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Ageing Management in the Prevention of Major Accidents in the Czech Republic

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This study examines the phenomenon of ageing in the context of major accident prevention, with a particular focus on the growing recognition of ageing as a significant contributor to industrial accidents. The concept of ageing has evolved from its initial association with material degradation to encompass a broader range of factors, including equipment obsolescence, spare parts availability and staff expertise. Legislation such as the European SEVESO III Directive has incorporated the issue of aging into safety management systems, reflecting its critical importance. A mixed-methods approach was employed, combining a literature review with a questionnaire survey, for the purpose of assessing ageing management practices in industrial facilities. The survey was completed by 103 respondents from the Czech Environmental Inspectorate. The results demonstrated that while 67% of respondents considered aging to be significant, gaps in documentation and planning still posed safety risks. A chi-square test revealed a statistically significant correlation between facility age and major accidents ($p < 0.05$). These findings highlight the necessity for enhanced awareness and training in aging management, advocating for structured information dissemination and methodological improvements in future studies.

1. Introduction

The aging of industrial facilities represents a significant challenge in the context of preventing major accidents. Over time, equipment can deteriorate, increasing risks and vulnerabilities. This article aims to provide an analysis of the aging phenomenon in the Czech Republic, particularly its impact on facility safety as outlined in The Seveso-III Directive (Directive 2012/18/EU) on the control of major-accident hazards involving dangerous substances. By examining the current state of facility aging in the Czech Republic and reviewing relevant literature, the objective is to identify key factors contributing to this issue and propose a framework for integrating aging management into major accident prevention systems.
The primary objectives of this study are:
• To evaluate the current understanding and management of aging in industrial facilities.
• To analyze data from a questionnaire survey conducted among various facilities.
• To develop recommendations for improving aging management practices based on the survey findings and literature review.
The methodology employed in this study encompasses a comprehensive literature review, a comprehensive questionnaire survey, and statistical analysis of the survey results. It is crucial to acknowledge that the findings of this study may not be universally applicable, as they are contingent upon the specific context of the survey.

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2. Literature review on the ageing phenomenon in the context of major accident prevention

The concept of aging as a phenomenon associated with increasing accident hazard is not a novel one. However, initially, the aging of technological equipment was primarily associated with material degradation over time (OECD, 1999) and was consistently separated from the phenomenon of obsolescence (Milazzo, 2018). Thus, the aging evaluation was part of the standard maintenance program. There is often little hard data to support strategic decisions for dealing with aging equipment, facilities, and infrastructure (Kelly, 2021).

At that time, knowledge of aging was based on the changes in the properties of materials and the state of operating conditions (or external environmental conditions). In 2010, the British Health and Safety Executive (HSE) published a report suggesting that aging aspects also contributed to a significant number of accidents (30 %) involving hazardous substances in the chemical and offshore industries in the United Kingdom (Horrocks et al., 2010). This report has provided a valuable impetus for further development of this issue. The phenomenon of aging was subsequently extended to other aspects (previously classified as the phenomenon of obsolescence), such as the provision of spare parts for obsolete equipment, changes in technical systems, and the replacement of obsolete equipment by new technologies. This can result in unexpected process failures, as well as the aging of staff, including the issue of maintaining the expertise necessary for the safe operation of the facility, keeping updated documentation and instructions, as well as the aging of the staff themselves (OEDC, 2017). We believe that this approach has already proven successful in ensuring the safety of nuclear power plants (International Atomic Energy Agency IAEA, 2009).

In response to these findings, European Union legislation was amended with the introduction of the SEVESO III Directive (Directive 2012/18/EU). This directive takes into account the impact of aging on the safety of facilities. In particular, it requires the integration of aging into the safety management system.

The adoption and implementation of procedures and instructions for safe operation, including plant, process, and equipment maintenance, as well as alarm management and temporary shutdowns; taking into account available information on best practices for monitoring and control in order to reduce the risk of system failure; management and control of the risks associated with aging of plant equipment and corrosion; inventory of plant equipment and strategies and methods for monitoring and inspecting the condition of equipment; appropriate follow-up measures and any necessary countermeasures.

In 2015, the European Commission also drew attention to the significant importance of the phenomenon of aging for industrial plants in the CAPP Bulletin (CAPP, 2015). Expert sources concerning the phenomenon of aging in facilities that are significant in terms of the hazard of a major accident are relatively wide-ranging. General publications address the issue of aging in terms of the classification of factors that contribute to the deterioration of equipment. For instance, the publication (Ansaldi, 2020) provides a comprehensive overview of the various factors that may contribute to the deterioration of equipment due to aging. The author presents a method for managing the risks associated with aging, illustrated by a case study. The publication (Bragatto, 2020) examines the mechanisms of damage that are associated with the phenomenon of aging, as well as diagnostic tools for risk prevention. Additionally, the Aging Fishbone model is proposed in this work as a potential solution to the aforementioned problem. A significant proportion of the publications address the issue of aging in refineries. This industry also employs detailed inspection techniques, which are standardised and take into account aging issues and individual aging phenomena. These include API 580 (API, 2016) and API 581 (API, 2016), which are widely used in the oil industry.

Some technical reports prepared by major institutions have identified aging as one of the main causes of major accidents (e.g., OECD, 2017) and have highlighted the importance of assessing aging and integrating it into the safety management system. In Italy, a screening method (Aging FishBone) was developed and tested for the audit of the aging management system; it was subsequently provided to the inspectors of SEVESO facilities. A working group comprising representatives of regulatory bodies, managers of industrial plants, and representatives of the academic community collaborated to develop the Aging FishBone method. This index approach involves assessing a number of key quantitative factors that are thought to contribute to the equipment aging (Ancione, 2020). Among the quantitative key factors that contribute to the aging of the facility are the following (Bragatto and Milazzo, 2016):

- Age and operating time.
- Shutdown of the operation.
- Accidents/incidents, and anomalies, failures (this factor includes only mechanical failures and is quantified by the intensity of failures).
- Detected damage (this factor refers to damage to components that are detected by inspections and do not endanger their function).
- Deterioration mechanisms (this factor is related to the ability to detect damage to the main mechanisms by inspections).

The same authors also list the key factors that allow for the aging process to be inspected (Bragatto and Milazzo, 2016):

- Company management system.
- Mechanical integrity inspections.
- Audits.

In 2017, the Netherlands initiated the BRZO+ project, which aimed to assess the state of equipment aging management at companies subject to the SEVESO legislation. During the inspections, particular attention was paid to corrosion under insulation and the aging of fire protection systems. A questionnaire investigation revealed that the majority of companies were still in the early stages of integrating aging management into their processes (Kieskamp, 2019).From analysing 83 material ageing loss of containment accidents that occurred on Dutch Seveso sites, it can be concluded that the dominant direct causes were corrosion (55%) and fatigue, creep or embrittlement (31%) (Hansler et al., 2022). As a consequence of the fact that a significant proportion of industrial plants currently in operation have reached or exceeded their rated service life, operators have raised the question of how to reduce the impact of aging on operational safety. In order to address this issue, a technology audit tool for aging has been designed and tested (Bragatto, 2018).

3. Methodology

This study employs a mixed-methods approach, combining a comprehensive literature review with a questionnaire survey to assess the current state of aging management in industrial facilities. The methodology is designed to capture both qualitative and quantitative data to provide a holistic understanding of the issue.
A structured questionnaire was developed to collect data from facility operators and inspectors. The questionnaire was designed based on insights from the literature review and expert consultations. It included sections on:

- General information about the facility.
- Current practices in aging management.
- Incidents and accidents related to aging.
- Perceptions of the effectiveness of aging management practices.

The questionnaire was distributed to inspectors of the Czech Environmental Inspectorate, who conducted on-site evaluations and completed the forms. A total of 103 completed questionnaires were received and analyzed. The data from the questionnaires were statistically analyzed to identify trends and correlations. Hypotheses regarding the impact of aging on facility safety were tested using statistical methods. The results were presented in graphical form and discussed in relation to the findings from the literature review.

4. Results of the questionnaire investigation

The analysis of the questionnaire data reveals several important findings:

4.1 Evaluation according to the date of commissioning

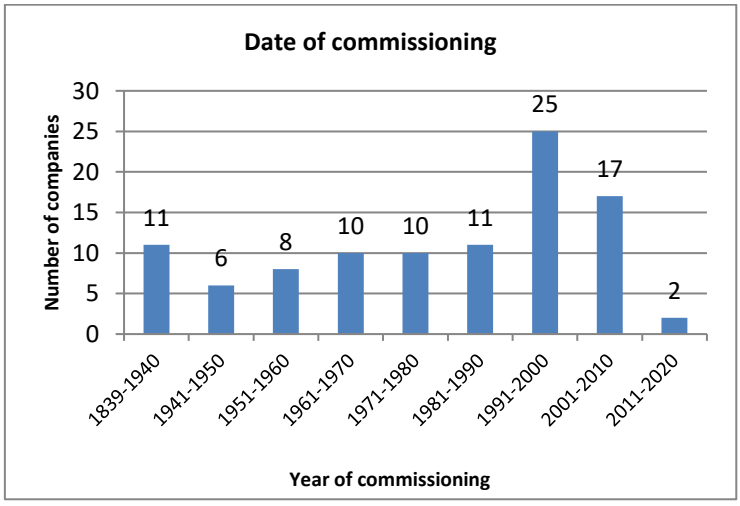

Figure 1: Evaluation graph according to the commissioning date

According to the results of the questionnaire, the phenomenon of aging affects most companies. The graph in Figure 1 shows that most of these companies were founded more than 20 years ago. The exact values of the percentages of companies according to the commissioning date can be found in the following figure.

4.2 Evaluation according to planning the technology service life

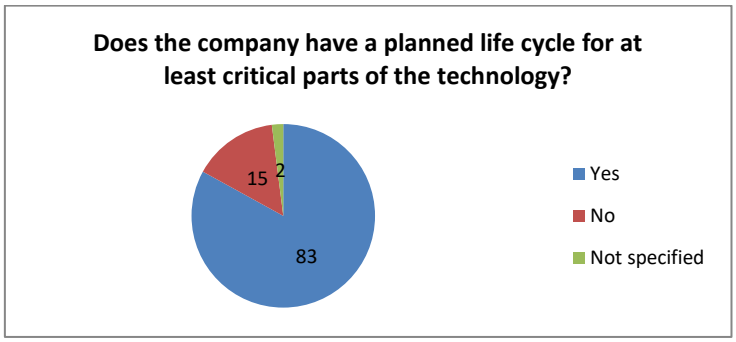

Figure 2: Graph of evaluation according to planning the technology service life

Most companies referred to the planned technology service life.

4.3 Evaluation according to the updated documentation of critical parts of the technology

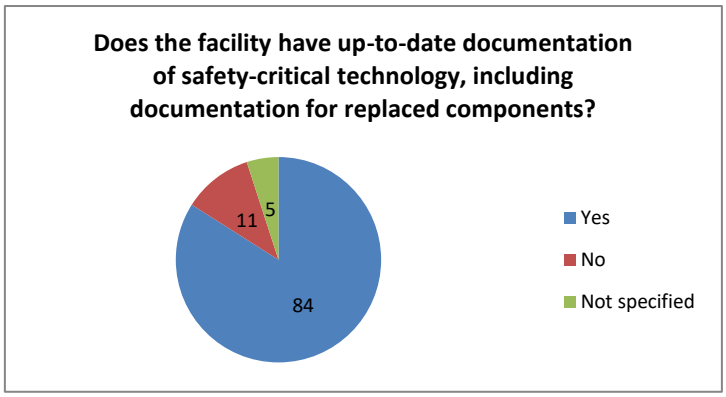

Figure 3: Graph of evaluation according to the updated documentation of critical parts of the technology

The investigation shows that about 11 % of respondents do not have a current operational documentation of critical parts of the technology. Another 5 % of respondents did not give a clear answer. As all companies should have the updated documentation, an information campaign for companies could be planned.

4.4 Evaluation according to whether a major accident has occurred

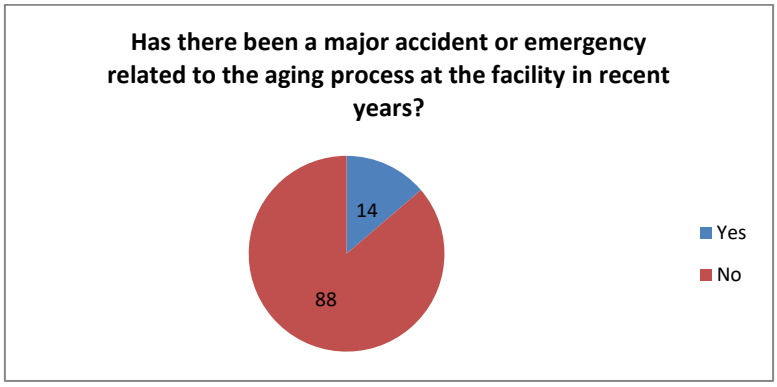

Figure 4: Graph of evaluation according to whether a major accident has occurred

According to the answers from the respondents, a major accident has occurred in 14 % of the facilities. All companies that experienced a major accident have had the updated documentation and have been planning the service life of technological equipment.

5. Discussion

To further validate these findings, a statistical test was conducted to test hypotheses related to aging and safety:
Hypothesis: Facilities with older equipment are more likely to experience major accidents.
A chi-square test was used to assess the relationship between the age of facilities and the occurrence of major accidents. The results indicated a statistically significant correlation ($p < 0.05$), supporting the hypothesis.
The results indicate that while many facilities have proactive aging management practices in place, there is still a significant proportion that lacks essential documentation and planning. This gap poses a risk to operational safety and underscores the need for enhanced awareness and training on aging management. The statistical analysis confirms that older facilities and those lacking updated documentation are at a higher risk of major accidents, aligning with findings from previous studies (OECD, 2017; Bragatto et al., 2020).

6. Conclusion

Ensuring the safety of objects falling within the scope of the Act on Prevention of Major Accidents is important for both operators and inspection bodies. Especially because "aging" has been recognized worldwide as a phenomenon that contributes significantly to major accidents.
This is legislatively ensured by the requirement to integrate aging in the safety management system in Directive 2012/18/EU (SEVESO III).
A questionnaire investigation conducted in the companies in 2020 shows that aging is considered a significant phenomenon by 67 % of respondents. This is somewhat at odds with other information from the questionnaire, where, for example, 89 % of businesses have maintenance plans in place, and maintenance is a way of reducing the consequences of aging. From other answers, it is clear that the phenomenon of aging is not very well established in the Czech Republic; respondents often do not know what to imagine under this term. The positive finding is that all respondents who have recently had a major accident consider the phenomenon of aging to be significant.
The results of the questionnaire investigation also show that, in order to obtain more relevant answers that would better reflect the reality, it is necessary to formulate the questions more precisely and accompany them with a text that would guide the respondent when filling the questionnaire.
Quantitative evaluation of questionnaires is also facilitated by a suitably designed structure of questions.
In the case of a further questionnaire investigation, it is necessary to pay attention to the exact specification and structure of the question in order to obtain the required and meaningful information.
To popularize the phenomenon of aging among companies falling under the Act on Prevention of Major Accidents and other subjects concerned, it would be appropriate to:

- propose an awareness campaign for all those involved in the prevention of major accidents; i.e., not only for key employees who are responsible for the prevention of major accidents and for company management, but also for all bodies of public administration,
- disseminate information among specialist workplaces, plant operators and trade unions,
- popularize the topic at seminars and professional conferences,
- carry out a pilot study of aging in a selected industrial company to compare various methods proposed abroad,
- develop a methodology for more detailed evaluation (for example, according to experience from abroad).

One potential avenue for disseminating information on this topic is through online workshops with lecturing experts in the field. These workshops could serve as a forum for participants to discuss the topics that are of concern to them. Another approach would be to have a centralized and systematic dissemination of information between specialist workplaces, trade unions, and operators of facilities falling under major accident prevention. This could be facilitated by an organization or small group of experts tasked with analyzing and disseminating information related to major-accident prevention. The French organization BARPI can be cited as an example. A more extensive collaboration with the academic community would facilitate the dissemination of knowledge on this topic at seminars and professional conferences.
Specific recommendations for improvement in aging management are related to the identification and management of risks associated with aging in relation to process safety (Vairo, 2018).

Key elements of this system, and therefore possible tools for improvement, include, for example

- Implementation of a maintenance management system.
- Implementation of an asset and integrity management system.
- Ageing audits and inspections.
- Implementation of risk management procedures.
- Implementation of change management processes.
- Correct definition of responsibilities and communication methods.
- Training and competency development in the area of aging.

The above recommendations should also be supported by systemic and legislative measures, such as specifications in the decree, specification of safety documentation requirements, etc.

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