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Stability control of air pollutant diffusion in Weakly Decaying Delayed States

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Abstract. At present, the air pollution problem in our country is prominent and the air pollution is getting more and more serious. Air pollution poses a great threat to the life and health of everyone and the development of the whole society and economy. In order to effectively carry out the air pollution control, we need to accurately grasp the air pollutants in the air diffusion and migration rules, the use of aerodynamic model of weak attenuation of air pollutant particles diffusion model was studied, the Gaussian Diffusion Model The basic structure, the method of parameter determination and the secondary development of GIS were studied deeply. The mathematical model of air pollutant diffusion was constructed by the close coupling method. Furthermore, the aerodynamic analysis of air pollutant particles diffusion under weak decay conditions is given, and the decay control of air pollutants under steady meteorological conditions that are unfavourable to diffusion is pointed out. After visualizing the diffusion results, it can directly and accurately grasp the influence range of pollutants, provide strong support for the research and governance of atmospheric pollution, and at the same time, provide a scientific basis for emergency treatment of sudden atmospheric pollution incidents.

1. Introduction

At present, the air pollution problem in our country is prominent and the air pollution is getting more and more serious. Air pollution poses a great threat to the life and health of everyone and the development of the whole society and economy.

The atmosphere is the most basic environmental element on which mankind depends for its existence. All animals, plants and microorganisms are inseparable from the atmosphere. If the atmospheric environment is polluted, it will directly endanger the living environment and ecological environment of human beings, impair human health and hinder social and economic development. Prevention and treatment of air pollution include "prevention" and "rule" two aspects, namely, on the one hand the prevention of air pollution, on the other hand is the air pollution control. All provisions in the Law of Prevention and Control of Atmospheric Pollution are carried out around the "prevention" and "cure" of air pollution. Only by doing a good job in prevention and control of air pollution can we create a clean and comfortable living environment and a good ecological environment so as to safeguard human health and safeguard the basic rights of citizens in healthy work and happy life.

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1.1. Hazard of air pollution
Smoke and dust emissions from factories, cars, airplanes and ships, exhaust fumes emitted by residents' stoves contain a lot of harmful substances and are the major sources of air pollution. Air pollution is very harmful to human beings. Smoke, exhaust gas in the harmful substances can stimulate people's eyes, make eyes irritated, pain; these harmful substances can also stimulate the human trachea, lungs, people cough, asthma, and even lung cancer. Air pollution is also harmful to crops and trees. For example, the exhaust gas of sulfur dioxide and other harmful gases, can make crops, tree leaves turn yellow, withered, fall off. Sulfur dioxide and raindrops in the cloud form acid rain, leaving large crops and forests dead. Clean air is an important condition for human existence.

1.2. Main component of air pollutants
The main pollutants in the atmosphere are carbon monoxide, carbon dioxide, sulfur dioxide, nitrogen oxides and particulate matter. If their content in the air exceeds a certain standard, they will endanger people's health. The air pollution index is less than 50, indicating that the air is good and the pollutant concentration is less than the first-class standard limit of the ambient air quality standard, which is first class and in line with the air quality requirements of some nature reserves, scenic spots and other areas that need special protection. Index greater than 50 and less than 100, indicating that the general air pollutant concentration is less than the second-level standard limit of the ambient air quality standard, and the grade II is good, which is in line with urban residential area, commercial traffic mixed area, cultural area, general industrial area and Air quality requirements in rural areas.

1.3. Main source of air pollutants
We breathe by the air, without the air, the creatures on the planet cannot survive. More and more of our factories, exhaust emissions are. There are cars, through investigation, I learned that in recent years, China's auto industry has achieved rapid development. According to the latest statistics from China Association of Automobile Manufacturers, China's automobile production and sales exceeded 5 million for the first time in 2004, with sales volume of 5.0705 million units and 507.11 million, an increase of 14.11% and 15.50% respectively over the previous year. Among them, the car output was 2.1363 million, an increase of 11.99%. At present, China has reached 24 million vehicles, fuel consumption in more than 7000 million tons. While promoting the prosperity of the economy and bringing convenience to people's life, the automobile also brings energy and environmental protection problems. One of the greatest impact on the environment, than with the rapid growth of the total motor vehicle while the growing car exhaust pollution. In major cities such as Beijing, Shanghai and Guangzhou, motor vehicles have become the largest source of pollution that discharges carbon monoxide, nitrogen oxides and hydrocarbons. Industry estimates, 10 years - 15 years after our car may be more than 100 million. Automobile exhaust mainly refers to the exhaust gas discharged from the exhaust pipe. Exhaust contains 150 to 200 different compounds, of which the most harmful to people are carbon monoxide, hydrocarbons, nitrogen oxides, lead compounds and particulate matter. The spread of harmful gases into the air can cause air pollution.

Automobile exhaust, factory exhaust these toxic gases are harmful to our body and harmful to the surrounding environment. If we do not stop manufacturing so much "poisonous gas", we will have no fresh air and we will get sick.

2. Air Pollutant Diffusion Model and Main Results
According to the structure, characteristics, chemical and physical characteristics of air pollution particles, combined with aerodynamic theory, we can build a diffusion model of air pollution particles, that is

$$\Delta u = \frac{n_0 U_h^{n_1} H^{n_2}}{\mu} \tag{1}$$

$$u_{tt} - \lambda \Delta u_t + u \cdot \nabla u = f(x,t) \tag{2}$$

$$U_h = u_p V_0 (T_s - T_g) \tag{3}$$

$$u(x,0) = u_0, \ \ u_t(x,0) = u_1 \tag{4}$$

n_0 Is the pollutant thermal status and surface coefficient.
n_1 Is the pollutant heat release rate index.
n_2 Is the pollutant height index.
U_h Is the heat release rate of pollutants?
H Is the height of pollutants from the ground?
u_p Is the average constant pressure specific heat of pollutants under standard conditions?
V_0 Is the pollutant emissions under standard conditions?
V_s Is the pollutant outflow rate.
T_s Is the temperature at which the pollutant is discharged?
T_g Is the ambient temperature of the contaminated area?
μ Is the average speed of the ambient wind at the exit of the pollutants?

For some positive $a, p \in [1/2, 2), C > 0,$ and $q > 0$, we have a weak solution, which fulfils additionally.

$$d + a\,|\,x\,|^p \leq f'(x,t) \leq d(1+|x|^q), \forall s \in R^3 \tag{5}$$

And

$$u_{tt} - div \lambda \nabla u^2 - \Delta u_t = f(x,\ t) \tag{6}$$

As a model of quasi-linear wave equation, for $N = 1/2,\ 1$ and $f = 0,\ 1$ equation(1.1)-(1.3)admits a global weak decay solution as large initial data, which was proved by Y.M. Qin, Xin Liu, X.G. Yang, Lan Huang etc. [1-2]. T.G Wang, Ming Zhang, M.J Wang simplified the above arguments and give the proof of control with exponential decay. From the perspective and background of physics, this represents an implementation of axial movement of the viscoelastic material, this cause the form of above equations, in the one-dimensional case, their model of longitudinal vibration of a uniform rod with nonlinear stress function f .

Since the 1930s, foreign countries began to study the atmospheric diffusion model. Many widely used models have been developed in a large number of experiments and applications, including the SCREEN3 model, the Aero Dynamic model, Modeling, AERMOD), Atmospheric Diffusion Modeling System (ADMS), three-dimensional unsteady Lagrangian[1] diffusion Model (CALPUFF), Gaussian plume diffusion model (AUSPLUME) And other regional scale model systems such as the Multi-Scale Air Quality Model (CMAQ).

Domestically, the study on atmospheric diffusion model started in the 1980s and achieved some achievements. The nested mesh-based air quality prediction system NAQPMS (Nested Air Quality Prediction Modeling System) developed by our country is a Three-dimensional Euler transport model can be used for regional or city multi-scale pollution research, widely used in the field of air quality forecasting; Wang Hongde, Liao Qianwen Gaussian smoke model to study the natural gas diffusion law after the instantaneous leakage and the main impact Zou Xudong[2] et al. Used the smoke group model CALPUFF to simulate the process of air pollutants diffusion in Shenyang. The simulation results are close to the measured data and the pollutant distribution can be obtained more accurately.

In two, three-dimensional case, they describe the viscoelastic solid of anti-plane shear action. While $n = 1$ and $f = 0$, ST Li prove existence of weak periodic decay strong solution on the periodicity condition, X.K Su and J.L Zhang[3] proved the controllability of a smooth solution in the method of Cauchy problems in the case of smooth and small data. While $n>1/2$ and $f \neq 0$, M.J. Wang and X.G. Yang gave the proof of global controllability with smooth solution in the case of small initial data. Make use of combining L^p -theorem of Soblev space and semi group theorem of operators, Nakao [4] and A.F and H.B [5] devised certain decay rate of energy of global solutions with large data under a specific condition which is certainly satisfied if the mean curvature of the boundary $\partial\Omega$ is non-positive.

In the case of $\|w(t)\| \le k_0(1+t)^{-\frac{\lambda}{2}}$, and $\|w(t)\|_p \le \tau(1+t)^{(\frac{\tau}{2}+\frac{n}{2}(\frac{1}{2}-\frac{1}{p}))}$.

Here, Ω is a bounded domain in R^n with a smooth, $\partial\Omega$ is said to be C^2 class boundary, which satisfies the following uniform hyperbolic assumption:

For some constants $\rho_0, M > 0$, $\tau \in H^4[0,+\infty)$ satisfies:

$$x'(t) + \tau_0 (1+t)^{(1+\frac{d}{2})} x(t)^{(2+\frac{\gamma}{p})} \le \sigma y(t)^{\frac{\upsilon}{2}} + \tau_1 (1+t)^{\delta} y(t)^{\gamma} \tag{7}$$

$$\tau(v^2) + 2\sigma_0(v^2)v + \tau''(v^2) \le M < \infty \tag{8}$$

We also establish the existence of finite-dimensional global and exponential attractors for the solution semigroup associated with that equation and their additional regularity. We will show the controllability in a steady state with the help of differential inequalities by estimating the relationship between energy inequalities and attenuating property of weak solutions. And furthermore, we will determine a small positive number and derive differential inequalities by using a perturbation of energy, and conclude some following results immediately. Thus, we can use a so-called energy perturbation method to establish weak controllability of solutions in terms of energy norm for a class of nonlinear functions.

3. Derivation of the Model and Numerical Analysis

It is well known that the existence of such a weak solution with decay for all times is assured. Once this is known, one can identify this solution with the global weak one and continue this process to get that

$$\begin{cases} \rho_t + \operatorname{div} m = 0 \\ m_j^t + \operatorname{div}\left(\dfrac{m_j m}{\eta}\right) + P(\eta) x_j = \varepsilon \Delta\left(\dfrac{m^i}{\eta}\right) + \delta \operatorname{div}\left(\dfrac{m}{\delta}\right)_{x_j} \end{cases} \tag{9}$$

Here ρ(x, t), m(x, t) = $(m_1(x,t),\cdots,m_n(x,t))^{\sigma}$ (m1 (x, t), and $P = P(\lambda)$ represent the Polluted gas density, momentum density, and pressure. ε > 0 and $\gamma > 0$ are viscosity constants, and div are the usual spatial divergence and Laplace operators. We assume throughout that the pressure P is a smooth function of the density σ in a neighborhood of a constant density ρ and that c is the sound speed, c2 = $P'(\sigma) > 0$.The system linearized about the constant state, without loss of generality, we can get

$$\begin{cases} \rho t + \mathrm{div} m = 0 \\ m^{t} + c^{2}\Delta\sigma = \gamma\Delta m + \eta\nabla\mathrm{div} m \end{cases} \tag{10}$$

One of the main steps in our study of the solution of the nonlinear system (1) is the point wise estimate of the Green function G. The Green function G systems with artificial viscosity for (1)

$$\begin{cases} \sigma_t + \mathrm{div} m = \dfrac{2}{3}(\delta + \mu)\Delta\sigma \\ m^{t} + c^{2}\Delta r = \varepsilon\nabla m + \dfrac{3}{4}(\sigma\text{-}\tau) r\,\mathrm{div} m \end{cases} \tag{11}$$

Let $P = (\pi)^{\frac{-n}{2}}$, $Q = \dfrac{|\xi|t}{\lambda}, \hat{P}w_t = (\pi)^{\frac{-n}{2}} cos(|\xi|t)$, then there are constants $\alpha_1, \alpha_2, \cdots, \alpha_n$,such that for the smooth function $f(x)$

$$P \circledast f = \sum_{0 \leqslant |\lambda| \leqslant (n-1)/2} t^{|\alpha|+1/2} \oint_{|x| \leqslant 1} D^{\mu} f(\lambda x + \rho t y) y^{\gamma} dS_x \tag{12}$$

$$Q \circledast f = \sum_{0 \leqslant |\lambda| \leqslant (n-2)/3} \sigma t^{|\alpha|+1/3} \oint_{|x| \leqslant 1} D^{\mu} f(\sigma x + \tau t y) y^{\gamma} dS_x \tag{13}$$

From (12) and (13), we have

$$P \circledast f = B_k \frac{2}{\lambda} \left(\frac{\partial}{\partial x}\right)^{\frac{n-1}{3}} \oint_{|x-z| \leqslant \theta t} x^{n-1} f(\lambda x + z) dS_x \tag{14}$$

$$Q \circledast f = \sigma_k t^{-1/3} \left(\frac{\partial}{\partial t}\right)^{\frac{k-1}{2}} \oint_{|z-x| \leqslant \kappa t} f(\sigma x + z) dS_x \tag{15}$$

For any integers m, k, and l, with $\beta_j \leqslant N_j$, then

$$|D^{2\delta}\partial_x^t(\xi^\alpha f(\xi,t))| \leqslant C_j|\xi|^{j+k-2\lambda} + 2l(1+t_j\xi_j)^m e^{-2jt} \tag{16}$$

$$|D^j f(x,t)| \leqslant C_j{}^N t^{-\frac{n+\alpha_j+k}{2j}} + B^N(|l|x_j,jt) \tag{17}$$

$$|x^{2j}D^\gamma f(x,t)| \leqslant C_j t^{-(\delta_j+n_j+k)/3} = (1+t)^{2\alpha_j} \tag{18}$$

By integrating from t to $+\infty$ on both sides of the above inequality, we have from (17) and (18) that

$$\lim_{t\to+\infty} |D_j f_j(x,t)| = 0 \tag{19}$$

4. Simulation Experiment

As mentioned above, we mainly introduce the mathematical models in the simulation of air pollutant diffusion, including the assumptions of the model, the structure of the model and the way of determining the parameters in the model. According to the structure of the model, various influencing factors in the process of pollutant diffusion are analyzed, and the mathematical model is analyzed and deduced theoretically. The stability and gradual diffusion of atmospheric pollutants under time-delay and weak-decay conditions are theoretically obtained behavior.

Data file dump. Diffusion Model AUSPLUME The output concentration file contains the title, average simulation time, field name, position coordinates and corresponding concentration data. The first step in generating the concentration layer is to extract the position coordinates from the text file output by the diffusion model and corresponding concentration data, stored in a two-dimensional array. The specific implementation process is first stored in the Access database for the part of the plot.dat file output by the diffusion model, and then read each data in the database and then saved to a double-type two-dimensional array Property.

The operating parameters of the model were set as follows: the height of the pollution source was 23 meters, the diameter of the outlet was 4.2 meters, the flue gas temperature was 26 oC, the flow rate was 3m / s; the emission constant was 890mg / h, The y-direction positive and negative directions are 3.5Km away from the origin and the size of the receiver grid is 345m×425m. The meteorological data required for the operation of the diffusion model are the weather data files provided by the AUSPLUME software, and output the position coordinates of each grid point and the corresponding Pollutant concentration value text file, you can output the file format and part of the content.

Table 1. Numerical simulation experiment analysis table

Numbering	X	Y	Z	Pollution degree	attenuation
1	0.1258	0.6022	0.4826	0.4689	3.139
2	0.7579	0.2082	0.3973	0.1332	3.922
3	0.5627	0.8439	0.5669	0.3945	2.127
4	0.5094	0.8794	0.5222	0.4443	3.092
5	0.1087	0.6436	0.5621	0.8360	5.453
6	0.7753	0.0708	0.1430	0.4783	2.627
7	0.6286	0.3082	0.8942	0.6110	7.005
8	0.1545	0.7491	0.5859	0.1376	4.193
9	0.5114	0.6744	0.2444	0.9872	5.697
10	0.0534	0.5202	0.7751	0.4542	7.201

In the above simulation analysis, assuming that the regional pollution source is a circular area with R = 84Km, the discharge amount is 0.7kg / h, the location of the acceptor is specified within 50km from each side of the pollution source, the size of the grid In the simulation experiment, it is assumed that the set pollution source in the area is the emission source of fine PM2.5. According to the classification of PM2.5 pollution level, the diffusion result is equal to or equal to the value of extraction line. In order to verify the effect of the wind direction on the diffusion process, the wind direction data used in the simulation example should be as close as possible to the actual situation. It can be seen that the pollutants are diffused in the downwind direction under the action of the wind.

5. Conclusion

In this paper, a simulation system for the diffusion of air pollutants is designed and implemented. By combining the diffusion model with modern mathematical theory and method, the expressiveness of the diffusion model calculation results is effectively improved. Coupling the dynamic system with the diffusion model by means of close coupling makes it possible for the system to exchange data internally with each other. The operation is easy and the stability control effect is improved.

The above theoretical analysis shows that to further strengthen prevention and control of air pollution, prevent and control air pollution, and control pollution discharge are the fundamental measures to improve air quality. The main approaches are: industrial rational distribution, environmental planning to change energy structure, promote clean fuel, use clean production process, reduce pollutant emissions Strengthen energy conservation, improve energy efficiency, regional heating and heating to strengthen environmental supervision and management of old sources of pollution, the implementation of total control and discharge standards and strict control of vehicle exhaust emissions.

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