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Environmental Failure Mode and Effect Analysis and Its Application in a Seafood Company

Metoda analizy rodzajów i skutków wpływów środowiskowych oraz jej zastosowanie w firmie branży owoców morza

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ABSTRACT

Objective: To present an EFMEA analysis using the example of a seafood organisation, including risk identification, in the context of a potential negative impact on the environment.

Research Design & Methods: Methods used include a case study with analysis of secondary data (documents), semi-structured interviews with a representative of the organisation, synthesis and logical reasoning.

Findings: EFMEA is a very complex analysis and is extended with additional considerations that are important for the organisation. Process EFMEA and its implementation was facilitated by

experience gained from the earlier implementation of the HACCP method and ISO 14001 system. The requirements of customers for conducting analysis in this area played a role.
Implications/Recommendations: The greatest environmental risk is associated with servicing refrigeration/cooling equipment, handling operations, maintaining social infrastructure and cargo storage. An obstacle to conducting the analysis was the lack of access to all comparative data. The leading benefit of the study was that it makes it possible to manage environmental consideration and then monitoring them effectively.
Contribution: The article is the first in Poland to look at the practical implementation of EFMEA. Thus, the spectrum of scientific knowledge has been expanded on the possible applications of this method in a food company and, more generally, how to control and minimise negative environmental impacts in the seafood industry.

Article type: original article.

Keywords: environment, sustainable development, FMEA, risk analysis, seafood company.

JEL Classification: L21, L66, Q01, Q51.

STRESZCZENIE

Cel: Przedstawienie analizy EFMEA na przykładzie wybranej organizacji z branży owoców morza, w tym zasad identyfikacji ryzyka w kontekście możliwego negatywnego wpływu na środowisko.
Metodyka badań: Metodą stosowaną w procesie badawczym jest studium przypadku z analizą danych wtórnych (dokumentów), wywiad częściowo ustrukturyzowany z przedstawicielem organizacji oraz metoda syntezy i logicznego wnioskowania.
Wyniki badań: EFMEA wykorzystana w firmie jest bardzo złożoną analizą, którą poszerzono o dodatkowe obszary ważne dla organizacji. Jest to rodzaj EFMEA procesu, której wdrożenie ułatwiły doświadczenia zdobyte podczas wcześniejszej implementacji metody HACCP oraz systemu ISO 14001. Nie bez znaczenia był wymóg ze strony klientów instytucjonalnych (klientów biznesowych) dotyczący prowadzenia analiz w tym zakresie.
Wnioski: Największe ryzyko środowiskowe wiąże się z serwisowaniem urządzeń chłodniczych/chłodzących, operacjami przeładunkowymi, utrzymaniem infrastruktury socjalnej oraz przechowywaniem ładunków. Problemem podczas analizy był brak dostępu do wszystkich danych porównawczych. Największą korzyścią była możliwość zarządzania aspektami środowiskowymi, a następnie ich skutecznego monitorowania.
Wkład w rozwój dyscypliny: Artykuł jest pierwszym w Polsce opracowaniem omawiającym wdrożenie w praktyce metody EFMEA. Tym samym poszerzono wiedzę naukową na temat jej możliwych zastosowań w przedsiębiorstwie spożywczym oraz sposobów kontrolowania i minimalizowania negatywnych wpływów na środowisko w branży owoców morza.

Typ artykułu: oryginalny artykuł naukowy.

Słowa kluczowe: środowisko, zrównoważony rozwój, FMEA, analiza ryzyka, przedsiębiorstwo branży owoców morza.

1. Introduction

Developing an organisation sustainably means managing it to simultaneously and evenly work on economic, environmental and social issues. In practice this often means installing management of a new quality (Brzozowski 2015), in accordance with Sustainable Development Goals (SDGs). This applies to the food industry as well, where the assumptions of the European Green Deal (EGD) have become essential. A key element of the EGD is the “from farm to table” strategy. A main element of the European Commission’s programme for reaching SDG (Wiśniewska & Wyrwa 2022), the EGD strategy considers the complex challenges of sustainable food systems and recognises essential connections between healthy people, societies and the planet. When planning operations, companies take a number of approaches to protect the environment and climate (Sałagan & Pietrzczyk 2020). These include designing eco-friendly products and processes, and monitoring and reporting non-financial data. One of the main solutions that can be used to accomplish these goals is Failure Mode and Effect Analysis (FMEA) (Spreafico 2021). When it is used for environmental protection, it is recognised as Environmental FMEA or Failure Mode and Environmental Impact Analysis (indicated by acronym EFMEA). While it has gradually become a subject of scientific research, its practical application is less common and mostly foreign to companies in the food industry (Wiśniewska 2022). Given the fact that food companies are among the culprits of a worsening climate situation in Europe and globally, the absence of EFMEA in the gastronomy industry is all the more conspicuous (*Global…* 2022).

Given the above conditions and the lack of studies done on the EFMEA method in the food industry, the aim of this article is to present an EFMEA analysis using the example of a seafood organisation (midway up the supply chain), including risk identification in the context of possible negative environmental impacts. An additional aim is to present the conditions, problems and benefits related to the use of the EFMEA method.

Several methods were used in the research process: a case study with the analysis of secondary data (documents), semi-structured interviews with the representatives from the organisations, synthesis and logical reasoning. The study, and the analysis, therefore covered both the documentation of the organisation and the statements collected during the interview. The article is organised as follows. The first section presents the general ideas behind EFMEA method and its application. The “Material and Methods” section presents the methodology and research design, including a description of how the data was collected. It also poses eight research questions. The next section discusses the main results in relation to the literature. The last section offers a synthesis of the main themes and conclusions, followed by a look at potential research possibilities.

2. EFMEA Method and Its Application

Among the most important risk assessment methods, FMEA was formalised in 1949 by the US Armed Forces with the introduction of the Mil-P 1629 Procedure, and next adopted in the Apollo space programme (Carlson 2014). Its universality is to thank for its widescale adoption in multiple sectors globally (Wu, Liu & Nie 2021) for operational risk assessment. FMEA is recognised as a powerful team-driven management tool for assessing the security and stability of products, services, processes, and systems that are designed to define, identify, and eliminate known or potential failures, problems, and errors (Heidary Dahooie *et al*. 2020). It can be implemented as (PN EN-IEC 60812:2018):

– product/project (as Design FMEA),
– system (as System FMEA),
– processes or services (as Process FMEA),
– software (as Software FMEA),
– installation/equipment (as Machinery/Infrastructure FMEA).

EFMEA was developed by the Swedish consultancy firm HRM/Ritline in the 1990s, initially as EEA (Environmental Effect Analysis) for use in product development (Jensen *et al*. 2001). The Volvo Car Corporation and other Swedish companies saw its potential for product development (Lindahl & Tingström 2001). EFMEA is based on the same assumptions as classic FMEA. However, the environmental application of FMEA takes into account the environmental impacts caused by technical problems, deficiencies and irregularity errors or processes. In other words, EFMEA is an analytical method for environmental risk assessment and can be considered a subcategory of FMEA.

This method identifies and ascertains as far as possible the potential risks in the area in which the risk assessment is carried out, as well as the causes and effects associated with it. It ranks alongside the most effective error prediction models. With EFMEA, the goal is to identify in a timely manner the most important environmental aspects affecting the environmental situation within the range affected by ongoing activities and processes (Dadgar & Payandeh 2019). EFMEA is very effective in identifying the extent of an environment that has been affected, quantifying risk and identifying appropriate risk mitigation measures (Salati & Jozi 2012). This analysis can be used to make constructional, process and system improvements (Roszak, Spilka & Kania 2015). EFMEA is used in environmental management to (Kania, Roszak & Spilka 2014):

– carry out preventive risk assessments of environmental impacts and design counteraction operations,
– identify critical components and potential,
– identify weak areas,
– conduct early diagnosis and locate possible errors and threats,

– determine environmental impacts,
– avoid environmental problems,
– improve systems, products and processes as they apply to environmental issues.

In general, in implementing FMEA or EFMEA, three categories are most often considered: severity (S), occurrence (O), and detection (D); they are generally evaluated on a numeric scale of 1 to 10 (Kardos, Lahuta & Hudakova 2021). At the same time, according to the literature, depending on the needs, 9-, 7-, 5- and 3-point scales can also be used (Rahim *et al*. 2021, Wiśniewska 2022). The severity rating ranks the importance of a risk to end-user requirements. The occurrence rating of a risk is the frequency with which a given risk occurs and refers to the average probability that that risk cause will occur. The detection rating is a measure of the capability of current controls (Cirovic *et al*. 2015).

Multiplying S, O, and D yields the risk index, the so-called Risk Priority Number (RPN), and based on the outcome of the RPN value one can decide when and what kind of measures will be taken to reduce the index level. It is recommended, where justified, that one have prepared reaction plans for individual failures/problems (Kardos, Lahuta & Hudakova 2021).

Since EFMEA is a qualitative method, it is effective in product development processes, identifying the structures and important aspects that have priority for environmental outcomes throughout the life cycle of a product or process (Salati & Jozi 2012). Research conducted by Wiśniewska (2022) covering work from 2000–2021 shows that the EFMEA is recognised in various areas of application, regardless of the sector or industry. It is most commonly used in the petrochemical industry. The number of publications on EFMEA has grown – gradually – but the short list of papers proves that there remains limited experience in this field, even globally.

In Poland, the only works done to date on EFMEA are publications by Roszak, Spilka and Kania (2015) and Kania, Roszak and Spilka (2014), but they are of a general and theoretical nature. The literature study which we did in July 2022 confirmed that there is just a single case of EFMEA being used by a food company – in Iran's sugar industry (Dadgar & Payandeh 2019). The case, described by Dadgar and Payandeh (2019), included three categories: pollution range, likelihood of occurrence, and severity. By multiplying them, the authors calculated the environmental degradation factor (equivalent to the RPN). In their research, Dadgar and Payandeh analysed 104 environmental risks, dividing them according to their environmental degradation factor of low-, medium- and high-priority risks. Those with high priority were related to noise and air pollution, two hallmarks of this industry (Kaur & Singh 2021). The number of such aspects and impacts on the environment is strictly dependent on the type of processes, their number and the size of the organisation.

3. Materials and Methods

The research done for this paper was carried out in a small seafood company in 2022 located in the north of Poland. It employs 21 staff and operates in the middle of the seafood supply chain, between the main producers of raw materials and food processors. The company has implemented different management systems, including ISO 14001, ISO 45001, and ISO 9001, and complies with the sector systems and practices including Hazard Analysis and Critical Control Point (HACCP), Good Manufacturing Practice, Good Hygienic Practice, IFS Logistics, BRC Storage & Distribution, and MSC Chain of Custody. It has also introduced the four-pillar Sedex Members Ethical Trade Audit norm requirements.

The research was carried out using a case study analysis, supported with a semi-structured interview method. A case study can be defined as "an intensive study about a person, a group of people or a unit, which is aimed at generalising over several units" (Heale & Twycross 2018). A semi-structured interview is a dialogue between a researcher and participant that allows the researcher to collect open-ended data, to explore the participant's thoughts, feelings and beliefs about a particular topic and to delve deeply into personal and sometimes sensitive issues (DeJonckheere & Vaughn 2019).

We interviewed the organisation's Quality Representative (QR), who is responsible for the implementation and maintenance of the management systems described above. The QR is recognised by a company's management as the most competent in that field, having completed numerous training sessions, and holding the qualifications of an auditor. The QR is also responsible for training employees in management systems and various methods of quality and environmental management. Our interview was based on the generally accepted steps described by DeJonckheere and Vaughn (2019):

– presenting the purpose and scope of the study,

– introducing participants (the organisation's representative and the study's authors),

– considering ethical issues (maintaining the organisation's anonymity, ensuring the truthfulness of the data provided),

– presenting questions to the QR,

– developing a schedule for the interview (greetings, presenting the work plan, indicating the importance of the research for science and practice, confirming logistics, substantive and ethical issues, asking questions, organising and confirming answers, reflecting on what has been discussed),

– planning and confirmation of logistics (confirmation of the days and places of subsequent meetings with QR),

– conducting the interview (following the schedule of the interview, asking questions and keeping notes on the answers),

– organising the responses and consulting with the QR again,
– analysing the data,
– presenting findings.

In analysing the data all information obtained was critically verified by two of the authors of this article, both specialists in the field of environmental protection and environmental impact assessment. Additionally, one of the authors holds a master's degree in chemistry. The interview took an hour, during which we took notes to be checked and corrected later on. We asked the following research questions:

Q1: What is the structure of EFMEA analysis worksheet and what areas does it cover?

Q2: What criteria and scale were used during analysis?

Q3: Which areas of the organisation's activities were at risk of having a negative impact on environment and why?

The following research questions were asked to achieve our secondary goal:

Q4: Why did the organisation decide to develop an EFMEA?

Q5: Who took part in developing and implementing this method in the organisation and was special training required?

Q6: What was the most difficult component of implementing this method, and why?

Q7: What benefits does the EFMEA method offer your organisation?

Q8: How often are the data in EFMEA worksheet updated and who is responsible for the updates?

4. Results and Discussion

4.1. The Results of the Analysis of Documents

We sought answers to the first three questions when reviewing the documentation. As the data analysis shows, the EFMEA worksheet (see Table 2) was tailored to specific needs of the organisation and was more developed than other worksheets used in the same conditions and identified in research conducted by Wiśniewska (2022). Apart from the main area for analysis, the sub-areas (sub-processes) were presented and, crucially, evaluated based on environmental aspects. An interesting and original solution is to equip the EFMEA table with retrospective data that helps to compare the situation from a given year with the preceding one. The impact of a given area/subareas on the environment are equivalent to potential non-conformities that are identified using the classical FMEA method. Methods of supervising environmental aspects and monitoring methods also reflect classical preventive actions, which, according to FMEA methodology, must be implemented. As can be observed, the equivalents of criteria O and S are included in this worksheet and are specified as "frequency of occurrence – OCC" and "severity – SEV".

Organisations often change the names of the categories to suit their needs. This is confirmed by the literature on the use of both FMEA (e.g. Van Hoof *et al*. 2022) and EFMEA (Dadgar & Payandeh 2019).

Finally, while no criterion D (detectability) has been taken into account, the criterion "scale of impact – IMP" has been used to monitor the value of the impact, and is based on a three-point scale (see Table 1). The organisation assumes that the impact value reflects the strength of the impact. For both the normal and special level, the value is equal to 1, regardless of whether the impact is constant or incidental. In turn, the value of the impact for the emergency level was assumed to be 2. Its strength has a greater impact on human life and health, product safety and the natural environment.

Table 1. Environmental Impact Scenario

Environmental impact scenario	Characteristics of impact	Value of impact
Normal	Constant work in "continuous mode" of all technological installations and technical infrastructure. Both main and supporting processes are executed without disruption in scheduled mode	1
Special	Incidental and planned replacement or maintenance activities required that the continuity and security of the organisation and processes be ensured	1
Emergency	Emergency situation of emergency nature, not planned, which threatens the safety of people, goods / properties and the environment	2

Source: the authors, based on company documentation.

The innovative solution has added new columns to the EFMEA worksheet. Columns 10, 11 and 12 are included to identify the character of a situation with a negative environmental impact. Crucially, data taken from those columns, in addition to the data from columns 14, 15 and 16, are used in determining RPN. This data has been added because the operational activity of the organisation requires the use of technological installations necessary to ensure that the main process is kept at a constant and controlled storage temperature. These conditions are ensured by an appropriate cooling installation that uses ammonia as the cooling medium. Ammonia has good thermo-physical properties and high energy efficiency, so it is used widely in the food industry to freeze food both for storage and distribution.

However, it is also toxic for all vertebrates, causing convulsions, coma and death (Randall & Tsui 2002). Each uncontrolled emission of ammonia to the environment may threaten the health and life of employees, local inhabitants and the environment around the organisation. In addition, it can not only compromise food safety by causing contamination, but also threaten food security. Due to the specificity of the industry, that kind of threat was at the heart of the organisation's focus from the very beginning of its operational activities, and has been reflected in the "Business Continuity Plan / Disaster Recovery Plan" document. The next environmental aspects are the other emissions of chemical substances in emergency scenarios (hydrogen, freon), and in normal mode generating industrial waste, as well as media consumption such as water, energy and wastewater. It is worth stressing that the correct and monitored execution of main and supporting processes in the organisation have minimal negative impact on the environment. That means there is no need to pay annual fees for emissions of gases or dust emitted into the atmosphere, for generating waste or waste management, all of which can generate environmental charges for environmental usage.

Another original solution is the addition of a column used to identify different requirements, including legal ones. However, EFMEA formula, to its detriment, lacks a column to show the nature of corrective actions taken. In their study of the sugar industry in Iran, Dadgar and Payandeh (2019) included corrective actions during the EFMEA analysis as well as in the worksheet. In general, omitting the corrective actions in a FMEA analysis does not provide the full picture of necessary changes and their prioritisation (Chen 2017). In some cases, it is also necessary to plan different scenarios and measures (Paciarotti, Mazzuto & D'Ettorre 2014). That is what the organisation under analysis has done.

To sum up, the organisation undertaking the EFMEA formular made significant modifications to the traditional form, making the approach more comprehensive. The final EFMEA is a combination of prospective evaluation and retrospective from an incident learning system (Gilmore & Rowbottom 2021).

Regarding Question Three, three main areas / processes – infrastructure maintenance, company activity, and office functioning – were analysed and then broken down into 25 sub-processes / actions / operations (see Table 2). This means the analysis can be interpreted as a typical Process EFMEA.

In the case of "infrastructure maintenance", analysis of the risk index showed that the greatest risk to the environment may be the following processes: cooling systems maintenance and cargo handling. This is due to the use of refrigerants that deplete the ozone layer (freon) and the discharge of hydrogen during handling operations. The risk index of the same value was noted for two "company activity" sub-processes: the use of social infrastructure and cargo storage in temperature--controlled conditions. The former consisted in the production of social-living wastewater. The second sub-process encompasses three aspects: electricity and water consumption and possible problems with an ammonia system. The sub-processes "cargo handling" and "company car usage" also returned relatively high indicators. In the former, the aspect taken into account probably concerns waste of a different nature, packaging, while the latter concerns fuel consumption (diesel or gasoline).

Analysis of these risk indicators leads to the conclusion that "infrastructure maintenance" has the most severe negative impact on the organisation and carries the greatest risk of adverse consequences. "Company activity", meanwhile, has lower negative impact. Surely, thanks to the environmental benefits of waste paper segregation, "office functioning/handling" presents no serious risk.

4.2. The Results of the Semi-structured Interview

During the interview we focused on getting answers to the remaining research questions. The fourth research question was why the organisation had implemented EFMEA. The QR confirmed that, first of all, the organisation needed to improve its integrated management system. It also identified a need to better organise its documentation on monitoring and managing environmental aspects. Further, the company recognised that participating in the seafood supply chain meant that while it had no choice but to exploit the environment and use its resources, it could promote sustainable fishing. According to QR, business relevance and market expectations regarding implementation of different voluntary sustainability standards and the methods that support them play an important role. The implementation of EFMEA is a step in the right direction. Voluntary sustainability standards can encompass required product quality and a wide range of sustainable development indicators, including respect for human rights, employee health and safety, the environmental impact of production, relations with societies, and urban planning (Bissinger *et al*. 2020).

As regards the fifth research question, it was confirmed that representatives of the Emergency Team took part in developing and implementing EFMEA. The Team comprises managers from all of the organisation's operational departments and representatives of general management. The Team's work was also supported by representatives of the department of administration and quality. Because the organisation had used FMEA method to assess food safety hazards, and because it also had the HACCP system in place, training during the development of the EFMEA method focused only on specific issues on monitoring and verification of environmental aspects of operational activities. HACCP, meanwhile, is considered an excellent foundation for preparing other approaches to risk assessment and analysis (Wiśniewska 2015).

Regarding Question Six, and according to QR, the most difficult task during the implementation of EFMEA was comprehensively identifying all aspects to be covered, especially those with lower risk priorities or a more marginal role in the organisation's operational activities. The next element of the assessment was one with a higher level of complexity, and therefore required more focus – designing a component for aggregating emissions data, assessing them (where there was a lack of data from measurements) and making them a part of permanent monitoring.

Table 2. EFMEA Worksheet

Process/ area	Subprocess/activity/ operation	Aspect	Quantity *per annum* (2020)	Quantity *per annum* (2021)	Change Y2Y	Impact on the environment	Methods of supervision over aspects/ operational control	Monitoring methods	NS	ES	SS	Key legal or other requirements	OCC	SEV	IMP	RPN
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
IM	maintenance of emergency power generator	storage of backup supply of diesel oil	consumption when needed (in litres)	consumption when needed (in litres)	+17%	pollution of the environment, soil and water contamination	maintenance activities, ongoing supervision	verification during the service		×		Act 7	1	1	1	2
IM	ICT maintenance	replacement of computer parts, computer batteries and UPS	negligible quantities – relatively new equipment	negligible quantities – relatively new equipment	–	pollution of the environment	equipment servicing by a specialised company	equipment servicing by a specialised company		×		Act 1	1	1	2	4
IM	infrastructure servicing	waste generation during periodic repairs and maintenance of machines and devices	aspect under the supervision of service contractors (minimal registered own consumption per year)	aspect under supervision of service contractors (minimal registered own consumption per year)	–	pollution of the environment	supervision over service providers, waste generation monitoring	service providers' declaration regarding waste management, waste log book based on EWC codes			×	Act 1	2	2	2	8
IM	service of forklifts, scrubbers, sweepers, wrappers	battery wear	based on individual battery wear	none	minor changes	pollution of the environment	regular maintenance checks and disposal at the end of service; used batteries are returned to the provider	monitoring the level of wear and damage			×	Act 2	1	2	1	2
IM	cooling system maintenance	refrigeration and air conditioning devices – use of refrigerants (freons) – ozone-depleting substances	refrigerant replenished in the event of failure	freon 410 A	minor changes	ozone-depleting substances	regular inspections (twice a year) and leak testing, installation labelling, maintenance activities carried out by authorised suppliers	tightness control, register of the replenishments		×		Act 3 Act 4	1	3	3	18
IM	infrastructure servicing	oils, greases, used spare parts	under the supervision of service providers	under the supervision of service providers	–	pollution of the environment	supervision over service providers	service providers' declaration regarding waste management	×			Act 1	2	2	1	4
IM	cargo handling	hydrogen emission during battery charging	–	–	–	pollution of the environment, threats to human well-being and to infrastructural safety	maintenance activities, permanent supervision of devices	charging room is equipped with hydrogen sensors, emergency ventilation system, emergency power cut-off system		×		Regulation 1 Regulation 2	1	3	3	18
IM	cargo handling	battery acid leaks	–	–	no change	pollution of the environment, threats to human well-being and to infrastructural safety	maintenance activities, permanent supervision of devices	charging room is equipped with drainless tanks, environmental first aid kit		×		Regulation 1	1	3	1	6
IM	facility lighting	used fluorescent lamps	in kg	in kg	no change	pollution of the environment	selective waste collection, storage in designated, labelled containers, return of used ones to point of sale	one to one replacement of used one by new ones	×			Act 1 Act 5	1	1	1	1
IM	rainwater and snowmelt drainage to the sewage system	sewage system	aspect under landlord's control	aspect under landlord's control	–	soil and water pollution	regular inspections of sewer system and sewage separators	supervision over service providers	×			Regulation 1	3	1	3	9
IM	pest management	DDD	according to GHP/GMP pest procedures (P1ZS)	according to GHP/GMP pest procedures (P1ZS)	–	negative impact on free-living animals	traps are serviced by the service provider	according to the GHP/GMP pest procedures (P1ZS)	×			Act 6	3	1	1	3
IM	floor maintenance and conservancy	usage of chemicals	according to GHP/GMP pest procedures (P1MD/ I1MD)	according to GHP/GMP pest procedures (P1MD/ I1MD)	–	soil and water pollution	storage and use of chemicals according to safety data sheets	registers of chemicals usage, monitoring of the sewage water parameters	×			Act 7	3	1	1	3

Table 2 cnt'd

Process/ area	Subprocess/activity/ operation	Aspect	Quantity *per annum* (2020)	Quantity *per annum* (2021)	Change Y2Y	Impact on the environment	Methods of supervision over aspects/ operational control	Monitoring methods	NS	ES	SS	Key legal or other requirements	OCC	SEV	IMP	RPN
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
IM	compressor maintenance	oil	in litres	in litres	no change	soil and water pollution	supervision over service providers	used oil verification done by service provider, service providers' declaration regarding waste management			×	Act 7 Regulation 3	1	2	1	2
BA	employees' activity	generation of social and household sewage	in m^3	in m^3	minor changes	pollution of the environment	sewage system	monitoring of usage	×			Act 7 Act 8	3	2	3	18
BA	cargo storage in temperature-controlled conditions	electric energy usage	in MWh	in MWh	minor changes	depletion of natural resources, pollution of the environment	regular checks and proper maintenance, optimalisation of usage	monitoring of usage	×			Act 7	3	2	3	18
BA	cargo storage in temperature-controlled conditions	water supply usage	in m^3	in m^3	minor changes	depletion of natural resources	regular checks and proper maintenance, optimalisation of usage, monitoring of parameters, separation of water and oil	monitoring of usage	×			Act 6 Act 7 Act 8	3	2	3	18
BA	cargo storage in temperature-controlled conditions	operational work of devices and installations	in dB	in dB	no change	noise emission to the environment	regular checks, emission monitoring	regular noise emission measurements	×			Regulation 2 Act 7	3	1	1	3
BA	cargo storage in temperature-controlled conditions	re-irrigation of cargo – leakage of ammonia system	–	–	–	pollution of the environment, threats for human life and wellbeing, as well as for the safety of the infrastructure, threat for the stored frozen food cargo	permanent monitoring, regular maintenance	ongoing monitoring of cooling devices, automated notification system in case of irregularities or malfunction of ammonia system, drainless tank for ammonia, dry riser to neutralise the ammonia cloud, ammonia detection sensor system		×		Regulation 1	1	3	3	18
BA	cargo storage in temperature-controlled conditions	forklift LPG cylinder leakage	–	–		pollution of the environment, threats for human life and wellbeing, as well as for the safety of the infrastructure	regular maintenance	storage in the designated safe zone, operational checks before use		×		Regulation 1	1	2	2	8
BA	cargo storage in temperature-controlled conditions	utilisation of cargo not fit for human consumption	in kg	in kg	minor changes	threat for the food security	permanent monitoring and reporting according to GMP procedures (P1MP)	weekly reporting according to GMP procedures (P1MP), verification of the cargo during intake according to GMP procedures (P1ZZ)			×	Act 6	1	1	2	2
BA	cargo handling	waste generation	in Mg	in Mg	minor changes	pollution of the environment	waste management based on procedures (P1UO, P2UO)	regular reporting	×			Act 1 Act 7 Act 9	3	2	2	12

Table 2 cnt'd

Process/ area	Subprocess/activity/ operation	Aspect	Quantity *per annum* (2020)	Quantity *per annum* (2021)	Change Y2Y	Impact on the environment	Methods of supervision over aspects/ operational control	Monitoring methods	NS	ES	SS	Key legal or other requirements	OCC	SEV	IMP	RPN
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
BA	cargo handling	propane butane gas for forklifts	in Mg	in Mg	minor changes	pollution of the environment	regular maintenance	storage in the designated safe zone, operational checks before use	×			Act 1	1	2	2	4
BA	facility heating	electric energy usage	in MWh	in MWh	minor changes	depletion of natural resources, pollution of the environment	regular checks and proper maintenance, optimalisation of usage, recuperation of waste heat from refrigeration system	monitoring of usage, regular maintenance checks	×			Act 7	3	1	3	9
BA	company's car usage	consumption of gasoline and diesel fuel	in Mg	in Mg	minor changes	depletion of natural resources, pollution of the environment	regular service checks	regular monitoring and reporting	×			Act 7	3	2	2	12
BA	documentation printing	paper consumption	reams of paper	reams of paper	no changes	depletion of natural resources	waste segregation, recycling of printer toners	regular monitoring	×			Act 1	1	1	1	1

Legend: IM – Infrastructure maintenance; BA – Business activity; NS – Normal scenario; ES – Emergency scenario; SS – Special scenario; OCC – Occurrency; SEV – Severity; IMP – Impact; Act 1 – Ustawa z dnia 14 grudnia 2012 r. o odpadach (Journal of Laws 2021, item 779); Act 2 – Ustawa z dnia 21 grudnia 2000 r. o dozorze technicznym (Journal of Laws 2021, item 779); Act 3 – Ustawa z dnia 15 maja 2015 r. o substancjach zubożających warstwę ozonową oraz o niektórych fluorowanych gazach cieplarnianych (Journal of Laws 2020, item 2065); Act 4 – Ustawa z dnia 12 lipca 2017 r. o zmianie ustawy o substancjach zubożających warstwę ozonową oraz o niektórych fluorowanych gazach cieplarnianych oraz niektórych innych ustaw (Journal of Laws 2017, item 1567); Act 5 – Ustawa z dnia 11 września 2015 r. o zużytym sprzęcie elektrycznym i elektronicznym (Journal of Laws 2020, item 1893); Act 6 – Ustawa z dnia 25 sierpnia 2006 r. o bezpieczeństwie żywności i żywienia (Journal of Laws 2020, item 2021); Act 7 – Ustawa z dnia 27 kwietnia 2001 r. Prawo ochrony środowiska (Journal of Laws 2021, item 1973); Act 8 – Ustawa z dnia 20 lipca 2017 r. – Prawo wodne (Journal of Laws 2021, item 2233); Act 9 – Ustawa z dnia 13 września 1996 r. o utrzymaniu czystości i porządku w gminach (Journal of Laws 2021, item 888); Regulation 1 – Rozporządzenie Ministra Infrastruktury z dnia 12 kwietnia 2002 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie (Journal of Laws 2022, item 1225); Regulation 2 – Rozporządzenie Ministra Zdrowia z dnia 11 października 2019 r. zmieniające rozporządzenie w sprawie badań i pomiarów czynników szkodliwych dla zdrowia w środowisku pracy (Journal of Laws 2019, item 1995); Regulation 3 – Rozporządzenie Ministra Gospodarki z dnia 5 października 2015 r. w sprawie szczegółowego sposobu postępowania z olejami odpadowymi (Journal of Laws 2015, item 1694).

Source: the authors, based on company documentation.

This was a difficult task because there was not only a lack of access to relevant and reliable data, but also a lack of experience in analysing them.

Despite these initial difficulties, the organisation achieved very concrete benefits: It structured and systematised management of all environmental aspects of activities of the organisation, including medium- and long-term monitoring of aspects and observing changes in trends. It can also now examine the use of raw materials and possible changes in the assessment of risk priorities. Importantly, data included in the EFMEA worksheet (see the eighth research question) are updated at least once a year, at the end of the first quarter. The assessment is done by the same team that developed the primary analysis. However, due to legal and system requirements, as well as the results of the risk assessment, hazards with the highest priority risk, such as ammonia, are monitored continuously or on a monthly basis (waste generation, raw material consumption). This is important because input data used in the EFMEA method, as with those in FMEA, must be systematically reviewed and updated to account for the changing context of operations in the organisation (Mascia *et al*. 2020). Dagdar and Payandeh (2019) offered similar recommendations in their work.

5. Conclusions

When an organisation uses sustainable development principles, it commits to implementing different approaches and risk assessment methods. In the age of climate change and widescale environmental pollution caused by industry (among other factors), implementing EFMEA appears wise, and generates results. The organisation considered in this paper is a good example of such an approach. It adapted the EFMEA worksheet to its needs to address environmental concerns.

In the light of the research questions we set out, the following take-aways are the most relevant:

– the EFMEA formular the organisation used is a very comprehensive tool that includes additional areas and allows it to predict how much harm it may be causing to the environment;

– the EFMEA analysis includes retrospective data, helping the organisation monitor progress it has made to date in minimising its impact on the environment;

– servicing the cooling installations and handling cargo, processes which employ refrigerants and release hydrogen, respectively, pose the greatest threat to the environment;

– the organisation pooled its resources and used teamwork to implement EFMEA, with the Emergency Team playing the key role. The implementation method was facilitated by experience gained from the use of systems including HACCP and ISO 14001;

– the biggest problems during the EFMEA analysis included the lack of access to relevant and reliable comparative data and the lack of experience in developing EFMEA;

– the largest benefit the implementation afforded was endowing the organisation with the ability to manage all environmental aspects of its operational activities and effectively monitor the environmental aspects in terms of the changing context of its operations.

We are aware of limitations of the research reported herein. First, inferences based on a case study are always subjective. As the results apply strictly to the case we have shared, the results cannot be generalised. We further acknowledge that our analysis is only one of innumerable studies that could be done. Other researchers will choose to evaluate another "piece of reality".

On the other hand, the research is one small step to bridging the research gap in the theory and practical experience by expanding the spectrum of scientific knowledge about possible applications of the EFMEA method in a food company and, more generally, the ways to control and minimise negative environmental impacts in the fish industry. This is the first study of this type in Poland, and hopefully not the last. Others should also look at the food industry, including companies of different sizes. Comparative studies would help to define potential changes in environmental strategy in this sector.

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