

Article

Environmental Risk Assessment of a Diesel Fuel Tank: A Case Study

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Abstract: The article deals with the application of the environmental damage assessment procedure and H&V index II method to the diesel fuel tank storage facility in a sand mining company using a case study. The procedures enabled the researchers to semi-quantitatively assess the operated diesel fuel tank's impact on the selected environmental components and the possible damage risk by the leakage of stored fuel. It was discovered, by assessing the operating conditions, the state of the environment at the mining facility, and the risk of a diesel fuel leakage accident, that it is not necessary for the company to implement further steps in the field of environmental damage minimization. The H&V index II method examined both the impacts of diesel fuel leakage on soil, biotic component, groundwater, surface water, and the impact of flammable substances on the biotic environmental component in six steps. Slight or significant impacts were identified depending on the environmental component during the determination of the accident severity. The accident severity, together with the estimated probability, was plotted in the risk matrix which resulted in acceptable risks for all affected environmental components. The results of both approaches showed that the diesel fuel leakage in the mining company represents an acceptable environmental risk in relation to the countermeasures implemented so far.

Keywords: risk assessment; sand mining; transport; diesel fuel; tank; H&V index II method; environmental damage; environment



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1. Introduction

Sand and gravel are two of the most mined commodities. These commodities historically represent the most important building materials [1] and an important base for local economies. They are mined worldwide and represent the largest volume of globally extracted solid material [2,3]. At the same time, this material cannot be obtained from our interior, river, and marine environment in the quantities needed to meet the world's demand of 10 billion people without effective planning, regulation, and management policy. Based on the most conservative approximation [2], sand is mined more than three times faster than nature can create it [2]. Expert discussions (e.g., Round Table, Geneva, 2018) highlighted potential solutions to sand mining impact mitigation and created adequate support for responsible consumption options [4,5]. The 2019 United Nations Environment Programme report "Sand and Sustainability" concluded that the current sand mining policies of individual countries provide a starting point for regulation; however, they are not comprehensive and thorough enough [4]. The demand scope for a given commodity across different industry fields, as well as the efforts to maintain it, means that this issue requires a fully integrated view of resource management, planning, and management [4].

Mining of river aggregates (sand, gravel, etc.) is usually carried out for its further industrial use and processing (e.g., cement production, glass industry, construction, etc.) [6,7];

however, sometimes it is also in order to provide preventive environmental protection in a certain natural area. Mining in such cases is mainly carried out as a single intervention for the purpose of restoring or returning the environment to its original state. Agricultural and natural habitats, such as wetlands and watercourses, which are often threatened by quicksand and mobile dunes can serve as examples [8]. Siltation of wetlands and watercourses with quicksand (possible effects of frequent strong winds, prolonged droughts, and floods) can have an adverse impact on agricultural land and other environmental aspects. Wetlands are known to be important ecosystems that promote the survival of severely endangered species of fauna and flora (the risk of habitat loss for migratory birds and protection of rare species of frogs and fish, etc.) and help retain water in the landscape. This issue was addressed, for example, by Van Diemen Consulting (VDC) company in its “Environmental Effects Report and Planning Information”, which was carried out to support and develop an application for the land-use decision-making process for sand mining on the “Manuka Park” site in Bridport [8].

Long-term mining in one location, which causes a number of direct and indirect physical, ecological [7,9–11], and socio-environmental [12,13] negative and positive impacts [5,14], depending on the chosen method of mining, is the most common. However, the extraction of gravel is inevitable, as the sustainability of the construction industry depends on it to a large extent. Different methods of extraction (mechanical or manual) are used for dry (above groundwater level) or wet (below groundwater level) sand extraction from various sources (rivers, lakes, canals, floodplains, etc.) [1,15,16]. Different extraction methods/techniques are also partly related to different technical procedures, work and safety processes, technological equipment, and many other aspects that affect the extent of the environmental impacts. It is necessary to transport the commodity from the place of wet mining to the mainland for further processing, treatment, and transport. For this purpose, pusher tugs are mainly used. The proximity of fuel tanks is necessary for their continuous operation. Their presence thus causes a further potential source of threat to the given location [17].

Regardless of the type of extraction chosen, direct impacts on the environment are considered to be those where the material extraction is directly responsible for the impacts on the ecosystem, for example, as a result of habitat removal [18]. Indirect impacts are related to the changes in ecosystems that spread through them due to physical changes resulting from sand mining [11], such as changes in riverbeds, river hydraulics, or sediment capacity [19], which may change habitat distribution and ecosystem functioning [20,21]. Furthermore, it may cause changes in the landscape (formation of mining pits or water areas), a decline in groundwater levels, etc. Some impacts of wet mining and related processes/aspects were addressed by T. Nasrabadi, H. Ruegner, et al., in their study “Using total suspended solids (TSS) and turbidity as proxies for evaluation of metal transport in river water” [22]. The negative impacts of mining are minimized (during or after finished mining) at the site by recultivation which forms a necessary part of land restoration. A nature-friendly solution is usually chosen during recultivation.

The logistics process of sand mining, sorting, transport, and processing is a complex technological process, interlinked by means of labour at the input and output of processes determined by the place of operations, as well as the technical means used [23]. The efficiency, productivity, and cost of long-distance transportation depend on factors such as the form of the transported material, the solid volume content of the material, the moisture content, the transportation distance, and the technical properties of the transport vehicle used [24]. The chosen method of raw material transport depends on the accessibility of the mining deposit and the transport possibilities in the vicinity of the deposit; however, it also affects the environment (especially by greenhouse gas emissions and noise [25]) at the same time. The most common form of raw material transport is road transport, followed by rail and water transport. The transport of the raw material takes place in a bulk form; therefore, the means of transport for bulk raw materials have a modified construction in order to prevent the loss of material during transport. Transport by using

roads has gained popularity thanks to the speed of order delivery, and the ability to quickly adapt to customer needs, by providing just-in-time deliveries, reducing storage space, and increasing cash flow. Transport (the distance between production and consumption) nowadays represents an assessed factor in determining environmental sustainability. The road transport used represents a significant environmental burden. Heavy goods vehicles are responsible for about a quarter of CO₂ emissions from road transport in the European Union and about 6% of total European Union emissions [26]. Despite the implementation of measures to reduce or eliminate emissions making the efficiency requirements of heavy goods vehicle consumption stricter, the situation cannot be improved, as the share of road transport costs is still growing for the above-mentioned reasons.

Methods for identifying initiating events, causes of failures and risks leading to technological accidents of the tanks, are commonly used and described in the scientific literature [27–29]. Both qualitative (checklist) and quantitative (hazard and operability analysis (HAZOP) [30], what if [31], failure mode and effect analysis (FMEA) [32], fault tree analysis (FTA) [33], event tree analysis (ETA) [34], Mond index [35], fuzzy Bayesian network [36], etc.) methods are used to identify and assess the technological risks of tanks. Some of these methods can generally describe environmental risks. A comparison of the suitability of these methods for the needs of environmental risk assessments was carried out in [37,38]. In response to past leakages of hazardous substances from tanks, domino effects [39,40] and technological accidents caused by the impacts of natural disasters (so-called NAT-ECH) [40–42] have begun to be researched. The scientific literature research shows that the risk assessment of tanks (regardless of the type of stored substance) is primarily focused on technological risks and only marginally on environmental risks [43]. Ahmadi [43] and Pouyakian [36] reached similar conclusions and gave priority to disregarding human and organizational problems in refinery risk assessments and storage of oil products in tanks. The same findings for the sand mining industrial area were provided by Nasarwanji [44].

In the case of risk assessment concerning the presence of hazardous substances in the environment, it is not possible to rely on such a wide variety of methodologies in comparison with the risk assessment of the impacts of accidents on human health or property; for this reason, it is not easy to select a suitable methodology for the currently addressed environmental problem [45]. There is no unified environmental risk assessment method for assessing the environmental risks of tanks storing diesel or other oil products. An environmental impact assessment that assesses the anticipated impacts of mining on the environment is performed as a standard for the anticipated mining intentions. In such cases, the assessment contains a large amount of uncertainty and is based on a qualitative evaluation. The presented case study concerns an existing and long-term used tank, so it was appropriate to determine other methods of identification and assessment of environmental risks. There are a number of national guidelines for environmental risk assessment (e.g., EPA [46], DEFRA [47], Government of Canada [48], Australian Government [49]). A comparison of significant elements of various environmental risk assessments is made in [50]. These guidelines describe the general steps of an environmental risk assessment [51] and their assessment of exposure to biological and environmental impacts on the risk characteristics is based on direct measurements of the concentration of pollutants in individual environmental components, i.e., on quantitative data that are not always available. The guidelines are intended for any type of leakage of a hazardous substance into the environment, regardless of the leakage source. At the same time, these assessments emphasize the need to approach each one individually according to local conditions. This makes obtaining data for this assessment really costly and time-consuming and can be burdened with uncertainties (e.g., in relation to proven ecotoxic impacts, use of biological models instead of in situ conditions). For this reason, priority was given to the use of semi-quantitative methods for the environmental risk assessment. The use of any methods or their combination for risk identification serves the prediction and prevention of environmental risks [37].

The above-presented analysis of the scientific literature and research studies show that at the present time, direct and indirect environmental impacts related to individual forms

of sand mining are very well mapped; however, environmental impacts related to the whole process operation are not sufficiently addressed. This statement was also supported by the [52] study. Therefore, the research focused on other risks associated with the mining operation which are not paid sufficient attention, in contrast to the primary mining risks [53,54]. Environmental risk assessment for diesel fuel tanks intended for the individual needs of facility operation is not sufficiently addressed. The use of detailed environmental risk assessment methods can represent both a financial and time-related burden for facility operation. Based on these findings, the aim of this article is to provide a case study of a semi-quantitative assessment of environmental risks related to the operational activities of sand mining and diesel fuel storage for the vehicle operation needs. The case study identifies the most affected environmental components and estimates the risk of diesel fuel leakage into individual environmental components. Threats associated with such mining activity have not been addressed in studies of the sand mining environmental impact, although potential impacts on the individual environmental components may have a long-term and irreversible effect. The case study also presents the use of a combination of suitable semi-quantitative methods for environmental risk assessment.

For the needs of the case study, a mining company facility in the Czech Republic, which forms part of an international consortium, was chosen. The site of the mining company lies in a protected landscape area and at the same time in a protected area of natural water accumulation. The diesel fuel tank functionality failure, leakage, or overfilling of the emergency sump could have a negative impact on the quality of both surface water and groundwater in the location and affect their long-term usage. The company has not performed any environmental risk assessment in this field using appropriate risk assessment methods. This case study provides an opportunity to obtain relevant data to identify the risks and scenarios of fuel leakage into the environment, including subsequent risk acceptability determination.

2. Materials and Methods

The researched facility characteristics were assessed with the emphasis on the analysed diesel fuel tank and a description of the application of assessment methods of the environmental risks arising from the diesel fuel tank operation in order to achieve the study goal.

2.1. Researched Facility Characteristics

Neither the name of the mining company nor a more specific identification of the researched facility location can be published in order to maintain the company anonymity; therefore, a neutral general designation is used throughout the article. The company has implemented a certified environmental management system according to ISO 14001. The subject of the research study was a mining facility located in a protected landscape area near the Lužnice river in the Czech Republic. The facility extracts raw material: gravel from the riverbed with a suction dredger which loads the raw material into a barge. Then, the barge with loaded extracted material is connected to a self-propelled vessel, called a pusher tug. The pusher tug provides movement to the tow of barges [55]. The constant presence of a fuel tank (in this case, diesel) is necessary for its operability. The advantage of using pusher tugs is higher sailing efficiency due to the lower resistance of the barge tow (connected barge and a pusher tug) when moving.

The subject of the research is an above-ground single-shell diesel fuel tank with a pipe fitting with a volume of 20 m³. It is used as a non-public fuel filling station designated for the reception, storage, and dispensing of diesel fuel by the mining company to provide vehicle operation (loaders, lorries) and push tugs. The tank is refilled from tank trucks on average 7 times a year up to a volume of 18 m³. The tank has the shape of a horizontal undivided cylinder, which is roofed and stored in a metal emergency sump. The diameter of the tank is 2 m, length 6.6 m, and the thickness of the steel tank wall is 5.8 mm. The emergency sump is made of 7 m long, 3 m wide, and 1.5 m high metal. There are two

entrance domes with a diameter of 0.5 m in the upper part of the tank. The filling device is designed in such a way that it prevents the backflow of the stored substance. Internal tank reinforcements and leak indications are not installed. On the contrary, an overflow indication, fuel level measurement, and explosion-proof protection fuse are installed. The surrounding handling area is paved. The outer surface of the tank is accessible, and the entire mining company facility is fenced with a square galvanized fence to a height of 2 m without a CCTV camera system. The diesel fuel tank is located 15 m from the mining lakeshore for the purpose of filling the push tugs.

Both the diesel fuel tank and the explosion-proof fuse regularly undergo annual independent professional inspections and maintenance, as stated in the submitted internal company documents. The results of the 2020 revision protocol showed that the tank is not deformed or otherwise mechanically damaged. For welded and bolted joints, no signs of leaks were determined during the pressure tightness test. Slight local surface corrosion up to a height of 0.8 m was found in the upper and lower part of the tank. The deposits were removed by cleaning during the inspection.

2.2. Environmental Risk Assessment Methods

The environmental management system requires regular evaluation of internal and external issues, which includes an assessment of environmental aspects and risks. It follows that it is necessary to apply methods of environmental risk assessment instead of using just verbal descriptions of environmental aspects, as is currently a common practice. When selecting a suitable method for environmental risk assessment, it is necessary to define the objective of the method (i.e., the form of the required results), the availability of input data, and the experience and knowledge of the specific method by the evaluators [45].

The assessment of environmental damage is governed by the uniform legal framework of the European Union [56]. The objective is to prevent and remedy environmental damage including a defined range of damage liability. A comparison of member states' approaches to this issue show that the member states have implemented the directive differently, inconsistently, and with diverse effectiveness [57]. Some states use the environment-accident index (see its characteristics below) to estimate the environmental damage risk.

The procedure of environmental damage assessment is presented with regard to the possibility of its extension beyond the national concept, as it represents a simple universally applicable tool. In this way, it could contribute to the consistency of approaches that are not uniform within the European Union. The environmental damage assessment deals with the immediate threat to protected species of wild fauna and flora, natural habitats, water, or soil. The assessment of environmental damage is carried out for specified operational activities, and a point rating [58,59] is assigned to the individual parts of the assessment.

One of the oldest methods for environmental impact assessment is the Leopold matrix [60] which consists of a column representing organizational procedures such as mineral processing, freight transport, blasting, and drilling. The matrix contains rows that represent elements of the environment, such as water quality and atmospheric quality. There is also space to assess the extent and importance of the identified impacts on a scale from 1 to 10 [60]. The Leopold matrix method offers no standardized way to assess scores, nor is there any means of assigning weights to different impacts to determine their relative importance. For this reason, the scoring values in the matrix present the opinions of experts from different fields rather than objective facts [61].

The Process Safety Leadership Group (PSLG) guideline sets safety and environmental standards for fuel storage sites [62]. PSLG uses a semi-quantitative method of the layers of protection analysis (LOPA), which allows one to examine the risks of selected scenarios before overfilling the flammable fuel storage tank. LOPA is defined as a simplified risk assessment of a one cause–one consequence pair [63]. Safety protection of a facility or chemical plant is broken down into layers [64]. The disadvantage of this method is that it does not focus on individual components of the environment, and the assessment requires knowledge of frequencies and several mitigation layers that prevent the risk activation,

which is not available in the case of the diesel fuel tank under research. Therefore, the method was not included in the comparison.

Recognized European methodologies suitable for environmental risk assessment include the hazard & vulnerability index II (H&V index II) and the environment-accident index [45,65]. Their common feature is that they are not usable for unknown chemicals.

The H&V index II method was developed in the Czech Republic. It is intended for the assessment of short-term leakage of hazardous substances into the environment, which does not exceed hours or days in its time horizon [66]. When assessing the impact of accidents involving a hazardous substance impact on the environment using the H&V index II method, the substance hazard index for environmental components and the environment vulnerability index to a potential accident involving a hazardous substance, are created separately. The substance hazard index for the environment represents a combination of the substance (eco) toxic, physical, and chemical properties and the substance spread potential. The environment vulnerability index is determined separately for the environmental components: surface water and groundwater, soil environment, and biotic environmental components. It includes the characteristics of the following environmental components: soil permeability, hydrogeological subsoil permeability, land use, use of groundwater and surface water, specially protected natural areas, protection zones, etc. For this study, partial indices, which give information about a specific substance hazard for the assessed location, were obtained by the synthesis of the indices (the environment vulnerability index and the substance hazard index for environmental components). The next step was to determine the potential accident severity. Severity was determined by the combination of the substance amount that may leak into the relevant environmental component and the partial indices (see Figure 1). The toxic substance severity impact on surface water, soil environment, groundwater, and the biotic environmental component were estimated separately, and subsequently, the toxic and flammable substance severity impact on the biotic environmental component was estimated [66].

The environment-accident index (EAI), developed in Sweden, represents a fast and simple semi-quantitative method. The EAI is an example of a tool based on a strategy to join the properties of a chemical with site-specific properties to facilitate this assessment and to be used in the planning process [67]. The EAI is built on three parts: the first part contains information on the acute toxicity to aquatic organisms, the second part concerns the transported or stored amount of the chemical, and the third part deals with chemical mobility [68]. The EAI is limited to leakage to ground, water, or groundwater and is not applicable on fires, explosions, or accidents with release of gas into the air. The EAI is only applicable to the acute phase of an accident and should not accordingly be used in a long-term perspective [68].

The advantage of both methods is their ability to be used for a wide range of stored hazardous substances. The authors of the article included the Leopold matrix, environmental damage assessment, H&V index II, and EAI methods in the comparison. The results are presented in Table 1. The comparison used lessons learned from the environmental risk assessment within the framework of the Seveso directive in the Czech Republic and Italy [45].

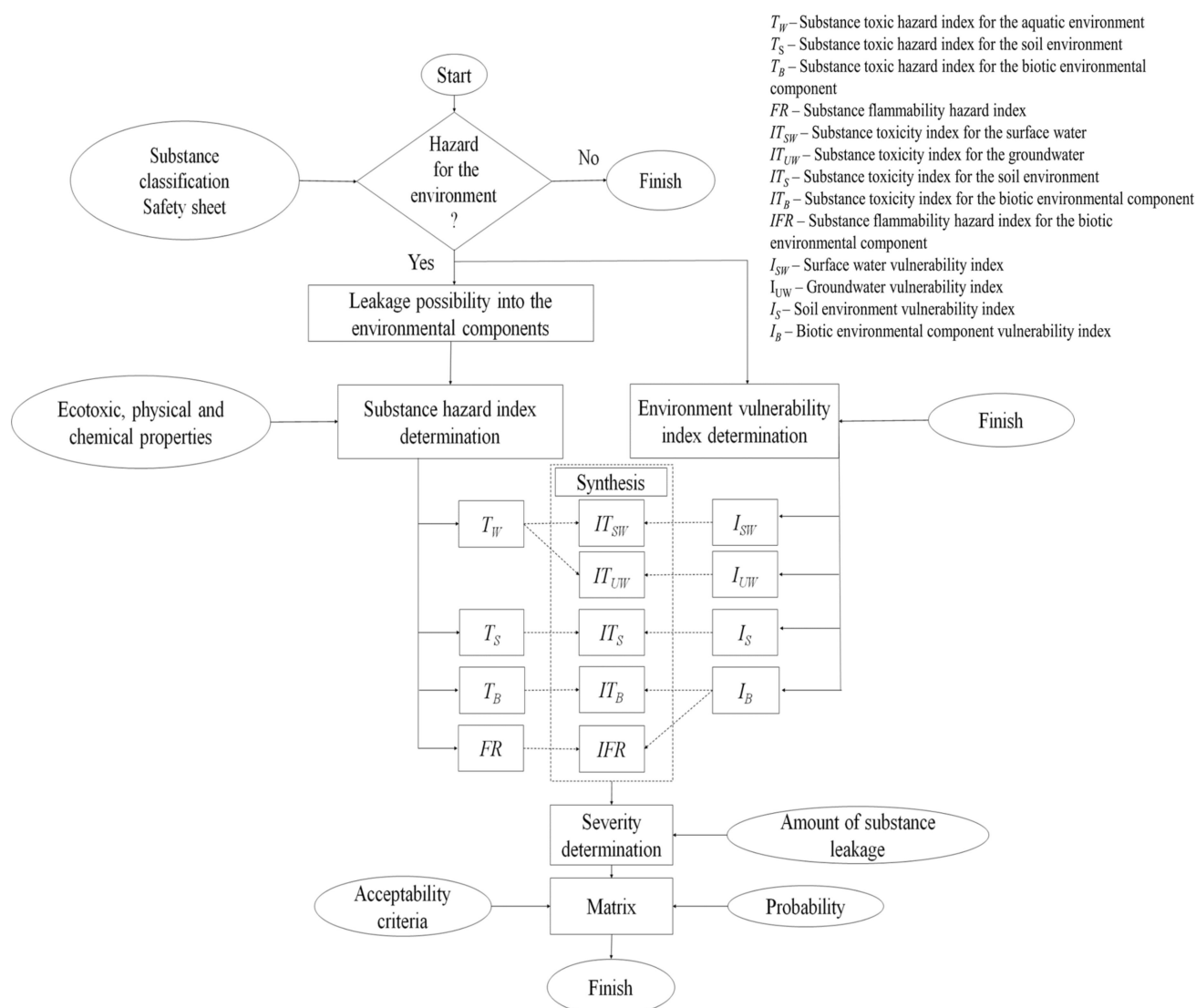


Figure 1. Possible basic transport routes of environmental pollution in case of diesel fuel tank leakage (source adapted [66]).

Table 1. Comparison of methods suitable for environmental risk assessment.

Environmental Component	Method			
	Leopold Matrix	Environmental Damage Assessment	H&V Index II	EAI
Surface water	✓	✓	✓	✓
Groundwater	✓	✓	✓	✓
Soil	✓	✓	✓	✓
Biotic	✓	✓	✓	-
Athmosphere	✓	-	-	-
Amount of input data needed	0, qualified estimate	>20	>10	5–10
Time demandingness	Easy	Medium	Time consuming	Easy

Methods for the assessment of the case study were selected based on the identification of suitable methods that require the largest amount of input data resulting in minimizing the uncertainties associated with risk assessment, while allowing the impact assessment of most environmental components.

The results of the comparison show that the largest number of environmental components can be assessed by the Leopold matrix; however, the assigned values of impacts are

subjective, and the results may be subject to error. The environmental damage assessment requires the largest amount of input data and its collecting is time-consuming. On the other hand, the calculation itself is time-saving. The result of the Environmental Damage Assessment falls within the points achieved within acceptability borders. The H&V index II method requires the second largest amount of input data, it is the most time-consuming to estimate the risk; however, it allows the assessment of all environmental components except the impact on the atmosphere, making this method the most comprehensive. The EAI assesses the smallest number of environmental components, requires a limited amount of input data and is easy to process in terms of time. The environmental damage assessment method [58,59] and the H&V index II method [66] were chosen as the most suitable methods for the environmental risk assessment of the operated diesel fuel tank with regard to the established selection conditions and the comparison of methods carried out. The environmental damage assessment method was used for the initial assessment, and the H&V index II method for the detailed risk assessment. Since the H&V index II method is rather complex, the procedure of its implementation is presented in Figure 1.

The application of the H&V index II method required knowledge of the diesel fuel hazards which were listed in the safety data sheet. The necessary data for the application of the H&V index II method included H-statements (standard hazard statements), which were H226, H304, H315, H332, H351, H373, H411, and toxic impact on the aquatic environment (LC₅₀, IC₅₀, EC₅₀).

The IAEA-TECDOC-727 method [69] could not be used for risk assessment, although the diesel fuel tank met the requirement for fixed equipment in the fuel storage activity and activity classification reference number 6. The criterion of distance from populated areas, where the nearest inhabited houses were in distances greater than 50 m, was not met to obtain objective results of the consequences of a possible diesel fuel leakage.

3. Results and Discussion

No risk assessment has been carried out for the assessed facility yet; therefore, the selection of a suitable method concentrated on semi-quantitative methods of identification and analysis of environmental hazards. The requirements that the method should allow the impact assessment with an emphasis on the environment and be recognized by normative legal acts in the Czech Republic were taken into account when selecting the appropriate methods.

The first step was to examine whether the facility meets the requirements of the Act on the Prevention of Major Accidents [70]. According to Annex 1 of the Act [70], it was found out that the subject handles a smaller number of hazardous substances according to the tank volume than was specified for classification. The facility belongs to the unclassified facilities, which means that it is not necessary to meet the requirements of the legislation for minimizing serious accident impacts on the lives and health of humans and animals, the environment, and property in the facility and its surroundings.

3.1. Environmental Damage Assessment

The Act on the Prevention and Remedying Environmental Damage [58] is another normative legal act addressing the impact of selected operational activities, including handling hazardous chemicals (so-called operational activity 10), on the environment. As the company has implemented and certified a voluntary environmental management system according to ISO 14001, the facility performs only a basic environmental damage assessment [58].

Table 2 shows the basic environmental damage assessment for the evaluated facility. According to the basic risk assessment procedure set out in Annex 1 of the government regulation [59] for the assessed facility, it follows that the stored number of chemical substances and mixtures dangerous for the environment do not exceed 20 t, and 0 points were assigned to it. If the number of achieved points in the subtotal of Part B is 0 for operational activity 10, Part C of the basic assessment is not filled in, according to the

government regulation. For this reason, Part C is not included in Table 2. In the past ten years, none of the listed events in Part E took place in the facility. Therefore, no points were assigned to points 21, 22, and 23. The tank is not secured against diesel fuel leakage into the surroundings; however, it has a preventive measure against the occurrence of an adverse event installed, therefore in Part E, 5 points were not counted in point 24.

Table 2. Basic environmental damage assessment for the assessed tank facility (source adapted [59]).

Assessment Part	Assessment Phase Characteristics	Points According to the Government Regulation	Assigned Points
Part B, Point 5	Quantities of chemicals and mixtures (d) dangerous for the environment R51, R-52, R-53, R-54, R-55, and R-56, H411, H412, H413	10	0
Subtotal of Part B			0
Part D, Point 18	Identification of possible scenarios of environmental damage for the evaluated operational activity: leakage of a liquid substance into soil/water	5	5
Part D, Point 19	The possible consequences of the scenario identified in Point 18 will manifest themselves as ecological damage to:		
	Water	5	5
	Soil	2	2
Part D, Point 20	The severity of possible consequences of environmental damage identified in Point 19: Significant	5	5
Subtotal of Part D			17
Part E, Point 21	Existence of previous unauthorized interventions, accidents, or environmental damage that occurred in the past 10 years due to:		
	Technical defect	5	0
	Human factor failure	3	0
	External causes	2	0
Part E, Point 22	The consequences of previous unauthorized interventions, accidents, or environmental damage listed in Point 21 were reflected in:		
	Water	5	0
	Soil	2	0
	Protected species or natural habitat	5	0
Part E, Point 23	The consequences of previous unauthorized interventions, accidents, or environmental damage listed in Point 22 were:		
	Insignificant costs for liquidation of consequences below CZK 1 million	2	0
Part E, Point 24	The operator has not taken any preventive measures or does not have a detection device installed to prevent environmental damage	5	0
Subtotal of Part E			0
Part F	Total number of points achieved		17

The total number of points achieved was 17, which is lower than the set level of 50 points for carrying out a detailed risk assessment. In relation to the above-mentioned application of ISO 14 001, the company would not carry out a detailed risk assessment, even if it exceeded the limit of 50 points. The results show that the company is not subject to any other obligations and does not have to provide financial security in case of environmental damage occurrence.

3.2. Environmental Risk Assessment by the H&V Index II Method

The national H&V index II method was used to assess the accident impact on the environment [66]. The accident severity assessment was carried out in six interrelated steps, corresponding to Figure 1.

3.2.1. Toxic Substance Assessment for the Environmental Components

In this step, based on the safety data sheet, the hazardous properties of diesel fuel were assessed with respect to endangered environmental components, i.e., surface water, soil and hydrogeological environment, and biotic environment. The methodology works with three groups of hazards for environmental components:

1. A substance is hazardous for the aquatic environment if classified as H400, H410, H411, H412, and H413. Diesel fuel is dangerous for the aquatic environment since H-statement H411 was listed in the safety data sheet.
2. A substance is hazardous for acute toxicity for the biotic environment if classified as H300, H301, H302, H310, H311, H312, H330, H331, and H332. Diesel fuel is dangerous for the biotic environment and terrestrial ecosystems since H-statement H332 was listed.
3. A substance is hazardous due to flammability if classified as H200, H201, H202, H203, H204, H205, H220, H221, H222, H223, H224, H225, H226, H228, H240, H241, H242, H250, H251, H252, H260, H261, H270, H271, H272, and H280. Diesel fuel is classified by H-statement H226 in accordance with normative legal acts.

The results of the first step show that diesel fuel falls into all three hazard groups, which were assessed in the following steps.

3.2.2. Hazard Indices Determination

This index classifies substances mainly according to endangered environmental components. Physical and chemical properties and information on (eco) toxicity from safety data sheets and available databases were used to calculate the indices. The substance toxic hazard indices, which were divided based on the impacts on three environmental components and the substance flammable hazard index, were determined separately. Index assignment or calculation was as follows:

- Substance toxic hazard index:
 - For the impact on the aquatic environment (T_W), diesel fuel was classified by the standard hazard statement H411; therefore, it can be directly assigned the toxic hazard index for the aquatic environment. An index of 3 ($T_W = 3$) was assigned on the basis of toxicity according to the determined values.
 - For the impact on the soil environment (T_S), diesel fuel was classified by the standard hazard statement H411, which was directly assigned the toxic hazard index for the soil environment according to toxicity codes at level 3 ($T_S = 3$).
 - For the impact on the biotic environmental component (T_B), the index was determined according to the values of acute toxicity in combination with selected physical substance properties, which indicate its mobility (state, volatility). T_B is the product of:
 - Partial index for the biotic environment (A_B), diesel fuel is classified by the standard hazard statement H332 and LD₅₀ oral for a rat at the level

of 2000 mg.kg^{-1} , low toxicity, thus it was possible to directly assign an index at level 1 ($A_B = 1$).

- Partial index B_B , which represents the substance physical properties. Diesel fuel is a liquid with a vapor pressure at $20^\circ\text{C} < 0.005 \text{ MPa}$ (specifically 0.0001 MPa). According to the table for the substance physical property assessment, the B_B index was assigned at level 1.
- The product of the indices A_B and B_B was the value of T_B calculated at level 1.
- Substance flammable hazard index:
 - For the impact on the environmental biotic component (FR), the ability of the substance to evaporate after leakage was assessed on the basis of a physical and chemical property scale, for flammable liquid vapor pressure at $20^\circ\text{C} < 0.03 \text{ MPa}$, the index was assigned at level 1.

3.2.3. Environmental Component Vulnerability Assessment

This step represents a preliminary identification of the endangered environmental component (surface water and aquatic systems; groundwater; soil environment; biotic environmental component and terrestrial ecosystems). The environmental components were assigned an index on a five-point scale: negligible environment vulnerability; low environment vulnerability; average environment vulnerability; high environment vulnerability; very high environment vulnerability.

- Determination of surface water vulnerability (I_{SW})—individual surface water categories were assigned a specific index. The resulting index was given by the sum of the types of surface water in the surroundings. In the case of the researched facility, there was just surface backwater in the form of flooded mining pits, i.e., index 3. I_{SW} was therefore assigned a value of 3.
- Groundwater vulnerability assessment (I_{UW}) was carried out for:
 - Rock environment of the collector—the rock environment at the evaluated location is porous and penetrable in the unpaved area, mostly gravel-sand sediments, with hydraulic connection to surface flow. In this case, contamination risk is very high and the point value assigned was 5.
 - Cover character—the evaluated location is without a cover and with a permeable cover layer, which corresponds to a point value of 5.
 - Protection degree—the assessed location belongs to the protected area of natural water accumulation, which was rated by 2 points.
 - Collector water management importance (according to hydrological maps)—the use of groundwater in the location has the character of concentrated extractions of smaller regional importance (minor group waters). A point value of 4 was assigned to this characteristic.

Groundwater vulnerability was subsequently determined by summing the above-mentioned four characteristics. The value of 16 points was obtained as the sum of the characteristics. The sum value was assigned to the appropriate interval of the five-point scale. A value of 16 corresponds to an interval of 15–18 points, which indicates a high vulnerability, i.e., the I_{UW} index was 4.

- Determination of the soil environment vulnerability (I_S)—the bonity of the soil-ecological unit was not determined in the location, as it is not agricultural land. The soil map of the Czech Republic was used as an alternative. It follows that these are highly susceptible alluvial soils with an I_S index of a value of 4.
- Determination of the environmental biotic component vulnerability (I_B)—vulnerability assesses the ecological value of the environment. The evaluated facility is located in the protected landscape area; therefore, the I_B index was set at the value of 5.

The vulnerability assessment resulted in the risk matrix (Table 3) showing the relationship between each environmental component and its vulnerability index, which falls

within the 1–5 range. The results in Table 3 show that the most endangered environmental component is the biotic environment, due to the location of the diesel fuel tank and the mining facility in a specially protected area. The vulnerability indices of the soil environment and groundwater had the same value of 4. Indices were affected by the character and vulnerability of the environment.

Table 3. Matrix of area's vulnerability indices.

Index Value	Index Type			
	I_{SW}	I_{UW}	I_S	I_B
5				X
4		X	X	
3	X			
2				
1				

3.2.4. Synthesis of Hazard and Vulnerability Indices

Each index was obtained by the synthesis of the relevant environmental component hazard and vulnerability indices according to the corresponding formula.

- Calculation of the substance toxicity index for the surface water (IT_{SW}) was calculated using the Formula (1):

$$IT_{SW} = \max\left(\frac{I_{SW} + T_W}{2}; \frac{I_{SW} + T_W + I_S}{3}\right) \quad (1)$$

I_{SW} —Surface water vulnerability index

T_W —Substance toxic hazard index for the aquatic environment

I_S —Soil environment vulnerability index

$$IT_{SW} = \max(3; 3.3)$$

- Calculation of the substance toxicity index for the groundwater (IT_{UW}) was calculated using the Formula (2):

$$IT_{UW} = \frac{I_{UW} + T_W + I_S}{3} \quad (2)$$

I_{UW} —Groundwater vulnerability index

T_W —Substance toxic hazard index for the aquatic environment

I_S —Soil environment vulnerability index

$$IT_{UW} = 3.6$$

- Calculation of the substance toxicity index for the biotic environmental component (IT_B) was calculated using the Formula (3):

$$IT_B = \frac{T_B + I_B}{2} \quad (3)$$

T_B —Substance toxic hazard index for the biotic environmental component

I_B —Biotic environmental component vulnerability index

$$IT_B = 3$$

- Calculation of the substance toxicity index for the soil environment (IT_S) was calculated using the Formula (4):

$$IT_S = \frac{T_S + I_S}{2} \quad (4)$$

T_S —Substance toxic hazard index for the soil environment

I_S —Soil environment vulnerability index

$$IT_S = 3.5$$

- Calculation of the substance flammability impact index on the biotic environmental component (*IFR*) was calculated using the Formula (5):

$$IFR = \frac{FR + I_B}{2} \quad (5)$$

FR Substance flammability hazard index for the biotic environmental component

I_B Biotic environmental component vulnerability index

IFR = 3

3.2.5. Assessment of the Substance Amount Leakage into the Environment, Accident Severity Determination, and Acceptability Assessment

An estimate of the accident severity category depending on the leakage of diesel fuel into the relevant environmental component was performed in this step. The tables created by the above-introduced methodology, in which the relevant toxicity index was compared with the leaked substance amount, were used to determine the accident severity category for the environmental component. The maximum level of stored diesel fuel was maintained at 18 m³, i.e., below the maximum storage capacity of 20 m³ within the case study. With a diesel fuel density of 840 kg.m^{−3} and a filling of 18 m³, the weight of stored diesel fuel was 15.12 t. According to the operator, the minimum amount of stored diesel fuel does not fall below 5 tons. The methodology of the set intervals of the leaked substance amount shows that leakage can occur with a different amount of the stored substance. All accident severity categories were considered within the presented case study, while the capacity of the emergency sump should retain the entire maximum amount of leaked diesel fuel, and thus minimize the environmental impact.

Determination of the accident severity category of the toxic substance leakage into the surface water:

To determine the leakage accident severity, the amount of diesel fuel leaked was compared with the surface water toxicity index (*IT_{SW}*), and Table 4 was used. Table 4 indicates the accident severity categories depending on the leakage amount in green. The highest achieved category was category C: significant impact on the surface water if an emergency sump was not installed or damaged.

Table 4. Determination of the accident severity category of the toxic substance leakage into the surface water (source adapted [66]).

		Amount of Leaked Substance (t)					
		<1	1–5	5–10	10–50	50–200	>200
<i>IT_{SW}</i>	1	A	A	A	B	B	C
	2	A	B	B	C	C	D
	3	B	C	C	C	D	E
	4	B	C	C	D	E	E
	5	C	D	D	E	E	E

Legend: A–E = accident severity category of the toxic substance leakage into the surface water, A—negligible impact on the surface water, B—slight impact on the surface water, C—significant impact on the surface water, D—highly significant impact on the surface water, E—maximum impact on the surface water, *IT_{SW}*—substance toxicity index for the surface water. The green color indicates the possible categories of the substance leakage into surface waters.

Determination of the accident severity category of the toxic substance leakage into the soil environment:

The amount of substance leakage in combination with the calculated soil environment toxicity index (*IT_s*) was assessed. The individual accident severity categories are listed in Table 5. Table 5 indicates the accident severity categories depending on the amount of leaked substance in green. The highest achieved category was category D: a highly significant impact on the soil environment if an emergency sump was damaged or not installed.

Table 5. Determination of the accident severity category of the toxic substance leakage into the soil environment (source adapted [66]).

		Amount of Leaked Substance (t)					
		<1	1–5	5–10	10–50	50–200	>200
IT_S	1	A	A	A	B	B	C
	2	A	B	B	C	C	D
	3	B	C	C	C	D	E
	4	B	C	C	D	E	E
	5	C	D	D	E	E	E

Legend: A–E = accident severity category of the toxic substance leakage into the soil environment, A—negligible impact on the soil environment, B—slight impact on the soil environment, C—significant impact on the soil environment, D—highly significant impact on the soil environment, E—maximum impact on the soil environment, IT_S —substance toxicity index for the soil environment. The green color indicates the possible categories of the toxic substance leakage into soil environment.

Determination of the accident severity category of the toxic substance leakage into the groundwater:

The groundwater accident severity was determined by combining the leakage substance amount into the hydrological environment with the groundwater toxicity index (IT_{UW}). The accident severity categories depending on the amount of leaked substance are marked in green in Table 6. The highest achieved category was category D: a highly significant impact on the groundwater if an emergency sump was damaged or not installed.

Table 6. Determination of the accident severity category of the toxic substance leakage into the groundwater (source adapted [66]).

		Amount of Leaked Substance (t)					
		<1	1–5	5–10	10–50	50–200	>200
IT_{UW}	1	A	A	A	B	B	C
	2	A	B	B	C	C	D
	3	B	C	C	C	D	E
	4	B	C	C	D	E	E
	5	C	D	D	E	E	E

Legend: A–E = accident severity category of the toxic substance leakage into the groundwater, A—negligible impact on the groundwater, B—slight impact on the groundwater, C—significant impact on the groundwater, D—highly significant impact on the groundwater, E—maximum impact on the groundwater, IT_{UW} —substance toxicity index for the groundwater. The green color indicates the possible categories of the substance leakage into groundwaters.

Determination of the accident severity category of the toxic substance leakage for the biotic environmental component:

The substance toxicity index for the biotic environmental component (IT_B) was combined with the amount of the leaked substance. Table 7 shows the combined results. The results in Table 7 show that there could be a significant impact on the environmental biotic component if an emergency sump was damaged or not installed.

Table 7. Determination of the accident severity category of the toxic substance leakage for the biotic environmental component (source adapted [66]).

		Amount of Leaked Substance (t)					
		<1	1–5	5–10	10–50	50–200	>200
IT_B	1	A	A	A	B	B	C
	2	A	B	B	C	C	D
	3	B	C	C	C	D	E
	4	B	C	C	D	E	E
	5	C	D	D	E	E	E

Legend: A–E = accident severity category of the toxic substance leakage for the biotic environmental component, A—negligible impact on the biotic environmental component, B—slight impact on the biotic environmental component, C—significant impact on the biotic environmental component, D—highly significant impact on the biotic environmental component, E—maximum impact on the biotic environmental component, IT_B —substance toxicity index for the biotic environmental component. The green color indicates the possible categories of the toxic substance leakage for the biotic environmental component.

Determination of the accident severity category of the flammable substance leakage for the biotic environmental component:

The estimated substance flammability hazard index for the biotic environmental component (IFR) was compared with the amount of leaked substance according to Table 8. At maximum tank filling, there could be a slight impact on the biotic environmental component (see Table 8).

Table 8. Determination of the accident severity category of the toxic substance leakage for the biotic environmental component (source adapted [66]).

		Amount of Leaked Substance (t)					
		<1	1–5	5–10	10–50	50–200	>200
IFR	1	A	A	A	B	B	C
	2	A	A	A	B	C	C
	3	A	A	A	B	C	C
	4	A	A	B	C	C	D
	5	A	B	B	C	D	E

Legend: A–E = accident severity category of the flammable substance leakage for the biotic environmental component, A—negligible impact on the biotic environmental component, B—slight impact on the biotic environmental component, C—significant impact on the biotic environmental component, D—highly significant impact on the biotic environmental component, E—maximum impact on the biotic environmental component, IFR —substance flammability index impact on the biotic environmental component. The green color indicates the possible categories of the toxic substance leakage for the biotic environmental component.

3.2.6. Acceptability Determination

The accident severity categories for individual environmental components (A–E) were plotted in the risk matrix shown in Figure 2 together with the estimated probability. The risk matrix indicates the individual risk acceptance limits in colours (green colour for acceptable risk, orange colour for tolerable risk, and red colour for unacceptable risk). The highest scenarios for the accident impact on various environmental components were plotted separately on the severity category axis. The probability of the individual accident occurrence was estimated qualitatively by the authors of the article together with the management of the company based on brainstorming sessions. The probability was estimated to be at level II for all scenarios. Plotting of individual scenarios in the risk matrix allowed the acceptability determination and the risk prioritization.

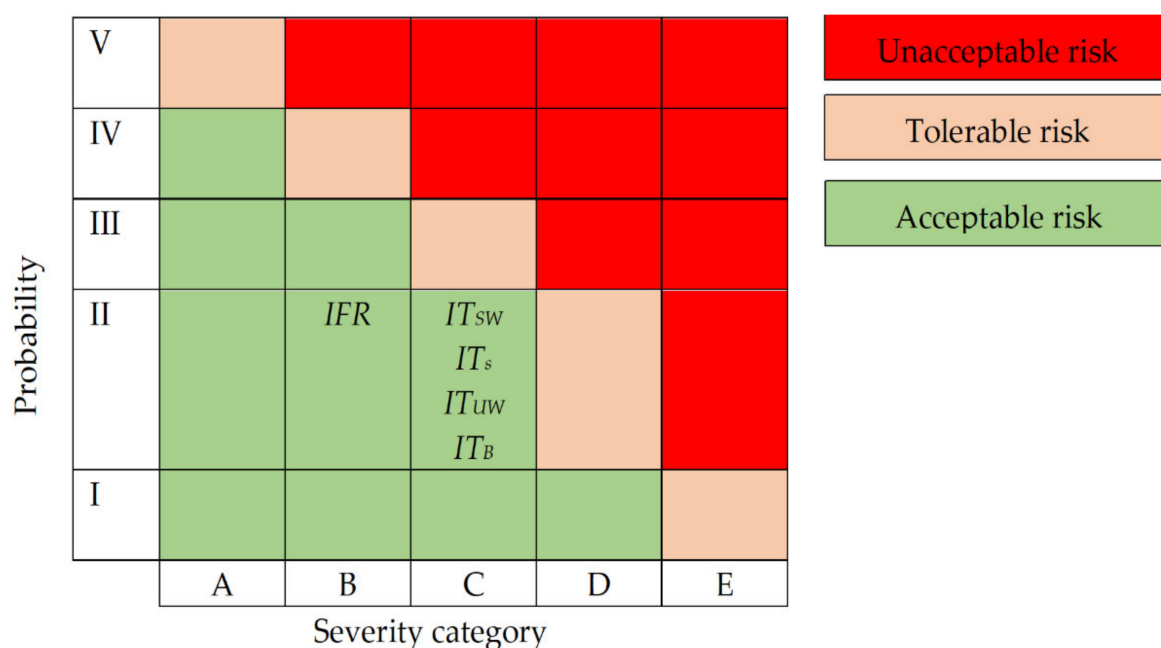


Figure 2. The risk matrix for the diesel fuel tank (source adapted [66]).

The results in Figure 2 show that an acceptable risk was estimated for all the highest scenarios. Acceptability was mainly due to the installation of an emergency sump, which serves to prevent diesel fuel leaks into individual environmental components.

3.3. Suggestions and Recommendations

Although the researched facility was classified as an unclassified facility according to the Act on Prevention of Major Accidents, the Act on Prevention and Remedying Environmental Damage was amended, and the results of the H&V Index II method show that the diesel fuel tank operation does not represent a significant risk for the environment, the company was recommended to implement the following measures to increase safety. No cost calculation was carried out for the proposed measures. The measures are listed in ascending order. It is recommended to carry out new surface treatment of the tank in order to minimize external corrosion, which was detected to a small extent on the tank body according to the 2020 revision report. It would be appropriate to install a CCTV camera system in the vicinity of the tank, which would monitor the movement, especially during non-working hours, as well as a fire detector to signal the fire detection in order to increase the security of the entire mining facility. In case of the planned tank exchange, replacing the existing single-shell tank for a double-shell tank with reinforcement of the footing which supports it is advised. The most financially costly proposed measure is the construction of a flood protection dike in the vicinity of the diesel fuel tank or the entire mining facility operating area so that the tank cannot be flooded or torn off by a flood wave. During the extensive floods in 2002, there were concentrated springs of water over the dam of a nearby watercourse. Emergency overflows were dug in the river dam crown with the aim of controlled outflow based on the instructions of the watercourse manager. Subsequently, however, there was a large increase in the flow due to the dam failure of the above-situated flooded sandpit, and the overflow of the dam river crown occurred in several places. It was not proven whether the main failure occurred after the overflow or as a result of the already advanced internal dam erosion. It was probably a combination of both phenomena with a predominant result of the violation of internal filtration stability [71]. It resulted in a flood wave and flooding of the mining facility to the height of approximately 1 m.

3.4. Discussion

Activation of the oil and oil product leakage threat has a low probability; however, a high impact on the environment [45]. Many accidents can be prevented by implementing preventive measures. Risk assessment is a suitable tool for disaster prevention and management [72]. The dynamic nature of the environmental risk places demands on the persons assessing the risk and the phases of risk assessment and management [47]. The analysis of approaches and methods of environmental risk assessment has shown that the amount of input data has a crucial impact on the diversity of results achieved. This was confirmed by a study [73]. The study recommends that the risk assessment should be specifically adapted to the regions in which it is applied. This leads to improvements in the risk management effectiveness as well as the risk assessment results' validity [73]. It resulted that in accordance with this study and the comparison of individual semi-quantitative methods (see Table 1), it was appropriate to use the environmental damage assessment and the H&V index II methods for the presented case study assessment.

The properties of hazardous substances, in particular toxicity and flammability, are key to the environmental risk assessment. They affect the impact extent on the individual environmental components. Therefore, these properties were examined within the methods of environmental damage assessment, the H&V index II, EIA, but also DEFRA, and EPA methods. In addition to these hazardous properties, the study [68] also mentions the influence of weather and climate on the spread of hazardous substances in the event of their leakage from the sources. Reference [45] further emphasizes that the rescue and liquidation activity implementation worsens the impact on the environment as the fire water, which can worsen the contamination of water and soil by its leakage, is not collected. Based on these findings, it is recommended that the fuel tanks should have, in addition to the emergency sump for leaked diesel fuel, a sump/tank for collecting fire water.

It is also necessary to choose suitable materials for hazardous substance storage tanks (i.e., corrosion resistant, corrosivity resistant, etc.) with regard to the properties of hazardous substances. All tank wall materials should be regularly maintained to detect any changes in tank wall quality in a timely manner. The presented proposal for the surface treatment of the tank corresponds to the findings of the study [74], which emphasizes the corrosive properties of fuels and the subsequent embrittlement of the tank walls. Regular inspection implemented on the presented tank wall material contributes to increased safety.

Further recommendations can be made according to the identified environmental impacts and in consistency with the EU strategies and other research studies [7]. One of the recommendations for effective management of the mining process is, for example, modernization by changing the type of fuel used [4]. However, this change is costly as it requires a technology change.

The authors recommend increasing the overfill protection system in the case of purchasing a new fuel tank. The individual possibilities of overfill protection systems are stated in [62]. The results of this present paper complement and are comparable in detail with the results of other analyses, for example [75], in the total amount of fuel used. It is obvious that fuel consumption in operation is affected by the intensity of sand mining. It is necessary to guarantee safe operation of the tank as well as the mining process while maintaining the sustainable consumption of these resources.

4. Conclusions

This article explores a case study of a semi-quantitative environmental risk assessment of a diesel fuel tank operation in a mining company. It is necessary to focus on other operational activities in addition to the visible impacts of mining on the environment. Crucial operational activities include the transport of extracted sand using push tugs and the loading of sorted sand using wheel loaders on lorries. Diesel fuel stored in a tank is essential for their operation. Diesel fuel is dangerous for the environment due to its properties; therefore, it is necessary to address the diesel fuel tank operation safety with regard to environmental components.

The case study, therefore, focused on the environmental risk assessment of the diesel fuel leakage scenario in the event of an emergency sump malfunction or overfilling. Prior to the actual commencement of the environmental risk assessment, it was verified whether the diesel fuel tank met the requirements of normative legal acts, in particular in accordance with the Act on Prevention of Major Accidents. The results showed that the diesel fuel tank is an unclassified facility, which is not subject to the conditions for emergency documentation processing. Subsequently, a risk assessment was carried out with regard to the Act on Prevention and Remedying Environmental Damage. A basic environmental damage assessment was performed with a total score of 17 points. Since the reference level of 50 points has not been exceeded and the company is both proactive in environmental protection and has a certified management system according to ISO 14001, it is not obliged to implement additional safety measures to minimize the risk. Subsequently, the H&V index II method, which determined the substance hazard indices and the environmental vulnerability indices, was used. The resulting accident severity represented a combination of these indices and the leaked substance amount in the accident to the relevant environmental component, considering the scenario with the stored substance leakage in the largest amount. The results were plotted into a risk matrix, which resulted in the conclusion that the accident was acceptable for all environmental components.

Although both approaches used for environmental risk assessment demonstrated an acceptable risk of a diesel fuel tank operation, the operator was recommended measures to minimize the diesel fuel leak activation from the tank. An acceptable risk level was achieved thanks to the installation of an emergency sump under the diesel fuel tank. The implemented safety measure can significantly contribute to reducing the negative impacts of accidents on the environment. The mining facility operator was provided with processed results for the needs of negotiations with public administration bodies or other stakeholders on the safety issues and the impact of the company on the environment.

The article presented the possibilities of using semi-quantitative screening methods for the identification and evaluation of environmental risks associated with the fuel tank operation. It is not possible to provide transport services within the company without fuel tank safe operation. Transport represents an important factor in providing operability and competitiveness for the company. The study results presented in this article can serve as suitable inputs for the evaluation of other analogous company facility operations and subsequent increases in their safety and environmental profile.

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