

Hazard Analysis through GIS Integrated Chemical Dispersion Modeling

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Abstract

Geographical Information System is among today's fast developing technologies and being integrated with large number of applications. Here we have tried to integrate it with chemical dispersion phenomenon for planning and analyzing chemical emergency management through a web based application. Various Chemical dispersion models are available, and one can customize them too, as per the requirements. In the portal, user interface has been designed with relevant spatial data in shape file format. It allows mapping of source info and metrological data with impact assessment. Users can analyze results, by providing some set of inputs or can optimize the inputs for required outputs. This application can be utilized in industries for planning as well as in chemical disaster management to study health impacts or risk assessments.

Keywords

Geographical Information System, Chemical dispersion, air dispersion, GIS based web application, hazard prediction, disaster management.

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Introduction

Geographical Information System is among today’s fast developing technologies and is being integrated with various other computer applications. Chemical dispersion models are computer tools that use mathematical equations to provide detailed information of chemical (gaseous) release in the atmosphere. The authors have integrated various GIS layers with chemical dispersion phenomenon for planning and to study it’s after effects, by developing a web application. It can be used for causality prediction, health impact measurement, environmental damage prediction etc. or hazard prediction. The application includes a simple but all-inclusive user interface along with real time metrological data.

Web based Approach

The web based design approach was chosen for two major advantages it offers. Firstly, it can be made a real time response system by sensor and communication integration, and secondly the availability of rapid development tools allows lower development time. Online sharing of the data and map resources shall definitely enhance the performance of decision makers or planners. This design approach also facilitates users to upload required details from anywhere, anytime, as per their convenience, which is not possible with desktop application. Following client- server network architecture was setup for deploying the application. If required, it can also be used as desktop application by merging client and servers wherever security of data is prime concern.

The Application server, hosting applications has Chemical Dispersion Model (CDM) and user interface. It links with GIS through ArcGIS Server. The non spatial database holding information for chemicals, medicine, resources, etc is designed on Oracle Database Server. A real time metrological data input is made available through internet websites/ sensor integration.

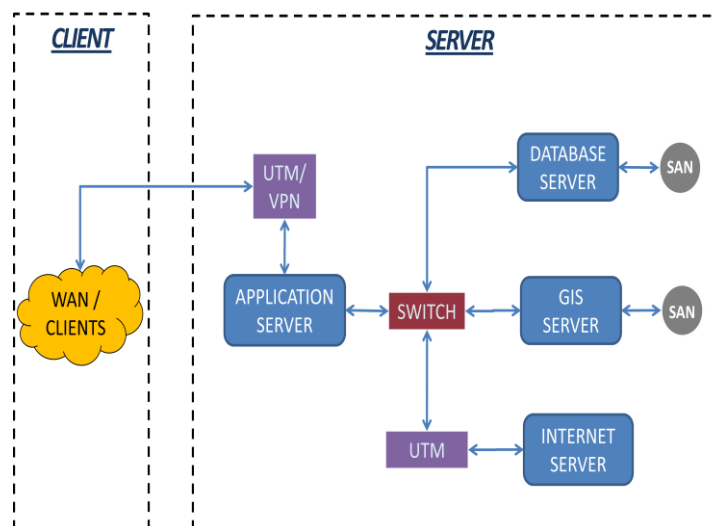


Fig: 1 – Network architecture

Chemical Dispersion Modeling

Chemical dispersion modeling has become a very important tool for management of chemical emergencies. When this is used in conjunction with GIS, it is expected to give an overall scenario of the situation in detail and in digital map format. Various chemical dispersion scenarios can occur. For this task, chemical emergencies have been categorized into five major types namely explosion, industrial, leakage, spray, and trespass.

Gaseous dispersion plays dominant role in the first four categories. The behavior of dispersion cloud, wherever applicable; is dependent on various factors such as source parameters, weather conditions, geographic data, physical properties of chemical, thermal and kinetic energy of release, etc. Various models have been developed by researchers over the years e.g. ALOHA, DEGADIS, SLAB and many more. Almost all the models concentrate on heavy gas dispersions and are based on Gaussian dispersion model with few changes.

In general, the dispersion of cloud has three major stages. In the first stage, near the source, the dispersion is primarily guided by thermal and kinetic energy of release and the mass flow decided by density difference between the cloud and surrounding air; in addition to other factors such as wind velocity, turbulence, etc. This is called as active dispersion phase. In the second or intermediate phase, the dispersion is to some extent guided by density difference and diffusion. The initial release conditions are subdued. In the third stage of passive dispersion the important parameters are only diffusion and atmospheric conditions. The model adopted here, combines active or heavy gas dispersion with passive dispersion. The model initially checks the dispersion class by density related criterion and decide dispersion type. Depending on the density difference between air and pollution cloud it computes shape and position of the polluting cloud. The model is implemented in java. For quick action planning a second model that relates only release conditions with weather data and generates shape files of immediate affected zone and delayed effect zone has been implemented specifically for online emergency management.

In this application, a user is required to first fill the basic event information i.e. event occurrence date, time, location, source characteristics, etc through simple user interface. The expert system then collects detailed information i.e. weather data, chemical properties etc. as per the given inputs from its own resources. All mathematical computations are run at backend and integrated with GIS layers. A GIS database has been designed for managing chemical disasters. Complete GIS database has been created on ArcGIS software and Model is implemented using JAVA. Some Screen shots of web application are presented in Fig 2.

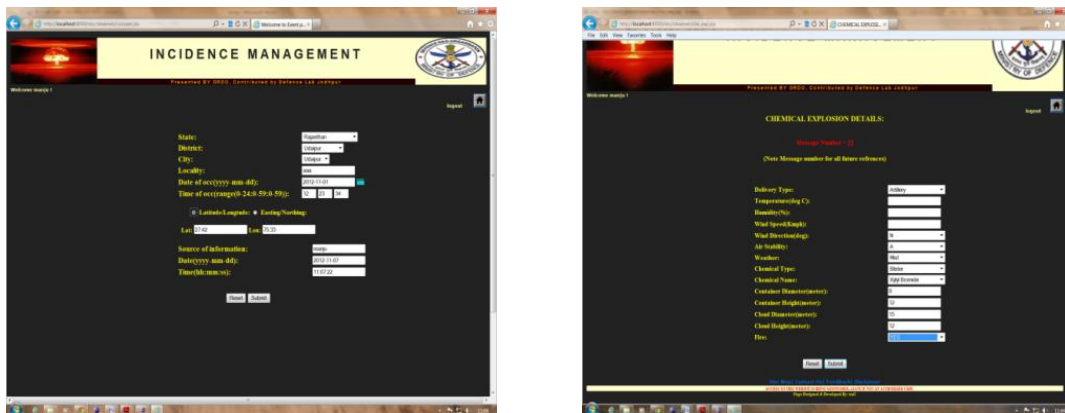


Fig: 2 – Web Application Interface screenshots for non spatial data input

Model Flow Chart

The dispersion model takes 4 types of inputs namely source details, Weather data, chemical properties details and event occurrence/ site details, and then generates outputs in the form of different concentration zones and distance from ground zero location, time of arrival and departure, etc. The output is then integrated with GIS database and damage database. A copy of GIS database of affected area is created as GIS damage database and displayed in the map. The original GIS data is not disturbed. A brief description of inputs is given in Table 1.

The metrological data or weather data is regularly updated online every 4 hrs and posted into database for current day and 5 day forecast or can be read on command.

Table 1: Chemical Dispersion Model input parameters

S N	Input type	Parameters/Description
1	Source parameters	Container height, diameter, capacity, cloud size, leakage/spray duration, area
2	Weather data	Temperature, humidity, stability, weather type, wind direction, wind speed, sunset and sunrise time.
3	Chemical parameters	Chemical agent category, name, yield, vapor pressure, Boiling point, threshold concentration, comm. name, mol structure, density, lethal dose, Freezing point, mobility, mean FP, neutralizing agents etc.
4	Basic event details	Time, date, site (lat/lon) or location of occurrence and type of event

Fig 3 represents flow of inputs and outputs of Dispersion Model along with database requirement.

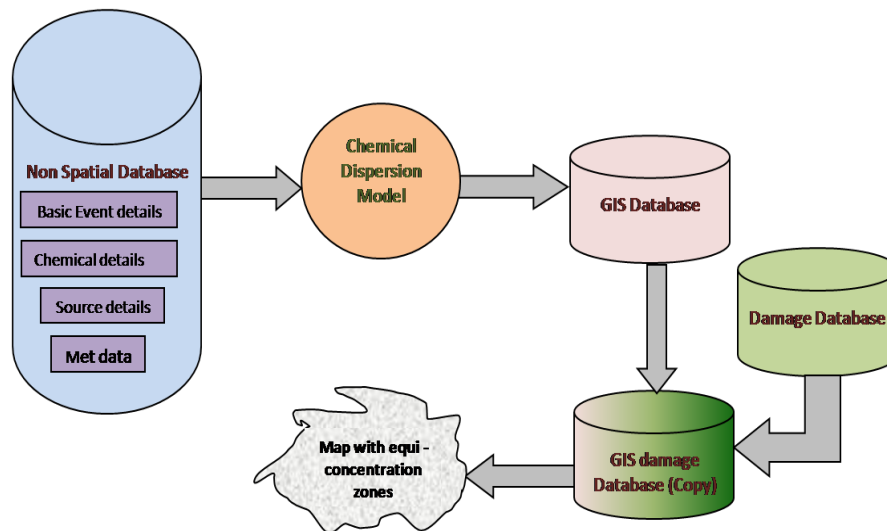


Fig: 3 – Dispersion Model data flow

GIS Layers

The outputs of dispersion models have been integrated with GIS data of Jodhpur city on ArcGIS platform. The application predicts damage of human resources as well as various GIS layers and other assets. Initially base map of Jodhpur city was taken and different GIS layers were linked into it using ArcMap/ ArcInfo software. Table 2 describes the various GIS layers identified for this application and Fig 4 shows linking of Hospital layer to Jodhpur city base map.

Table2: GIS Layers integrated with Dispersion Model

S N	GIS Layer	Remarks
1	Surface hydrology and Water sources	To provide details of different water sources, this can be used during disaster management. Here type of water source, contaminated or not, capacity, use and other information is stored.
2	Hospitals	For medical help during disaster management as well as damage prediction. It includes information about location, facilities, capacity, specialization etc.
3	Educational Institutes	As shelter during disaster management as well as for damage prediction
4	Bridges, Flyovers, UG passages, Road / Rail Network	This layer is required for recci specially and for traffic control.
5	Malls/ Theaters/ Community centers/ Public halls	It can be used as shelter resource for disaster management as well as damage prediction, if affected by the event.
6	Playgrounds/ Stadiums	It can also be used as shelter during disaster management
7	Govt. Offices	For prediction of loss of government assets and properties and resource pulling for disaster management.
8	Police Stations	To keep track of law and order information for disaster management.
9	Fuel depots	For damage prediction.
10	Electricity, Water, Gas Distribution	To keep track of supply in affected areas
11	Communication Channels	To keep track of means of communication in affected areas
12	Traffic Spots	For causality prediction
13	Fire Stations	For disaster management

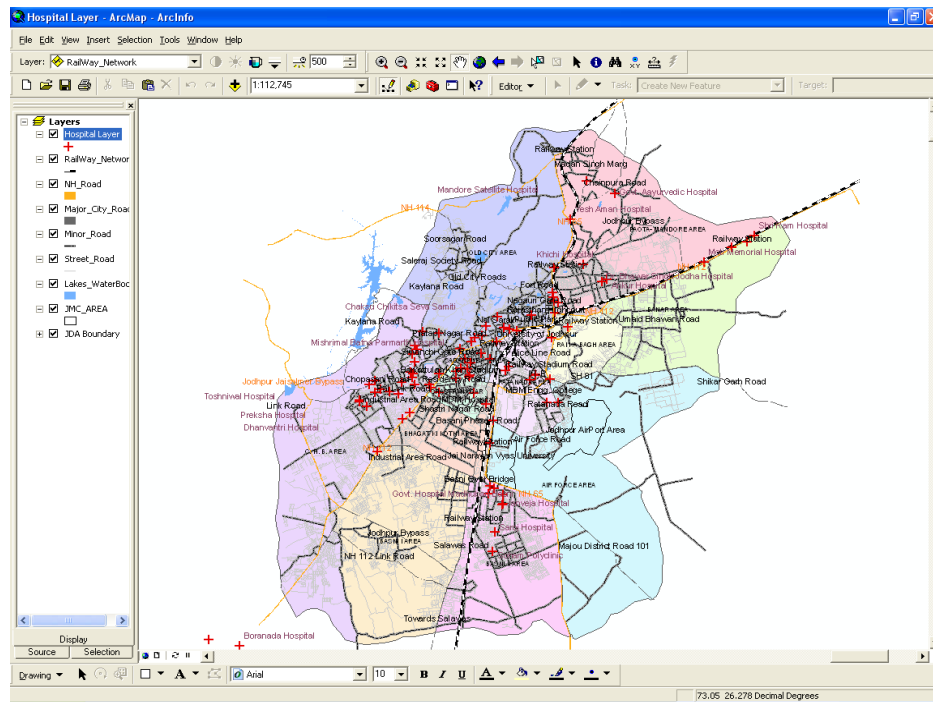


Fig 4 – Linking of Hospital layer to Jodhpur city map

As per the changing requirements, layers can be added, removed, or modified.

Results

- (i) Programs for chemical dispersion have been implemented in Java and validated with theoretical. Sensor integration worked out as prototype demonstration. On screen shot is given in Fig 5.
- (ii)

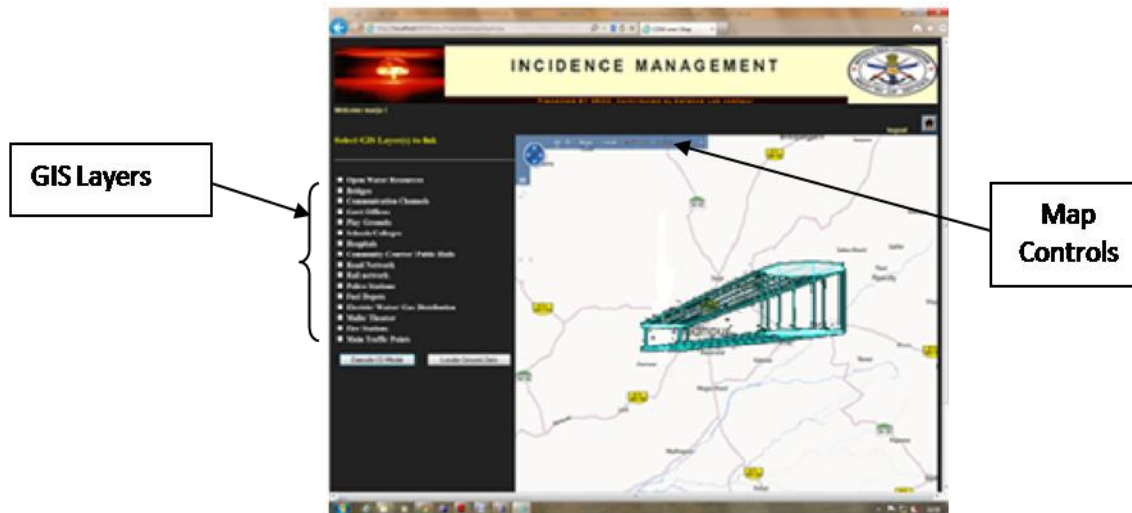


Fig: 5 – Web Application Interface for box model output on Jodhpur city map

- (iii) The GIS data design and demonstration purpose implementation for sample location has been accomplished.
- (iv) Various disaster manager functionalities and the required help have been identified for user friendly assistance.
- (v) Since the task is aimed at technology demonstration all features of disaster management viz. on line alert through GSM/ GPRS for reported events and system abnormalities have been implemented and tested.

Conclusion

Emergency Managers have realized the benefits of using Geographic Information Systems for visualization of information and as an important planning tool. The combination of this technology with the capabilities of air dispersion modelling softwares; has proved to be an invaluable resource for responding to chemical release scenarios. These tools can be used to respond to all emergency release scenarios, whether it emanates from natural, accidental, and intentional causes and also for planning and training purposes like contingency planning and short-term site assessments.

The use of GIS enabled air dispersion modeling provides an additional level of situational awareness not available from either stand-alone GIS software or dispersion modeling software and it should be a tool available to every emergency manager.

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