Volatile organic Compounds Diffusion Model of Atmospheric Pollutants in Central Urban Area Based on GIS

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Atmospheric pollutant VOCs are negative products brought about by economic development and urbanization. They are mainly produced by chemical production and transportation industries, which have seriously affected people's daily life. GIS has superior spatial analysis and data management functions. This paper builds a diffusion model of urban atmospheric pollutant VOCs based on GIS technology, provides intuitive, scientific and effective data for assisting atmospheric pollution emergency work, and studies and analyzes the atmospheric pollution diffusion simulation in Central Urban Area of Changsha City. The results show that GIS has a wide range of applications in the atmosphere, including data preprocessing, secondary development of models, final data processing, and display output of computing results. Map Objects is introduced to confirm the feasibility and necessity of integrating atmospheric pollution diffusion research with GIS. The study on VOCS diffusion model of atmospheric pollutants in central urban area based on GIS finds that the atmospheric pollution characteristics and pollution sources distribution of VOCs in the central urban area of Changsha City are closely related to the environment of the built-up area.

1. Introduction

With the continuous advancement of China's urbanization process and the continuous expansion of urban scale, urban atmospheric pollution problems are becoming prominent in the city at the same or faster speed. In recent years, the smog weather in China happens frequently, and the problem of regional atmospheric composite pollution characterized by ozone, fine particulate matter (PM2.5) and acid rain has become increasingly prominent. As an important precursor of ozone and secondary organic particulate matter, Volatile Organic Compounds (VOCs) play an extremely important role in the atmospheric chemical reaction process, and are receiving more attention. Therefore, revealing the diffusion law of urban atmospheric pollutant VOCs through GIS technology will play an active role in further revealing the inherent relationship between urban spatial layout and the diffusion of atmospheric pollutant VOCs, improving air quality and alleviating urban smog weather (Xin, 2018).

Atmospheric pollution is an environmental and safety issue that is of universal concern in all countries of the world. With the rapid development of urban economy, the emission rate of atmospheric pollutant VOCs is getting higher and higher, and the types and quantities of environmental risk sources are increasing (Vizcaino and Pistocchi, 2014). Atmospheric pollutant VOCs are different from general environmental pollution, and they are sudden, dangerous, and difficult to handle (Allajbeu et al., 2016). The diffusion of atmospheric pollutant VOCs has obvious temporal and spatial variation characteristics. The interaction of these characteristics with environmental factors determines the evolution of pollution properties, the intensity changes and the dynamic evolution paths in time and space (Righini et al., 2014, Nadal et al., 2011). It has been found that Geographic Information System (GIS) can realize the evolution mechanism and dynamic simulation process of air pollutants, thus effectively reducing accidents and economic losses caused by air pollution (Pinto et al., 2010). The atmospheric diffusion model, also known as the "atmospheric turbulent diffusion model", often uses physical simulation and mathematical simulation for simulation and numerical analysis. The established models include the diffusion K model, the Taylor statistical model and the Gaussian analytical model (Li et al., 2018., Maisey et al., 2013). Among them, the Gaussian analytical model is divided into bounded elevated

continuous point source diffusion mode and unbounded instantaneous point source mode according to different atmospheric pollution and meteorological fields (Mansha et al., 2011). GIS can manage spatial data by spatial location and study the interrelationship between various spatial entities. Developing accident warning and application systems on GIS platform can quickly obtain the required information and express them in maps and graphs (Zhang et al., 2017). This paper builds a diffusion model of urban atmospheric pollutant VOCs based on GIS technology, and provides intuitive, scientific and effective data for assisting atmospheric pollution emergency work.

2. Basic theory of VOCs diffusion simulation of urban atmospheric pollutants

2.1 Atmospheric diffusion mode

The diffusion of atmospheric pollutants in the city refers to the process of concentration dilution of pollutants in the atmosphere. The main influencing factors include atmospheric turbulence, underlying surface, atmospheric pollution factors, layered atmospheric structure, meteorological factors and atmospheric stability (Yurdakul et al., 2017, Król et al., 2010). The diffusion of pollutants is not a simple diffusion process, especially for VOCs, where a series of physical changes occur during the diffusion process (Martins and Fuentes, 2015). Figure 1 shows the general composition of the atmospheric diffusion model. The pollutant emission status, natural meteorological conditions and underlying surface conditions are used as mathematical models and input parameters for atmospheric diffusion simulation. Urban atmospheric pollution modes include point source plume diffusion mode, line source pollution diffusion mode, and surface source pollution diffusion mode. Urban pollutant VOCs are generally emitted by chemical plants, and the lift height of flue gas is extremely important for the spread of pollutants. The higher the lift height, the more favorable it is for the diffusion of pollutants (Kumar et al., 2009). The lift height ΔH is calculated as shown in Equations 1 and 2:

$$\Delta H = n_0 Q_h^{n1} H n^2 U^{-1} \tag{1}$$

$$Q_h = 0.35 P_\alpha Q_v (\Delta T / T_s) \tag{2}$$

Where: n_0 is the degree of gas heat, n_1 is the heat release rate, and n_2 is the discharge height. The specific numerical values are shown as Table 1;
Q_h is the heat release rate of atmospheric pollutants;
H is the vertical height of the emitting chimney;
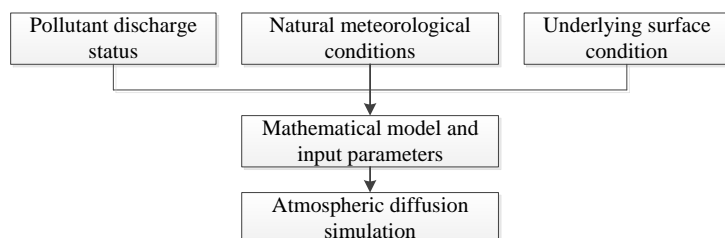Q_v is the effective blowdown rate.

Figure 1: General composition of atmospheric diffusion modes

Table 1: Parameter selection in different regional environments

Qh	Surface condition	n_0	n_1	n_2
≥20000	Urban far suburb	1.438	0.33	0.67
	Near urban suburb	1.314	0.33	0.67
2000 ~ 20000	Urban far suburb	0.343	0.6	0.67
	Near urban suburb	0.303	0.6	0.67

2.2 Integration of GIS and environment models

It has been found that the use of GIS can achieve integration with the atmosphere quality model, and the timely and superior information collection and management analysis functions of GIS can be effectively used for atmospheric environmental quality models. GIS has a wide range of applications in the atmosphere, including data preprocessing, secondary development of models, final data processing, and display output of computing results. The data source included in the environmental model includes industrial exhaust emission data, topographic map data, meteorological condition parameters and linear pollution of road traffic flow. After

data collection, the data should be discretized, and then the influence range of pollution source diffusion should be determined and substituted into various types of natural data and source data for the calculation of the concentrations at the prediction points.

3. GIS-based design and implementation of atmospheric pollutant VOCs diffusion

3.1 System design

The development platform designed basing on GIS technology includes the hardware environment and software environment for system development and operation. The framework level includes user layer, function layer, middle layer and data layer. Figure 2 shows the GIS-based atmospheric diffusion simulation calculation process, through user-defined parameters, it establishes the Gaussian point source coordinates and performs coordinate transformation, then it uses fan shape to screen the coordinate calculation point, calculates the concentration of the discrete points, and uses the normal Kriging interpolation method to calculate and generate approximate contours by the ellipse method. Figure 3 is the contour of the pollutant concentration value C, the contour determination method calculates the contour concentration value of each layer according to the maximum and minimum concentrations in the points and the required contour numbers. Table 2 shows the horizontal and vertical atmospheric diffusion power function index table structure. The table shows the index tables yests and zests stored in the environmental professional database, which respectively give the data types and lengths corresponding to different field names.
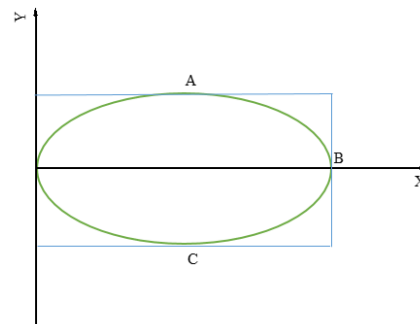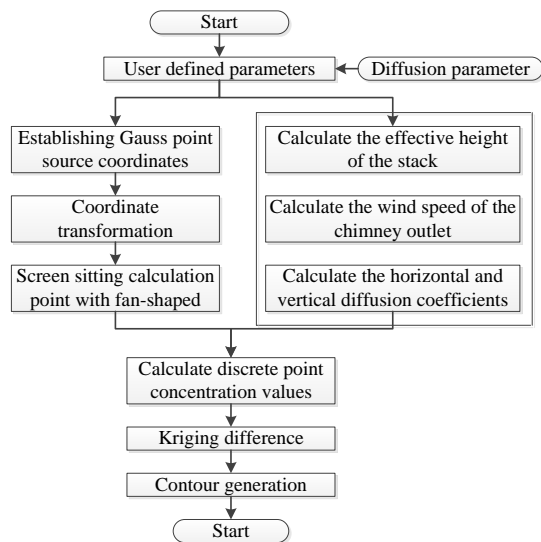
Figure 2: GIS-based atmospheric diffusion simulation calculation process

Figure 3: Contour of pollutant concentration value C

Table 2: Horizontal and vertical atmospheric diffusion power function index table structure

Field name	Data type	Length	Whether to allow null	Description
PS	Char	3	No	Atmospheric stability
a	Double	7	No	Atmospheric diffusion regression index
b	Double	7	No	Atmospheric diffusion regression index
Max	Int	3	No	Maximum lower wind distance
Min	Int	3	No	Minimum distance of lower wind

3.2 System function realization

Figure 4 is a system function library division diagram. The atmospheric diffusion model system consists of four modules, respectively are: map browsing, map query, map editing and atmospheric diffusion. The atmospheric diffusion module includes defined parameters and diffusion simulation. MapObjects has a map control and several AutoX objects of ActiveX type, which can be used to access the map database. Figure 5 is the composition of MapObjects, which consists of five parts of data access object group, map display object group, geometric figure object group, projective object group and practical object group. MapObjects has a

wide range of functions, it can symbolize maps, support the management and operation of map layers, provide various query functions and spatial database access.
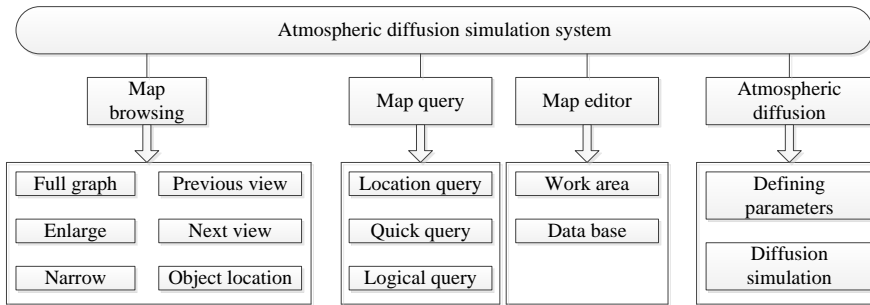
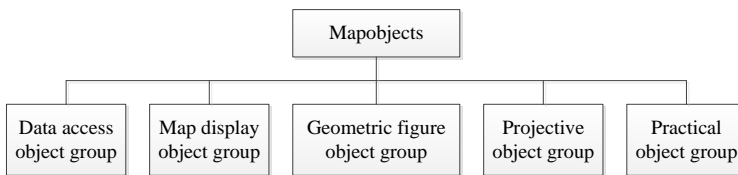Figure 4: System function library division

Figure 5: The composition of MapObjects

4. Study on VOC$_S$ Diffusion Model of Atmospheric Pollutants in Central Urban Area Based on GIS

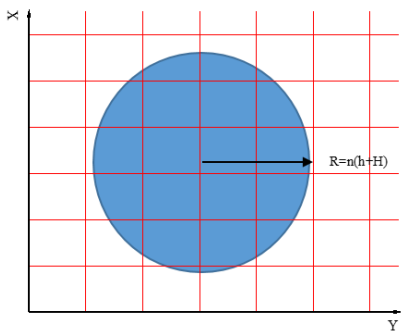### 4.1 Functions of the simulation system

Figure 6: Areas formed by point source pollution diffusion in static wind state
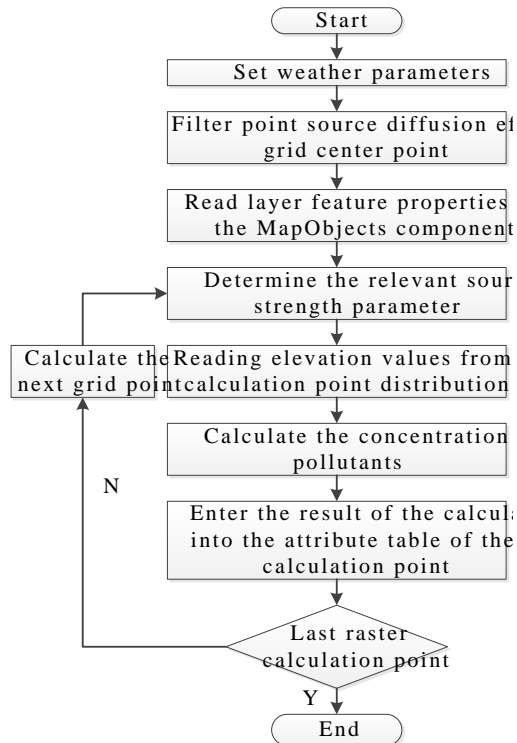
Figure 7: Calculation process of point source pollution diffusion in static wind state

Table 3: Distribution of major industrial pollution in Central Urban Area of Changsha City

Area name	Factory quantity	Factory area /km^2
Chengguan district	2	28.37
Qilihe district	1	141.11
Anning district	2	19.67
Xigu district	11	749.27
Honggu district	3	146.61

The main pollution sources of atmospheric pollutant VOCs in Central Urban Area of Changsha City include industrial pollution and traffic pollution. Table 3 shows the main industrial pollution distribution in Central Urban Area of Changsha City. It can be seen that Xigu District accounts for more than 60% of the city's main pollution sources, including large petrochemical enterprises. The smog pollutant leads to high concentration near the pollution source, and it is regarded as point source pollution in the static wind state. Figure 6 shows the areas formed by diffusion of the point source pollutant under the static wind conditions, the radius of the pollution surface of the point source pollutant is n times the sum of the smog lift height and the chimney vertical height. Figure 7 shows the calculation flow of point source pollution diffusion under static wind condition, in the static wind state, set the meteorological parameters and determine the center point of the point source diffusion, read the map layer element information from the MapObjects component to determine the relevant source strength parameters, read the elevation value from the grid calculation point distribution map layer and calculate the concentration of the pollutant, and then record the calculation result value into the attribute table of the grid calculation point.

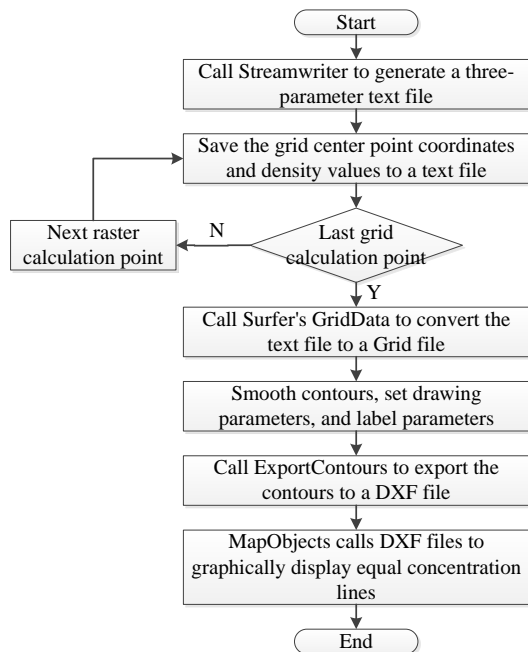**4.2 Calculation of pollutant concentration at fixed points**

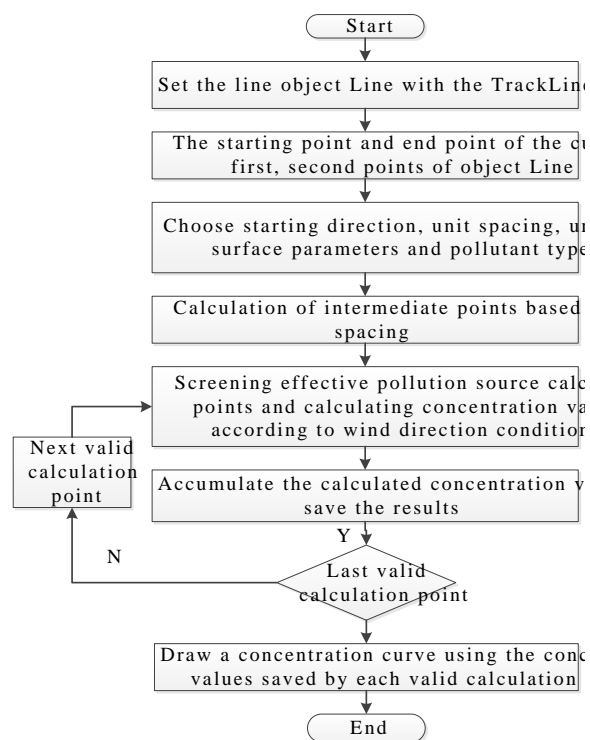Figure 8: Concentration contour drawing process

Figure 9: Calculation process of atmospheric pollution diffusion concentration curve

In the process of environmental monitoring, we will query the environment information of the atmosphere pollution at a certain point. Therefore, the calculation application of the concentration of pollutants at a fixed point is very extensive. The existing research method uses interpolation method for calculation according to nearby atmospheric pollution situation. This section uses statistical methods to screen out the nearby pollution sources to draw the concentration contours, and to calculate the pollutant concentration values at fixed points.

Figure 8 shows the drawing process of the concentration contours, by using the compiled simulation system, the StreamWriter is called to generate a three-parameter text file. The coordinates and concentration values of the grid center point are stored in the text file, and then the GridData of Surfer is called to convert the text file into a Grid file, draw smooth contours, and set drawing parameters and label parameters, then call the DXF file with MapObjects, and graphically display the concentration contours. Figure 9 shows the calculation flow of the atmospheric pollution diffusion concentration curve. Select starting point and end point on the map, screen out effective pollution source calculation points according to the wind direction conditions, then accumulate to calculate the result concentration value and draw the concentration curve using the concentration values saved by each valid calculation point.

5. Conclusion

This paper builds a diffusion model of urban atmospheric pollutant VOCs based on GIS technology. The specific conclusions are as follows:

(1) GIS has a wide range of applications in the atmosphere, including data preprocessing, secondary development of models, final data processing, and display output of computing results.

(2) MapObjects consists of five parts: data access object group, map display object group, geometric figure object group, projection object group and practical object group. It has a wide range of functions, it can symbolize maps, support the management and operation of map layers, provide various query functions and spatial database access.

(3) For the atmospheric pollution source, under the static wind state conditions, draw a circular area of n times the sum of the smog lift height and the chimney vertical height, then superimpose the area with the selected analysis point layer, so as to obtain that the target covered by the circle are all effective calculation points.

Acknowledgments

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