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AN INITIAL DATA-LIMITED MODELING OF THE ENVIRONMENTAL CONSEQUENCES: CASE-STUDY OF THE VASYLKIV FUEL RESERVOIR FIRE

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Abstract. The paper presents the application of the Multi-Criteria Evaluation of environmental damage under the conditions of limited available data. War actions often cause damage to industrial facilities, which in turn impacts the environment. At the same time, access to such sites and information about the development of specific events may be limited or fragmented. To support the decision-making process in such situations, the Multi-Criteria Evaluation offers structured and transparent utilization of the known quantitative and qualitative information. The Vasylkiv fuel depot fire in Kryachki village during the early days of the war was analyzed in terms of potential damage to soil, which is often omitted in the assessments of the environmental impacts of fire. The case-study analysis included a definition of the "fire-environment" system components and the factors affecting the final level of damage, the weighting of these factors and formulation of the trends describing the intensity of soil pollution as a product of particular factor values. The set dependencies were then used to model scenarios with variable meteorological conditions and varied infrastructural conditions of the reservoir park. The modelling results imply the need to account for meteorological parameters in the evaluation of environmental damage and the development of post-accident mitigation plans. The Multi-Criteria Evaluation is also recommended for preparing for potential accidents since it can compensate for the lack of data through theoretical knowledge and practical experience if a multidisciplinary team is involved.

Keywords: **e**environmental damage, environment, soil pollution.

1. Introduction

Fires are among the most typical forms of anthropogenic disasters caused by failures of man-made systems. Despite the long history of fires as by-products of human activity, their consequences are not well-studied and unpredictable, especially in the case of warfare, which is always an act of destruction. Moreover, damage from fires is predominantly considered in terms of material assets lost, while environmental effects are given limited attention. Considering the specific case of Ukraine, its territory has both rural farmlands and areas densely built with large industrial facilities, and war-induced fires at

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industries can raise concerns about heavy chemical pollution in all environments.

Even though the conflict is covered by the mass media in detail, many of the primary and secondary consequences of war are missed in official information and thus pass by the authorities and environmental agencies. The situation is further complicated by the inability of authorities and researchers to get access to the areas of damage directly after the attacks to collect the necessary information for a reliable and complete assessment of effects and consequences. Therefore, all initial economic assessments of the damage are incomplete, as they do not account for many of the purely environmental processes violated if their societal effects are often not immediately evident.

The paper aims to initially evaluate the environmental consequences of the Vasylkiv fuel reservoir fire during the early days of the war when the environmental control was largely disrupted, and minimal data were available on the essence of the problem. To deal with the limited data, we have used a modelling methodology that allows us to combine quantitative and qualitative data based on a systems approach.

2. Theoretical part

Russian missiles struck the oil depots of the Kryachki village, Vasylkiv community, Kyiv Oblast, on February 27, 2022. The fire on site lasted for over 24 hours and burnt ten cisterns with petrol and diesel, 2000 m^3 each. As a result of burning, 41.830 tons of pollutants entered the air of Kyiv region. In addition, as a result of damage to the pipeline and limited control of the evolving emergency, over 9.000 square meters of land were contaminated with hazardous substances. The preliminary assessment of the damage from the fire amounts to 810 billion UAH (ca. 29 billion USD), according to the information available from the Kyiv Oblast Department of the State Emergency Service of Ukraine and the State Environmental Control Agency. The mass media also noted that residents complained of dizziness, nausea, stomach pains and breathing problems.

Fires are the most typical form of emergency caused by human activity. There is a wide range of publications on the assessment of the environmental impacts of fires. Thus, the meta-analysis of related research works (Martin et al., 2016) indicates more than 150 resources consisting of published papers, research reports, standards and books dealing with adverse environmental impacts of fires, the types of environmental impacts that have been identified and the associated exposure pathways, and the tools and methods used to assess impacts and associated costs. However, most assessments assume that a thorough analysis of the fire conditions and parameters was conducted, providing background for the assessment and prognosis. Moreover, most assessments consider fire consequences as a short-term issue affecting primarily humans and causing reversible deterioration of air quality.

Our research considers the environmental impacts of the Vasylkiv fuel reservoir fire in spatial and temporal dimensions. Specifically for the Vasylkiv fire, there was a lack of reliable data on the emergency and the current state of the environment. We also focus on the question of the possible long-term consequences of the fire, apart from resource losses and infrastructure destruction.

Accidents at oil depots are not rare. According to a study conducted by 16 oil companies, there are 15 to 20 large oil fire accidents every year (Yuan et al., 2021). Oil storage tank accidents are predominantly caused by lightning (Ahmadi et al., 2020). Other causes involve human errors, equipment failure, sabotage, tank cracking and rupture, and natural disasters (Chang, Lin, 2006). Attacks on oil facilities have often been waged during armed conflicts, despite being essentially forbidden by the Geneva Conventions (Henckaerts et al., 2009). Oil storage tank fires cause contamination of the natural environment, which can include air contamination via the fire plume and its subsequent diffusion; deposition of particulate and other materials in soil and water; contamination of soil and water from fire suppression runoff; and direct leaks of fuel to soil and water if the tanks are breached (Martin et al., 2016). The severity of contamination depends on the nature and progression of the accident.

The character of the oil storage tanks burning can differ depending on the ignition source. Most accidents start with the fuel-air mixture ignition, which can lead to a vapour cloud explosion. Ignition of the stored fuel tends to lead to pool fire, surface burning or deflagration (Zhou et al., 2016). The progression of the burning also depends on the overall design of the oil tanks, e. g. whether they are open or have fixed or floating roofs; have single or double walls; are protected by earth walls or reinforced concrete walls and other spatial and constructional differences (Horvath et al., 2018).

Another parameter that significantly affects the progression and aftermath of accidents is weather conditions. For example, when a major explosion and fire occurred at the Hertfordshire Oil Storage Terminal, UK, on December 2005, it did not result in significant pollution of the ground areas due to the favourable local wind and weather conditions that allowed the smoke to rise to the higher levels of the atmosphere and be trapped there (Troop, 2006). It was predicted that ground-level air pollution would have been far higher had this event occurred in the summer months when the lower atmosphere is more turbulent and well-mixed.

Finally, methods that are used to extinguish fire also have an impact on environmental pollution. For example, some fire-suppressing foams can cause environmental pollution with perfluorinated compounds, including perfluorinated carboxylates and sulfonates, which are toxic to living beings and very persistent in the environment (Dauchy et al., 2017). On the other hand, surfactants in firefighting foam can enhance contaminated soil remediation by aiding the removal of petroleum derivatives (Rakowska, 2020).

3. Materials and Methods

The research methodology is based on Multi-Criteria Evaluation (MCE), also called Multi-Attribute Utility Theory (MAUT) – a type of decision-support modelling. The MCE is a typical tool for predicting outcomes under different scenarios (options) and providing decision support. It is often applied for initial case study-based research and, thus, yields different results in each case. The early development of the deductive fundamentals of the decision-making and evaluation process was presented by E. Brunswick in the form of the lens model – a conceptual framework for understanding "achievement" or judgment performance by comparing the relationship between the human and an idealized (normative) judgment process (Wigton, 2008). Later, a general approach to MCE was formulated by Scholz and Tietje (2002) and further developed by Saaty (2005, 2008) into Analytic Hierarchy Process and Analytic Network Process (2005, 2008).

The case study analysis, as applied here, includes three simplified methodological steps or tools:

1. System description (sketch) – defining and describing the system in terms of components (ideally, distinct variables) and their interactions.

2. System structure analysis – studying the internal relationships and building a variable impact matrix.

3. Multi-criteria evaluation – predicting the impact of the variables with the conditions for each scenario. The MCE is focused on a specific issue that allows alternative scenarios to be tested. In this study, environmental damage due to the fuel depot fire was the basis for the research questions formulated.

Construction Steps of the MCE model are aimed at the acquisition of numerical values which characterize the attributes of alternatives under consideration:

1. Selection of scenarios. Considering the dynamics identified in the system sketch and variable impact matrix, different scenarios that reflect variations in most essential parameters are formulated.

2. Determining parameter "weights" (w_i) – a relative comparison of the importance of the parameters in the specific situation. It may include "expert" judgment based on theory or experience, and documented data, which can be statistically interrogated for correlations and trends. In this research, pair-wise estimates of the relative importance of parameters were used.

3. Evaluation of standardized dependencies between the factors that shape the situation and the development of the event in the system and the state of the system, which in the methodological terminology is called "utility".

The utility (u_i) takes on a value from 0 to 1, and the form of dependence (linear, logarithmic, etc.) between it and each parameter is established based on actual data or motivated assumptions and expert judgments regarding the relationships between the range of each parameter and its impact on the state of the studied systems.

Standardized values (0–1) for each parameter "utility" (ui) are estimated based on the actual (or estimated) relationships between the range of this parameter and its variable impact in the defined system. This step is aided by plotted utility functions where each scenario is separately represented.

4. Calculation of total utility for each scenario by multiplying weights by utilities and summing the products for all parameters with each scenario:

$$\Sigma_i\, w_i \bullet u_i = \text{Total "utility".} \qquad (1)$$

The resulting total utility is used to rank different scenarios concerning the intended predictions.

This structured approach to system analysis is suited for an early stage, often desk-top study, of a problem, which will ideally help focus on more detailed research work.

It should also be mentioned that a distinctive trait of the given research methodology was the multidisciplinary character of the research team, including a chemist, a biologist, a meteorologist, an environmental engineer, and a geologist. The transparency and need for joint communication also make the MCE methodology an efficient approach for combining knowledge and experience within a newly created team with multiple backgrounds.

4. Results and Discussions

4.1. System Sketch

The environmental impacts of the fire are transferred through the air, which receives the mass of combustion products and is then introduced into exposed physical components of the environment, especially in the local region. Apart from air pollution, soil and surface waters are normally the first recipients, but these become the source of secondary pollution, connecting it to underground waters (Fig. 1).

The possibility for delayed effects at global and regional level is also recognized, as products of combustion are both GHGs and precursors to the formation of acidic precipitations. But this is not considered in the analysis below.

The final receptors of environmental pollution are living organisms, in particular, humans, plants and soil biota, which interact with the physical components of the environment in a number of ways. The system sketch, given below, is obviously a simplified presentation of the "fire-environment" system, yet it depicts the pathways of impacts that have importance for this analysis.

Based on the system sketch, the list of the factors driving the system dynamics was considered. Brainstorming in reference to these factors produced parameters of different hierarchical levels, and the next step was to group those considered most important into subsets for further modelling (Table 1). Since modelling usually requires prioritization and reduction of the parameters involved, the final list of factors was shortened, keeping in mind that each parameter of the fire is highly influential for the final damage caused, while meteorological parameters usually work in complex association relative to the specific setting and typically vary between yearly seasons. In addition to the seasons, changes over time are to be expected. During the fire, the system goes out of the "balanced state". The stabilization of the system is a time-dependent process. Therefore, a separate variable, "post-fire period", was included in the model. By this, we mean the time after the fire, which defines the extent to which the self-treatment process in the environment has progressed.

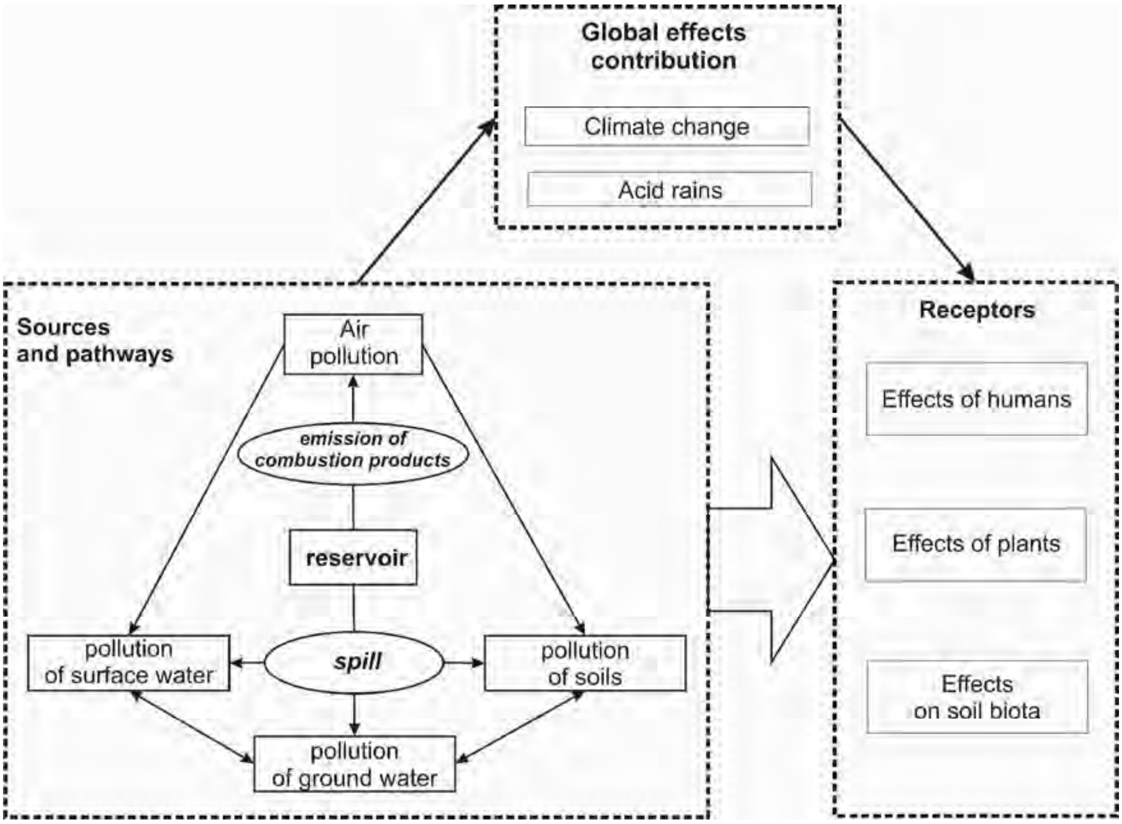

Fig. 1. System sketch

Table 1

Factors subsets for modelling

Duration of combustion	Parameters of fire
Volume of fuel	
Type of fuel	
Integrity of reservoir	
Wind parameters	Meteorological parameters
Atmospheric inversion	
Atmospheric stratification	
Atmospheric air	Receiving media
Surface water	
Ground water	
Soil	
Post-fire period	Post-fire period

4.2. System structure analysis

The system was modelled using two separate perspectives – analytical and synthetic, respectively, aiming to understand the internal relationships and apply them to predictive modelling.

The first stage in conceptual modelling aims to identify and specify the parameter relationships in a system. It assumes that the system can approximately be represented by the defined factors and components identified with the help of the system sketch, which essentially works as a closed framework for analysis. The basic tool for this is the construction of a "system interaction matrix" (sometimes called an impact matrix). The factors were located on both matrix axes, and the impact of each of the row parameters on each column parameter was rated using a 0 to 4 scale in the corresponding off-diagonal cells of the matrix (Table 2). These relative ratings are based on theory, expert experience and literature information. The diagonal cells do not have values since these represent the same parameter in the rows and columns. The matrix is not symmetrical since the impact of A on B is not necessarily the same as B on A.

Table 2

Impact matrix (system interaction matrix)

Factors	Meteo parameters	Parameters of fire	Post-fire period	Air pollution	Surface water poll	Ground water poll	Soil pollution	**Cause**
Meteorological parameters	–	**0**	**0**	**4**	**2**	**1**	**2**	**9**
Parameters of fire	**1**	–	**0**	**4**	**3**	**3**	**4**	**15**
Post-fire period	**0**	**0**	–	**4**	**3**	**2**	**2**	**11**
Air pollution	**1**	**0**	**0**	–	**3**	**2**	**3**	**9**
Surface water pollution	**0**	**0**	**0**	**1**	–	**4**	**3**	**8**
Ground water pollution	**0**	**0**	**0**	**0**	**3**	–	**3**	**6**
Soil pollution	**1**	**0**	**0**	**2**	**2**	**4**	–	**9**
Effect	**3**	**0**	**0**	**15**	**16**	**16**	**17**	**67**

Using the row sums to represent the combined impact of each parameter on all the other parameters and the column sums to represent the effect of the other parameters on each of the individual parameters, it was possible to differentiate the factors by their role in the system – causes or effects. The results were plotted on the "Cause and Effect" diagram (Fig. 2). The intensity of the combined parameter interaction increases along the diagonal and is the greatest for parameters plotted in the upper right corner. Those in the lower left corner are less influential and less responsive but may still be very important for the overall system functions. The position in the diagram was discussed in terms of the relative impact and the volatility (changeability/responsiveness) of each parameter.

From the results of system analytical modelling, the soil is considered the most affected component of the environment. This is logically due to the adsorption properties of soils and the long-term effects. The parameters of fire and meteorological conditions are the most important factors shaping the extent of the damage. Meteorological conditions can be partially modified by changes in the regional environments due to pollution from the fire. The post-fire period is another highly influential aspect, but this "factor" is a generalization since the intensity of the impact depends on the dynamics inherent to each affected component of the environment. From this perspective, soil and ground water are least influenced by post-fire conditions, largely because of their more limited exposure and slower accumulation processes compared to those of surface water and air.

All receiving environments are grouped in one area of the plot, which reflects their similar interconnectivity with the other parameters and between them. As a result, pollution of each component may cause another component's degradation; this is the reason for their moderately high (6–9) values on the "cause" scale.

The impact evaluation is the next step of the analysis, when the impacts can be considered from different perspectives: negative/positive, mitigating/enhancing, primary/secondary, and direct/indirect. The influence diagram (Fig. 3) illustrates only the positive/negative perspective and was constructed to show the strength of the relationships between the components of the system, accounting for the values in the interaction matrix (Fig. 2). This figure shows the interaction of system components in the context of positive and negative effects, where positive impacts imply an increase in the specifically affected component. Some arrows have + and – signs at the same time. This means that depending on the exact conditions, the impact of the component can be either positive or negative. For example, meteorological parameters, such as wind speed, may cause the retention of pollutants in the vicinity of the fire (critical wind speeds of 0–2 m/sec or calm), whereas more intense removal processes (at wind speeds of 5 m/sec and more) would distribute combustion products over wider areas. Similar considerations would explain alternative impacts due to atmospheric stratification in connection with, for instance, temperature inversions or fog or cloud layers. At the same time, precipitation allows the wet deposition of pollutants from the air, which affects air quality positively, but this leads to more intensive pollution for soils.

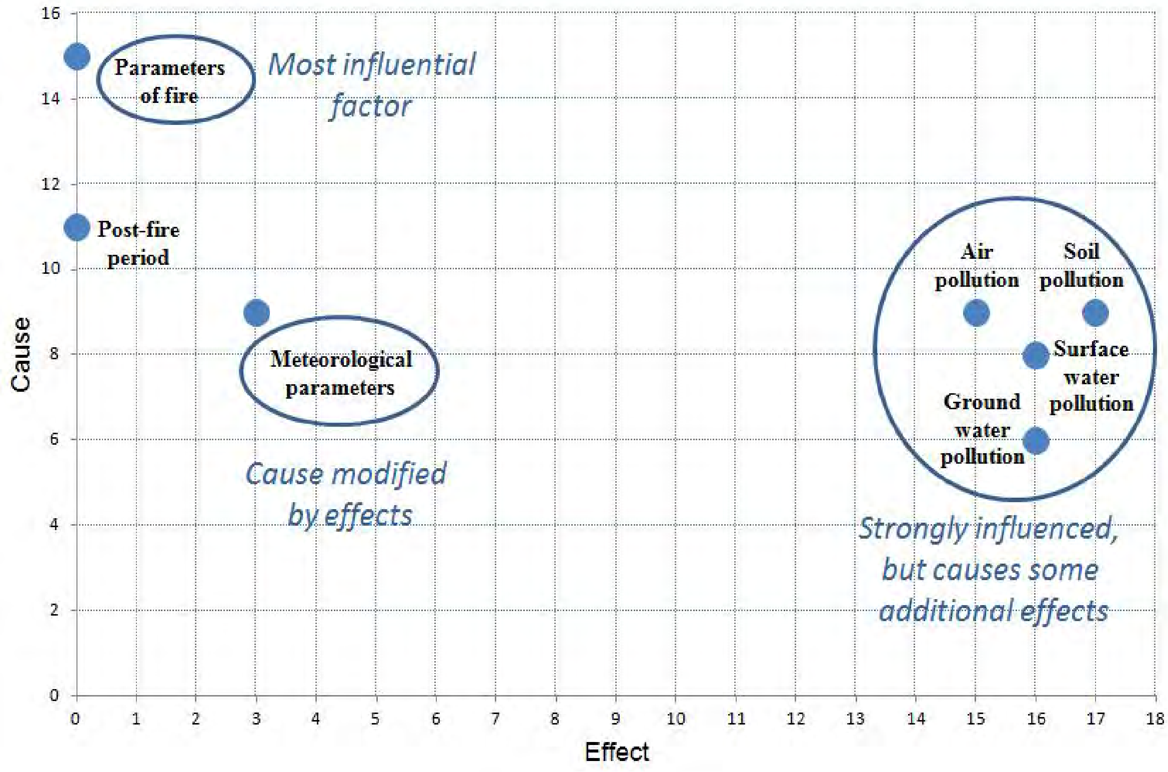

Fig. 2. "Cause-and-effect" diagram

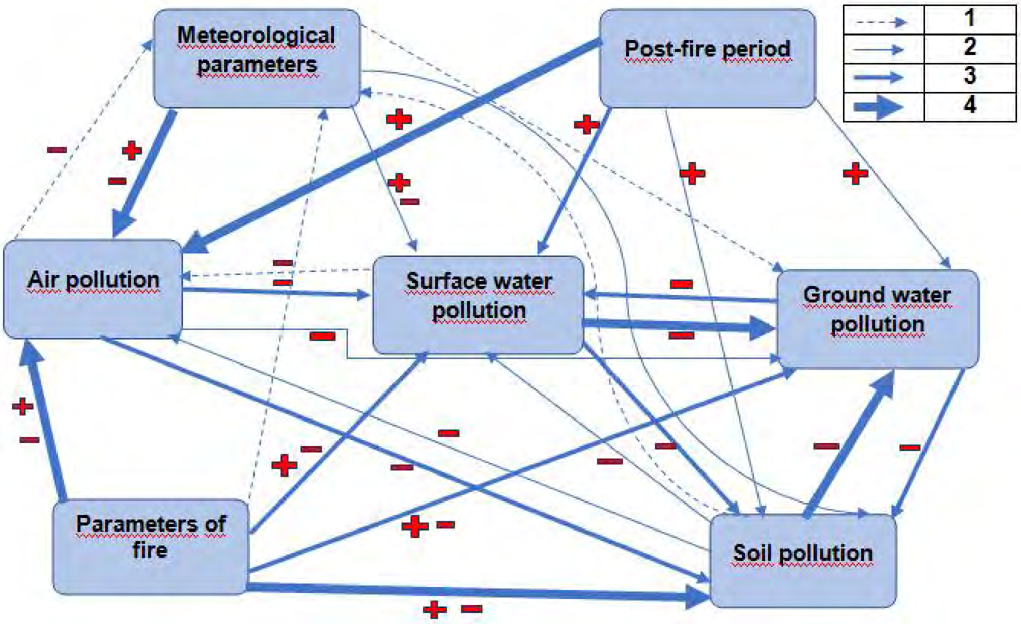

Fig. 3. The interaction of system components in the context of positive and negative influences. The arrows thicknesses show the relative impact strengths

Using the influence diagram and the interaction matrix, the most important feedback loops, showing the dynamics of the system, were identified. Positive feedback loops tend to destabilize, and negative loops tend to stabilize the system. In this system, pollution of one component of the environment may turn it into a source of secondary pollution for other media, causing disturbance to the system. At the same time, the post-fire period is the time that elapsed after the fire, which gradually reduces the intensity of pollution. But the rates of pollution degradation and neutralization differ depending on the intensity of matter and energy cycles in each media (air, soil, water). However, with time, the metabolism of pollutants may lead to the formation of more toxic compounds compared with the initial products of combustion, which may further degrade the quality of the environment. The opposite is also true in some cases with hydrocarbon products (i. e. toxicity decreases with time). Generally, positive feedback dominates in the system, tending to make the system unstable over time, which may also imply the long-term effects of the fire.

4.3. Multi-Criteria Evaluation

The results of the structural analysis were used to predict the possible relative levels of soil pollution under different meteorological conditions and fire parameters.

Weights (w) were assigned to all factors in the model based on pair-wise matrix comparisons according to their relative importance for the question/issue considered, which is “the level of soil pollution” (Table 3). The scale used for this comparison includes values 1/9 – 1/7 – 1/5 – 1/3 – 1 – 3 – 5 – 7 – 9 (from the least to the most important compared to the second parameter). The sum of the rows is an estimation of their overall importance, and this value can be used as the parameter “weight”. Matrix values are more mathematically correct to use, but the row sums are used here for approximate weights and are more accessible for most users (cf. Stevens, 2021).

The weights in Table 3 were derived by averaging evaluation results produced by members of the research team. Thus, the final sum is balanced between opinions of experts with different backgrounds.

The standardized “utility” diagrams were constructed for each factor in the MCE model by representing the relation between the factor and its variable impact on the level of soil pollution with the variable conditions used for the system scenarios. These relationships were partially estimated (for the parameters of fire) or calculated (for meteorological parameters). The estimation of the dependence between the parameters of fire and soil pollution was based on the authors’ overall experience and theoretical logic. For meteorological parameters, the utility diagrams were based on published research results and the professional experience of the authors. The general meteorological situation has a major influence on the distribution of air pollution, with wind speed and direction, temperature and pressure being the most important factors (Perez et al., 2020; Rahman et al., 2022). Nevertheless, the effect of meteorological conditions on soil pollution is not extensively researched or well-established in the literature. The meteorological variables accounted for in the model include wind parameters, atmospheric inversion and stratification. The choice was made in favour of factors potentially having the biggest relation to soil pollution intensity. For this reason, atmospheric inversion and atmospheric stratification were included as separate parameters, although inversion is an element of the entire layer of the atmosphere and can be considered an element of stratification. While atmospheric stratification is constant for relatively long periods, the inversion distribution of temperature is often more infrequent and local and thus affects the sedimentation of pollutants near the affected area. Precipitation was excluded from our consideration since its role in cleaning the air from pollution is ambiguous and correlates with, for instance, the size of droplets and the duration of rain. Moreover, the case study under investigation was carried out in winter conditions, when no snow was reported, and there is limited data about the interaction between snow and pollutants settling.

Table 3

Weighting matrix

Parameters	Duration of combustion	Volume of fuel	Type of fuel	Integrity of reservoir	Wind parameters	Atmospheric inversion	Atmospheric stratification	Sum
Duration of combustion	–	**1**	**3**	**1**	**1**	**3**	**3**	**12.00**
Volume of fuel	**1**	–	**3**	**1**	**3**	**5**	**5**	**18.00**
Type of fuel	**1/3**	**1/3**	–	**1/3**	**1/3**	**1**	**1**	**3.33**
Integrity of reservoir	**1**	**1**	**3**	–	**3**	**5**	**5**	**18.00**
Wind parameters	**1**	**1/3**	**3**	**1/3**	–	**3**	**1**	**8.66**
Atmospheric inversion	**1/3**	**1/5**	**1**	**1/5**	**1/3**	–	**1**	**3.07**
Atmospheric stratification	**1/3**	**1/5**	**1**	**1/5**	**1**	**1**	–	**3.37**

So, a range of assumptions was made to construct utility diagrams based on available data to describe the possible relationships. For instance, the critical wind speed, which contributed to the settling of pollutants to the ground, was defined and is supported by a number of publications (Park et al., 2015; Liao et al., 2021). Atmospheric inversions are also known to affect the distribution of pollutants in the air, but in this study, we also needed to interpret the known dependence (Samad et al., 2019) in terms of the preconditions for substances settling. A related parameter, air stratification, can also affect the settling of particulate matter (Błaszczak et al., 2020; Zhou et al., 2022) and thus affect soil pollution according to the proposed dependence in our study. The factor of seasonal variation is also important for the other meteorological variables, but the suggested utility diagrams represent the general trends and thus can be considered acceptable for varied but similar associations.

The range of the utility scale is from 0 to 1, which shows the relative change in the impact of each factor on soil pollution intensity and magnitude. These Utility diagrams are used to convert the variables observed or hypothesized for different scenarios to a unity scale, which then allows their mutual comparison and combination in the following calculations of “total utility”, using equation (1) for each scenario (Fig. 4).

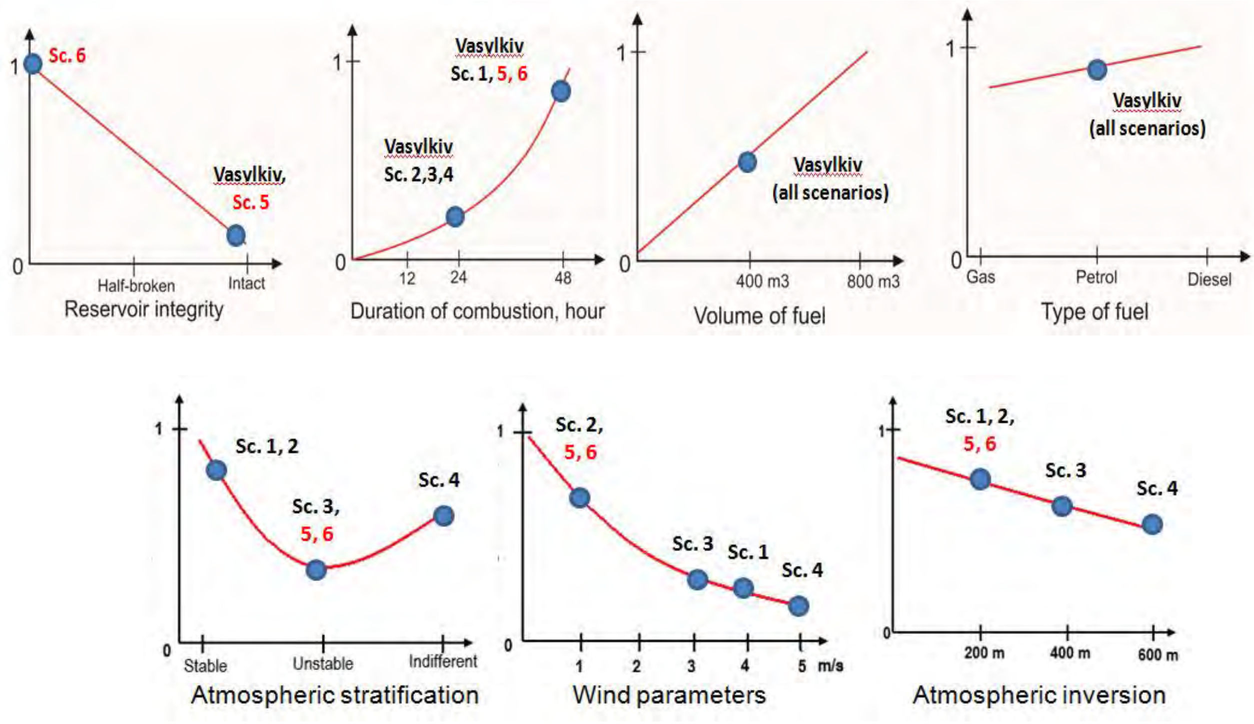

Fig. 4. Utility diagrams

The scenarios used for modelling were of two types – specific and reference. Site-specific scenarios are all the same in terms of the fire parameters, which are the intact reservoir, 50 % filled with petrol, and 24 hours of burning fire. These are based on reliable data presented in official information from the fuel depot owner and an unpublished Report of the State Environmental Control Agency. An additional scenario involved a possible 48 duration of the fire since nearby residents reported through social networks the signs of a fire to be longer than the 24 hours stated by officials. The differences between scenarios also deal with variations in the meteorological parameters, since regular monitoring data were not fully provided due to war conditions. Thus, the difference in the type of atmospheric stratification (stable, unstable or indifferent), wind speed (1, 3, 4 or 5 m/sec) and level of atmospheric inversion (200, 400 or 600 m) were taken into consideration. The two reference scenarios are the worst case options, with intact and broken reservoir construction. The worst meteorological parameters are those contributing to the retention of pollutants in the air and poor dispersion under the given conditions, which eventually means intensive sedimentation of pollutants on the soil.

The results obtained are presented in the form of a bar chart, illustrating that the combination of meteorological parameters used in modelling is highly influential for the expected level and area of soil pollution (Fig. 5). Thus, it is seen that for the Vasylkiv fire, wind speed has a most profound effect on the potential soil pollution, which is expected to increase in connection to weak atmospheric mixing and wider dispersal of emitted pollutants. This is the actual case if we consider official information about this event. However, people in neighbouring areas noted a longer duration of the fire. Under such conditions, prolonged combustion, even at wind speeds favourable for the dispersal of pollutants, would likely cause significantly more damage to soils. Another possible issue is that with a longer combustion process in the reservoir, it is more likely that heavier fractions of petrochemicals stored at the bottom of the reservoir will be burned. The products of heavy fraction combustion are also heavier and precipitate on the soil faster, raising additional concerns about their higher toxicity. The worst-case scenarios of the diagram demonstrate another important finding: the combination of unfavourable meteorological conditions is probably able to cause soil pollution comparable to that expected in the case of reservoir destruction. This stresses the need to account for the situation from a system perspective while assessing the potential damage from fire and for necessary mitigation and restoration planning.

The main purpose of this paper is to illustrate decision-support modelling of the environment and risks, despite conditions where initial data are very limited or only approximated. The reasons for such data-limiting challenges could be diverse, and not only wars or accidents can prevent access to the data. Also, poorly planned coverage of monitoring systems, malfunctioning equipment and human errors are all able to create gaps in the information. The application of MCE, in this case, provides the necessary background for making decisions when time and resources are limited. This is also the case in small communities, unable to finance the extensive research of their problems. Since MCE builds universal models with factors specific to a type of problem, it may be used to develop preliminary assessments for the most typical accidents at specific sites. It also contributes to a general understanding and building preparedness for man-made and natural emergencies.

A possible limitation on the quality of the answers obtained from MCE modelling stems from the number of experts involved: the level of reliability increases with the level of multidisciplinarity of the assessment team. Under the conditions of many emergencies, diverse specialists might not be available on short notice. If the assessment is conducted in advance as a component of planning a response to potential accidents, this limitation could be effectively removed. Similarly, modern communication technologies enable the involvement of all possible specialists online and allow their expert opinion to be included in asynchronous mode using a standard MCE approach to process iteration with feedback received from experts.

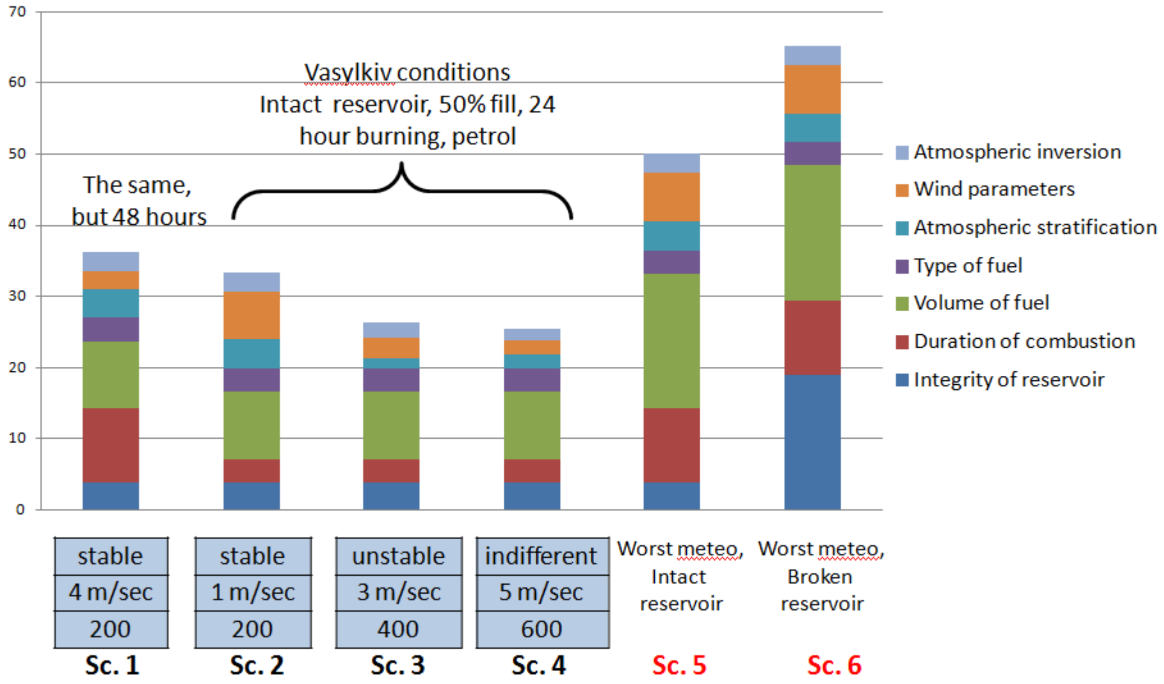

Fig. 5. Comparison of scenarios

5. Conclusions

The results of the impact matrix compilation suggest that soil is the most affected component. Probably, this is related to the fact that soil is the least dynamic environment of all, and the residual pollution effects are the longest. Therefore, soil pollution must be considered a likely, crucial and persistent effect of fuel depot fires. Due to unknown meteorological parameters during the fire, the potential risk of soils pollution in our models varies considerably, raising future questions, such as:

- What is the overall and cumulative economic damage of fire in terms of soil and ecosystem disturbance?
- Is there a need for soil remediation activities at the impact area?
- What are the possible limitations for agricultural activity in the area?

The MCE aims to support the decision-making process when considering these issues.

Although the most important factors leading to environmental damage are the volume of fuel and integrity of the reservoir, the meteorological parameters are also of great importance for soil pollution. Thus, under certain meteorological conditions, the damage to the soil after reservoir failure and fuel spill is similar to the burning of all petrochemicals within the intact reservoir, illustrated by a comparison of the two worst case scenarios – "Worst meteo + intact reservoir" and "Worst meteo + broken reservoir".

In the case of the Vasylkiv fire, modelled soil pollution is likely to range from moderate up to an increased level where there is a need to reconsider lasting damage to the environment and to apply certain remediation activities for most affected areas of agricultural use. The developed model includes a wide range of parameters, which makes it possible to modify and apply it to the assessment of other accidental events.

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