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Determining the atmospheric stability classes for Mazoe in Northern Zimbabwe

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ABSTRACT

The paper presents the method that was used in determining the atmospheric stability classes for a place called Mazoe Citrus situated in Northern Zimbabwe for two consecutive years, 2011 and 2012. The stability classes are an important tool to be used in the environmental impact assessment for an area before an industrial power plant is set up. The study has shown that conditions favoring neutral stability are prevalent and that there is moderate to strong winds with slight insolation and a cloud cover of more than 50% for 60% of the time

Key words: *stability class, effluent, insolation, temperature*

I. INTRODUCTION

The tendency of the atmosphere to resist or enhance vertical motion and thus turbulence is termed stability. It is related to both the change of temperature with height, called the lapse rate and the wind speed. A neutral atmosphere neither enhances nor inhibits mechanical turbulence. An unstable atmosphere enhances turbulence, whereas a stable atmosphere inhibits mechanical turbulence. The turbulence of the atmosphere is by far the most important parameter affecting the dilution of a pollutant [1]. The effluent dilution increases with increase in atmospheric instability. The most commonly used atmospheric stability classification is that of Pasquill originally developed in 1961[2], and later modified by Gifford in the same year, and referred to as the Pasquill-Gifford (P-G) stability class.

II. METHODS OF DETERMINING THE ATMOSPHERIC STABILITY CLASSES

There are many methods of determining the atmospheric stability classes [3] but the most commonly used ones are; the simplified method, the modified method and the temperature lapse rate method. However the study concerns the first two methods and the temperature lapse rate was not used.

III. THE SIMPLIFIED METHOD

The method uses the wind speed, insolation, and cloud cover to determine the atmospheric stability classes. The reliability of dispersion estimates from this method is not good but may be used in preliminary site survey. The unreliability is mainly due to human error in determining the cloud cover [4]. The method is summarized in Table 1.during the day, strong refers to the incoming solar radiation when the solar elevation is greater than 60°, while moderate refers to incoming solar radiation when the solar elevation lies between 35° and 60°. If the solar elevation is below 35°, then the incoming solar radiation is referred to as slight. The letters (A-F) refers to different combinations of these conditions as shown in the tables.

Table 1: the simplified method classification criteria

	DAY Incoming solar radiation			NIGHT (cloud)	
Wind speed (m/s)	Strong	Moderate	Slight	>4/8	< 3/8
< 2	A	A-B	B	-	-
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

IV. THE MODIFIED METHOD

This is the method that have been used in this work and it uses wind speed, solar radiation, net radiation, ambient air temperature and wind direction to determine the atmospheric stability classes. This method has been chosen because it is fairly reliable following the reliability of instruments used to collect the data. The method is shown in table 2 and 3 below. U is the wind speed (m/s) at a height of 10 m above the ground; R_D is the solar radiation (Langley/hr). R_N is the net radiation during the night.

Table 2: The modified method criteria (During the day)

U	**Stability class (Day)**			
	$R_D \geq 50$	$50>R_D \geq 25$	$25>R_D \geq 12.5$	$12.5 >R_D$
U<2	A	A-B	B	D
2≤U<3	A-B	B	C	D
3≤U<4	B	B-C	C	D
4≤U<6	C	C-D	D	D
6≤U	C	D	D	D

Note: 1Lahgley = 1 Cal. Cm^{-2} = 4.187 $J.cm^{-2}$

Table 3: The modified method criteria (During the night)

U	**Stability class (NIGHT)**		
	$R_N>-1.8$	$-1.8 \geq R_N>-3.6$	$-3.6 \geq R_N$
U<2	D	-	-
2≤U<3	D	E	F
3≤U<4	D	D	E
4≤U<6	D	D	D
6≤U	D	D	D

V. MATERIALS AND METHODS

The required environmental parameters were measured using the appropriate sensors connected to a data logger.

1 SOLAR RADIATION

The solar radiation depends upon the location and has pronounced effects on the type and rate of chemical reaction in the atmosphere. It affects the ambient air temperature and hence the air convection and mixing. Therefore its determination is very important for the sake of air pollution modeling. A CM11 pyronometer (Kipp and Zonen, Delft, Netherlands), installed 2.1 m above the ground was used to measure the global solar radiation , while the net radiation was measured using a Q-7.1 net radiometer (radiation energy balance systems, Seattle, USA), mounted at 0.8 m above the ground. The pyronometer contains a sensor installed on a horizontal surface that measures the intensity of solar radiation. The sensor is protected and kept in a dry atmosphere by a glass dome that should always be wiped clean. The Net all wave radiation is then measured by recording the difference in output between the sensor facing upward and downward. The CM 11 pyronometer is suitable for measuring global sun plus sky radiation. This also is a measurement of energy flux density for both direct and diffuse radiation passing through a horizontal plane of known unit area. The pyronometer was set on a level surface free from any obstruction to either direct or diffuse radiation. It has got a photodiode, shunted by a resistor, which produces a voltage output. Using the CR23X data logger and the P2 command (Voltage measurement command in the CR23X), the output voltage was measured every two seconds. The voltage obtained for each two second interval was converted to W/m^2 by linear regression equation obtained through calibration.

2 WIND SPEED AND DIRECTION

Pollutants are dissipated in the atmosphere by both horizontal and vertical movements of wind. In general, the greater the wind velocity, the greater the dilution. As the wind speed at a given location varies with time, it is necessary to express it as an average over a given time interval. The wind speed and direction were measured using a wind sentry set mounted 1.9 m above the ground. The anemometer was used to measure the wind speed.

3 THE CR23X MICROLOGGER

This is a portable, rugged and powerful data acquisition system. All the sensors mentioned above were wired to the data logger accordingly and programmed in such a way that the data for every five minutes interval was collected. The operating voltage of the data logger was kept between 12 V and 16 V from the AC mains drawn from nearby pump house and sampling interval was 15 seconds averaged over a 5- minute’s period.

VI. RESULTS

Determination of the atmospheric stability classes was done using a developed computer program. Generally, it was observed that the stability classes peaks during mid day due to larger net radiation. The typical daytime stability classes (A, B and C), start increasing significantly around 0700 hrs in the morning and stop decreasing significantly at around 1700 hrs. The D, E and F stability classes which are typical night classes also penetrate into daytime. Class A is very unstable and corresponds to hot, calm days which lead to the greatest amount of dispersion. A plume of smoke is broken up and spread widely. The neutral class D can occur during the day or night and corresponds to windy days or to the transform times of dawn and dusk. This is the most frequently occurring stability class. The stable classes (E and F) only occur at night. Class F is very stable and corresponds to nights with low winds. A plume experiencing “F” stability will suffer very little dispersion. Overally, it was discovered that the hourly accumulation of the stability classes depends upon the season.

Table 4: monthly distribution of the stability classes for the year 2011

MONTH	FREQUENCY OF STABILITY CLASS %					
	A	B	C	D	E	F
JAN	16.532	17.608	1.478	53.629	0	10.753
FEB	15.923	18.155	2.535	50.000	0.149	13.244
MAR	12.231	19.758	2.016	46.774	0.672	18.548
APR	12.778	20.556	1.528	32.643	0.556	31.944
MAY	11.022	19.223	1.882	44.624	0.134	23.118
JUN	6.528	22.083	3.333	42.639	0.417	25.000
JUL	4.435	22.043	5.782	39.382	1.075	27.282
AUG	6.855	22.043	6.317	24.597	0.672	39.516
SEP	7.917	23.056	5.972	14.722	1.528	46.806
OCT	5.278	15.278	4.306	14.306	5.000	55.833
NOV	7.222	19.028	7.639	27.222	2.083	36.806
DEC	11.425	15.945	3.226	31.989	0.806	36.559

From the frequency distribution shown, we note that the stability classes on a yearly basis is such that D>F>B>A>C>E. We see that class A have high frequencies at the beginning of the year and attains its lowest value in July. As for atmospheric stability class B, there is no remarkable change throughout the year. Its frequency almost remains the same. For class D, high values above 50 % are observed in January. However, its probability of occurrence decreases with month until it attains its lowest value in September through October, from which again it start to increase. Stability class E always has low values whereas class F has low values in January from which it starts to increase attaining maximum value in October. It seems that class F is the opposite of class D.

Table 4: Monthly distribution of atmospheric stability classes for the year 2012**.**

STABILITY CLASS	MONTHLY STABILITY CLASS FREQUENCY %						
	FEB	MAR	APR	MAY	SEP	OCT	NOV
A	0	20.2	19.0	16.9	14.1	13.6	12.2
B	0	20.0	18.9	18.5	23.3	24.2	20.6
C	10.6	0.94	0.69	2.0	2.0	2.4	5.9
D	89.4	58.9	61.4	62.5	60.6	59.9	61.5
E	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0

Comparing with the year 2011, the sequence of stability class distribution on a yearly basis is such that D>B>A>C. the classes E and F did not occur for the whole of the 2012 year. However, it can be seen that the stability class D dominates for the whole period under consideration, with the highest frequency distribution being 90% in February of 2012, and the minimum is 155 in September of 2011. For the year 2012, the monthly occurrence of stability class D is almost constant from March to December, with a value that is about 60% of all the stability class distribution. This is in accordance with Pasquill classification criteria. This implies that the atmosphere was mainly neutral for the year 2012. Classes A and B are almost equally distributed, translating to the fact that for at most 20% of the time, the atmosphere is extremely unstable to moderately stable. The distribution of these classes has not significantly changed for the whole of the period under study. Class C, interpreted as being slightly unstable is the second least distributed occupying at most 10% of the time as observed in February of 2012. It is mostly observed from 1100 hrs in the morning to 15 00 hrs in the afternoon. This is the time of maximum solar radiation on the site. At most two counts of class C are observed. Class E is hereby observed occupying a nearly constant percentage of time which is 20 % of the whole period from January 2011 to December 2012, with very slight variation. Class f which represents a moderately stable atmosphere shows a remarkable variation. In the year 2011, it occupied the atmosphere with competitively high frequencies, but in the year 2007 it did not occur at all.

VII. CONCLUSION

From the analysis done, it can be seen that the atmosphere for the climate of Mazoe Citrus area site, is in most of the time neutral. The conditions favoring neutral stability are prevalent. There is moderate to strong winds with slight insolation and a cloud cover of more than 50% for 60% of the time. That the atmosphere is predominantly neutral implies that it does not enhance or resist vertical motion. Any effluent released into the atmosphere has a tendency to form a plume which is shaped like a cone. Therefore if the source of the effluent is highly elevated, it will not contribute to much pollution on the ground. But if the effluent source is near the ground, it might encourage the effluent to sit on the ground.

REFERENCES

[1] Canepa. E, Dallorto. L, Ratto C.F, Plume rise description in the code SAFE AIR. *International journal of environment and Pollution,* 14 *(6),* 2000, 235-245.

[2] Essa, K, Mubarak S, Elsaid F, Effects of plume rise and wind speed on extreme values of air pollutants concentration. *Meteorology and Atmospheric Physics; Sprigler 93(3),* 2006, 247-253.

[3] Finnd K. Y, Lamb B leclers M.Y, Lovejoy S, Multifractional analysis of line source plume concentration in surface layer flows. *Journal of applied Meteorology 40*, 2001, 229-245.

[4] Georgopoulos P.G, sanfield J.H, Instanteneous concentration fluctuations in point source plumes, *AlChE journal 32*(10), 1986, 1042-1654.

[5] Gifford, F.A, Atmospheric transport and diffusion over cities; *Nuclear safety 13*, 1972, 391-402.

[6] Slade D.H, Meteorology and Atomic Energy,(National information services,1968)