DETERMINATION OF AIR QUALITY INDEX OVER TSDF-A CASE STUDY OF UDAIPUR

[1]Mayank Vyas, [2]Ruchika Purohit, [2]Pragya Bohra, [3]Dr. Anil Vyas, [4]Dr. S.K. Singh
[1]M.E. Scholar, [2]M.E. Scholar, [3]Associate Professor, [4]Professor
[1]Department of Civil Engineering, M.B.M. Engineering College, J.N.V. University, Jodhpur, Rajasthan, India
[2]Department of Civil Engineering, M.B.M. Engineering College, J.N.V. University, Jodhpur, Rajasthan, India
[3]Department of Chemical Engineering, M.B.M. Engineering College, J.N.V. University, Jodhpur, Rajasthan, India
[4]Department of Civil Engineering, M.B.M. Engineering College, J.N.V. University, Jodhpur, Rajasthan, India

Abstract—Udaipur is well known tourist place in India and is known as "Lake City". A hazardous waste disposal site was constructed in Udaipur for disposal of hazardous waste generated by the various industrial and commercial activities in the state of Rajasthan. The purpose of this paper is to discuss the analysis of the ambient air quality over TSDF site of Udaipur city in terms of air quality index (AQI). The 24-hourly average concentrations of five major criteria pollutants, viz. Particulate matter PM_{10}, $PM_{2.5}$, Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2) and Ammonia(NH_3) at three different locations in TSDF site were measured as per guidelines of CPCB of India. Selected stations were near store Room, security Room roof top and secured landfill. The AQIs were calculated using IND-AQI procedure. Concentration of PM_{10} and PM_{205} was found above the prescribed limit whereas concentration of SO_2, NO_2 and NH_3 was found below the prescribed limits laid down by CPCB of India at all considered sampling points. From the analysis of AQI it is concluded that PM_{10} is governing factor for determination of AQI at all the sampling station. According to AQI over TSDF, this site falls in the category of moderate type. Therefore now it is time to reduce the PM_{10} and$PM_{2.5}$ concentration at site by plantation and or by other means so that air quality is maintained in the nearby area of TSDF.

Index Terms— Air quality index (AQI), PM_{10}, $PM_{2.5}$, CPCB, TSDF

I. INTRODUCTION

Computation of the AQI requires an air pollutant concentration over a specified averaging period, obtained from an air monitor or model. Taken together, concentration and time represent the dose of the air pollutant. Health effects corresponding to a given dose are established by epidemiological research1.Air pollutants vary in potency, and the function used to convert from air pollutant concentration to AQI varies by pollutant. Air quality index values are typically grouped into ranges. Each range is assigned a descriptor, a color code, and a standardized public health advisory. The AQI can increase due to an increase of air emissions (for example, during rush hour traffic or when there is an upwind forest fire) or from a lack of dilution of air pollutants. Stagnant air, often caused by an anticyclone, temperature inversion, or low wind speeds lets air pollution remain in a local area, leading to high concentrations of pollutants, chemical reactions between air contaminants and hazy conditions. On a day when the AQI is predicted to be elevated due to fine particle pollution, an agency or public health organization might advise sensitive groups, such as the elderly, children, and those with respiratory or cardiovascular problems to avoid outdoor exertion. Declare an "action day" to encourage voluntary measures to reduce air emissions, such as using public transportation [2]. Recommend the use of masks to keep fine particles from entering the lungs [4]. During a period of very poor air quality, such as an air pollution episode, when the AQI indicates that acute exposure may cause significant harm to the public health, agencies may invoke emergency plans that allow them to order major emitters (such as coal burning industries) to curtail emissions until the hazardous conditions abate [5]. Most air contaminants do not have an associated AQI [6]. Many countries monitor ground-level ozone, particulates, sulfur dioxide, carbon monoxide and nitrogen dioxide, and calculate air quality indices for these pollutants [7]. The definition of the AQI in a particular nation reflects the discourse surrounding the development of national air quality standards in that nation [8]. Website allowing government agencies anywhere in the world to submit their real-time air monitoring data for display using a common definition of the air quality index has recently become available [9].

Central Pollution Control Board (CPCB) of India has formulated guidelines to calculate AQI and can be calculated as discussed below:

An air quality index is defined as an overall scheme that transforms the weighed values of individual air pollution related parameters (pollutant concentrations) into a single number or set of numbers. The result is a set of rules (i.e. set of equations) that translate parameter values into a more simple form by means of numerical manipulation .If actual concentrations are reported in $\mu g/m^3$ or ppm (parts per million) along with standards, then it cannot be considered as an index. At the very last step, an index in any system is to group specific concentration ranges into air quality descriptor categories. Primarily two steps are involved in formulating an AQI:

(i) Formation of sub-indices (for each pollutant) and

(ii) Aggregation of sub-indices to get an overall AQI.

Formation of sub-indices (I_1, I_2 ... I_n) for n pollutant variables (X_1, X_2,...X_n) is carried out using sub index functions that are based on air quality standards and health effects, Mathematically;

$Ii = f(X_i)$, $i = 1, 2, \ldots n$ [1]

Each sub-index represents a relationship between pollutant concentrations and health effects.

Aggregation of sub-indices, Ii is carried out with some mathematical function (described below) to obtain the overall index (I), referred to as AQI.

$I = F(I_1, I_2, \ldots, I_n)$ [2]

The aggregation function usually is a summation or multiplication operation or simply a maximum operator.

Sub-indices (Step 1)-Sub-index function represents the relationship between pollutant concentration Xi and corresponding sub-index Ii. It is an attempt to reflect environmental consequences as the concentration of specific pollutant changes. It may take a variety of forms such as linear, non-linear and segmented linear [10]

Typically, the I-X relationship is represented as follows:

$I = \alpha X + \beta$ [3]

Where,
α =slope of the line,
β = intercept at X=0.

The general equation for the sub-index (Ii) for a given pollutant concentration (C_p); as based on 'linear segmented principle' is calculated as:

$$I_i = \left[\left\{\frac{I_{HI} - I_{LO}}{B_{HI} - B_{LO}}\right\} \times (C_P - B_{LO})\right] + I_{LO} \quad [4]$$

Where,
I_{HI} = AQI value corresponding to B_{HI}
I_{LO} = AQI value corresponding to B_{LO}
B_{HI} = Breakpoint concentration greater or equal to given concentration.
B_{LO} = Breakpoint concentration smaller or equal to given concentration
C_p= Pollutant concentration

Aggregation of Sub-indices (Step 2)-Once the sub-indices are formed, they are combined or aggregated in a simple additive form or weighted additive form:

Weighted Additive Form I = Aggregated Index = $\Sigma W_i I_i$ (For i = 1, 2, 3 …... n) [5]

Where, $\Sigma W_i = 1$

Ii = sub-index for pollutant i
n = number of pollutant variables
W_i = weightage of the pollutant

Root-Sum-Power Form (non-linear aggregation form) [6] I = Aggregate index = $[\sum I_i^{\,p}]^{(1/p)}$

Where, p is the positive real number > 1.

Root-Mean-Square Form [7] I =Aggregate index = $\{1/k\,(I_1^{\,2} + I_2^{\,2} + \ldots\ldots\ldots\ldots I_k^{\,2})\}^{0.5}$

Min or Max Operator [8] I = Min or Max ($I_1, I_2, I_3 \ldots\ldots\ldots\ldots, I_n$)

II. Treatment, Storage and Disposal of Hazardous Waste

Treatment of Hazardous Waste

Hazardous waste can be treated by chemical, thermal, biological and physical method Chemical methods include ion exchange, precipitation, oxidation and reduction, and neutralization etc. The chemical, thermal, and biological treatment methods outlined changes the molecular form of the waste material. Physical treatment, on the other hand, concentrates, solidifies, or reduces the volume of the waste.

a. Physical treatment- "Physical methods don't destroy wastes; instead, they change them into forms that are easier to treat further or to dispose. In addition physical treatment; screening, sedimentation, flotation, filtration and centrifugation; dialysis, reverse osmosis, ultra filtration and electro dialysis evaporation; distillation /stripping; solvent extraction and adsorption.11

b. Chemical treatment- Chemical treatment methods use different properties of a chemical to alter its hazardous elements. Chemical reactions alter the chemicals, destroying the hazardous elements or producing new compounds that are easier to treat or dispose of." Chemical reactions or processes could for example chemically neutralize, oxidize, reduce, hydrolyze, precipitate, de-chlorinate and/or catalytically detoxify the component that renders the waste hazardous.12

c. Biological Treatment- In these process, the organic materials is used as substrate for microbial growth, resulting in the decomposition of the organics. Inorganic contaminants present in the waste are not treated by biological process and as a result are present in the sludge or effluent discharge. The presence of water is essential for all biological treatment process oxygen is also required for aerobic treatment, enabling these processes to decompose both simple and complex organic compounds. Anaerobic processes, due to the absence of oxygen. May only decompose simple organic such as carbohydrates, proteins, alcohols and acid.

d. Thermal Treatment- These are the treatment processes which involve the application of heat to convert the waste into less hazardous forms. It also reduces the volume and allows opportunities for the recovery of energy from the waste. Products from combustion of organic wastes are carbon dioxide, water vapour & inert ash. Other products can be formed Depending on waste composition.

Storage of Hazardous Waste

Hazardous waste is commonly stored prior to treatment or disposal, and must be stored in containers, tanks, containment buildings, drip pads, waste piles, or surface impoundments that comply with the Resource Conservation and Recovery Act (RCRA) regulations. A storage location for health-care waste should be designated inside the health-care establishment or research facility. The waste, in bags or containers, should be stored in a separate area, room, or building of a size appropriate to the quantities of waste produced and the frequency of collection. Unless a refrigerated storage room is available, storage times for healthcare waste (i.e. the delay between production and treatment) should not exceed the following: temperate climate: 72 hours in winter 48 hours in summer warm climate: 48 hours during the cool season 24 hours during the hot season Cytotoxic waste should be stored separately from other health-care waste in a designated secure location.

Disposal Method of Hazardous

The hazardous wastes after treatment are converted into a suitable form before they are sent for ultimate long term disposal. The techniques that were used for this purpose are immobilization, stabilization, fixation, and solidification. These techniques involve different physical and chemical processes which ultimately convert the hazardous wastes into different acceptable forms for land disposal.

III. Calculations and Results

RamkyEnviro Engineers Ltd. has set TSDF (Treatment, storage & disposal facility) site at Udaipur in 21acre of land near village Debari in Udaipur District of Rajasthan state. The location of TSDF site is located 14 km NE of Udaipur city, 2km away from NH-76 the Location map TSDF Plant at village Debari in Udaipur shown in Figure 1. The plant is operational under environmental clearance (EC) granted by Ministry of Environment and Forests vide letter CFE on 28.07.2005 and consent to operate (CTO) granted by Rajasthan state pollution control board. For analysing air quality index around the area of TSDF, three locations near store room, secured landfill, Room roof trust were selected.

Monitoring of Pollutants

As per CPCB guidelines five criteria pollutants concentrations (i.e. PM_{10}, $PM_{2.5}$, NO_2, SO_2 & NH_3)were measure at three selected sampling stations, location in TSDF and the sampling of the above pollutants was recorded continuously on 8 hourly basis for 24 hours.. The components covered for study of the area has been tabulate in table 1.

Table 1 Attribute, Parameters & Frequency of Monitoring

Attribute	Parameters	Frequency of Monitoring
Air quality monitoring	$PM_{10,}$ $PM_{2.5}$, SO_2, NO_2, NH_3	8 hourly samples for $PM_{10,}$ $PM_{2.5}$, SO_2, NO_2, NH_3 for 24 hours covering Three locations. Monitoring as per NAAQM norms.

Table 2 Pollutants concentration & AQI at near store Room

Month	Pollutants	Concentration in $\mu g/m^3$	Sub Index	AQI
December	PM_{10}	90.72	90.72	90.72
	$PM_{2.5}$	32.68	54.46	
	SO_2	16.05	20.06	
	NO_2	11.4	14.25	
	NH_3	1.42	0.355	
January	PM_{10}	68.71	68.71	68.71
	$PM_{2.5}$	24.86	41.43	
	SO_2	14.22	17.77	
	NO_2	10.99	13.73	
	NH_3	1.39	0.345	
February	PM_{10}	70.64	70.64	70.64
	$PM_{2.5}$	18.9	31.5	
	SO_2	23.31	29.01	
	NO_2	14.80	18.5	
	NH_3	1.38	0.344	
March	PM_{10}	69.87	69.87	69.87
	$PM_{2.5}$	30.93	51.54	
	SO_2	24.26	30.32	
	NO_2	13.8	17.25	
	NH_3	1.37	0.344	

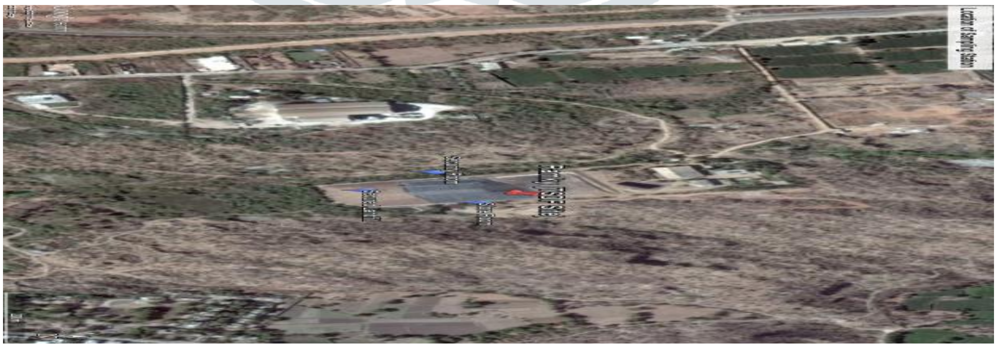

Figure 1 Location map of sampling stations

Table 3 Pollutants concentration & AQI at Security room roof top

Month	Pollutants	Concentration in $\mu g/m^3$	Sub Index	AQI
December	PM_{10}	92.38	90.38	90.38
	$PM_{2.5}$	34.01	56.68	
	SO_2	16.51	20.63	
	NO_2	11.8	14.75	
	NH_3	1.24	.31	
January	PM_{10}	103.30	102.30	102.17
	$PM_{2.5}$	35.121	55.12	

	SO_2	17.15	21.43	
	NO_2	12.39	15.48	
	NH_3	1.44	.36	
February	PM_{10}	87.63	87.63	87.63
	$PM_{2.5}$	24.63	41.083	
	SO_2	14.7	18.375	
	NO_2	11.77	14.71	
	NH_3	1.43	.357	
March	PM_{10}	99.22	99.22	99.22
	$PM_{2.5}$	38.42	64.03	
	SO_2	29.28	36.6	
	NO_2	23.09	28.86	
	NH_3	1.40	.35	

Table 4 Pollutants concentration & AQI at Secured land

Month	Pollutants	Concentration in $\mu g/m^3$	Sub Index	AQI
December	PM_{10}	93.34	93.34	93.34
	$PM_{2.5}$	34.62	57.7	
	SO_2	13.5	16.87	
	NO_2	11.37	14.46	
	NH_3	1.43	.357	
January	PM_{10}	103.39	102.26	102.26
	$PM_{2.5}$	33.67	56.11	
	SO_2	20.28	25.35	
	NO_2	11.59	14.38	
	NH_3	1.40	.35	
February	PM_{10}	105	110	110
	$PM_{2.5}$	34.75	57.91	
	SO_2	14.78	18.375	
	NO_2	11.77	14.71	
	NH_3	1.38	.345	
March	PM_{10}	100.06	100.4	100.4
	$PM_{2.5}$	40.51	67.51	
	SO_2	30.61	38.26	
	NO_2	18.88	23.6	
	NH_3	1.37	.345	

It can be concluded from the calculated AQI values for December, January, February & March month at near store room varies from 90.72 in December to 68.71 in January. The AQI is decreased from about 90 to nearly 70, from December to January –March. At sampling station .At sampling station near security room roof top, calculated AQI values for December, January, February & March month varies from 87.63 in February to 102.17 in January. The AQI is increasing from about 90 to nearly 102, from December to January and then decreased to about 90 in the month of February- March. At sampling station near at Secured land calculated AQI values for December, January, February & March month varies from 93.34 in December to 100 in February. The AQI is increasing from about 90 to nearly 110, from December to February and then decreased to about 100 in the month of March.

AQI change over TSDF shows uneven trends. This may be because of average value of $PM_{2.5}$ is almost same at all the sampling station. SO_2 and NO_2 concentration is almost same up to February but increasing in March. It may be because of increasing activity of bio-degradation of organic matter at landfill site. The concentration of NH_3 is be showing a decreasing trend from Dec to March .It may be because of decreasing rate of anaerobic decomposition of organic matter at land fill site and increase of wind velocity at site. The AQI is minimum at near store room but it is maximum at land fill site. AQI over TSDF is in the rage of 100 which indicates site is moderately polluted.

IV. Conclusion

Study of air quality index for the TSDF site of Udaipur city is done so that air pollution levels affecting health of people can be known. The overall AQI can give clear view about ambient air and critical pollutants mainly responsible for the deterioration of the air quality of air. An effort has been made to find out the pollution level by finding air quality index. Monitoring station were set up at three different location point i.e. Security Room Roof Top, Near store Room and Secured landfill site .IND-AQI value were calculated for each site to check different level of pollution within the study area . Concentration obtained for PM_{10}, $PM_{2.5}$ at all sites is above the standards level laid by down by CPCB while SO_2, NO_2 and NH_3 concentration at all sites is within the standard limits. From the analysis it is concluded that PM_{10} is governing factor for AQI, at all the sampling station. The air quality of landfill site is almost fall in the category of moderate type. Therefore now it is time to reduce the PM_{10} at site by plantation and or by other means so that air quality over TSDF site can be maintained.

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