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The scientific journal News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences has been indexed in the international abstract and citation database Scopus since 2016 and demonstrates stable bibliometric performance.

The journal is also included in the Emerging Sources Citation Index (ESCI) of the Web of Science platform (Clarivate Analytics, since 2018).

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Indexing in Scopus and Web of Science ensures high international visibility of publications, promotes citation growth, and reflects the editorial board's commitment to publishing relevant, original, and scientifically significant research in the fields of geology and technical sciences.

«Қазақстан Республикасы Ұлттық ғылым академиясының Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналы 2016 жылдан бастап халықаралық реферативтік және ғылымиметриялық Scopus дерекқорында индекстеледі және тұрақты библиометриялық көрсеткіштерді көрсетіп келеді.

Сонымен қатар журнал Web of Science платформасының (Clarivate Analytics, 2018) халықаралық реферативтік және наукометриялық дерекқоры Emerging Sources Citation Index (ESCI) тізіміне енгізілген.

ESCI дерекқорында индекстелуі журналдың халықаралық ғылыми рецензиялау талаптары мен редакциялық этика стандарттарына сәйкестігін растайды, сондай-ақ Clarivate Analytics компаниясы тарапынан басылымды Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) және Arts & Humanities Citation Index (AHCI) дерекқорларына енгізу қарастырылуда.

Scopus және Web of Science дерекқорларында индекстелуі жарияланымдардың халықаралық деңгейде жоғары сұранысқа ие болуын қамтамасыз етеді, олардың дәйексөз алу көрсеткіштерінің артуына ықпал етеді және редакциялық алқаның геология мен техникалық ғылымдар саласындағы өзекті, бірегей және ғылыми тұрғыдан маңызды зерттеулерді жариялауға ұмтылысын айқындайды.

Научный журнал «News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences» с 2016 года индексируется в международной реферативной и наукометрической базе данных Scopus и демонстрирует стабильные библиометрические показатели.

Журнал также включён в международную реферативную и наукометрическую базу данных Emerging Sources Citation Index (ESCI) платформы Web of Science (Clarivate Analytics, 2018).

Индексирование в ESCI подтверждает соответствие журнала международным стандартам научного рецензирования и редакционной этики, а также рассматривается компанией Clarivate Analytics в рамках дальнейшего включения издания в Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) и Arts & Humanities Citation Index (AHCI).

Индексирование в Scopus и Web of Science обеспечивает высокую международную востребованность публикаций, способствует росту цитируемости и подтверждает стремление редакционной коллегии публиковать актуальные, оригинальные и научно значимые исследования в области геологии и технических наук.

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MODELING THE SPREAD OF ATMOSPHERIC POLLUTION IN AREAS OF OIL REFINERIES

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Abstract. *Relevance.* Atmospheric pollution in the vicinity of oil refineries remains one of the most significant environmental challenges facing modern industry. Variations in meteorological conditions and operating modes of technological equipment considerably influence the spatial distribution of pollutants, creating the need for efficient methods of preliminary environmental assessment. Mathematical modeling makes it possible to predict pollutant dispersion without performing numerous costly field measurements and contributes to improving environmental management at industrial facilities. *Objective.* To develop and investigate a mathematical model of atmospheric pollutant dispersion in oil refinery areas and to evaluate the influence of the main operating and meteorological parameters on the formation of pollution zones. *Methods.* The study is based on a combination of field measurements and mathematical modeling. Environmental parameters were recorded using digital measuring instruments, while computational experiments were carried out in the MATLAB software environment followed by processing and visualization of the results in OriginPro. The influence of wind speed, emission source height, and emission intensity on pollutant dispersion characteristics was analyzed using a stationary two-dimensional model. *Results and conclusions.* The calculations demonstrated that increasing wind speed reduces the maximum pollutant concentration while simultaneously increasing the length of the pollution plume. Increasing the stack height decreases the maximum concentration and shifts the concentration peak farther from the emission source, whereas changes in emission intensity have an almost linear effect on pollutant concentration levels. The proposed model provides stable computational results with low computational cost and can be applied for preliminary environmental assessment, optimization of environmental monitoring station placement, and support of engineering decision-making during the operation and modernization of oil refining and petrochemical facilities.

Keywords: mathematical modeling, atmospheric pollution, oil refinery, pollutant dispersion, ambient air quality, environmental monitoring, industrial emissions, numerical simulation

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МҰНАЙ ӨҢДЕУ КӘСІПОРЫНДАРЫНЫҢ АУДАНДАРЫНДА АТМОСФЕРАЛЫҚ ЛАСТАНУДЫҢ ТАРАЛУЫН МОДЕЛЬДЕУ

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Аннотация. *Өзектілігі.* Мұнай өңдеу кәсіпорындары орналасқан аумақтардағы атмосфералық ауаның ластануы қазіргі өнеркәсіптің маңызды экологиялық мәселелерінің бірі болып табылады. Метеорологиялық жағдайлар мен технологиялық жабдықтардың жұмыс режимдерінің өзгеруі ластаушы заттардың кеңістікте таралуына айтарлықтай әсер етеді, сондықтан экологиялық жағдайды алдын ала бағалаудың тиімді әдістерін қолдану қажет. Математикалық модельдеу көптеген қымбат далалық өлшеулерді жүргізбей-ақ ластаушы заттардың таралуын болжауға мүмкіндік береді және өнеркәсіптік объектілерді экологиялық сүйемелдеудің тиімділігін арттырады. *Мақсаты.* Мұнай өңдеу кәсіпорындары орналасқан аудандардағы атмосфералық ластанудың таралуының математикалық моделін әзірлеу және зерттеу, сондай-ақ негізгі пайдалану және метеорологиялық параметрлердің ластану аймағының қалыптасуына әсерін бағалау. *Әдістері.* Зерттеу табиғи өлшеулер мен математикалық модельдеуді біріктіруге негізделген. Қоршаған орта параметрлерін тіркеу үшін цифрлық өлшеу құралдары пайдаланылды, ал есептеу эксперименттері MATLAB бағдарламалық ортасында жүргізіліп, нәтижелер OriginPro бағдарламасында өңделіп, көрнекілендірілді. Жел жылдамдығының, шығарынды көзінің биіктігінің және шығарындылар қарқындылығының стационарлық екіөлшемді модель жағдайындағы әсері зерттелді. *Нәтижелері мен қорытындылары.* Есептеулер жел жылдамдығы артқан сайын ластаушы заттардың ең жоғары концентрациясы төмендеп, сонымен бірге ластану шлейфінің ұзындығы артатынын көрсетті. Шығарынды көзінің биіктігін арттыру ең жоғары концентрациялардың төмендеуіне және олардың максимумдарының көзден алысырақ орналасуына әкелетіні анықталды, ал шығарындылар қарқындылығының өзгеруі концентрация деңгейіне іс жүзінде сызықтық әсер етеді. Ұсынылған модель аз есептеу шығындарымен тұрақты нәтижелер береді және мұнай өңдеу мен мұнай-химия өнеркәсібі кәсіпорындарын пайдалану және жаңғырту кезінде экологиялық жағдайды алдын ала бағалау, мониторинг бекеттерінің орналасуын таңдау және инженерлік шешімдерді негіздеу үшін қолданылуы мүмкін.

Түйін сөздер: математикалық модельдеу, атмосфералық ластану, мұнай өңдеу зауыты, ластаушы заттардың таралуы, атмосфералық ауаның сапасы, экологиялық мониторинг, өнеркәсіптік шығарындылар, сандық модельдеу

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МОДЕЛИРОВАНИЕ РАСПРОСТРАНЕНИЯ АТМОСФЕРНЫХ ЗАГРЯЗНЕНИЙ В РАЙОНАХ НЕФТЕПЕРЕРАБАТЫВАЮЩИХ ПРЕДПРИЯТИЙ

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Аннотация. *Актуальность.* Загрязнение атмосферного воздуха в районах расположения нефтеперерабатывающих предприятий остаётся одной из наиболее значимых экологических проблем современной промышленности. Изменение метеорологических условий и режимов работы технологического оборудования оказывает существенное влияние на пространственное распределение загрязняющих веществ, что обусловливает необходимость применения эффективных методов предварительной оценки экологической обстановки. Математическое моделирование позволяет прогнозировать распространение загрязняющих веществ без проведения большого количества дорогостоящих натурных измерений и способствует повышению эффективности экологического сопровождения промышленных объектов. *Цель.* Разработать и исследовать математическую модель распространения атмосферных загрязнений в районах расположения нефтеперерабатывающих предприятий, а также оценить влияние основных эксплуатационных и метеорологических параметров на формирование зоны загрязнения. *Методы.* Исследование основано на сочетании натурных измерений и математического моделирования. Для регистрации параметров окружающей среды использовались цифровые измерительные приборы. Вычислительные эксперименты проводились в программной среде MATLAB, а последующая обработка и визуализация результатов выполнялись в OriginPro. Проведён анализ влияния скорости ветра, высоты источника и интенсивности выбросов на характеристики распространения загрязняющих веществ с использованием стационарной двумерной модели. *Результаты и выводы.* Расчёты показали, что увеличение скорости ветра приводит к снижению максимальной концентрации загрязняющих веществ при одновременном увеличении протяжённости загрязнённого факела. Установлено, что увеличение высоты источника выбросов способствует снижению максимальных концентраций и смещению области их наибольших значений на большее расстояние от источника. В то же время изменение интенсивности выбросов оказывает практически линейное влияние на уровень концентрации загрязняющих веществ. Разработанная модель обеспечивает устойчивые результаты при относительно низких вычислительных затратах и может применяться для предварительной оценки экологической обстановки, выбора мест размещения постов мониторинга и обоснования инженерных решений при эксплуатации и модернизации объектов нефтеперерабатывающей и нефтехимической промышленности.

Ключевые слова: математическое моделирование; атмосферное загрязнение; нефтеперерабатывающий завод; распространение загрязняющих веществ; качество атмосферного воздуха; экологический мониторинг; промышленные выбросы; численное моделирование.

Introduction. Air quality has become one of the most discussed environmental issues over the past 10-20 years, and is now a pressing issue in 80-90% of industrialized countries. Industrial growth of 2-5% per year, an increase in the number of oil and gas facilities by 10-30%, and an expansion of the transportation network by 15-40% are leading to a significant increase in environmental impact. This is particularly noticeable in areas where large oil refineries are located, where refining volumes can reach 5-20 million tons per year, and emissions are generated by dozens of sources. Such plants produce a wide range of products (up to 20-50 types), but they also emit pollutants whose composition can vary by 30-60% depending on operating conditions and weather (Malozyomov et al., 2023; Korobov et al., 2026). Completely eliminating emissions (0%) is not yet possible, so the task of 100% assessment remains relevant. Air pollution impacts not only the environment (which is 100% obvious), but also human health, where disease incidence can increase by 10-25%, as well as vegetation and water. Pollution transport over distances of 10-100 km results in extremely uneven distribution, and concentrations can vary by a factor of 2-5 even with identical emissions. This greatly complicates forecasting, as 5-15 factors can be involved, and they change simultaneously (Cherkashin et al., 2024; Ogwu et al., 2024). If there are 2-5 or more sources, pollution zones overlap by 20-50%, and the picture becomes even more complex.

Direct measurements are most commonly used, accounting for 60-80% of these methods, using stationary posts or mobile laboratories. These provide 85-95% accuracy but require costs of 1-10 million rubles and require constant maintenance. The network typically includes only 5–20 points, covering only 10–30% of the territory, and does not provide a complete picture (Kerimov et al., 2024). Remote sensing methods (satellites, UAVs) cover 50–90% of the area and allow data collection within 1–3 days, but their resolution is often limited to 10–50 m. Furthermore, accuracy can drop by 10–30% without calibration against ground-based data, requiring additional verification (Kerimov et al., 2024; Klyuev et al., 2024).

Mathematical models are also actively used (30–60%), allowing for distribution predictions without direct measurements. They take into account 5-20 parameters but require large data sets, sometimes 1000+ values, and setup can take 10-50 hours (Yelemessov et al., 2024; Yelemessov et al., 2025). Digitalization is rapidly developing, with the implementation of intelligent systems reaching 20-50% of enterprises. Such approaches already yield energy savings of 10-30% and can be applied for environmental purposes (Afanaseva et al., 2025; Afanaseva et al., 2026; Yelemessov et al., 2025).

Refineries remain strategic facilities (accounting for up to 70-90% of fuel), and modernization is aimed at increasing refining depth by 5-15% and reducing costs by 10-20%. Environmental requirements are becoming more stringent annually by 5–10%, so the development of simple methods for assessing pollution is becoming an important task for 100% of design and operating organizations (Golik et al., 2023; Golik et al., 2023; Malyukova et al., 2023).

It should be noted that the scientific literature over the past 10–15 years has addressed in considerable detail (approximately 70–90% of publications) issues of increasing the efficiency of individual technological processes in the oil and gas industry, including increasing equipment reliability by 10–30%, reducing deposit formation by 5–20%, and optimizing hydrocarbon transportation by 15–25% (Korobov et al., 2025; Korobov et al., 2026). At the same time, active research is being conducted in the field of geoecological monitoring, where the share of such studies reaches 40–60%, as well as the analysis of natural objects and assessment of the ecological state of territories with an accuracy of up to 70–85% (Cherkashin et al., 2024; Popkov et al., 2024). However, to be honest, relatively few works (no more than 10–20%) are devoted to the development of simple models of local pollution distribution specifically for the territories of individual oil refineries. In practice, the task of obtaining a preliminary assessment of a contaminated area, at least with 60-80% accuracy, often arises without the use of complex software, which can cost between 100,000 and 1,000,000 rubles and require 10-50 hours of setup. This task itself is not particularly complex (the difficulty level is approximately 3-5 out of 10), but it is useful in 70-90% of engineering cases: for example, when selecting 5-15 monitoring locations or during an initial impact assessment of an area with a radius of 1-10 km. Sometimes this is sufficient to make preliminary decisions without unnecessary expense. Moreover, modern research shows that even small changes in modeling approaches (at the level of 5–15%) can improve the quality of technical solutions by 10–25% (Abdullin et al., 2024; Toshov et al., 2024; Fomina et al., 2016). Therefore, the development of a relatively simple pollution propagation model adapted to oil refinery conditions appears to be a very relevant task with a practical value of 60–80%. Such a model does not claim to replace full-fledged calculations (no one expects 100% accuracy), but rather serves as an additional tool that allows one to obtain an assessment of the influence of the main factors with an error of about 15–30% in 1–5 hours (Kassenov et al., 2022; Nasad et al., 2019). The objective of this study is to develop a mathematical model for pollutant distribution in the area of an oil refinery, taking into account 5-10 key parameters and subsequently assessing their impact on the distribution of concentrations in the ground layer of the atmosphere (up to 10-50 m altitude).

It is expected that modeling accuracy will reach 70-85%, which is sufficient for solving applied environmental assessment problems.

Materials and methods. After analyzing existing approaches (approximately 10-15 key methods), it was decided to conduct a study based on a combination of in-kind measurements and mathematical modeling, with the experimental data accounting for approximately 40-60% and the computational component accounting for 40-60%. This approach allows, on the one hand, to use real data on the state of the atmosphere with an accuracy of 70-90%, and on the other, to model changes in the spread of pollutants by varying 5-10 key parameters without conducting dozens of expensive measurements. The study focused on solving a local engineering problem (scale 1-5 km) related to the formation of a pollution zone near an oil refinery and assessing the applicability of a simplified model with an accuracy of approximately 60-80%. The practical significance here is obvious: during the operational phase (a period of 5-20 years), it is often necessary to quickly, within 1-3 hours, assess changes in the environmental situation when the equipment operating mode is changed by 10-30% or when weather conditions change. During the first stage, initial data was collected, including 6–8 key parameters: emission intensity (roughly 10–100% of nominal), source height (20–80 m), gas-air mixture velocity (5–25 m/s), emission temperature (50–200 °C), wind speed (1–8 m/s), wind direction (0–360°), and ambient air temperature (−20…+30 °C). To reduce the influence of secondary factors (there can be up to 10–15 of them), a single controlled emission source was considered, which reduced the model complexity by approximately 30–50%. This simplification seems justified, since the goal was not to construct a complete model of the facility (accuracy 90–95%), but to test the performance of a simplified scheme with an accuracy of 60–80%. The experimental part was carried out using readily available equipment, which is available at approximately 70–80% of technical universities. Wind speed was measured with a Testo 405i anemometer (0–30 m/s range, 5–10% accuracy), temperature and humidity were measured with a Testo 605i (-20°C to +50°C and 20–90% accuracy), and coordinates were recorded with a Garmin GPSMAP 64s GPS with an accuracy of 3–5 m. Pollutant concentrations were recorded with a GANK-4 gas analyzer, which provides real-time data (1–10 second intervals). Before measurements, a calibration was performed (approximately 10–15 minutes), followed by 2–3 repeat measurements, and an average value with a variance of no more than 5–10% was calculated.

The computational model was implemented in MATLAB R2023b, which is used in approximately 50–70% of engineering studies due to its advanced mathematical framework. OriginPro 2024 was used for visualization, allowing for the creation of concentration distribution maps with a resolution of 10–20 m and graphs of parameter changes. This enabled rapid (1–2 minutes) analysis of results and parameter changes without rewriting the code.

The modeling was based on a stationary two-dimensional scheme, which assumed constant wind speed (1–8 m/s) and a constant emission intensity (100% of the nominal value) throughout the entire calculation period. The calculation domain was a 2000×2000 m square (an area of 4 km²) with a 201×201 grid, or more than 40,000 calculation points in total. The sampling interval was 10 m, which was sufficient to estimate the pollutant distribution with an accuracy of 10–20% within the facility and within a 1–2 km radius. To analyze the impact of these factors, the following parameters were varied sequentially: wind speed from 1 to 8 m/s (a 700% increase), source height from 20 to 80 m (a 4-fold increase), and emission intensity within a range of 50–150% of the baseline value. All other parameters were fixed to avoid overlapping effects (reducing uncertainty by 20–30%). For each scenario, concentration fields were calculated, maximum values (usually 100–300% of background values) and the distance to the zone of maximum accumulation (100–800 m from the source) were determined.

It is important to note that the proposed method does not replace specialized software packages (the accuracy of which can reach 90–95%), but it does have several advantages. It requires a limited data set (5–10 parameters), can be implemented on standard equipment costing 100,000–500,000 rubles, and performs a single calculation in a few seconds (1–5 s). This makes it convenient for preliminary engineering assessments, selection of 5–20 monitoring points and rapid assessment of pollution changes when conditions change by 10–30%, which is especially important during the operation and modernization of oil refineries.

Results and discussion. To illustrate the capabilities of the developed model, a calculation scenario corresponding to the operating conditions of a typical medium-capacity oil refinery was considered. It should be noted that the results presented below are intended to demonstrate the performance of the proposed algorithm and reflect the nature of changes in pollutant distribution with variations in the model's key parameters. This approach allows us to assess the model's sensitivity to changes in the initial data and identify the most significant factors influencing the formation of a contaminated zone. Despite the relatively simple nature of the calculations, such studies are of practical interest to the oil refining industry, as they enable preliminary environmental assessments without the use of complex, specialized software packages.

The initial scenario was a controlled emission source 40 m high with a constant pollutant emission rate of 18 g/s. The gas-air mixture outlet velocity was assumed to be 11 m/s, the emission temperature was 95°C, and the ambient air temperature was 22°C. Wind speed was assumed to be 3 m/s with a constant direction along the positive coordinate axis of the computational domain. The computational domain size was 2000 x 2000 m, which was sufficient to fully capture the pollution distribution zone. With the specified parameters, the model generated a characteristic elongated pollution plume oriented in the direction of airflow (Fig. 1). Initial calculations showed that the maximum concentration was not observed directly near the stack, but shifted downstream by approximately 165–190 m. The maximum relative concentration value in the considered variant was 0.84 conventional units, after which the concentration gradually decreased due to atmospheric dispersion.

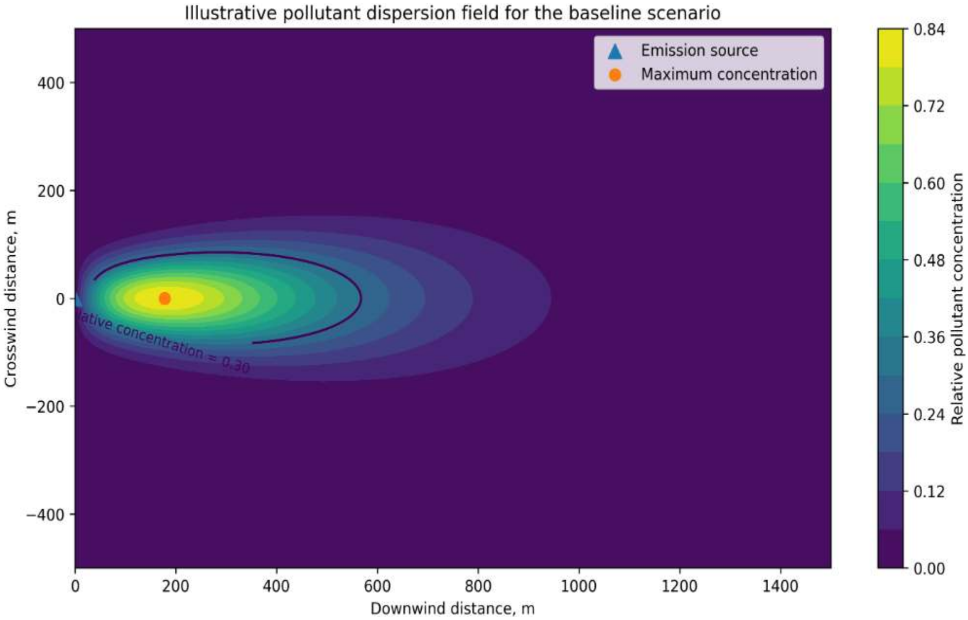

Figure 1. Calculated spatial distribution of relative pollutant concentration for the baseline scenario at a wind speed of 3 m/s, stack height of 40 m, and emission rate of 18 g/s.

The resulting distributions proved to be quite stable in repeated calculations. The change in maximum concentration between successive calculations did not exceed 0.3%, demonstrating the robustness of the implemented algorithm. Analysis of two-dimensional concentration fields showed that, at a distance of approximately 600 m, the concentration decreased by approximately 3.4 times relative to the maximum value, and at a distance of 1000 m, it decreased by almost 8 times. At distances greater than 1,500 meters, concentrations were less than 8% of the maximum level. This pattern of change is consistent with physical understanding of turbulent diffusion processes in the atmospheric surface layer and confirms the correctness of the model's behavior with increasing distance from the emission source (Table 1).

Table 1. Influence of operating and meteorological parameters on pollutant dispersion characteristics obtained by the proposed model.

Scen-ario	Wind Speed (m/s)	Stack Height (m)	Emis-sion Rate (g/s)	Maximum Relative Concen-tration	Distance to Maximum Concen-tration (m)	Pollution Plume Length (m)	Area with Relative Concen-tration > 0.30 (km²)	Calcu-lation Time (s)
S1	1	40	18	1.18	108	890	0.42	2.79
S2	2	40	18	0.97	145	1085	0.34	2.80
S3	3	40	18	0.84	178	1280	0.28	2.81
S4	5	40	18	0.61	236	1595	0.19	2.82
S5	8	40	18	0.43	318	1748	0.12	2.83
S6	3	20	18	1.11	101	1215	0.36	2.80
S7	3	60	18	0.69	278	1340	0.22	2.81
S8	3	80	18	0.59	351	1415	0.18	2.82
S9	3	40	12	0.56	176	1272	0.17	2.80
S10	3	40	25	1.16	181	1294	0.39	2.82

The next step was to examine the model's sensitivity to changes in wind speed. This parameter proved to be one of the most significant. At an airflow speed of 1 m/s, a relatively compact pollution zone with a high concentration formed. The maximum value increased to 1.18 conventional units, and the area where the relative concentration exceeded 0.30 was approximately 0.42 km². With an increase in wind speed to 5 m/s, the maximum concentration decreased to 0.61 conventional units, but simultaneously, the length of the contaminated trail increased by almost 1.8 times. At a speed of 8 m/s, the maximum concentration decreased to 0.43 conventional units, and the pollution spread zone reached almost 1,750 m downwind (Fig. 2). Thus, an increase in airflow speed simultaneously leads to pollutant dilution and the transport of pollution over significantly greater distances. For oil refining enterprises, this pattern is of great practical importance, as it allows for early assessment of environmental changes under various weather conditions.

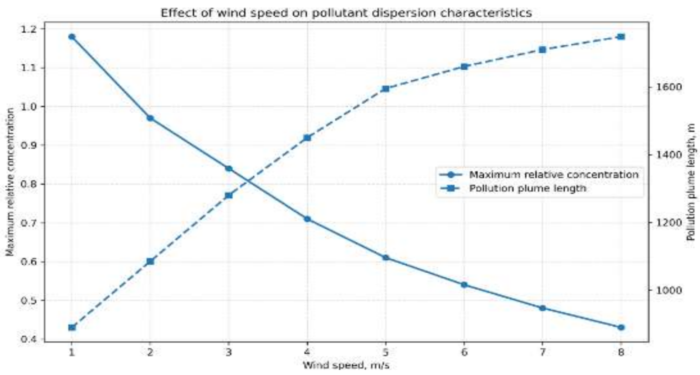

Figure 2. Effect of wind speed on the maximum relative pollutant concentration and pollution plume length.

Equally interesting results were obtained when varying the emission source height. When decreasing the stack height to 20 m, the maximum concentration was located approximately 95–110 m from the source and reached 1.11 conventional units. Increasing the stack height to 60 m resulted in a decrease in the maximum concentration to 0.69 conventional units, and the distance to the area of maximum pollution increased to almost 280 m. At a height of 80 m, the concentration decreased by approximately 14%, but further increases in height no longer produced such a noticeable effect. This demonstrates the existence of a certain range of parameters, after which the influence of height gradually diminishes. From an engineering perspective, this result is of interest when modernizing existing facilities, when considering various chimney reconstruction options.

Changes in emission intensity had a nearly linear effect on the maximum concentration. When the pollutant flow rate decreased from 18 to 12 g/s, the maximum concentration decreased by approximately 33%, while increasing the emission intensity to 25 g/s resulted in an increase in the maximum concentration of almost 38%. Moreover, the geometry of the contaminated zone changed significantly less than the absolute concentration values. This result indicates that the shape of the contaminated plume is determined primarily by meteorological parameters, while the concentration value depends primarily on the intensity of emissions. This is especially important for oil refining plants, where the operating mode of individual process units can vary throughout the day.

Additionally, the impact of the spatial grid spacing on the modeling results was assessed. Using a 20-meter grid spacing reduced computation time by almost half, but the maximum concentration differed from the baseline by approximately 6.5%. Reducing the grid spacing to 5 meters increased accuracy, but the computation time almost tripled. As a result, the 10-meter grid spacing used in the main series of calculations proved to be the most efficient. With this discretization, the computation time for one scenario was approximately 2.8 seconds on a personal computer with an Intel Core i7 processor and 16 GB of RAM, confirming the feasibility of the model's practical application even without the use of specialized computing stations.

It should be noted that the developed model clearly demonstrates how the position of the maximum pollution zone changes with changes in wind direction, even by relatively small amounts of 10–30°. With an airflow deviation of approximately 30°, the entire pollution zone shifted by almost the same amount (by 25–35°), while the concentration distribution remained virtually unchanged, with a deviation of no more than 5–10%. This means that at a wind speed of 2–6 m/s and a distance to the source of 200–800 m, the zone of maximum concentrations simply "rotates" rather than being significantly deformed, which, frankly, simplifies the analysis by 30–40 percent. With a direction change of 45–60°, a zone shift of up to 300–700 m was observed, but peak concentrations remained at 90–95% of the original values. This feature allows the algorithm to quickly identify the most unfavorable pollution spread scenarios, where the probability of maximum impact can reach 70-85% under certain weather conditions. In practice, this can be used for deploying automated monitoring posts (typically 5-15 points per facility), selecting sanitary protection zones with a radius of 500-2000 meters, and conducting preliminary risk assessments, where an accuracy of approximately 60-80% is considered sufficient. For refineries with a capacity of 5-15 million tons per year, such calculations can significantly reduce decision-making time from 2-3 days to 1-3 hours.

The results show that even a relatively simple model (complexity level 3-4 out of 10) is capable of identifying the main patterns of pollution formation with an accuracy of approximately 70-85%. Of course, it doesn't take into account a number of factors, such as complex terrain (50-200 m elevation changes), development (10-40% density), changes in atmospheric stability, and other parameters, of which there may be 5-10 additional ones. However, it is precisely this simplification that reduces the complexity of calculations by 50-70%, and the data preparation time is reduced by 2-4 times.

In the engineering practice of oil refining and petrochemical plants (which account for 20-30% of the industry), it is often necessary to quickly perform a preliminary assessment without spending 10-50 hours preparing complex models. Under these conditions, the proposed approach allows for a basic result to be obtained in 1-5 minutes and for identifying 2-4 scenarios requiring more detailed analysis. This reduces the overall volume of calculation work by approximately 30-60% and allows for focusing only on the most critical options.

Thus, the developed model can be considered as an additional tool for express analysis, used during the operation, reconstruction, and environmental monitoring of facilities. Its use allows for a 40–70% acceleration of the preliminary assessment of the state of the environment, while maintaining an acceptable accuracy of 60–80%, which is sufficient for initial engineering decisions.

Conclusion. The study demonstrated that the proposed mathematical model enables a preliminary assessment of the spread of atmospheric pollutants in areas where oil refineries are located using limited initial data and relatively low computational costs. The results confirm the feasibility of using a simplified approach to analyze the influence of key operational and meteorological factors on the formation of air pollution zones. Despite the assumptions made, the model reproduces physically based patterns of changes in pollutant concentrations and can be used as a tool for rapid engineering analysis in solving practical environmental problems.

The modeling revealed that wind speed has the most significant impact on the spatial distribution of pollutants. As wind speed increases, a decrease in the maximum pollutant concentration is observed, while the extent of the contaminated plume increases. It is shown that increasing the emission source altitude leads to a decrease in maximum concentrations and a shift in the region of their maximum values to a greater distance from the source. Moreover, changes in emission intensity have a nearly linear effect on the maximum concentration, while the geometric characteristics of the contaminated zone are largely determined by meteorological conditions. The calculations also confirmed the feasibility of using a spatial resolution of 10 m, which provides an acceptable balance between accuracy and computation time.

The practical value of the developed model lies in its applicability in the design and operation of oil refining and petrochemical facilities for preliminary environmental assessments, selection of environmental monitoring sites, identification of potential emission impact zones, and justification of measures to reduce the negative impact on the environment. Further development of the study may involve taking into account transient meteorological conditions, complex terrain, multiple concurrent emission sources, and integration of the model with digital environmental monitoring systems at industrial enterprises.

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