

Analyzing the Environmental Parameters using Software in the Design of Environmental Systems Modeling

¹M. Angeline Mary

¹Assistant Professor,

¹Civil Engg Department,

¹HKBK College of Engineering, Bangalore,
Karnataka, India

Abstract:- Environmental Modeling is one of the most critical area under concern. Modeling of various environmental parameters accordingly towards the current situation and prevailing condition is most risky job. This paper mainly focuses on various softwares associated with Environmental systems modeling. Huge number of softwares have been developed and used in the field accordingly. But according to our Indian scenario it is not possible to use all the softwares but certain softwares will be suited towards our environmental conditions. This paper mainly focus about the various softwares used in different types of environmental systems such as analyzing of Ground water quality, Surface water quality, Air quality, Landfill leachate, and Environmental Assessment of various parameters.

IndexTerms - Environment, Modeling, Softwares, Ground water quality, Surface water quality, Air quality, Landfill Leachate.

I. INTRODUCTION

A model is an abstract and partial representation of some aspect or aspects of the world that can be manipulated to analyze the past, define the present, and to consider the possibilities of the future. Environmental models make up a distinct family different from other classes of models in either the natural or the social sciences. They tend to be data intensive, cross disciplinary, dynamic and complex. Modeling the Environmental systems is one of the major task, and hence plenty of software's has been emerged to solve the complex multidisciplinary problems occurring in the environment Using these various softwares and simulation models it becomes a lesser task in analyzing the environmental risk assessments, formulate environmental management plans, evaluate potential environmental impacts, and make better environmental planning and resource management decisions. Most of the softwares are very much high in cost and hence it is not very easy to use in the developing countries like India. Here this paper aims

to discuss on some of the familiar and convenient softwares that can be adopted and used in our Indian Scenario

II. GROUND WATER MODELING

Ground water analysis is one of the most difficult cases in modeling process. As it cannot be modeled as it is but it can be predicted according to the assumptions and the boundary conditions adopted. There are two types of models such as Analytical models and Numerical models. Analytical models are the exact solution to equations which may be a simple flow or transport conditions. For ground water flow the differential equation that describes the water movement is often solved analytically using close form calculus techniques. Hence these models are best used for Initial assessment where a high degree of accuracy is not needed, to check the results of numerical model simulations, prior to beginning field activities to aid in designing data collection. Numerical models are approximations of equations which describe very complex conditions that describe the ground water flow and solute transport. These equations generally describe the multi-dimensional groundwater flow, solute transport and chemical reactions. There are different types in analysis such as flow model and transport model. In Flow model the simulation of groundwater flow requires a thorough understanding of the hydro geologic characteristics of the site. But in Transport models mainly depends on the chemical species and phase of interest.

The model simulates the movement of contaminants, spread and dilution of contaminants, removal or release of contaminants by sorption or desorption of contaminates onto or from subsurface sediment or rock, chemical alteration of the contaminant by chemical reactions which may be controlled by biological processes or physical chemical reactions. The basic concept of groundwater balance is,

Input to the system - outflow from the system = change in storage of the system (over a period of time)

$$R_r + R_c + R_i + R_t + S_i + I_g = E_t + T_p + S_e + O_g + \Delta S$$

where,

R_r = recharge from rainfall

R_c = recharge from canal seepage

R_i = recharge from field irrigation

R_t = recharge from tanks

S_i = influent seepage from rivers
 I_g = inflow from other basins
 E_t = evapotranspiration from groundwater
 T_p = draft from groundwater
 S_e = effluent seepage to rivers
 O_g = outflow to other basins; and
 ΔS = change in groundwater storage

Based on the factors considered the mathematical model will be developed and evaluated and tested for the best outfit. The

major software used for analyzing the Ground water flow is MODFLOW the recognized standard model. In Modflow analysis

the layers can be simulated as confined, unconfined or in a combination of both. Groundwater flow within the aquifer is

simulated in MODFLOW using a block centered finite difference approach. The flows from external stresses such as flow to

wells, areal recharge, evapotranspiration, flow to drains, and flow through riverbeds can also be simulated.

The other models used for analysis are MT3D (A Modular 3D Solute Transport Model), FEFLOW (Finite Element Subsurface

Flow System), HST3D (3-D Heat and Solute Transport Model), SEAWAT (Three-Dimensional Variable-Density Ground-

Water Flow), SUTRA (2-D Saturated/Unsaturated Transport Model), SWIM (Soil water infiltration and movement model),

Visual MODFLOW (Integrated Modeling Environment for MODFLOW and MT3D). Several versions are available such as

MODFLOW 88, MODFLOW 96, MODFLOW 2000, MODFLOW 2005. MODFLOW cannot solve density dependent flow,

heat flow, Multiphase flow. The conduit flow process for MODFLOW-2005 has the ability to simulate turbulent or laminar

groundwater flow. MF-OWHM represents a complete operational hydrologic model that fully links the movement and use of

groundwater, surface water, and imported water for consumption by irrigated agriculture, but also of water used in urban areas

and by natural vegetation. Stream flow Routing (SFR) within embedded grids. MF-OWHM also includes new features such as

the Surface-water Routing Process (SWR), Seawater Intrusion (SWI), and Riparian Evapotranspiration (RIP-ET) The family of

MODFLOW-related programs now includes capabilities to simulate coupled groundwater/surface-water systems, solute

transport, variable-density flow (including saltwater), aquifer-system compaction and land subsidence, parameter estimation, and groundwater management.

III. OPPORTUNITIES AND CHALLENGES IN GROUNDWATER MODELING

There is a Wide variation in climate from semi-arid to sub-humid/sub-tropical regions and hence it is not that much easy to include all climates governing factors. Also there is a Large-scale spatial variation in Soil texture and land-use pattern. It is a complicated job to analyze the Type of aquifers and its properties. While modeling a system or developing software, including the groundwater recharge and discharge components, Groundwater level monitoring is not being done regularly and it is not possible to incorporate all those data's inside the system. Setting up/optimizing monitoring networks and setting up groundwater protection zones cannot be effectively done using various models. Hence providing software with all these requirements becoming a great challenge faced nowadays. Groundwater resources too need to be planned and managed for maximum basin-level efficiency.

Apart from this the Diversified geological climatologically and topographic set-up, giving rise to divergent ground water situations, Excessive use of our rivers, are causing downstream problems, of water quality and ecological stress cannot be accounted inside the system modeling. Climatic changes impacts directly on the availability of water resources both in space and time. The precarious balance between growing demands and supplies ground water must be matched. Application of existing groundwater models include water balance (in terms of water quantity) but there should be development in knowledge about the quantitative aspects of the unsaturated zone thus Simulating the water flow and chemical migration in the saturated zone including river-groundwater relations.

IV SURFACE WATER MODELING

The surface water quality modeling includes river, lake, and estuarine etc., in any type of surface water analysis first and foremost thing is to identify the point and non point source of pollution. For river water quality analysis Streeter Phelps Equation is one of the important models considered for analysis purpose. If it is assumed that the river and waste mixed completely at the point of discharge then the concentration of a constituent in the river waste mixture at $x=0$ is given by,

$$C_0 = \frac{Q_r C_r + q_w C_w}{Q_r + q_w}$$

C_0 = Initial Concentration of constituent at point of discharge, g/m³.

Q_r = river flow rate, m³/s.

C_r = concentration of constituent in river before mixing, g/m³.

q_w = waste water flow rate, m³/s.

C_w = concentration of constituent in wastewater, g/m³.

While developing models for Lake Eco system, Eutrophication is the major response of the ecosystem to the addition of artificial or natural nutrients, mainly phosphates, through detergents, fertilizers and sewage. Oxygen sag curve analysis is the basis for analyzing the river stream condition.

For lake water bodies the thermal stratification must be considered while analyzing. According to the Liebig's law of minimum "Growth is limited by the availability of nutrient that is least available relative to the need". Most of the plants in the lake system are phosphorus limited.

QUAL2K is a river and stream water quality model. It is typically used to assess the environmental impact of multiple pollution discharges along rivers. It requires various input parameters such as river hydraulics, rates and constants, and pollutant source quality. River Hydraulics includes channel length, elevation, widths, slopes and roughness. Manning's equation is used to calculate the flow rate from these parameters.

Flow rates are required for the river entering the model and for each pollution source. Rates and constants include the processes to be simulated such as CBOD (Carbonaceous Biochemical Oxidation demand) decay coefficients, re-aeration rate, algal growth rate, turbulent eddy diffusivity and settling velocity. The pollutant source quality needs

parameters such as dissolved oxygen, CBOD, nitrogen and phosphorus species, alkalinity and pH. There are two output types such as spatial and temporal outputs. Thus, the user can see how each measured parameter in the river changes with space and time.

Estuarine modeling is very difficult to analyze and Fick's law is used to estimate the mass transport. They are broadly classified into two categories such as Black box models and Advection-Dispersion Models. The process involved in the estuarine systems is transport, decay, dispersion, diffusion and tidal effect. Estuarine systems involve complex hydrodynamics to be considered while modeling, and hence the system can be divided into infinite units and studied for the hydrodynamics behavior of each unit and then approximated to a single unit.

EPANET is freely downloadable computer software generated by US Environmental Protection agency for studying the behavior of water quality inside the pressurized water supply pipes. Figure 1 shows the input sheet of EPANET package. The nodes are first selected according to the requirement, showing tanks, reservoirs, pumps and valves. Then they are connected by means of pipes and further proceed for analysis.

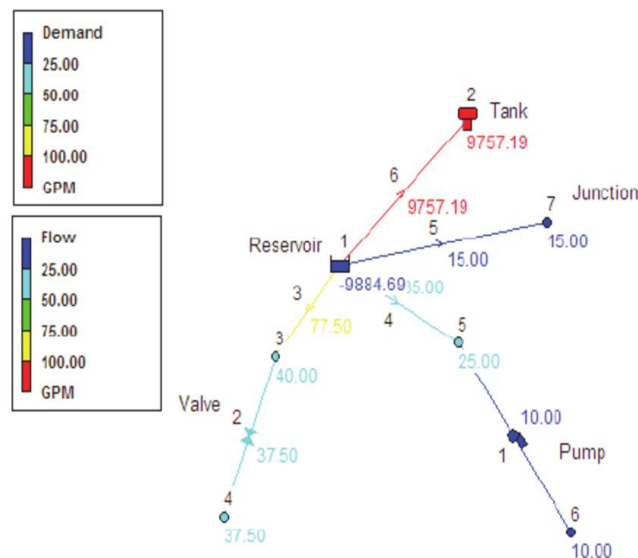


Fig: 1 EPANET INPUT DATA

It is able to track the flow of water in each pipe, the pressure at each node, the height of water in each tank and the concentration of a chemical species throughout the network during a simulation period which comprises of multiple time steps. Running under OS, EPANET provides an integrated environment for editing network data, performing hydraulic and water quality simulations and viewing the results in a variety of formats.

IV AIR QUALITY MODELING

Air quality modeling is a mathematical simulation of how air pollutants disperse and react in the atmosphere to affect

ambient air quality. Several modeling approaches have been applied to describe the dispersion of pollutants in the urban environment. Gaussian plume model is one of the most important models used in analyzing the dispersion of pollutant concentration. The first method for analyzing the complex type of solution is by numerical integration and the second approach is simplifying the assumptions that the wind and turbulence functions are independent of time and position. The formation of the Gaussian plume model for the continuous point source is given Figure 2.

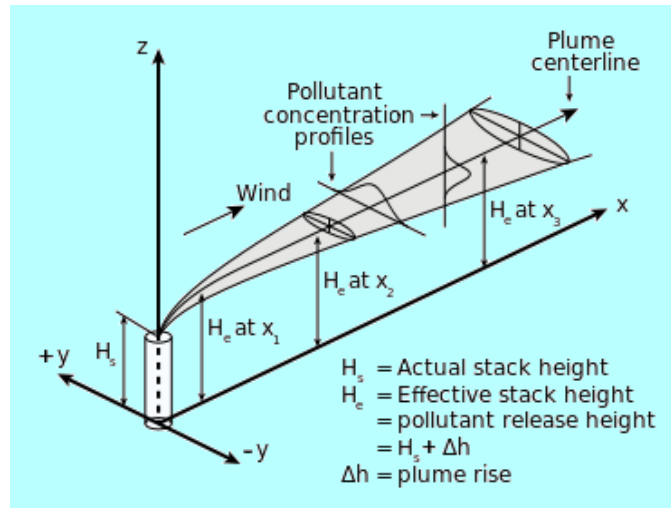


Fig:2 Plume rise distribution

$$C(x,y,z) = \frac{Q}{2\pi * u * \sigma_y * \sigma_z} * e^{\frac{-y^2}{2*\sigma_y^2}} * e^{\frac{-(z-h)^2}{2*\sigma_z^2}} * e^{\frac{-(z+h)^2}{2*\sigma_z^2}}$$

C (x,y,z) = concentration (g/m³)
 Q = stack emissions (g/s)
 u = wind speed (m/s)
 H = height (m)

The vehicular exhaust emission from roadways are modeled as line source Artificial Neural Network modeling is also used for analysis where only input data set will be given without any assumptions. This feature makes such computational models very appealing in application domains where one has little or incomplete understanding of the problem to be solved.

For line source modeling MLP (Multilayer Perceptron) structure of the neural networks seems to be the most suitable for predicting vehicular pollutant concentrations. The multilayer perceptron consists of a system of layered interconnected ‘neurons’ of ‘nodes’. The nodes are arranged to form an input layer, one or more ‘hidden layer’ and an output layer with nodes in each layer connected to all nodes in neighboring layers. The time series analysis may be done using ARMA (Auto regression moving average) and ARIMA (Auto regression integrated moving average) and seasonal arima models. AERMOD (American

Meteorological Society/Environmental Protection Agency Regulatory Model)

is a steady-state Gaussian plume model. It uses a single wind

Field to transport emitted species. The wind field is derived from surface, upper-air, and onsite meteorological observations. AERMOD also combines geophysical data such as terrain elevations and land use with the meteorological data to derive boundary layer parameters such as mixing height, stability class, turbulence, etc.

CALPUFF (California Puff Model) is a non-steady state Lagrangian puff dispersion model. The advantage of this model over a Gaussian-based model is that it can realistically simulate the transport of substances in calm, stagnant conditions, complex terrain, and coastal regions with sea/land breezes.

CMAQ (Community Multiscale Air Quality modeling) system is to improve 1) the environmental

Management community's ability to evaluate the impact of air quality management practices for multiple pollutants at multiple scales.

V ENVIRONMENTAL ASSESSMENT SOFTWARES

The Environmental Impact Assessment is the process of examining the environmental, social and health effects of a proposed development. RIAM (Rapid Impact Assessment Matrix) is one of the software packages for analyzing the impacts of any proposed project. To overcome these drawbacks in the execution and reporting of EIA's, the Rapid Impact Assessment Matrix (RIAM) was developed. This system is based on the knowledge that certain specific criteria are common to all impact assessments, and by scaling these criteria it becomes possible to record the values of the assessments made. RIAM works with both negative and positive impacts. Not all criteria can be given the same weight, and so the criteria are divided into two groups: those which individually are important in their impact; and those that collectively important. By a simple formula the values ascribed to these criteria can be combined to produce a score for the component being assessed. Scores by themselves cannot be used to separate, or scale impacts, as they are still attributable to subjective assessments. Thus ranges have been defined, with set conditions for the maximum and minimum scores in each range, and the final result is represented by the range value so derived. In this a very comprehensive set of values can be built up across all components assessed in a holistic manner. The system allows for direct evaluation and comparison of components from different sectors, and provides a transparent record for future use.

RIAM has been developed to enable it for comparing different options, including working with mitigating measures on specific negative (or positive!) impacts. Using the obtained environmental scores it categorize the projects and tells the major positive and negative impacts, but in this assessment giving score for each parameter is mainly depends on the input fed towards

the package. Hence if the input given is valuable and reasonable then the output obtained will give the best result of the project. Research on improving the system is continuing, concentrating on improving the means by which scoping can be undertaken, and considering new criteria which may improve the sensitivity of the method.

By US Environmental Protection Agency, Center for Exposure Assessment Modeling (CEAM). The Multimedia, Multi-pathway, Multi-receptor Exposure and Risk Assessment (3MRA) technology provides the ability to conduct screening-level risk-based assessment of potential human and ecological health risks resulting from long term (chronic) exposure to HWIR chemicals released from land-based waste management units (WMUs) containing currently listed waste streams. The 3MRA system consists of a series of components within a system framework.

Major environmental issue consider nowadays are the intrusion of leachate from the landfill towards the ground water. Landfill dumping site should follow the standards and if not possible then proper provision must be adopted for removing and treating the leachate developed inside the land fill. Before developing any models for analyzing the leachate flow the basic datas must be required and they are the Size of Solid Waste Dumping site cell, Cover design, Waste thickness, Liner and Leachate collection system design Climatic considerations (actual or default), Recirculation or addition of liquids, Runoff Curve Number based on US Dept of Agriculture – Soil Conservation Service method (considers texture, vegetation quality, slope, and inclination).

Landfill Leachate can be modeled using UNSAT-H software. Quasi 2-D water routing/water balance computer program for SWD sites Calculates percolation rates through covers and it uses Simplified empirical and mechanistic equations. It is a Simplified unsaturated flow model with unit gradient and thus Widely accepted and straightforward input parameters are required evaluation.

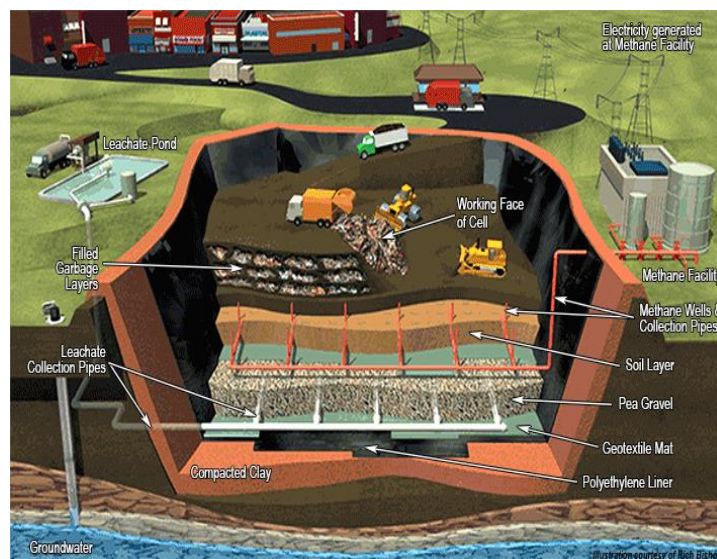


Fig:3 Landfill Dumping site with leachate collection system

Figure 3 shows the landfill dumping site with all treatment arrangements. The Hydrologic Evaluation of Landfill Performance (HELP) computer program is a quasi-two-dimensional hydrologic model of water movement across, into, through and out of landfills. Version 3.07 is most recent revision of HELP model. The model accepts weather, soil and design data and uses solution techniques that account for the effects of surface storage, snowmelt, runoff, infiltration, evapotranspiration, vegetative growth, soil moisture storage, lateral subsurface drainage, leachate recirculation, unsaturated vertical drainage, and leakage through soil, geomembrane or composite liners. Simplified Water balance model, LWB (Leachate water balance Model) developed by University of Rome, Italy, estimate effective infiltration and infiltration rate through bottom liner and closure cap systems for dumping sites. Limited number of input data is required and easier than HELP Model.

The **SewerCAD** is best used in systems that have complicated pumping, pressure sewers. SewerCAD should be used in places where there is a need to perform a constraint-based automated design or to run a steady state simulation, such as for a peak flow analysis with Extreme Flow methods.

The **SewerGEMS/Civlstorm** is used for dynamic wave simulation with ArcGIS integration support. It is best for analyzing existing problematic systems, where catchment rainfall-runoff calculations are required or dynamic wave solutions are needed. SewerGEMS can handle complex things like control structures, diversions

HydrauliCAD is used in water pipe design hydraulic analysis software program. It is useful for both pro Water Modelers and any Engineers with a basic AutoCAD fluency. It is used for simulation water modeling of water pipe networks

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REFERENCES

- [1] Alberti, M. 1999, Modeling the urban ecosystems: a conceptual framework. *Environment and planning B* 26, no. 4: 605-30.
- [2] Jakeman, A. J., Simpson, R. W. and Taylor, J. A. 1988. Modelling distributions of air pollutant concentrations-III. The hybrid deterministic statistical distribution approach. *Atmospheric Environment*, 22(1), 163-174.
- [3] Bisset, R., 1988. Developments in EIA methods. In: P. Waltherm (ed.), *Environmental Impact Assessment – Theory and Practise*. Unwin Hyman, UK.
- [4] CEQ (Council on Environmental Quality), 1978. National Environmental Policy Act – Regulations. Federal Register, 43, 55978-56007. Washington DC.
- [5] Gupta, C. P. and Thangarajan, M. (1990) Management of groundwater resources in India using simulation models. *Water Resources Jour.*, March 1990, pp.34-42.
- [6] Kolb A, Puttmann W (2006) Comparison of MTBE concentrations in groundwater of urban and nonurban areas in Germany. *Water Res* 40(19):3551-3558
- [7] Pollock DW (1994) User's Guide for MODPATH/MODPATH-PLOT, version 3: a particle tracking post-processing package for MODFLOW, the U.S. Geological Survey finite-difference ground-water flow model. US Geological Survey, Reston, VA
- [8] Van den Akker C (1986) Calculation of path lines and travel times using analytical solutions. In: *Groundwater modelling for water management (short course, March 3-7)*, IGWMC-IHE, Delft, The Netherlands
- [9] Javandel I, Tsang C (1986) Capture-zone type curves: a tool for aquifer cleanup. *Groundwater* 24(5):616-625
- [10] Nicolini, M. and Zovatto, L. (2009). "Optimal Location and Control of Pressure Reducing Valves in Water Networks." *Journal of Water Resources Planning and Management*, 10.1061/(ASCE)0733-9496(2009)135:3(178), 178-187.
- [11] Puust, R., Kapelan, Z., Savic, D., and Koppel, T. (2010). "A review of methods for leakage management in pipe networks." *Urban Water Journal*, 10.1080/15730621003610878, 25-45. Online publication date: 1-Feb-2010. Burger, G., Sitzenfrei, R., Kleidorfer, M., and Rauch, W. (2015). "Quest for a New Solver for EPANET 2." *Journal of Water Resources Planning and Management*, 10.1061/(ASCE)WR.1943-5452.0000596, 04015065. Online publication date: 1-Mar-2016.