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Creation of Environmental Pollution Monitoring Systems Using Digital Educational Technologies

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Abstract. This article explores the development of environmental pollution monitoring systems utilizing digital educational technologies. It emphasizes the global focus on creating mathematical models, effective numerical algorithms, and software packages to aid decision-making in mitigating the adverse effects of anthropogenic waste. The study highlights the importance of monitoring the migration and diffusion of toxic substances in industrial atmospheres, as well as assessing and predicting their concentration levels while considering background pollution, weather conditions, and the area's orographic features. The findings underscore the theoretical and practical significance of these monitoring systems, which are essential for effective environmental protection and management. By integrating advanced digital technologies, this research contributes to the ongoing efforts to enhance environmental monitoring practices and supports the development of more effective strategies for safeguarding ecological health.

INTRODUCTION

"Atmospheric air as a component of natural resources is a national asset and is protected by the state. A person can live without water for several days, without food for a month, and without air for only a few minutes. In the Republic of Uzbekistan, large-scale measures are being taken to prevent the disturbance of the ecological balance of the existing ecosystems due to the pollution of the atmosphere by natural and anthropogenic sources. In particular, in the Action Strategy for the further development of the Republic of Uzbekistan in 2017-2021" [1] , "... to ensure that people live in an ecologically safe environment, ... to prevent environmental problems that harm the natural environment, population health and gene pool, ... creation of effective mechanisms for solving environmental problems in the regions, ... development of a unified system of monitoring and forecasting the possibility of natural, man-made and ecological emergency situations" [1], ecology and environment by our state - indicates that important attention is paid to environmental protection. Today, in order to carry out the above-mentioned tasks, adequate mathematical models, effective computational algorithms for environmental load assessment and prediction, as well as for making management decisions aimed at environmental protection It is unimaginable without automated automated systems. Basic aspects of the methodology of mathematical modeling of the process of short and long distance migration of toxic substances in the boundary layer of the atmosphere L. Thaning, E. Naslund, W.J. Layton, C. Berselli, J.M. Germano, H. Ferziger, J. Geiser, U. Piomelli, G.S. Winckelmans, W.C. Reynolds, It is covered in the works of foreign scientists such as N.A. Fuks [6], O.I. Xinse [5], G.I. Marchuk [9], M.Ye. Berlyand [8], Ye.P. Mednikov [7], V.V. Penenko, V.M. Belolipeskaya, M.V. Menshov, V.I. Naas, V.K. Arguchinsev. N. Ravshanov [2], [3], N. Toshtemirova [2], D. Akhmedov [2], D.K. Sharipov [3], D.D. Akhmedov[4] and other scientists studied.

The stages of the process of ensuring environmental sustainability are identification of environmental risks, prediction of their consequences, impact assessment, etc. It is characterized by non-linearity, multifactoriality and some level of uncertainty. Therefore, GIS technologies, methods of multidimensional processing of environmental indicators and, most importantly, mathematical modeling methods [11].

The correct methodology of mathematical modeling and computational experiments, together with the use of appropriate ICT tools, is designed to fill existing gaps in ecological research and to make the process of environmental sustainability as effective as possible [10].

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For the developed mathematical models, a calculation algorithm is created for it using analytical or numerical methods. With the help of a structured calculation algorithm, a special software package is created on the computer based on some programming languages. This trinity created - "mathematical model-numerical algorithm - software complex" is an effective tool for monitoring and forecasting the problem of migration and diffusion of toxic substances in the atmosphere. This type of ternary complexes is detailed in the work of many authors who conducted scientific research in this field and obtained effective results [12; 13; 14; 15;].

The speed of a particle moving in the atmosphere in a turbulent flow is expressed by the following differential equation in the works of several authors [16, 17]:

$$\frac{\pi}{6} d_ч^3 \rho_p \frac{du_{p_i}}{dt} = 3\pi\eta d(u_i - du_{p_i}) - \frac{\pi}{6}\left(\rho_p - \rho\right)\frac{du_i}{dt} -$$
$$-\frac{1}{2}\frac{\pi}{6} d_ч{}^3 \rho \left(\frac{du_i}{dt} - \frac{du_{\rho_i}}{dt}\right) + \frac{3}{2} d_ч^3 \sqrt{\pi\rho\eta} \int_{t_0}^{t} \frac{du_i/dt' - du_{\rho_i}/dt'}{\sqrt{t-t'}} dt' + F_e, \quad (1)$$

where u_i- $i$the speed of the air flow - in the direction; u_{p_i}- the speed of the particle in the same direction; t - time; t'- the considered moment of time; F_e- an external force, such as gravity $m_p g_i = \frac{1}{6}\pi d^3 \rho_p g_i$.

In the differential equation given above, the equation for finding the velocity of a particle in the atmosphere in a specified time interval is expressed, and the improved version of this equation is Yu.A. Cited in the works of Buevich [18], but it is mentioned by the author that it is possible to check the adequacy of the model only at high velocities of the ambient air flow.

The problems of mathematical modeling of the processes of dispersion and diffusion of toxic substances released into the atmosphere of production, industrial facilities and their solutions are presented in the works of ME Berland [19; 20] is cited. In the mathematical modeling of the process, the author uses a mathematical model that includes the type of toxic substance being released into the atmosphere, the distribution of wind from the center to different directions in the area under consideration, the power of sources to release toxic substances into the atmosphere, dangerous wind speeds and several other factors, and depends on this model proposed a complex of functional dependence formulas.

The main equations of migration and diffusion of particles spreading in the atmosphere - the migration equation of mixtures, the constant diffusion equation of substances, the diffusion approximation, the migration and diffusion of heavy aerosols, and the structure of turbulent motion in the atmosphere and its modeling in the work of GI Marchuk [21] is cited. In his work, the author associates x, y, z the components of the wind speed in the diffusion equation u, v, w with the appearance of the following function changing over time:

$$u = \bar{u} + u', v = \bar{v} + v', w = \bar{w} + w'; \quad (2)$$

where is u', v', w' the wind speed vector after several hours; $\bar{u}, \bar{v}, \bar{w}$ - the speed of the main wind flow.

The writer additionally introduces techniques for addressing mathematical models pertaining to the movement and dispersion of hazardous materials in the air employing computational methods, such as the strategy of subdividing the issue into segments tailored to the physical characteristics.

Analysis of mathematical models related to the migration and diffusion process of toxic substances in the atmosphere and their improvement is discussed in the works of A.E. Aloyan [22; 23] we can also see. The author recommends expressing the migration and diffusion processes of toxic particles released into the atmosphere using hydrodynamic models as a solution to the problem, as they are in a turbulent atmosphere. An efficient numerical algorithm has been developed for calculating the basic hydrodynamic equations Nave-Stokes, Reynolds equations, heat flow and moisture equations, as well as the coefficient of vertical turbulent exchange (model). $k - \varepsilon$

We can get acquainted with the processes of migration and diffusion of toxic substances in the atmosphere by the chemical transformation of toxic particles, the type of toxic substance emitted from an anthropogenic source and the mathematical model that takes into account the orography of the area under consideration and its solution using numerical methods in the work of VO Arutyunyan [24]. The migration and diffusion model was built by the author based on the turbulent diffusion equation. The vertical turbulent exchange coefficient is expressed using the Reynolds viscosity equations, as well as the dissipation rate and turbulent energy balance equations.

In the works of VI Tikhonov and AA Samarsky [25; 26] tried to solve the problem of convection-diffusion. In particular, the issue of constructing discrete analogues of approximation of the approximate solution to the exact solution is considered. Problems of iterative solutions in solving convection problems are discussed and general approaches for choosing iteration parameters are analyzed. Also, the use of finite difference schemes in solving convection problems and their stability characteristics are discussed.

METHODS

Many mathematical models have computer programs - from simple console programs to complex software systems consisting of a number of subsystems: data entry and preprocessing, modeling, postprocessing, reporting, and more. The latter, in addition to the original mathematical models, is complemented by the relevant regulatory methods for calculating the distribution of toxic emissions, source inventories, classifiers and instructions in other management documents.

Such software systems, as a rule, are developed under the auspices or at the behest of interested government bodies, respectively, existing regulatory documents are somehow implemented in business logic and program algorithms.

Recommended, preferred and alternative models for calculating the pollution of the atmosphere and the surface below it with toxic compounds:

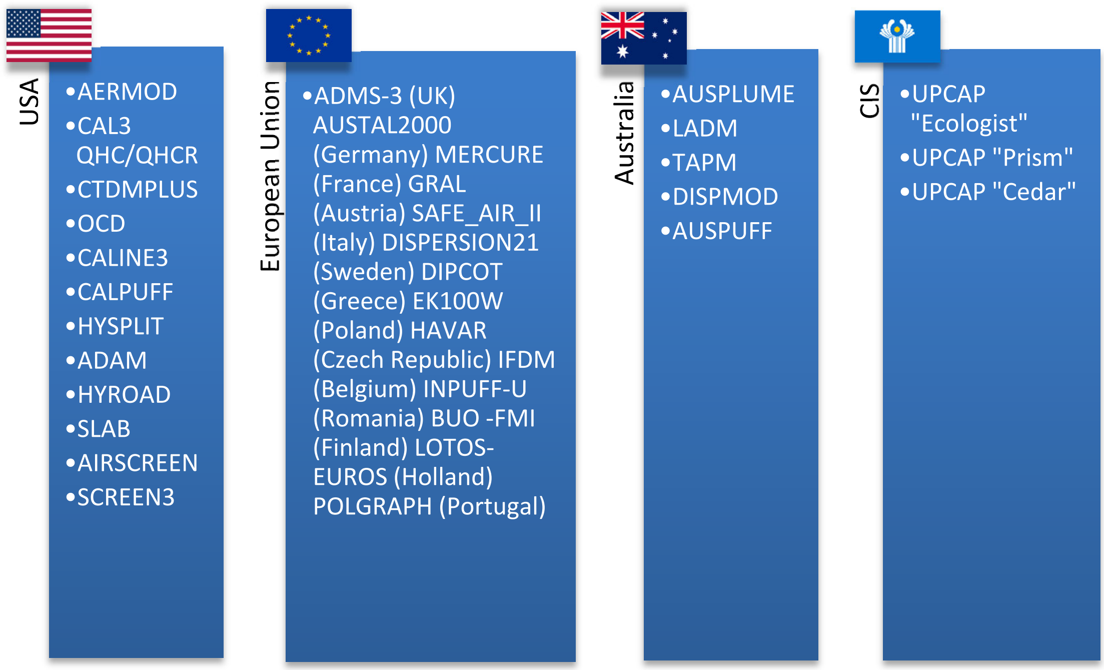

FIGURE 1. Recommended, preferred and alternative models for calculating pollution of the atmosphere and underlying surface by harmful impurities.

Among software products based on Gaussian models of the distribution of toxic compounds in the atmosphere, AERMOD is the most common [27]. The mathematical model of the same name has a high level of theoretical and experimental confirmation of its adequacy. Since 2005, the model has been accepted as a regulatory document by the US Environmental Protection Agency.

AERMOD is designed to estimate the distribution of emissions from stationary air pollutant sources (APS) covering the point, line, and non-line area within a 50 km radius. A system consisting of several modules, two of which are regulatory [28].

AERMET is a preprocessor of initial meteorological data for atmospheric parameters.

AERMAP is a geospatial data preprocessor for calculating the structure of the atmospheric air mass flow, taking into account the effects of the terrain.

The output data of these two modules are required to perform the basic procedure of calculating the distribution of toxic compounds over a certain average time interval. Minimum time average step 1 hour.

The remaining modules include:

AERSCREEN- for simplified "screening" of single-source impact assessment without the need to refine meteorological and geographic relief data; AERSURFACE is a pre-processor of data on the characteristics of the base surface for setting roughness classes;

BPIPPRIME – construction of a data preprocessor in the computing area to take into account the influence of building plume movement, shadow formation, etc.; AERPLOT is a postprocessor designed to convert AERMOD output files into a format suitable for visualization of pollutant concentration distribution data in third-party GIS applications.

The original software package was created in the FORTRAN programming language for 32- and 64-bit operating systems and is distributed under a free license. It should be noted that the main version of AERMOD does not have a graphical interface, and all input / output operations are based on the processing of text files of a certain structure. There are also commercial partners implemented on the basis of modern development technologies and filled with many functions: "BREEZE AERMOD" from Trinity Consultants and "AERMOD-View" from Lakes Environmental.

The leading representative of the family of Lagrangian models is the CALPUFF computer system for atmospheric air quality modeling based on the mathematical model of the same name. CALPUFF is a nonstationary layered transport and diffusion model for emission clubs. The system allows to model the process taking into account the following factors: meteorological conditions changing in time and space, including calm conditions; simultaneous monitoring of various types of pollutants; chemical transformation of pollutants; wet and dry deposition of pollutant particles and their absorption by the environment; difficult terrain; interaction with the base surface, the presence of buildings, etc.

The software package consists of three main modules and a set of individual pre- and post-processors. The core modules include CALMET, a meteorological model that generates a three-dimensional hourly wind field on a three-dimensional grid area to solve the problem;

CALPUFF is a real module for calculating the distribution of toxic compounds in the atmosphere;

CALPOST is a post-processing module for output data to provide their visualization. In addition to the main modules, CALPUFF geophysical data and meteorological data preparation, as well as interaction with external computer models, for example, the WRF (Weather Research and Forecasting) digital weather forecasting model may include various preprocessors designed to

Since development began in the early 1990s, the original implementation of the software was in FORTRAN, as in the case of AERMOD, and has similar drawbacks from a user perspective. Modern graphical additions to the core CALPUFF modules are being developed by commercial companies including Exponent, Trinity Consultants and Lakes Environmental.

Among software products for atmospheric pollution modeling based on Euler models and approaches, the TAPM system can be distinguished, developed on the basis of the mathematical model of the same name. TAPM is a 3D weather forecast model for air pollution developed by the Australian Public Research and Development Association in the late 1990s. Since TAPM is a relatively new model, its software was originally designed to work interactively using a graphical interface in a Windows operating system environment. The program is distributed under a commercial license. TAPM is an example of a program that is very difficult to learn and requires users to have a high level of domain expertise.

CIS countries, including Uzbekistan, are dominated by software products developed according to the OND-86 methodology. In Russia, since 2018, the ODN-86 methodology has been replaced by methods for calculating the emission of toxic (polluting) substances into the atmosphere (MRR-2017). The methodology of MPP-2017 does not differ significantly from OND-86. There are many computer programs that implement the OND-86 / MRR-2017 model, for example, "Ecolog", "Prisma", "Kedr", "Rainbow", etc. The common name of all programs of this type. appears to be a unified program for calculating atmospheric pollution (UPRZA).

UPRZA is fundamentally different from computer programs used in non-CIS countries. Shown in the Fig. 1 and the software products considered above are highly specialized systems for modeling the process of atmospheric pollution and are not intended to solve other related problems.

UPRZA, especially modern versions of programs such as UPRZA of the Ecolog series, have signs of information systems that solve the problems of storage, retrieval and processing of data related to the sources and emissions of atmospheric pollutants - a standardized process. identification and systematization of data on atmospheric air emissions of economic entities. IZA inventory is the main concept of the state regulatory system in the field of ecology, which serves as a basis for many related works:

- identify categories of objects that have a negative impact on the environment;
- drafting of deputies;
- planning activities during adverse meteorological conditions;

- development of sanitary protection zones (SPZ) projects, etc.

Thus, the noted UPRZA "Ecolog" (current version 4.60) is a multi-module software package that provides operation in a network multi-user environment. Features of the program include the ability to calculate the surface concentration of individual pollutants and groups of pollutants with the sum of toxic effects; accounting for different types of API, cold and heated emissions; taking into account the influence of terrain, buildings, background concentrations of pollutants; Determination of CVD boundaries; entering and editing maps of enterprises and lands; visualization of distribution maps; formation of reports and statistical documents, etc. Despite the fact that UPRZA "Ecolog", "Prisma", "Kedr" and others are modern application software, they have a much higher access limit and require the appropriate skills of users. Almost all UPRZA are distributed under commercial licenses.

RESULTS AND DISCUSSION

The criteria for computing the levels of harmful substances in the air are established in the site selection and layout of industrial facilities, in the standardization of emissions from enterprises undergoing reconstruction and in operation, and in the design of air circulation systems. It is targeted towards agencies and organizations involved in the planning, design, and construction of industrial facilities, the regulation of toxic emissions into the air, and the assessment and coordination of air pollution control measures.

Key Points:

These regulations outline the methodology for assessing the concentration of harmful substances in atmospheric emissions from industrial facilities. Compliance with these regulations is mandatory in the design and operation of enterprises, as well as in regulating emissions from facilities under reconstruction.

The regulations aim to determine surface concentrations within a two-meter layer above ground level, as well as vertical concentration distributions.

The severity of air pollution risk is determined by the highest calculated concentration under adverse meteorological conditions, including hazardous wind speeds. These regulations do not cover concentration calculations for distances exceeding 100 km from emission sources.

3. Depending on the height and mouth of the source of release of toxic substances from the surface of the earth, the indicated source belongs to one of the following four classes: a) high sources, H ³ *50* m; b) sources of medium height, H = 10 ... 50 m; c) low sources, H = 2 ... 10 m; d) underground sources, $H \leq 2$ m.

The calculation formulas for sources in all of these categories involve dimensions such as length (height) measured in meters, time in seconds, the mass of toxic substances in grams, their concentration in the atmospheric air measured in milligrams per cubic meter, and the concentration at the outlet of the source measured in grams per cubic meter.

4. When multiple (n) substances, each with its own toxic effects as per the list sanctioned by the Ministry of Health, are present simultaneously in the atmospheric air, the toxic effect for each group of these substances is unilaterally represented. The dimensionless total concentration, denoted as 'q' or the sum of toxic effects, consolidates the concentrations of these n toxic substances, simplifying their combined impact to the concentration of one among them.

Dimensionless concentration q is determined by the formula

$$q = \frac{c_1}{REMK_1} + \frac{c_2}{REMK_2} + \frac{c_3}{REMK_3} + \cdots + \frac{c_n}{REMK_n} \tag{3}$$

where $c_1, c_2, ..., c_n$ (mg/m^3) - calculated concentration of toxic substances in atmospheric air at the same point of the territory;

REMK $_1$, REMK $_2$, ..., REMK $_n$ (mg/m ^{3}) - the corresponding maximum one-time maximum permissible concentration of toxic substances in atmospheric air.

The reduced concentration c is calculated by the formula

$$c = c_1 + c_2 \frac{REMK_1}{REMK_2} + c_n \frac{REMK_1}{REMK_n} \tag{4}$$

The maximum value of the surface concentration of a toxic substance in the discharge of a gas-air mixture from a single point source with a round mouth c_m (mg / m ^{3})

$$c_m = \frac{AMFmn\eta}{H^2 \sqrt[3]{V_1 \Delta T}} \tag{5}$$

V_1 (m ^{3} / s) is the flow rate of the gas-air mixture determined by the formula.

$$V_1 = \frac{\pi D^2}{4} \omega_0 \tag{6}$$

D (m) represents the diameter of the discharge source opening, while ω_0- signifies the average velocity of the gas-air mixture exiting the discharge source opening. A value corresponding to adverse meteorological conditions, where the concentration of toxic substances in the atmospheric air reaches its maximum, is selected as follows:

In the design of enterprises, the emission power M (g / s) and gas-air mixture flow rate V_1 (m^3 / s) values are determined or accepted by calculation in the technological part of the project. in accordance with the applicable standards for this production (process). In the calculation, combinations of M and V_1 are obtained, which actually occur during the year in the specified (normal) working conditions of the enterprise, in which the maximum value of c_m is reached.

M should be shown for an average period of 20 - 30 minutes, including in cases where the release time is less than 20 minutes

The value of the *dimensionless F* coefficient is obtained:

a) for gaseous toxic substances and small aerosols (dust, ash, etc., the rate of orderly settling is practically zero) - 1;
b) for fine aerosols with an average operational cleaning coefficient of at least 90% -2 from 75 to 90% - 2.5; Less than 75% and in the absence of cleaning - 3.

The values of the coefficients *m* and *n are determined depending on the parameters f*, v_m, v'_m and f_e:

$$f = 1000\frac{{\omega_0}^2 D}{H^2 \Delta T} \tag{7}$$

$$v_m = 0.65\sqrt[3]{\frac{V_1 \Delta T}{H}} \tag{8}$$

$$v'_m = 1{,}3\frac{\omega_0 D}{H} \tag{9}$$

$$m = \frac{1}{0{,}67+0{,}1\sqrt{f}+0{,}31\sqrt[3]{f}} \text{f<100} \tag{10}$$

$$m = \frac{1{,}47}{\sqrt[3]{f}} \text{f} \geq 100 \tag{11}$$

$f_e < f < 100$coefficient m is assumed to be f =.f_e

$f < 100$value of n when v_m depends on the parameter.

n = 1 if v_m For cases where 2; (10a)

$n = 0{,}512v^2 - 2{,}13v_m + 3{,}13$if $0.5 \leq v_m < 2$(10b)

Useful in formulas $c_m$can be seen as follows.

$$c_м = \frac{AMFn\eta}{H^{2/3}}K, \tag{12}$$

Here K is calculated by the following formula

$$K = \frac{D}{8V_1} = \frac{1}{7{,}1\sqrt{w_0 V_1}}, \tag{13}$$

In adverse meteorological conditions, the distance from the emission source, where the surface concentration reaches c (mg/m c_m ^{3}), is determined by the formula x_m (m)

$$x_m = \frac{5-F}{4}dH \tag{14}$$

The value of the dangerous speed u_m (m/s) is at the level of the weather curtain (usually 10 m above the ground level), where m reaches the highest value of the surface concentration of toxic substances. $c_m$of f < 100 is determined by the following formulas:

$$u_m = v_m(1 + 0{,}12\sqrt{f}) \tag{15}$$

d at f < 100 is found by the following formulas:

$$d = 2{,}48(1 + 0{,}28\sqrt[3]{f}) \tag{16}$$

The maximum value of the surface concentration of the toxic substance c_{mu} (mg/m^3) in adverse meteorological conditions and wind speed *u (m / s),* differs from the dangerous wind speed u_m (m / s). Formula

$$c_{mu} = rc_m \tag{17}$$

Here

$$r = 0{,}67\left(\frac{u}{u_m}\right) + 1{,}67\left(\frac{u}{u_m}\right)^2 - 1{,}34\left(\frac{u}{u_m}\right)^3 \text{where } \left(\frac{u}{u_m}\right) \leq 1 \tag{18}$$

$$r = \frac{3\left(\frac{u}{u_m}\right)}{2\left(\frac{u}{u_m}\right)^2 - \left(\frac{u}{u_m}\right) + 2} \text{where } \left(\frac{u}{u_m}\right) > 1 \tag{19}$$

x_{mu} (m) from the emission source, where the surface concentration of toxic substances reaches the maximum value at wind speed *and unfavorable meteorological conditions, is determined by the formula c* $_{mu}$ (mg/m^3):

$$x_{mu} = px_m \tag{20}$$

Here p -$\frac{u}{u_m}$ a dimensionless quantity determined by proportion,

$$p = 3 \text{ in which } \frac{u}{u_m} \leq 0{,}25 \tag{21}$$

$$p = 8{,}43\left(1 - \frac{u}{u_m}\right)^3 + 1 \text{ in this } 0{,}25 < \frac{u}{u_m} \leq 1 (3.18b)\; p = 0{,}32\frac{u}{u_m} + 0{,}68 \text{in this } \frac{u}{u_m} > 1 \tag{22}$$

At the dangerous wind speed $u_{m,}$ the surface concentration of toxic substances in the atmosphere c (mg/m ^{3}) x (m) along the emission plus axis is determined by the formula.

$$c = s_1 c_m \tag{23}$$

where s_1 is the dimensionless coefficient determined depending on the ratio x / x $_m$ and the coefficient F according to the figure.

$$s_1 = 3(\frac{x}{x_m})^4 - 8\left(\frac{x}{x_m}\right)^3 + 6\left(\frac{x}{x_m}\right)^2 \text{ if } \frac{x}{x_m} \leq 1; \tag{24}$$

$$s_1 = \frac{1.13}{0{,}13(\frac{x}{x_m})^2} \text{if } 1 < \frac{x}{x_m} \leq 8\;; \tag{25}$$

$$s_1 = \frac{\frac{x}{x_m}}{3{,}58(\frac{x}{x_m})^2 - 35{,}2\left(\frac{x}{x_m}\right) + 120} \text{if F} \leq 1{,}5 \text{and } \frac{x}{x_m} > 8; \tag{26}$$

$$s_1 = \frac{\frac{x}{x_m}}{0{,}1(\frac{x}{x_m})^2 - 2{,}47\left(\frac{x}{x_m}\right) - 17{,}8} \text{if F} > 1{,}5 \text{and} \frac{x}{x_m} > 8; \tag{27}$$

CONCLUSION

Using digital educational technologies to create environmental pollution monitoring systems is an effective approach to solving environmental problems. These technologies make the monitoring process more accessible and convenient for a wide audience, and also contribute to increasing the level of environmental awareness in society. The development and implementation of such systems can help reduce pollution and create a healthier planet for future generations.

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