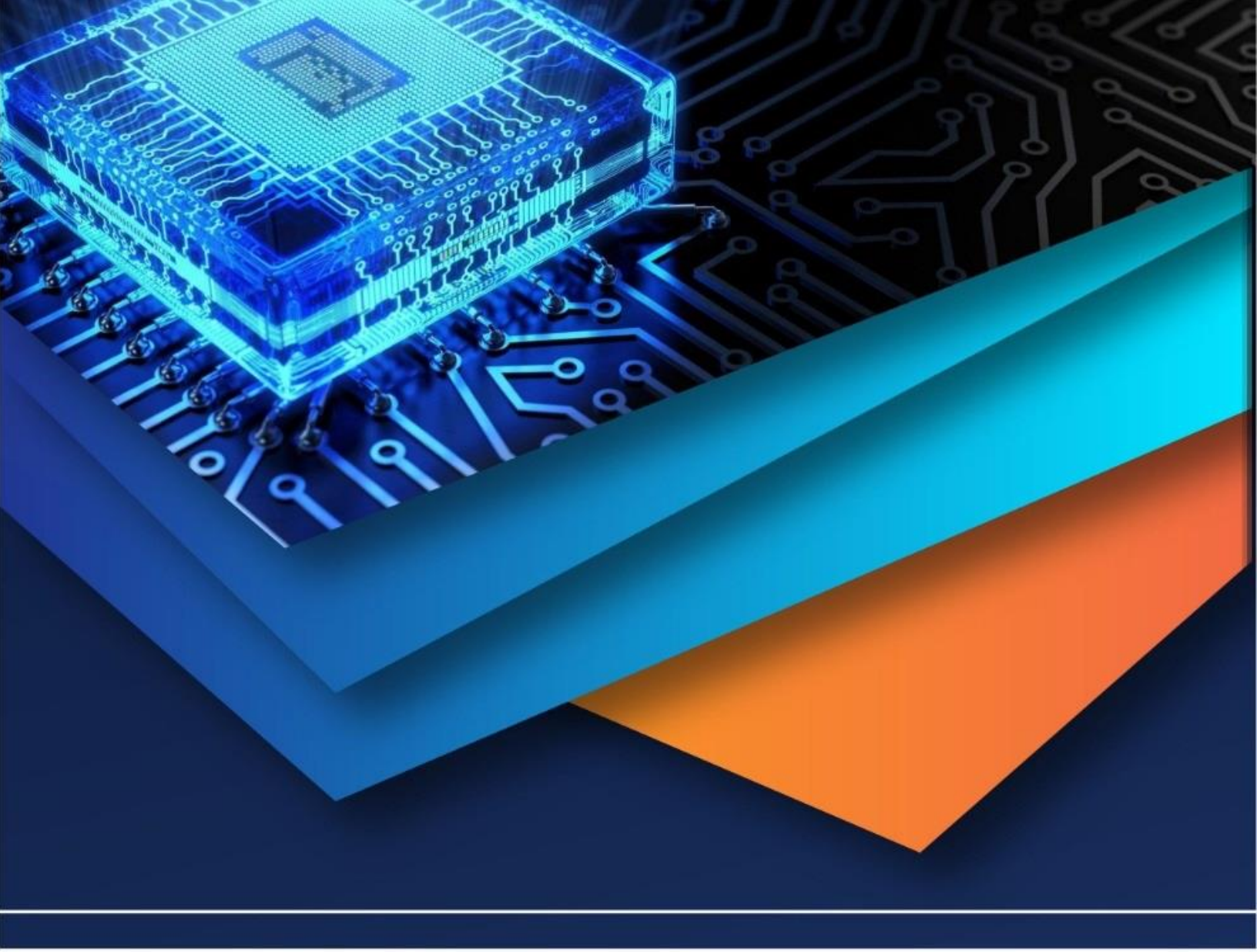

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