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# AIR DISPERSION MODELLING CALCULATOR

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## ABSTRACT

*The study of the atmospheric dispersion modelling is a specialized research area that holds great importance in the human health and emergency management industries (among others disciplines). The World Health Organization states that over 2.5 million people die each year from causes directly attributable to air pollution, with 1.5 million of these deaths attributable to air pollution. Several pathways into the human respiratory system will cause severe damage and lead to death, so there significant importance in preventing emission from moving into open air.*
*Modelling an emission plume requires knowledge of the source, the state of the atmosphere, and a few assumptions to simplify the physics of the model. Although a mathematical model tries to capture the closest approximation to reality, they still can be used operationally in time sensitive moments. Ultimately, like many models attempting to mimic a realistic phenomenon, the main goal is to prevent human fatalities and ecological disasters. In urban settings, the most basic dispersion models do not integrate additional processes (e.g. trapping from buildings, heat plumes from other industrial sources, etc.) so other methods of dispersion modelling are needed (e.g. CDF modelling, particle track modelling, GIS models[1] ).The most general model considers the dynamics of advective and diffusive movements in both the horizontal and the vertical directions. Horizontal advection is determined by mean wind speeds, whereas the vertical advective force is gravitational (Okubo 1989). The model doesn't consider fumigation or trapping characteristics that plumes experience in transition from stable to unstable atmospheric conditions or obstructions to buildings.*

**Keywords*: Air Pollution , Gaussian Model , Plume ,Chimney ,Concentration Calculator***

## 1. INTRODUCTION:

Our aim in this project is to guide the entire mathematical modelling process, from the original conception of the model to the interpretation of results in the context of an actual industrial application. We begin by deriving the Gaussian plume solution to the advection-diffusion equation, investigating its mathematical properties, and drawing conclusions regarding the usefulness and limitations of the Gaussian plume approach. The model is illustrated using a simplified version of an real industrial emissions scenario in airborne contaminants are released from a large smelting operation. Throughout the discussion of the plume model and associated inverse problem, we provide details of various derivations that although elementary, are not easily found in the literature or textbooks on the subject. Consequently, we hope that this material will also be a useful reference not only for applied and industrial mathematics, but also for environmental engineers and other practitioners who use Gaussian plume and related models in their everyday work. The contaminant concentration can found according to Gaussian Model are:

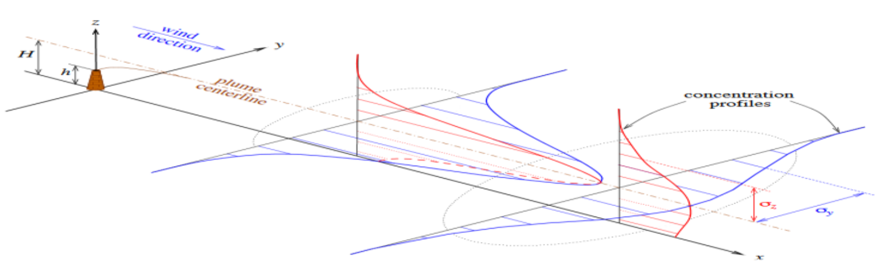


**Fig 1 : Cross-section Concentration Profiles Downwind of Point Source Release**

## 1.1 Gaussian Plume Model Case Study:

This model can be built using virtually any computational tool. Spreadsheets, especially the newer ones with the ability to do table lookups, are particularly well-suited for this case study. A programming language such as Fortran or C, or tools like Mathematica or MathCAD, also are suitable computing environments for this project.

For this model, you will need ten input parameter[2]:

the height of the stack above the ground (in meters)

- The diameter of the opening of the stack (in meters)
- The velocity of the gas emitted from the stack (in meters per second)
- The temperature of the gas as it exits the stack (in degrees Celsius)
- The rate at which pollution is emitted from the stack (in grams per second)
- The atmospheric stability in terms of one of six categories
    1. Very unstable (Class A )
    2. Moderately unstable (Class B )
    3. Slightly unstable (Class C )
    4. Neutral (Class D )
    5. Somewhat Stable (Class E )
    6. Stable (Class F )
- The number of wind velocities that you wish to investigate
- The wind velocities (separated by commas)
- The number of distances downwind to calculate
- The actual distances downwind

The atmospheric stability categories accounts for the fact that a parcel of air changes temperature **.**

## 2.1 Atmospheric Dispersion Modelling Calculator:

In the field of *environmental engineering*, while working with designing the stacks or environmental impact analysis, sometimes it's important to analyse the air pollution dispersion model. The above formula & the step by step calculation may useful for users to understand how the values are being used in the $C_{max}$ [2]formula, however, when it comes to online for quick calculations, this Gaussian maximum ground level[3] emission concentration calculator in fig 1 helps the user to perform & verify such calculations as quick & easy as possible.

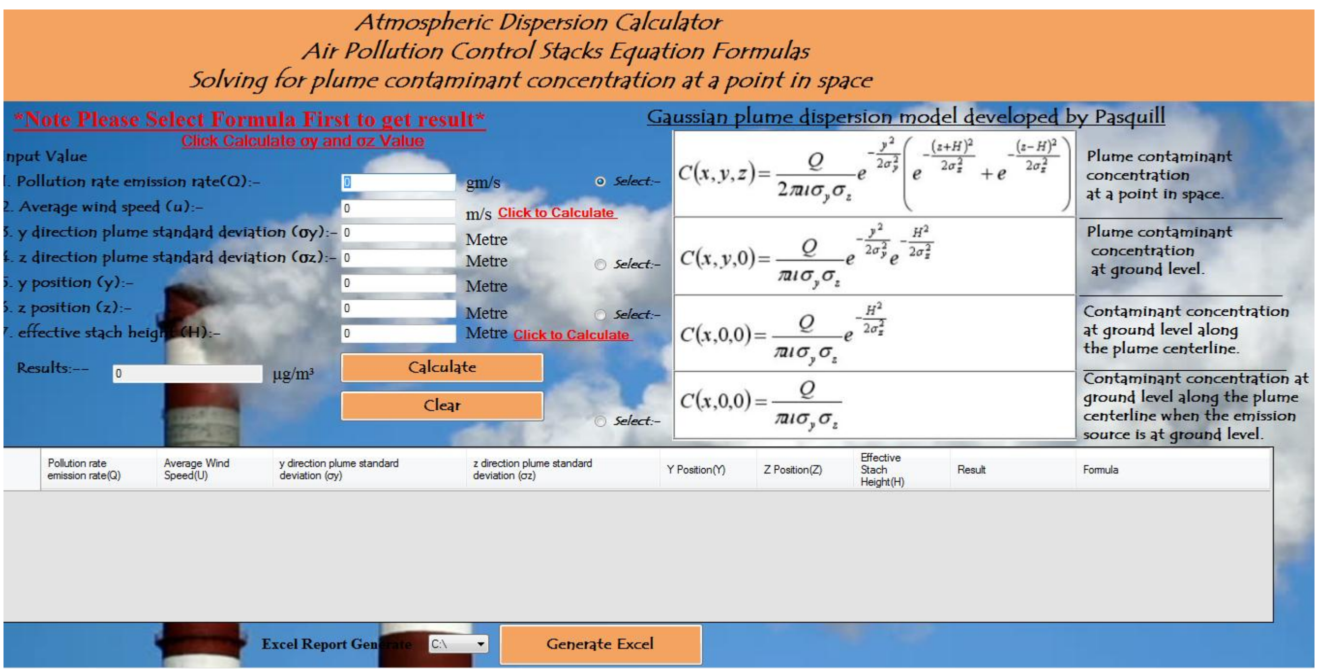


**Fig 2 : Atmospheric Dispersion Modelling Calculator Front Page (for concentration calculation of Plume)**

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## 2.2 Calculation of stability Parameters

The most commonly used method of categorizing the amount of atmospheric turbulence present was the method developed by Pasquill in 1961.He categorized the atmospheric turbulence into six **stability classes** named A, B, C, D, E and F with class A being the most unstable or most turbulent class, and class F the most stable or least turbulent class. Fig 3 shows six classes and provides the parameters of each class.

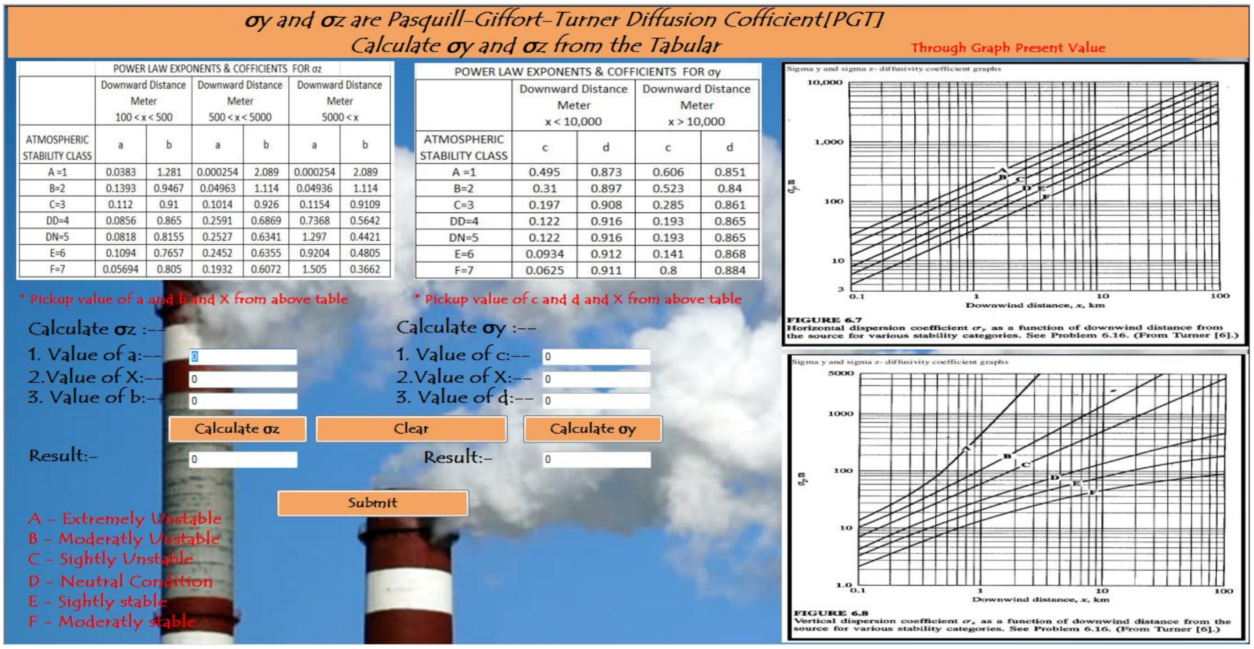


**Fig 3 : Atmospheric Dispersion Modelling Calculator Second Page (for calculation of $\sigma_y$ & $\sigma_z$)**

## 2.3 Calculation of Stack Height , Plume Rise & Wind Speed at Elevation:

To determine Δ*H*, many if not most of the air dispersion models developed between the late 1960s and the early 2000s used what are known as "the Briggs equations."[6] In fig 4 G.A. Briggs first published his plume rise observations and comparisons in 1965.

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| S No | PARAMETERS | VALUES |
|---|---|---|
| **1** | **Stack diameter (m)** | **4.57 m** |
| **2** | **Exit Velocity(m/s)** | **7.62 m/s** |
| **3** | **Exit Temperature(°C)** | **177°C** |
| **4** | **Emission Rate(gm/sec)** | **151 gm/sec(for $SO_2$)** |

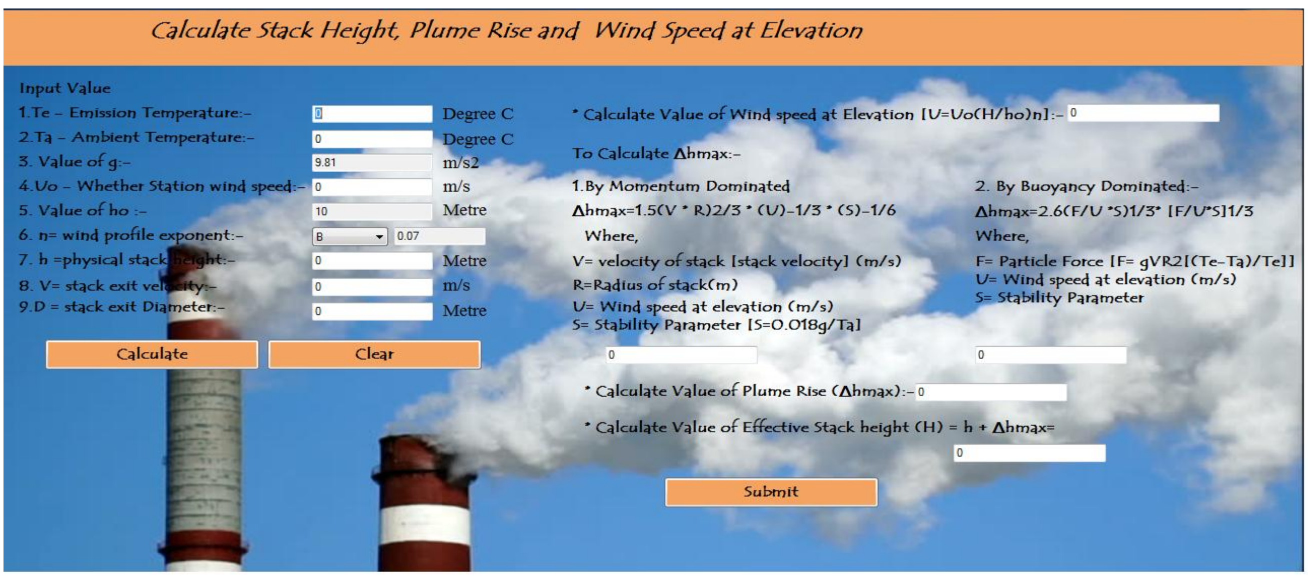


**Fig 4 : Atmospheric Dispersion Modelling Calculator Third Page (for calculation of δH,δu,δh)**

## 3 Parameters used for model:

In order to verify the predictions of the program, a comparison of program output with experimental data collected from the literature is presented. Table 1 shows the stack parameters that were used to perform various simulations. Figure 5 shows a comparison between experimental data, the Gaussian simulation Table 2 of program model and the program results. As can be seen, there is good agreement between the experimental data and simulation results

| | | |
|---|---|---|
| **5** | **Wind Speed at Stack(m/s)** | **2.75 m/s** |
| **6** | **Ambient Temperature(°C)** | **32°C** |
| **7** | **Surface Roughness** | **0.2** |
| **8** | **Boundary Layer Height(m)** | **360m** |
| **9** | **Stability Category** | **A/B/C/D/E/F** |

**Table 1 : showing different parameters use in calculators**

**Table 2 : Showing Concentrations of different Classes in Comparing Form**

| S.No | X DISTANCE | STABLITY CLASSES CLASS A | CLASS B | CLASS C | CLASS D1 | CLASS D2 | CLASS E | CLASS F |
|---|---|---|---|---|---|---|---|---|
| | | CONCENTRATION IN(µg/m³) | | | | | | |
| 1 | 100 | 1.72 | 3.86 | 7.63 | 4.19 | 0 | 0 | 0 |
| 2 | 150 | 1.67 | 2.37 | 5.93 | 1.91 | 3.07 | 2.37 | 0 |
| 3 | 200 | 0.41 | 1.42 | 1.69 | 1.78 | 8.86 | 8.26 | 5.47 |
| 4 | 250 | 18.34 | 0.617 | 1.48 | 2.48 | 1.78 | 1.65 | 5.42 |
| 5 | 300 | 97.95 | 0.05 | 1.09 | 1.31 | 1.38 | 1.54 | 1.16 |
| 6 | 350 | 218.14 | 0.875 | 0.000256 | 1.16 | 7.65 | 8.01 | 1.05 |
| 7 | 400 | 320.69 | 4.93 | 0.009127 | 2.62 | 8.85 | 2.85 | 4.18 |
| 8 | 450 | 383.59 | 15.69 | 0.107 | 1.65 | 1.34 | 2.08 | 1.93 |
| 9 | 500 | 405.82 | 34.9 | 0.63 | 9.8 | 3.03 | 3.28 | 6.63 |
| 10 | 550 | 418.66 | 71.46 | 0.931 | 5.04 | 5.66 | 6 | 2.1 |
| 11 | 600 | 391.16 | 112.75 | 2.92 | 1.11 | 2.29 | 3.33 | 2.49 |
| 12 | 650 | 348.8 | 155.46 | 7.04 | 1.41 | 1.41 | 5.85 | 3.16 |
| 13 | 700 | 304.02 | 195.04 | 14.04 | 1.16 | 2.17 | 4.72 | 5.53 |
| 14 | 750 | 262.28 | 228.81 | 24.22 | 4.95 | 7.45 | 1.84 | 2.41 |
| 15 | 800 | 225.51 | 255.55 | 37.46 | 0.000299 | 1.53 | 4.41 | 3.39 |
| 16 | 850 | 193.98 | 275.3 | 53.33 | 0.001079 | 2.13 | 7.02 | 1.86 |
| 17 | 900 | 167.3 | 288.7 | 71.05 | 0.003234 | 2.08 | 7.68 | 4.66 |
| 18 | 950 | 144.84 | 296.59 | 89.99 | 0.008476 | 1.56 | 6.21 | 6.04 |
| 19 | 1000 | 125.95 | 299.96 | 109.24 | 0.019673 | 9.1 | 4.03 | 4.98 |
| 20 | 2000 | 39.52 | 156.55 | 247.95 | 15.58 | 0.03297 | 0.02878 | 1.51 |
| 21 | 3000 | 16.96 | 78.1 | 179.93 | 65.74 | 1.77 | 1.87 | 8.03 |
| 22 | 4000 | 4.79 | 45.52 | 124.01 | 103.43 | 9.26 | 10.64 | 0.000156 |
| 23 | 5000 | 2.18 | 29.55 | 88.85 | 119.05 | 21.21 | 25.55 | 0.000416 |
| 24 | 6000 | 1.12 | 20.66 | 67.82 | 117.69 | 28.3 | 41.6 | 0.000849 |
| 25 | 7000 | 0.65 | 15.23 | 52.6 | 112.22 | 33.86 | 55.4 | 0.001452 |
| 26 | 8000 | 0.41 | 11.68 | 42.01 | 105.13 | 37.99 | 65.82 | 0.002204 |
| 27 | 9000 | 0.28 | 9.23 | 34.34 | 97.8 | 40.91 | 72.95 | 0.003077 |
| 28 | 10000 | 0.91 | 7.48 | 28.61 | 90.67 | 42.87 | 77.3 | 0.001034 |

## 3.1 Comparison of Different Classes:

As can be seen in the Fig 5 , stabilities A, B, and C refer to daytime hours with unstable conditions. Stability D is representative of overcast days or nights with neutral conditions. Stabilities E and F refer to nighttime, stable conditions and are based on the amount of cloud cover. Thus, classification A represents conditions of greatest instability, and classification F reflects conditions of greatest stability[8]

The stability classes demonstrate a few key ideas. Solar radiation increases atmospheric instability through warming of the Earth's surface so that warm air is below cooler (and therefore denser) air promoting vertical mixing. Clear nights push conditions toward stable as the ground cools which is faster establishing more stable conditions and inversions. Wind increases vertical mixing, breaking down any type of stratification and pushing the stability class towards neutral The tendency of the atmosphere to resist or enhance vertical motion and thus turbulence is termed **stability**. Stability is related to both the change of temperature with height (the lapse rate) and wind speed.

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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 dilution of a pollutant. The more unstable the atmosphere, the greater the dilution. Stability classes are defined for different meteorological situations, characterized by wind speed and solar radiation (during the day) and cloud cover during the night

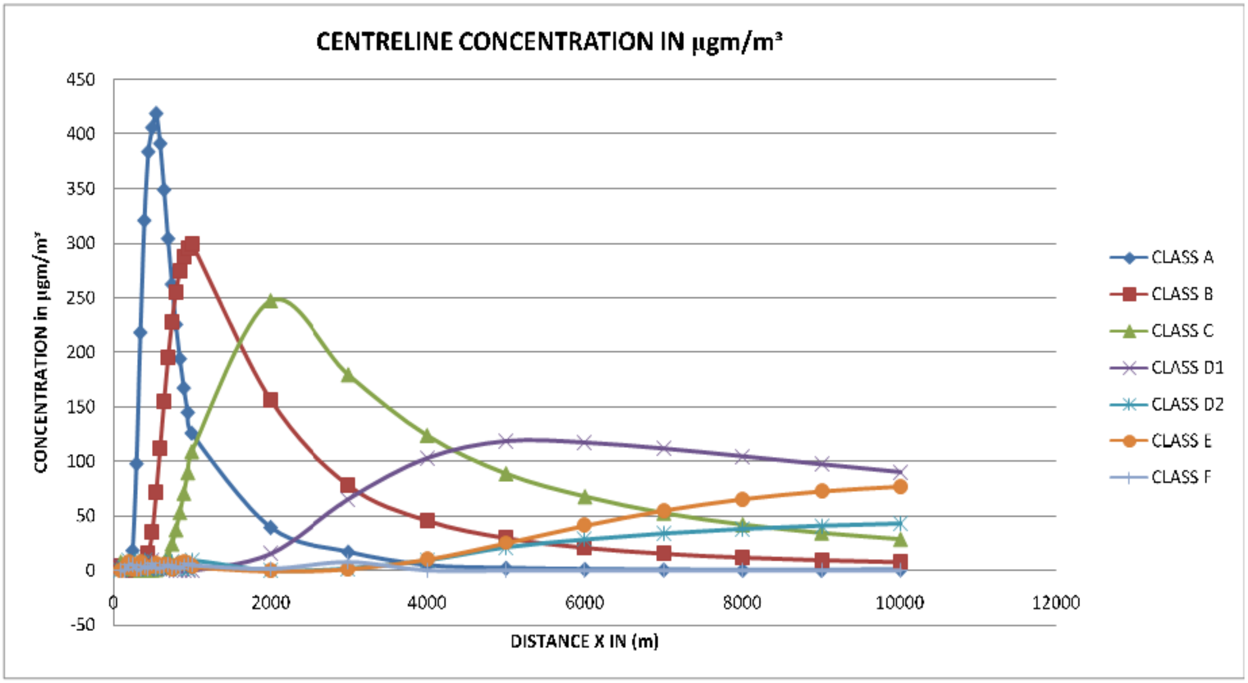


**Fig 5 : Centerline Concentration of Different classes in parameters mentioned**

## 4 Conclusion:

Gaussian dispersion modeling necessitates the knowledge of stability of the atmosphere, mixing height, plume rise, dispersion parameters etc. In India, the methods of obtaining values of these parameters are all taken from available literatures and to ascertain their applicability in Indian context has not gained any attention. Validation of these formulations is thus necessary through extensive monitoring of various parameters. It is thus aimed in this article to propose computational algorithm in order to validate these formulations through extensive monitoring of various parameters. In the process, various strategies of pollution control are elucidated so that the most appropriate combination of industrial activities would be chosen for arriving at an environment friendly air quality. An assessment of suitability of a site for setting up of new industry would thus be possible. However, the full strength of the model[9]proposed can only be exploited if sufficient information on environmental parameters is available for reasonable period of time. In view of the fact of sparse Indian mixing height data, efforts are needed to generate mixing height data.

## 5 Acknowledgement :

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