

# Application of FMEA to the Environmental and OHS Risks Assessment

*Emilija Kozhovska<sup>1</sup>*

<sup>1</sup>*LTH Castings, 15<sup>th</sup> Corpus 89, 6000 Ohrid, Macedonia*  
*E-mail: [emilija\\_kozovska@yahoo.com](mailto:emilija_kozovska@yahoo.com)*

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**Summary:** *The study has attempted to present the practical application of widely used risk assessment tool Failure Mode and Effect Analysis (FMEA) in function of occupational health and safety and environmental protection. In fact, FMEA is used for identifying potential environmental aspects and ohs risks and hazards, discovering the reason for their occurrence and propose actions for their elimination. Thus severity values, occurrence number, Detection and Risk Priority Number (RPN) are some parameters, which need to be determined. Furthermore through FMEA this article aims to provide a basis for implementation of internationally recognized standards, ISO 14001 and OHSAS 18001 and compliance with the legislation in the field of occupational health and safety and environmental protection within a company.*

**Key words:** *FMEA, occupational health and safety, environmental protection, ISO 14001, BS OHSAS 18001.*

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## 1. INTRODUCTION

Through a well designed, modern and efficient management system and many other efforts, activities and processes, society needs a systematic change in the perception of the importance of occupational health and safety and environmental protection as a basic prerequisite for sustainable development and all associated components. Shortly, the economic and social transformation and globalization should be integrated into the strategy for occupational health and safety and environmental protection of each enterprise, every social group, governmental and non-governmental organizations and the entire community. The intensive development and application of science and technology on the one hand and global processes on the other significantly changed the general picture of the modern society. New sophisticated technologies are facing with very fast and effective application and implementation in the generation of various weaknesses in all spheres of human activity [1]. Today occupational health and safety and environmental protection in production systems can no longer be seen as one of the functions which involves a relatively small number of qualified people, but these disciplines should be seen as particularly important internal or

inherent feature of any company in whose realization should be no excluded employees. It is realistic to expect in the future, sooner, and exponential growth of changes and achievements in science and technology and their wide application in various fields. It is certainly not just predictions but actual danger and threat that facing modern society in terms of finding a more complex, more efficient and more successful solutions to problems for occupational health and safety and environmental protection challenges.

## **2. NORMATIVE LAW REGULATION OF OCCUPATIONAL HEALTH AND SAFETY IN MACEDONIA**

The implementation and compliance of the legal law requirements is required for any business system and entitles. These legal requirements are contained into a number of regulations (national legislation, laws, regulations, strategies etc.). Their number and dynamics of change is particularly expressed in the field of occupational health and safety. The reason is that OHS is a broad area and requires monitoring of its development and continued compliance with international law, and thus tendency towards global legislature.

After the independence of the Republic of Macedonia has been adopted Law of Occupational Safety, which defines responsibilities of employers and the rights and obligations of workers ("Official Journal of the Republic of Macedonia", No. 92/07). The Macedonian OHS law is almost fully harmonized with the Framework Directive 89/391/EEC for introducing actions and activities aimed to continuous improving of the health and safety of employees.

Therefore the law determines preventive actions against occupational risks, elimination of risk factors, informing, consulting, training of workers and their representatives, and also provides participation of employees in planning and undertaking measures for continuous improvement of OHS system [2]. OHS law involves measures, resources and methods to create safe working conditions where safety at work is an integral part of the organization of work and working processes and it is organized, regulated and provided by the employer.

The basic principle in the Law is "the principle of prevention of workplace injuries, professional diseases and diseases related to work". The Law of Occupational Health and Safety introduces the category of "risk assessment", which entered a new approach to protect the health of workers.

Figure 1 shows the model of process direction with legal requirements for health and safety in the production system, shown in flowchart process.

## **3. ENVIRONMENTAL LEGISLATIVE IN REPUBLIC OF MACEDONIA LAW ON ENVIRONMENT**

In the Republic of Macedonia according to the framework of environmental legislation of Council of Europe, in 2005 has been developed Macedonian law on environment. This Law regulates the rights and the responsibilities of the Republic of Macedonia, municipalities as well as the rights and the responsibilities of legal entities in the provision of conditions required to ensure protection and improvement of the environment, for the purpose of exercising the right of citizens to a healthy and clean environment.

Legislation for the protection and improvement of the environment of the Republic of Macedonia incorporate the principles of European environmental policy, but also a lot of attention is dedicated to the principles of environmental protection with national, regional and local mark.

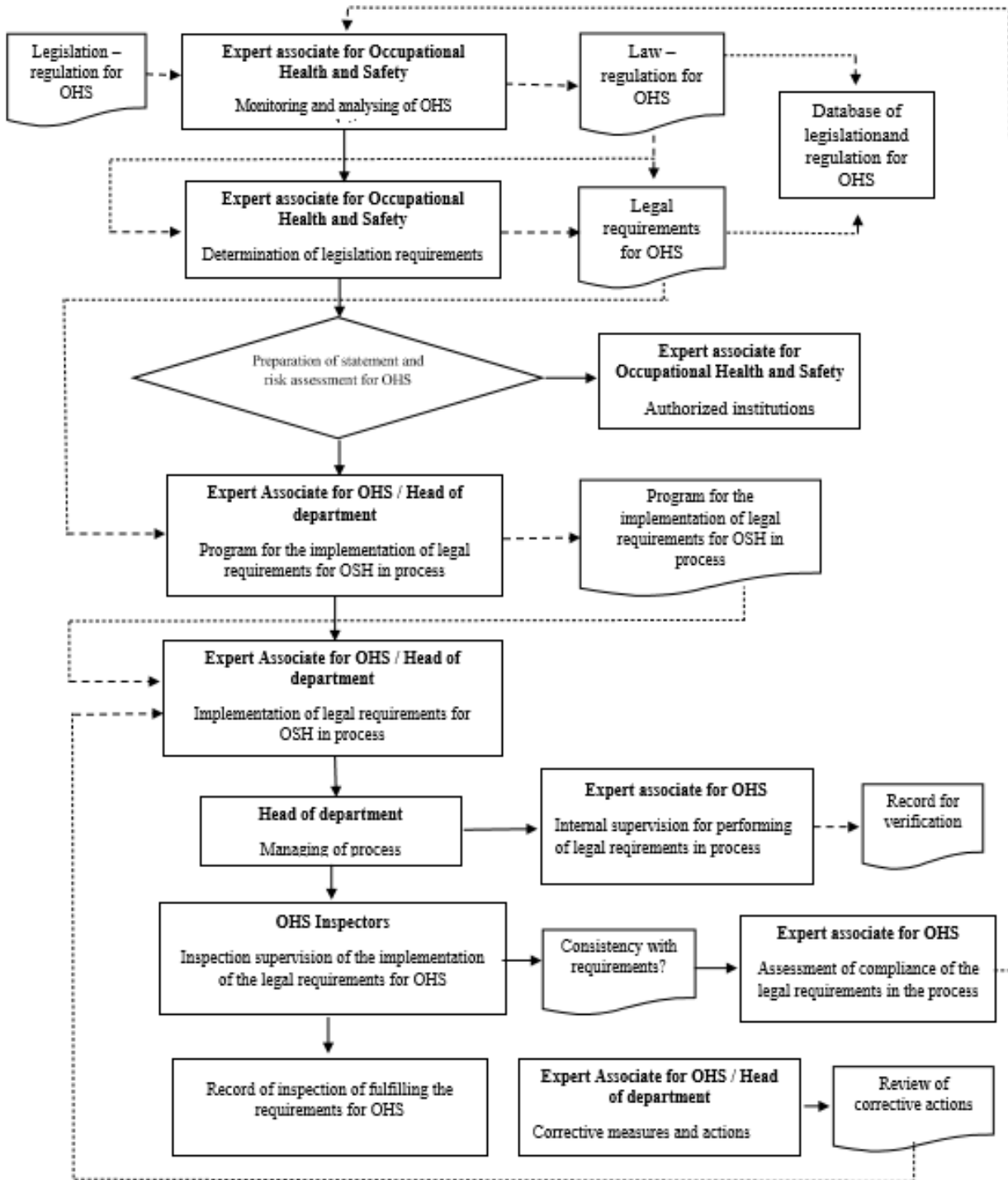


Figure 1. Model of Managing With OHS Legal Requirements in Production System

So the environmental law is structured according to environmental principles, including ecology, management, responsibility and sustainability and aims to promote sustainable development for present and future generations. The law is based on preventive action, the polluter-pays principle, elimination of environmental damage at source, shared responsibility and the integration of environmental protection into other EU policies. So, according to the law, the environment is defined as a space with all living organisms and natural resources, i.e. natural and man-made

values, their interaction and the entire space in which people live and in which settlements, goods in general use, industrial and other facilities, including the media and the areas of the environment, are situated [3].

The primary purpose of the Law of environmental protection is improvement of the quality and condition of soil, water, air; the areas of the environment, biodiversity and other natural resources, and the protection of the ozone layer and prevention the negative human impact on global warming and climate system.

According to the law, the protection and promotion of the environment is a system of measures and activities (social, political, social, economic, technical, educational etc.) that provide support and create conditions for reduction of the pollution, degradation and influence on areas and media environment (protection of ozone depletion, prevention of harmful noise and vibration, ionizing and non-ionizing radiation, use and disposal of wastes etc).The law regulates the issue of access to environmental information, public participation in decision-making, the procedure for assessment of environmental impact, plans for controls of industrial accidents and supervision mechanisms of the environmental inspectors.

Especially accented in the law are IPPC permits, which introduces a system of gradual adjustment to the required standards for integrated control and pollution prevention. Through the introduction of integrated permits for harmonization with operation plans that is a requirement for continuing operation of the existing installations in the country.

#### **4. REQUIREMENTS OF BS OHSAS 18001**

The organization shall establish, implement and maintain a procedure(s) for the ongoing hazard identification, risk assessment, and determination of necessary controls [4]. Besides for the identification and assessment of risks organizations should take into consideration following points:

- routine and non-routine activities,
- activities of all persons having access to the workplace(including here subcontractors and visitors),
- human habits, awareness, capabilities and other human factors,
- infrastructure, equipment, materials in the workplace regardless of whether they belong to the organization or owned by someone else,
- changes or proposed modifications in the organization and the scope of its activities or materials
- any legal obligations relating to risk assessment and risk management,
- design of the workspace, processes, installations, machinery/equipment, operating procedures and organization, including their adaptation according capacity and capability of employees.

Methodology of company for identification of hazards and risks should be defined in terms of the area of application in order to provide proactivity – not reactivity and also ensure the identification, prioritization and documentation of risk and implementation of appropriate actions.

#### **5. REQUIREMENTS OF ISO 14001 STANDARD, POINT 4.3.1**

The organization shall establish, implement and maintain a procedure(s) [5]:

- a) to identify and have access to the applicable legal requirements and other requirements to which the organization subscribes related to its environmental aspects, and
- b) to determine how these requirements apply to its environmental aspects.

The organization need to document and update this informations continuously. Significant environmental aspects should be taken into account in establishing, implementation and maintenance of Environmental Management System (EMS). In order to begin designing of the EMS it is needed to understand the interaction between the organization and its products and processes to the environment. According to ISO 14001, environmental aspect is an element of organizational activities, products or services that can interact with the environment. Figure 2 shows model for identification and evaluation of environmental aspects.

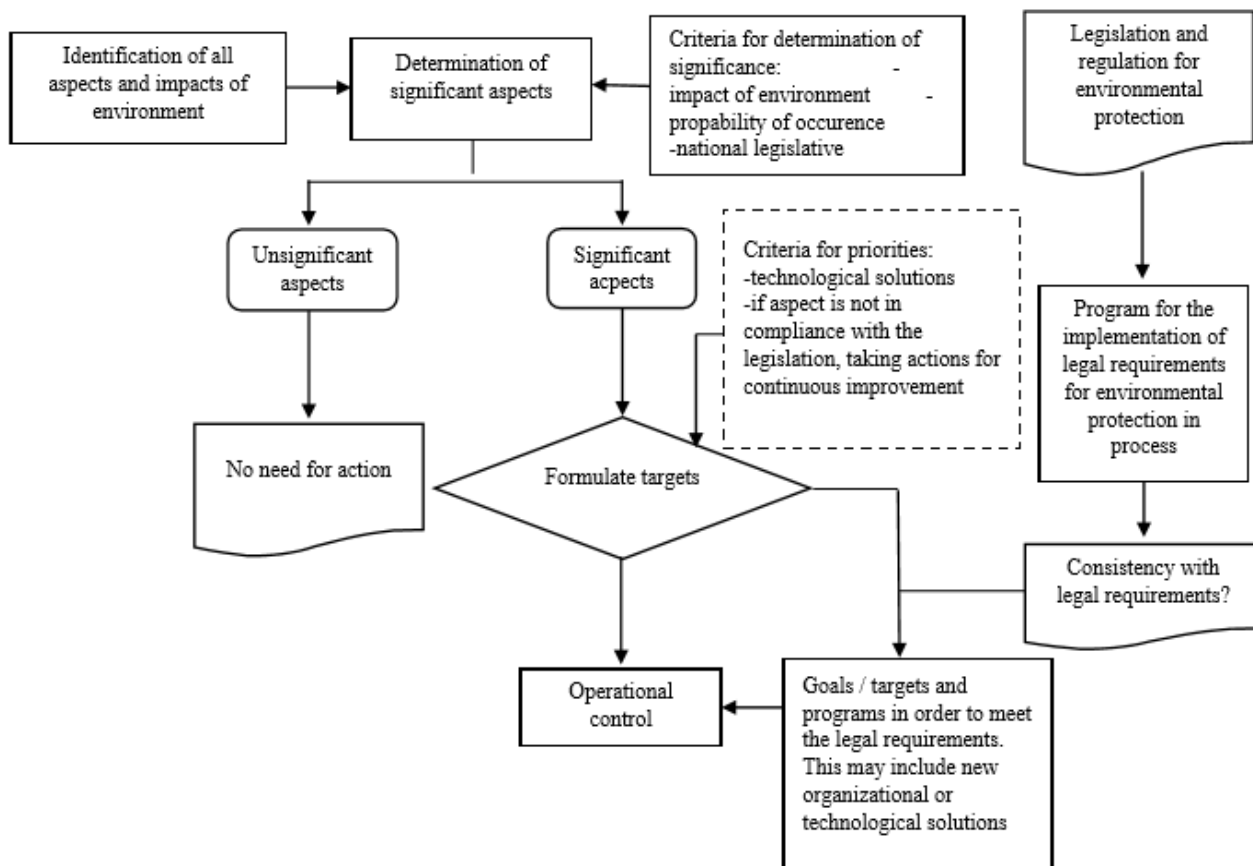


Figure 2. Model for Identification and Evaluation of Environmental Aspects

As remark it is important to emphasize that a significant aspect of the environment is one that has or may have a harmful impact on the environment. Any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products or services – ISO 14001.

Overall environmental impacts can be divided into the following components, depending on the circumstances:

- consumption of resources such as energy, materials, water, soil and so on,
- emissions of harmful substances into water and air,
- generation of waste and by-products,
- creation of noise and radiation,
- disruption of relief and cultural heritage.

Harmful substances are substances that change the natural, physical, chemical, biological, bacteriological properties and composition, and radiological properties of the environment. In order to determine the correlation of product and process environment it is necessary to do the following:

- to select the categories of products and services into the company,
- to identify environmental aspects for each category of products, services and activities,
- evaluation (estimation) of the significance of the environmental impact of each identified aspect,
- to define actions for eliminating, reducing and/or managing the risks and impacts of the environment.

## 6. FAILURE MODE AND EFFECT ANALYSIS

Failure mode and effects analysis (FMEA) is commonly defined as "a systematic process for identifying potential design and process failures before they occur, with the intent to eliminate them or minimize the risk associated with them" [6]. FMEA is a method of reliability analysis intended to identify failures affecting the functioning of a system. It enables priorities for action to be set [7]. FMEA - method is a systematic procedure for analysis system in order to identify potential causes of failure and subsequent effects on system performance. The analysis is carried out at a relatively early stage of the system, so elimination or at least mitigating the potential failures is a very effective method, economically. The standard FMEA process evaluates failure modes for occurrence, severity, and detection [8]. FMEA method used Risk priority number RPN which is a mathematical product of the severity, the occurrence and the detection.

**Determination of the severity rate.** Severity is a rating corresponding to the seriousness of an effect of a potential failure mode. Severity or seriousness of the risk is considered just in case of "the effect"; reducing the risk severity is possible only through changing the process and the manner of performing activities.

**Determination of the occurrence rate.** Occurrence is ranked according to the failure probability, which represents the relative number of failures anticipated during the design life of the item.

**Detection possibility** is an assessment of the ability existing to identify a cause/mechanism of a risk occurrence. In other words, detection possibility is a rating corresponding to the likelihood that the detection methods or current controls will detect the potential failure mode. Assessing control process of standards, requirements and laws of labor and how to apply them to achieve this number are very useful.

These three criteria, receive grades from 1 (very small / negligible risk) - 10 (major / critical risk – shown into the Tables 1-3).

*Table 1. Severity Index*

Effect	Severity index
Dangerous without warning	10
Dangerous with warning	9
Very high	8
High	7
Moderate	6
Low	5
Very low	4
Slight	3
Very slight	2
None	1

Table 2. Occurrence Index

Failure probability	Severity index
Dangerous without warning	10
Dangerous with warning	9
Very high	8
High	7
Moderate	6
Low	5
Very low	4
Slight	3
Very slight	2
None	1

Table 3. Index Detection

Detection	Severity index
Uncertain	10
Very remote	9
Remote	8
Very low	7
Moderate	6
	5
High	4
	3
Almost certain	2
	1

Calculation of risk priority number - the risk priority number is calculated as a mathematical function that depends on: the likelihood of failure, the severity of failure and the probability of detection or monitoring of potential failure before it reached an undesirable effect. As a function that looks like this:

$$RPN = [S] \times [O] \times [D].$$

The determination of the reasonable value of the Risk Priority Number (RPN) is a specific difficulty and is associated with a subjective approach to the problem by the team for making FMEA. In any case there should be taken into account external conditions and the current state of the company. Working team determines acceptable values of RPN, so it is based on professional opinions of experts according to their previous education and experience in the field concerned.

If the value of RPN is higher than the critical value, it is necessary to propose further actions in order to reduce the potential effects on the environment, and to minimize the risks and hazards to the health and safety of the employees. Then the RPN number is re-calculated and the revised RPN confirms the effectiveness of the corrective action undertaken.

The RPN is a product of the three risk factors, and accordingly RPN factor to obtain the number of 1-1000. Based on that it is determined in which area of risk is necessary to take preventive and corrective actions. The Table 4 shows the significance of the risk values in relation with needed actions.

Table 4. General Indication of the Level of Risk

Risk Priority Number $RPN = [S] \times [O] \times [D]$	
RPN < 50	Low risk
50 < RPN < 100	Medium risk
RPN > 100	High risk

## 7. GUIDELINES FOR ASSESSMENT OF ENVIRONMENTAL AND OHS RISKS USING FMEA

Companies need to identify all the aspects, risks and hazards of their work related to the environment, occupational health and safety in order to assess and rank the environmental impact, evaluate the related risks and bring them to tolerable level on a continuous basis.

Practical application of FMEA analysis in function of risk assessment in the workplace, development, planning and manage with OHS system is very realistic and achievable. Besides, FMEA analysis is tool for identifying potential hazards in the workplace, discovering the cause for their occurrence, risk assessment and propose measures for their elimination. Importance of FMEA analysis in this area is actually a possibility for a systematic approach to identifying and analyzing risks and measures to be undertaken, i.e. implementation of preventive and corrective actions in order to eliminate and reduce potential hazards.

### 7.1 Environmental FMEA (E-FMEA)

The environmental application of FMEA takes into account the environmental impacts caused by technical problems, deficiencies or irregularity errors or processes. This analysis can be used to make constructional, process and system improvements [9]. Also, the purpose of E-FMEA is to identify and assess potential environmental impacts at all stages of the product life cycle by defined way (Life Cycle Assessment - LCA) - quantitative technique which takes into account the entire product life cycle from extraction of raw materials for its manufacture to recycling and disposal). E-FMEA enables a systematic review of potential environmental aspects associated with a product or process and eliminates them before occurrence of any irreversible consequences.

The objectives of the E-FMEA are:

- preventive assessment of environmental impacts and elaboration of appropriate actions,
- identification of critical components and potentially sensitive areas,
- early detection and locating possible failures and their impacts on the environment,
- avoiding potential environmental disasters,
- improve systems, products and processes in terms of environmental protection.

The main purpose of FMEA analysis as a tool of environmental protection is minimizing the excessive influence of production processes to the use of energy, water, raw materials, auxiliary materials and emissions and waste disposal. Comparative assessment of different impacts on the environment requires social consensus and that's why it is necessary to develop internal regulations (standards, specifications, principles).

These actions can be maintained regulations in tolerance, but every company should aim at continuous improvement and at least reduce the impact on the environment. Below is shown an example of FMEA analysis for OHS hazards and risks, and environmental aspects and impacts into production process. The FMEA examples shows on Tables 5 and 6 contains only several points, but illustrates declining of RPN number, accordingly with corrective actions.



Table 5. FMEA for Occupational Hazards and Risks

FMEA Analysis for identification of occupational hazards and risks												
Risks and hazards	Potential failure	Potential effect	S	Potential cause	O	Prevention	Detection	D	RPN	Recommended actions		
<b>Mechanical hazards</b>	Unprotected parts of work equipment / mechanical stroke	Injury / fractures	6	Machinery / Work equipment	4	Checking the equipment according to the legislation	Timely periodic testing of equipment / Visual detection - human factor	6	144	To train and educate workers for safe handling with the equipment, machines and tools; To provide protective devices and blocking devices; Continuous preventive and corrective maintenance of machinery and tools; To provide and use appropriate protective equipment.		
								Risk:	S	O	D	RPN
									4	4	6	96
	Slippery floor	Injury / fractures	5	Slippery, unprotected areas	4	Preventive maintenance and cleaning of floors and slippery surfaces by appropriate detergent	Visual detection - human factor	6	120	Carefully selecting the floor, tidy and proper maintenance of floors and traffic routes, removing the cables, gaps, cracks and other obstacles on routes; If necessary, use appropriate methods of floor cleaning and chemical treatment of slippery surfaces.		
								Risk:	S	O	D	RPN
									4	4	6	96
<b>Physical and chemical hazards</b>	Noise	Hearing disorders, headaches, nervous system disorder	4	High noise level – under legislative tolerance	4	Providing personal protective equipment (ear plugs)	Timely periodic measurements of noise in the working plants	6	96	To implement technical measures to reduce noise at source (isolation of machines);		
								Risk:	S	O	D	RPN
									2	4	6	48

Table 6. Environmental FMEA

Environmental FMEA													
	Aspects of Environment	Impacts on Environment	S	Potential Cause	Indicator	O	Prevention	Detection / Monitoring	D	RPN	Recommended Actions		
<b>USING OF NATURAL RESOURCES: ENERGY, WATER, etc.</b>	Irrational use of energy,	Depletion of natural recourse	6	Production process; (machines, lighting, ventilation, air conditioning); Employees	kWh / per month	4	Plan for continuous reduction of energy consumptions; Investing in renewable sources of energy	Periodic - monthly review of the consumption of energy	5	120	Optimal use of all types of energy and reduce costs associated with power consumption.		
									Risk:	S	O	D	RPN
										4	4	5	80
	Irrational use of water	Depletion of natural recourse	6	Production process; Characteristic of machinery and equipment; Employees	m <sup>3</sup> / per year	4	Plan for continuous reduction of drinking water consumptions;	Periodic - monthly review of the consumption of water	5	120	Closing the water cycle - cleaning of waste water and return to the process; Review the loss of water from the technological process  Using groundwater for the requirements of the manufacturing process		
									Risk:	S	O	D	RPN
										4	4	5	80
<b>CONTAMINATED WATER</b>	Discharge of contaminated water	Soil pollution; Pollution of local ground and underground waters	7	Production process; Technical characteristic of machinery and equipment	m <sup>3</sup> / per year	4	Monitoring of the quantity and quality of wastewater - authorized laboratories in accordance with legal regulations; Collection and treatment of wastewater and optimal use of water in accordance with the manufacturing process	Visual inspection of the nearest area for spills and leaks that could affect of soil, surface and groundwater quality; Periodic monitoring and laboratory examination of local soil and water	6	168	Installation / reconstruction of water treatment plant		
									Risk:	S	O	D	RPN
										7	2	6	84

FMEA document is a dynamic act and once the analysis is complete, it is reviewed, revised and updated in accordance with any change in the company and its environment, which may affect the environment and occupational health and safety (new or potential legal and other regulations, new technologies, new products, new facilities, new demands of stakeholders, new raw materials, deviations from standard operating processes, emergency etc.), thereby performing the identification, analysis and evaluation of new aspects and environmental impacts and new hazards and risks, determining measures to protect the environment, and removing and reducing ohs risks to minimum.

## **8. CONCLUSION**

With some minor modifications of the standard FMEA format, this method provides increased value in the process of risk management in the field of occupational health and safety and environmental protection. FMEA method as a tool for identification of risks in the field of occupational health and safety and environmental protection broadens the concept of quantification of risk based on the likelihood and significance or effect of a particular event by adding attribute detection of risk. However, by adding value detection is enabled improved prioritization of risk. FMEA method is based on evaluation and assessment of risk and the value RPN enables identification of critical risks that require fast appropriate response.

The implementation of FMEA method gives a clear and transparent picture of the potential risk situations, as well as a clear indication of the justification of investments and education to protect the health and safety of employees and keep the environment clean, so preventive and corrective actions aimed to reduce the risk to an acceptable level.

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