CHAPTER 1

INTRODUCTION
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Introduction

Uranium is a naturally occurring heavy metal which serves as the basic energy mineral in nuclear power plants. World’s primary nuclear power station was started in the 1950s and Uranium came into lime light among the industrially developed countries like Germany, France etc. In India, earliest Uranium mining and ore processing operations were initiated approximately during 1965 at Jaduguda. Nuclear power generation has gained importance recently with the increased energy needs in India.

To meet the challenge of clean, secure and inexpensive quantitative demand of electricity and to gain energy independence, Government of India has set an immediate goal to obtain an established capacity of 20,000 MWe of nuclear power by the year 2020 So far we could achieve 8000M We (Figure 1.1) [2].

![India’s Nuclear Power Capacity - 25 units to 2016](image)

Source: World Nuclear Association

Figure Error! No text of specified style in document..1: Portrayal of India’s nuclear capacity forecast till the year 2020

Background Information Uranium Mine at Tummalapalle

The mining by UCIL was proposed to meet the Uranium requirements of nuclear power industry in India. In order to increase the Uranium production capability as to achieve the set forth goal, Uranium Corporation of India Ltd (UCIL) is ardently planning to mine and process all possible Uranium reserves identified until now. Development of existing divisions and
establishment of new Uranium production units (mines and mill) have facilitated in meeting the requirement of fuel. Continuous exploration by Atomic Minerals Division (AMD) since 1986 has showed major Uranium deposits exist at many places like Tummalapalle, Peddaghattu, Lambapur, etc., to meet the requirement As mentioned in Figure 1.2, these mine are actively generating Uranium ore in India.

In August 2007 the government of India approved underground mine and mill at Tummalapalle, Kadapa district in association with Uranium Corporation of India (UCIL). Tummalapalle deposit is located in Tummalapalle area in Kadapa (Dist) of Andhra Pradesh and is the most prominent Uranium ore reserves and has 60,000 Tons of Uranium. Here, an imminent vast mineral carbonate deposit hosts strata bound Uranium mineralization, along 160 km long belt of the Vempalle formation. It consists of large tonnage Uranium deposit of impure, low grade dolostone with a grade of 0.15 kg U3O8/Ton approximately.

Figure Error! No text of specified style in document.2: Active Uranium mines in India

Uranium mining generally involves extraction of ore from earth either by underground or open pit method, based upon its depth of occurrence in the earth crust. Afterwards, the ore is crushed and ground for further processing operations, subsequently it undergoes acid leaching to dissolve the Uranium and thereby it is recovered. Uranium is present at fairly low concentrations 4 ppb;
First commercial ore production at Tummalapalle was started in June 2012 using a pioneering pressurized alkaline leaching process, after numerous trail runs and partly completed infrastructure. Tummalapalle project is expected to extend further towards southern mineralization near Motuntulapalle, Muthanapalle and Rachakuntapalle [2]. The Tummalapalle Uranium mining project encompasses 36 km ore belt of Vempalle deposits. All ore extracted through mining is processed by the onsite mill. Uranium ore composition is low grade (0.2 %). Daily production is nearly 3000 Tons and an enhanced production of 4500 Tons per day (TPD) is anticipated in coming years.

In the beginning, the cutoff grade has been considered as 0.02 % of U3O8 and the production was expected to reach 220 Tons of U/yr in future. The ore body is almost continuous over the whole 6.6 km strike length and steadily extending down, up to a depth of 275m. The minerals recognized in the zone which are radioactive are U-Ti complex pitchblende and Coffinite occur as fine grained aggregates closely correlated with pyrite. Additional associated minerals are molybdenite, pyrite, collophane and chalcopyrite. Dolomite, quartz and microcline are the gangue minerals [3]–[5].

Motivation for the Present Work and Need for the Study

Most of the Uranium mining entails high volume-intensive processes and different mining activities might contribute to the release of numerous air borne inhalable contaminants ensuing significant health effects. Along with this contaminants and radiation, mining also generates considerable amount of pollution, from mining, transportation and processing of Uranium ore in the form of particulates (TSP, PM10, particulate Uranium ) into the environment through, burning of fuel, vehicle usage, ore transportation, chemical treatment, construction, etc. Loading, hauling and dumping trucks, scissors trucks, tunnel borers and rock bolters are employed to excavate ore from the mine to stock piles.

Above mentioned mining activities produce air pollutants onsite and the resulting pollution has to be analyzed for health and environmental effects. Mine employees involved in Uranium extraction and processing and people living around will be deeply exposed to Uranium [7]. As per OSHA guide lines, a threshold value of 200 µg/m3 of Uranium on prolonged exposure can cause health problems if it is present as insoluble compound in air [2]. Particulate matter carries numerous dangerous trace metals (Tl, As, Sr, Cd, Cs, Cu, Cr, Mn, Fe, Pb, Ni, Se, U, V, Co, Zn)
and can find its way to lungs through the human respiratory system causing damage [6]. Monitoring of pollutant interaction is particularly pertinent to understand the phenomena controlling the transport and fate of pollutants in atmosphere to understand its impact on surroundings.

Thorough assessment of hazardous elements is of importance in order to reduce and/or determine potential air pollution resulting from likely exodus of toxic metals coming from mine. So, it is imperative to approximate the pollution released from the mining activities that could affect surrounding environment and health of people living around the mine.

Air monitoring studies have many practical applications with different degrees of significance in and around mining facilities. Unfortunately there is still a deficiency of well-established dispersion modeling of airborne particulates from Uranium mining activities.

Metallurgical and Engineering Consultants (India) Limited (MECON) instigated pre mining survey and Environmental Impact Assessment (EIA) in 2006 [7]. Usually air quality monitoring is utilized to survey the pollutant releases into the atmosphere using dust collectors like high volume air samplers. Baseline survey was initiated by the Chemical Engineering Department of JNTUA, Ananthapuramu at the end of November 2010 [1].

Incidentally evaluating these impacts manually at each and every location is practically difficult. Air quality modeling aids better in such situations, so air quality modeling using suitable model could lessen the manual and economic burden as well as give us the accurate situation of the current impacts of mining.

A modern and revised model, AERMOD (AERMOD-American Meteorological Society/Environmental Protection Agency Regulatory Model) was employed to estimate air quality. This model is suggested by the U.S.A Environmental Protection Agency (EPA) to forecast the dispersion and deposition of air pollutants. The USEPA suggests that AERMOD might be employed in complex topographical and meteorological conditions where circumstances vary swiftly with respect to time and space. AERMOD employs Gaussian plume dispersion simulation model representative of the atmosphere and estimates discharged air contaminants from industrial sources such as stacks.

Study Area Topography
The study area is shown in Figures 1.3 and 1.4. Tummalapalle mine and surroundings are located in Vemula Mandal, by 70 km distance from Kadapa, A.P, India, at 14°18'36" N & 14°20'20" N latitudes and 78°15'16" E & 78°18' 03.3" E longitudes. Geographically, Tummalapalle area is in the SW side of the Kadapa basin, close to the Archean crypt. Vempalle formation consists of solid carbonate rock and the belt of the formation is from West-North-West to East-South-East with the total dunk varying between 15° to 17° due N22°E.
Figure Error! No text of specified style in document.4 : Study area
The nearest town is Pulivendula, about 15 km away in the direction of North-West. In this study, impending mine emission impacts were assessed near Tummalapalle site within a 50 km area from the location (modeling domain/study area). The selected area would be adequate to embrace the maximum possible impacts as all emission sources at Tummalapalle were at or in close proximity to ground-level, forcing impacts to diminish as distance from the site increases. Additional emissions from mine other than mining processes include tailpipe discharges from process equipment and vehicles utilized in mining and processing operations. As there was insufficient continuous back ground concentration data was available, to prepare the emission inventory, no back ground concentrations were considered in this study. The data published by National Pollution Inventory [8] for emission factors was used to estimate emission rates during mining.

In order to study the effects of pollutants on atmosphere, we have to understand air pollution, its impact on environment, pollutants responsible for air pollution, their sources etc. A brief account is presented in the following sections.

Air pollution

Air pollution influences our atmosphere and can jeopardize human health and survival of plants and animals. Air pollution results from the buildup of primary and secondary pollutants in association through a temperature inversion. These high pollutant concentration occurrences results considerable effects on community wellbeing and the surroundings.

Primary and Secondary Pollutants

Primary and secondary pollutants responsible in causing damage when present in elevated concentrations are:

- CO, CO2, CH4, and VOCs,
- NO, N2O, and NH3,
- SO2, H2S,
- Fluorides, Chlorides and Bromides and
- Particulate Matter PM10 and PM2.5 in solid/ liquid form.

Dispersion from Emission Sources
Distribution of air pollution into the atmosphere occurs from different sources/contributors, depending on their, shape (Point source, area, line and volume sources), by motion (stationary/mobile) and elevations (surface or ground level, near surface and elevated) from ground. Airborne releases occur during each phase of the mining. Large-scale long term mining like in the case of Tummalapalle has the ability to contribute considerably to air pollution, during construction, development and especially in the operational phase which might in turn cause health hazards. During construction process, road paving, ore loading and transportation, hauling on unpaved roads and wind erosion from exposed area sources/stockpiles, fine particulate dust is produced and it remains suspended in air due to its small size. This dust is fugitive in nature whose sources can’t be defined simply. Collective impacts of stock-piling, crushing, grinding and transport can significantly enhance the atmospheric pollution and deteriorate the quality of personnel occupational environment [9].

Air pollution and its effects on human health demanded to comprehend and identify the links between emission sources, rates and corresponding air quality deterioration and health consequences. After assessing the impacts of sources, it will be likely to plan and execute consistent, practical, and competent policies to improve air quality. Sources recognized as possibly altering air quality in the study area include,

- Mining operations related fugitive emissions,
- Vehicle tailpipe emissions.

The parameters that vary the level of pollution, impact and duration are mentioned below.

**Emission source height (H)**

The height of an emission source above ground is termed as emission source height. It is a vital parameter in dispersion calculation. Due to the thermal lift/inversion in the air, the effective emission height may be above the stack height (thermal augmented region). Higher the emission source lesser will be the pollutant impact on nearby areas. Sources nearer to the ground, release plume into the planetary boundary layer (PBL), depending on the mixing height available the pollutants disperse into the atmosphere.

**Local geographical features**

Geographical feature like mountains, slopes, tall buildings or valleys also affect pollutant plume dispersion
Sources of Air Pollution

In general air pollutants emission occurs from following types of sources.

Point sources

In this kind emissions release from an opening at the top like a boiler stack or vent and these sources fixed are at a height above ground level. These are of two types.

Wake-affected point sources, where close by buildings hinder the pollutant plume trajectory and growth and wake-free point sources, whose height is greater than 2.5 times the height of the building, in order that adjacent heights does not affect the stack top air stream.

Area sources

It has an apparent two-dimensional shape and limited vertical height. It is having a huge surface area like an open pits or waste pile.

Line sources

A line source is a long, very thin area source. Generally these kinds of sources are taken from ground level and thin. If width of line source is more than 20 % of its length then it can be treated as area source.

Air Pollution Impacts

Air pollution in the form of dust and its effects on individual health has been a serious crisis throughout the world, with the increasing technology and rapid industrialization to cater the needs of growing population.
Impacts on human health

Several severe health problems like lungs related deceases (Pneumoconiosis), as well as visual impairment and allergic reactions etc. occur due to air pollutants. Proper control methods are ought to be adapted to decrease the impending hazards to public health. Dust has been documented through the years as one of the biggest occupational killers [10] and a wide range of occupational diseases may develop in mine workers depending on the properties of the inhaled dust. Silica exposure is worst when it is a component of respirable dust and known to cause silicosis disease. Personnel at Uranium mines are exposed to the risk of inhaling respirable dust, rich in silica, radionuclides and their decay progeny which can lead to chronic diseases on long term exposure. Another health hazard owing to the inhalation of respirable dust containing Uranium, Thorium and Vanadium traces is lung cancer.

Impacts on environment

The effects of dust on agriculture and ecosystem, depends on the particle size, deposition rate and the concentration of dust in the atmosphere. The effects of particulates matter (PM) on flora and fauna, depends on the constituents of PM. Dust in the form of PM10 reduces growth, over all yield and reproduction of plants. Particulate emission can also contribute to climate change in the form of greenhouse effect.

Ambient Air Quality Standards

These are the guidelines that are maximum limits on the amount of a given pollutant in the air for precise averaging periods. These ambient standards primarily aim at human health protection and have been estimated to permit a margin for citizens susceptible to risk. These guidelines and standards are critical to efficient air quality administration, and they provide the link between the emissions source and the receptor that is provided in the downstream location. These values specify harmless daily exposure quantities for the greater part of the population, all over an individual's life period. Reference was made to the World Bank Group (WBG) guidelines and the latest (2007) World Health Organization (WHO) guidelines [11].

CPCB Authorized mine Emission Levels

In order to assess the dust fallout levels, reference was also made to the CPCB/MoEF residential and industrial action levels [12]. CPCB has fixed emission standards for different industries and is responsible for industrial emissions compliance with NAAQS as specified in EIA Guidance Manual-Mining of Minerals (Refer Appendix-A, Table A.1 and A.2).
Once the effects of air pollution and standards established were studied, a proper plan to analyze the mine impacts has to be devised and followed.

General Approach towards Air Pollution-Air Quality Modeling Criteria

It necessary to conduct proper observation and analysis of the pollutant sources and apportions the pollutant release to eradicate its ill effects. The analysis of environmental pollution, its sources and its impact can be postulated into three inter related areas:

1) Monitoring,
2) Modeling and
3) Control of the pollutant generation at the source.

Monitoring

Monitoring of pollutants involves modeling and measuring pollutants for long duration to estimate the present impact and future effects. CPCB requires mining bodies to monitor pollutant releases from the facility, to maintain safe environment to comply with regulations and to review yearly emission scenario, so as to provide cleaner and better ambiance. Though Tummalapalle mining is underground mining still there are sources of pollution like stock ROM piles, waste piles, ore and personnel transport, mine construction activities, power plant boiler and other Uranium processing operations. Various pollutants produced in turn can be breathed in by mine workers or public surrounding the mine.

The monitoring is a crucial part of the impact estimation and hence complete long term monitoring is compulsory. Here in our study area, monitoring was carried out by using High Volume Air Sampler (HVAS), which uses sampler equipment and filter paper [1], [13] and [114]. Monitoring could not cover the vast area of 32 km of 50 x 50 km area for studying each and every location that might be affected by the mine emissions. So atmospheric dispersion modeling is advisable.

Modeling

The modeling is the forecasting of the selected pollutant concentrations in the vicinity of the chosen mining area depending upon local meteorological conditions, type of emissions, local topography, meteorological parameters, particle deposition and other factors. Particulate matter and other pollutant monitoring and estimation of Tummalapalle underground Uranium mine emissions was carried in this work for dispersion modeling purpose by AERMOD View 8.5.0.
Atmospheric dispersion modeling is the mathematical simulation of the pollutants dispersion and estimation of ground-level concentrations predominantly in the atmospheric boundary layer using meteorological and topographical data and consequently we obtain pollutant concentrations and dispersion patterns (Figure 1.5).

Figure Error! No text of specified style in document.5: The input and output of an atmospheric dispersion model

This modeling aims at estimating/forecasting the ambient impact of pollutants at various distances from one or more sources of air pollutants with respect to distance and time. These models are used to express conformity with NAAQS as part of new source evaluation, environmental impact assessment, avoidance of noteworthy deterioration and non-attainment permitting trials. It considers various sources of emission from the mine, topographical conditions of the area and also the local meteorological conditions. Upper air data is also incorporated into the meteorological data for predicting concentration levels. Plume models were commonly used earlier generally steady state and Gaussian, whereas sophisticated models were beginning to be used nowadays more extensively for regulatory applications from previous decade.
Air pollution models are based upon numerical equations that depict and predict downwind ground level pollutant concentrations based on the input emissions parameters (stack exit velocity, exit plume temperature, stack diameter, etc.), terrain (local topography, land use land cover data, surface roughness, nearby obstacles) and condition of the atmosphere (stability, wind speed, mixing height, etc.). Various steps involved in modeling are shown in the Figure 1.6.

Modeling of pollutant dispersion is employed for the following two main reasons:

Modeling can estimate pollutant concentration values at almost all locations wherever air monitoring network is not possible,

Models can also predict the impact of original sources prior to construction of the facility in addition to how novel pollution control and mitigation devices will influence the generation of the pollutant.

Need for dispersion modeling

The atmospheric dispersion modeling can be useful in planning and designing urban setup, locating air quality monitoring stations, identifying maximum concentration occurring points. They play vital role in estimating future impact of the proposed expansion of any industrial activity or new industry.

To forecast ambient air concentration resulting from emission sources,
To prepare and accomplish air pollution control program cost effectively,

To quantify the process expansions impact and environmental impact assessment,

To assess the performance of emission control techniques

The Tummalapalle mine expands over approximately 4 km radius and due to the valley like existence with hilly terrain on two sides (South-West to South-East) hence, the pollutants released from mine construction activities and the dust emission effect will most likely be restricted to the site (local).

The impact evaluation was limited to airborne particulates since, Tummalapalle mine is underground mine and the ore grade is very low, so the radon exposure is very limited and health physics Unit-HPU of BARC is measuring and monitoring local radiation levels. Stringent measures are being taken to regulate the radioactivity exposure.

Factors effecting dispersion of pollutants in atmosphere

Dispersion, i.e. the transport of pollutants from their source, consist of diffusion and advection processes. It determines whether a pollutant will accumulate or dilute in the atmosphere. Dispersion is influenced by several aspects including weather conditions and local topography (altitude, rivers and streams, etc.). Wind velocity and direction, atmospheric stability and location topography affect plume interaction in complex terrain and cause changes in the transport and dispersion of air pollutants. Drilling, loading and crushing of the ore at both primary and fine crushing plants generate dust which ends up being emitted in the atmosphere. Another possibility of generating dust at the processing plant is wind erosion from coarse and fine ore stockpiles especially during windy conditions. Wind erosion of tailings generates a high quantity of dust at mine. The magnitude of the problem becomes larger during windy conditions

Pollutant dispersion modeling helps as an extensive aid for visualizing the results of these complex interactions and assessing the quantity of ground-level pollution at different distances from origin. Dispersion causes convenient pollutant reduction near the source and harmful pollutant increases at the receptors.

Pollution dispersion in the air is affected by many factors:

Dispersion from Emission Sources (stationary point, area, or mobile sources such as cars).

Height of the pollutant emission sources
Local topographical features

Meteorological conditions

Air Temperature Lapse Rates

Atmospheric Boundary layer /Mixing Height

Wind speed & direction

Atmospheric air Inversions

Humidity & Temperature

Dispersion Coefficients

Atmospheric stability

Classification of dispersion models

The air pollutant dispersion in the atmosphere is described by physical and mathematical models. Physical modeling is minor level simulation carried out by using a physical experiment in the laboratory to represent atmospheric flows, when comprehensive mathematical models and/or experimental field observations tend to be economically not viable. E.g. Lab simulations like wind tunnels, water channels.

Mathematical models are

Statistical models, and

Deterministic models (Figure 1.7).
Statistical models investigate past monitoring air quality statistical information. Deterministic models use mathematical representation of physical and chemical processes taking place in the atmosphere[14].

These mathematical models offer flexibility to develop a large variety of modeling scenarios and could generate swift results[15].

Box models

Box model depends on law of conservation of mass. Box model assumes the air shed as a simple box as well as the inside air follows homogeneous concentration distribution.
The box model requires input of plain meteorology and emissions. The box model can handle puff or plume behavior of pollutant (Figure 1.8). This model has a restricted application due to the hypothesis of homogeneous pollutant dispersion which does not happen easily in the reality. Box model can be used to predict average pollutant concentration over a huge area around the source.

The equation of is

\[
\frac{dCV}{dt} = QA + uC_{in}WH - uCWH
\]

Where,

Q: pollutant emission rate/unit box area. (g/s)

C: uniform pollutant concentration within the modeling area. (mg/m³)

V: volume of box. (m³)

Cin: species concentration entering the modeling area. (mg/m³)

A: horizontal area of the box (L*W). (m²)

L: length the box. (m)

W: width of the box. (m)

u: wind speed perpendicular to the box. (m/s)

H: mixing height. (m)

Lagrangian Models

These mathematical models are analogous to box models and describe location of polluted air area as a box. Lagrangian models integrate variations in concentration owing to molecular diffusion, turbulence of the wind components and average fluid velocity. It computes the air pollution distribution by estimating the statistics of the pollution plume parcels trajectory depending on a changing reference grid. The model is used to compute the long distance transport and dispersion of pollutants [16]. The Lagrangian model can be represented as,

\[
< c(x, t) > = \int_{-\infty}^{t} \int p \left( x, \frac{t}{\chi}, t \right) S ( x', t \prime ) dx' dt'
\]
Where,

\[ < c(x, t) > : \text{mean pollutant concentration at the location (x) at time (t)} \, \text{((mg/m}^3)}, \]

\[ (x', t') : \text{source emission rate (g/m}^3), \]

\[ p(x, t | x', t') : \text{probability function of an air parcel moving from location } x' \text{ at time } t' \text{ (source) to location } x \text{ at time } t. \]

The probability function is derived by considering meteorological conditions. Particle size distribution and density must be considered if the source of emission consists of particles.

Eulerian Models

The Eulerian model considers law of conservation of mass for the specified pollutant to calculate the concentration levels. The equation for Eulerian model is,

\[
\frac{\partial < c_i >}{\partial t} = -\bar{U} \cdot \nabla < c_i > - \nabla < c_i U' > + D \nabla^2 < c_i > + < S_i >
\]

Where,

\[ U : \bar{U} + U' \, \text{(m/sec)} \]

\[ \nabla : \text{wind field vector in (x,y,z) directions. (m/s)} \]

\[ \bar{U} : \text{mean wind field vector. (m/s)} \]

\[ U' : \text{variable wind field vector. (m/s)} \]

\[ c_i : <C> + C' \, \text{(m/sec)} \]

\[ c_i : \text{pollutant concentration. (mg/m}^3) \]

\[ < c_i > : \text{mean pollutant concentration. (mg/m}^3) \]

\[ C' : \text{changeable pollutant concentration. (mg/m}^3) \]

\[ D : \text{molecular diffusivity (m}^2\text{/s)} \]

\[ S_i : \text{source term. (g/s)} \]
Eulerian model is similar to a Lagrangian model and follows the progress of pollution plume parcels, but, the this model uses a predetermined 3-D Cartesian grid as an outline comparatively than a moving grid as a Lagrangian model. A Cartesian co-ordinate system categorizes each grid point absolutely in a plane by a pair of numerical coordinates. Ex: CALGRID model.

**Gaussian Dispersion models**

This model assumes that the pollutant plume concentration at every downwind distance has independent Gaussian distribution both in the horizontal and in the vertical direction, thus the Gaussian plume equation (Equation 1) will describe a 3-D concentration field produced by a point source under stationary meteorological and emission conditions (Figure 1.9 and 1.10). The Gaussian dispersion equation is the basis for AERMOD and CALPUFF models [17]. The model exemplifies the pollutant being released as the plume from the stack tip and performs calculations based on the effectual vertical displacement of the plume, as per wind (downwind/crosswind directions) and meteorological conditions of the surrounding area.

Figure Error! No text of specified style in document. 9: Horizontal and vertical Gaussian distribution in the air
Dispersion coefficients can be estimated by means of different air quality models and/or dispersion equations. Gaussian model equation is simple in nature and is extensively employed to express the dispersion of concentrations away from plume center line and to estimate the ground level concentrations of pollutant based on time-averaged meteorological parameters (e.g. temperature and relative humidity, wind speed etc.). The Gaussian models are only suitable for shorter distances (up to about 50 km).

Assumptions in Gaussian Modeling [18]

The emission rate of pollutant is steady and uninterrupted throughout the modeling period,

Plume dispersion follows normal distribution,

Wind speed and its direction are uniform

The total reflection of the plume takes place at the ground surface.

The Gaussian plume equation is,

$$\chi = \frac{C(x, y, z)}{2\pi \sigma_x \sigma_y} e^{\frac{-y^2}{2\sigma_y^2}} e^{\left(\frac{-(x-H)^2}{2\sigma_x^2}\right) + \left(\frac{-(z+H)^2}{2\sigma_z^2}\right)}$$

Equation 1: Gaussian plume equation
Where: \( \chi \) = ground level pollutant concentration in downwind direction (g/m³)

\( Q \) = pollutant emission rate

\( \sigma_y \) = pollutant concentration’s standard deviation in horizontal (y) direction

\( \sigma_z \) = pollutant concentration’s standard deviation in horizontal (z) direction

\( u \) = down wind velocity

\( y \) = distance in horizontal down wind direction

\( z \) = distance in vertical direction

\( H \) = effective stack height

Gaussian Model limitations

Model assumption that there is no contact between two plumes, is not always true, it becomes significant within urban environments.

Gaussian equation cannot account for recirculation effects due to intersections or multiple buildings.

Gaussian models cannot explain dispersion under calm or low wind conditions (wind velocities less than 0.5 m/s) or at locations nearer to the source (< 100m).

Assumption of a uniform wind field is not advisable for far-field modeling, as the meteorology changes over great distances (>50 km).

Prognostic meteorological models and their output as inputs to Gaussian-plume models (AERMOD)

Prognostic models deal with large-scale synoptic weather conditions and numerically solve the atmospheric dynamics equations in order to study the local meteorological conditions. These models do not need local meteorological data to run; These models could represent all scales, from global range to smaller scales of 1–10 km, and are run in a nested grid format with the external realm covering distances up to 500–1000 km in provincial scale. Some prognostic meteorological models like MM5, ARPS and TAPM, generate output data in a configuration that can be utilized by the plume models. Prognostic model results can be obtained for a particular place (the site of interest) in a format suitable with, AERMOD or ISCST3 or CALPUFF and can be regarded as pseudo-observation input to the selected
dispersion models. This is a promising substitute in the case of non-availability of site-specific observations as in our case.

Review of some Atmospheric Dispersion Models

Few models were reviewed to test the suitability to our research include, ASPEN, FDM, ADMS, ISCST3, CALPUFF and AERMOD.

ASPEN

U.S. EPA developed (ASPEN), Assessment System for Population Exposure Nationwide for Cumulative Exposure Project's inhalation constituent. ASPEN incorporates handling of wet/dry particle deposition and chemical change. The estimated concentrations from ASPEN are devised to signify population-weighted averages over a size scale square kilometers. ASPEN employs meteorological information from various locations and includes secondary formation of gaseous air toxics phenomenon. ASPEN could not fully incorporate 3-dimensional (3-D) wind fields. ASPEN emission releases are assumed to be straight lines, far from reality and is a micro-scale model and useful for distances less than 50 km [19].

FDM

Fugitive Dust Model estimates fugitive dust concentration and deposition impacts from unknown pollutant sources by US-EPA. The model works on the principle of Gaussian Plume dispersion and revised with enhanced gradient-transfer deposition algorithm. Concentration and deposition are calculated at all user-defined receptors (~500). The model accepts its meteorological data in the form of pre-processed hourly meteorological data output from the USA-EPA RAMMET meteorological processor and STability ARray (STAR) format hourly meteorological data in card images. Output will be in basic textual report, as well as a plotter output file containing two dimensional x-y coordinate average concentrations for each averaging time (1h, 3h, 8h, 24h and a long-term average) requested.

ISCST3

ISCST3 (Industrial Source Complex Short Term) is a steady-state model with straight line trajectory like Gaussian plume model [19]. It can address building downwash effects, dry and wet deposition. This model utilizes PCRAMMET pre-processed hourly meteorological data and serves as a screening model. ISCST3 model is relatively simple over AERMOD and ADMS and delivers strong predictions. Wind speed, stability class, wind direction and a presumed mixing depth are sufficient to run
the model. Receptor terrain elevations, structure measurements additionally to emissions and stack variables are also required.

ADMS

ADMS (Atmospheric Dispersion Modeling System) is an advanced steady state, Gaussian-like model. It can simulate continuous plumes and short period puff releases [19]. The model is applicable to point, area, line and volume sources. It has to be licensed for business applications and training along with this license is economically not viable.

EPA specified atmospheric dispersion models

For modeling pollutant dispersion more than 50 km (long range transport) CALPUFF is recommended. US EPA recommends to use AERMOD for near field pollution approximation up to 50 km from the source.

CALPUFF

CALPUFF (CALifornia PUFF model) is a multi-layer, multi-species non-steady-state, Lagrangian puff transport and dispersion model that calculates advection of multiple pollutants puffs which follow Gaussian dispersion from the modeled sources (Figure 1.11).

Figure Error! No text of specified style in document.11: Gaussian puff distribution of pollutants from a point source
The model can predict emissions at downward distances in the range from 10m up to 300 km for numerous point, area, volume and line sources with steady or unsteady emission rates. It predicts the impacts of spatial and temporal meteorological conditions on pollutant transport, transformation, and elimination. The model consists of algorithms, sub-grid scale, coastal terrain and interaction effects, and terrain impingement.

CALPUFF uses 3D meteorological fields produced by the CALMET pre-processor. CALMET could utilize data from single station, or combinations of surface and upper air data and 3D prognostic model outputs. CALMET also encloses overwater and overland boundary layer algorithms to study the effects.

AERMOD

AERMOD stands for AMS/EPA Regulatory Model [20]. This model is based on planetary boundary layer principle. Basically it is a steady-state plume model and is most frequently used for calculating pollutant concentration released from various sources. AERMOD models an air shed with three individual modules: AERMAP- Terrain Preprocessor, AERMET-Meteorological Preprocessor and AERMOD-Aermic Dispersion Model. AERMAP simplifies and standardizes the terrain input data for AERMOD, AERSURFACE-sub processor, deals with surface characteristics.

Input data contains receptor terrain elevation data. Output data comprises, location and height scale for every receptor and this scale/elevations are used for calculation of airflow around hills. AERMET uses, hourly meteorological observations like wind speed, temperature, wind direction, rainfall, humidity, along with the emission characteristics. It calculates the concentration of the pollutants released by different sources (Figure 1.12).

AERMOD integrates the AERMAP and AERMET into one interface. These models are used for determination of dispersion, concentration levels and deposition of various pollutants for different sources. This model is applicable to surface and elevated releases, rural and urban areas, flat and complex terrain and for multiple sources like point, area and volume sources [16].

Conclusively, useful high-end models were grouped into three types: Particles, Puff, and Grid models. Puff model (e.g., CALPUFF) is the most widely used sophisticated model as it effectively takes into account all the meteorological factors to be simulated. While puff model is more sophisticated and could better stand for real weather condition, it still has some drawbacks when judged against plume models. For one, it is more difficult to handle the weather data in Puff models as it treats plume as individual puff
combination. Puff model performs well, where the meteorological condition or terrain is very complex or low wind speed states prevail often.

![Modeling system structure](Image)

Figure Error! No text of specified style in document. 12: AERMOD data flow

Our study area meteorological factor analysis showed less calm conditions and the terrain is not very complex. So it was proposed to use the particle and grid based models. Of these entire models reviewed AERMOD model seems to be promising. Hence a comprehensive review of the model was carried out in addition to considering other models.

By using AERMOD or any other advanced models users/industries will be in a position to view, analyze, predict the current impacts and future impacts of the releases from ones facility and effectively devise control technologies and revise again and again based on the outcome of the atmospheric dispersion modeling results.

Control of the Generation of Pollutants at the Source

The control policy needed for any environmental impact plan entails the following four processes:

(1) Removal of the affecting source or operation,

(2) Amendment of the source operation,

(3) Repositioning of the source and

(4) Selecting the suitable control technology.
Some other techniques used to organize particulate and gaseous emissions are, usage of suitably planned long stacks to dilute pollution or changing operational methods a few times.

Objectives of the Research Work

The key aim of this research is to use air quality modeling to identify the problems related with uranium mining activities and their impact on the environment and to establish the present ambient air concentrations scenario prevailing in the surrounding area of Tummalapalle mine. This work also aims to verify whether these concentration levels comply with the National Ambient Air Quality Standards (NAAQS) /National Minimum Emission Standards for listed activities and to get better air quality around this area.

In order to meet this purpose, this investigation addressed these specific objectives:

Assess the potential impact of the Uranium mining on Tummalapalle and surrounding area for the year 2011.

To predict Pollutant concentrations from the current scenario (3000 TPD) for 1h, 24h, monthly, seasonal and annual for selected pollutants.

To validate predicted concentrations of PM10 and U with the measured HVAS 24h concentrations.

Establish the effect of seasonal and diurnal variation, compliance of pollutants to seasonality.

Estimate the conformity of pollutants resulting in air quality based on local limiting factors.

To carry out future impact (4500TPD) prediction for selected pollutants.

To suggest control technologies for the existing methods after analyzing the mitigated and unmitigated cases.

Scope of the Work

This study uses Lakes Environment’s AERMOD ViewTM which incorporates AERMET with local meteorology, reported daily PM10, PM2.5, SO2, NOx and Particulate Uranium emissions. Geophysical data, land use data and local terrain data were given as inputs, to model the dispersion of PM10, PM2.5, SO2, NOx and Uranium containing dust emitted by the Tummalapalle mine. Modeling was done over a year period (2011) to assess the effects of seasonal meteorological variability. 1 hour, daily, monthly, seasonal and annual average pollutant concentrations were predicted. Predicted ambient concentrations were evaluated with the Air pollution Quality Standards to assess the compliance of mine
emissions with the regulations. To validate the model, model-predicted 24h PM10 and U concentrations based on actual mine emissions were compared with corresponding ambient monitored data available from ten local monitoring stations.