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Performance Evaluation of CFD Model PANAIR for Air Pollution Dispersion of Industrial Stack Emissions

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Air pollution problem has become a major concern because of rapid industrialization and urbanization especially in cities like Mumbai in India. This has resulted in development of numerous air pollutant dispersion models for prediction so that they can be used for rational air quality management. Conventionally, most popular are Gaussian Plume Models (GPM) which have been widely used for regulatory purposes in most of the countries including India. GPM are simple to use, require less computational time and input data and there are many years of experience supporting these modeling techniques. However, semi-empirical by nature GPM is based on many assumptions and are not able to provide complete understanding of the atmospheric processes and chemical transformations. GPM are refined time to time in order to handle complex flow geometries and multiple sources (e.g AERMOD, ADMS-Urban). AERMOD initially was developed to replace the USEPA regulatory model ISCST3. However, AERMOD currently does not handle downwash, wet and dry deposition and also cannot be used to assess the local effects of complex of buildings on the flow field and turbulence.

In view of the above, Computational Fluid Dynamics (CFD) models are being promoted that can take the effect of complex terrain and also predict short term dispersion of pollutants. CFD can give accurate results even in difficult cases like areas with many buildings in close proximity (e.g. industrial site). Development of CFD software for air pollution dispersion studies in India is very few as they require huge amount of infrastructure and time. Models developed based on CFD are restricted to research purpose and mostly applied for determining the air flow inside the buildings and on structures. Commercial codes based on CFD are available today for calculating fluid flow and dispersion of air pollutants at local scale. However, limited work has been done to test the performance of these models for air pollution dispersion studies.

The objective of this study is to evaluate and validate the performance of CFD model PANAIR for an industrial area in Mumbai. The results of this study will help to determine whether CFD models can be suitable for regulatory purpose. The model used for the study is fluidyn PANAIR (version 3.1.8). This numerical model is tested here for the first time in an industrial region located at Chembur, Mumbai. Listed in Federal Register and recommended by USEPA, PANACHE is an Eulerian, 3-dimensionl CFD code designed to simulate continuous and short-term pollutant dispersion in the atmosphere, in simple or complex terrain. fluidyn – PANAIR is a specialized version of PANACHE which was developed and evaluated in collaboration with ADEME (French Ministry and Environmental Agency). This model has been supplied to our institute from Transoft International, Bangalore for academic purpose. Contrary to probabilistic models, PANAIR uses deterministic approach to analyze the effects of variation of each parameter used for dispersion. Gaussian models are not applicable at a close range from the source (about 100 meters), in calm conditions and also for dispersion of heavy gases, but in such cases PANAIR is most suitable. It incorporates all types of terrain features including, undulating terrain, forests, vegetation, water bodies, road/tunnels, etc. In addition, the surface roughness and the influence of topographical features on the wind field are also taken into account. Thus, although computational time is high for this model, it is capable of giving the short term effects of the pollutants.

Earlier referred as "Gas chamber of Mumbai" the major polluting industries in Chembur are a giant fertilizer/chemical complex, two oil refineries and a thermal power plant. Fertilizer Company called Rashtriya Chemical Fertilizer (RCF) located in this region has been identified as study area because data on hourly ambient air quality, emissions from the stacks and meteorology are available. Also, since NH3 is a pollutant specific to RCF; it will act as a tracer for the study and help in validating the model so stacks of ammonia are chosen for validation study. NSNT solver with k-eps model is used along with log law wind and temperature profile for the performance testing. The size of the domain taken is 8.61 sq km (3.25 km x 2.65 km x185 m height). A non-uniform type of mesh of size (X, Y, Z) is 89, 76, 16 is prepared using standard model. Very fine mesh is prepared around the stacks to capture the stacks appropriately although this will result in large computational time. For simulations wind fields are generated using WINDROSE file for each sector for 12 hours. These sectors are used for dispersion. The results are validated with hourly ambient air quality data for NH3 being monitored in the factory premises at four different locations. The overall results of PANAIR compare satisfactorily with monitored values as shown by the statistical analysis. It has been observed that, at the monitor points which are located in upwind direction of the source, concentration of NH3 is below detection limit (less than 0.1 ppb). However, some of the contours of the NH3 show a very high concentration around the region where monitor points are not located. The model results are compared with other Gaussian models like ISCST3, ADMS and AERMOD. After testing, simulations are performed for other pollutants like SOx, NOx and TSPM. Scenarios are generated for different model options and meteorological conditions. The model can give real time dispersion output in visual form. The results can be used for identifying the hot spots of air pollution in the region as well as the stacks and pollutants which need mitigation measures.

Thus, the performance of PANAIR shows that it can serve as a useful integrated package for industries like RCF, for policy decisions, prediction of accidental releases, monitoring site selection and other management purposes.

Poster Session 1, Formal Poster Viewing (with hors d'oeuvres and cash bar)
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