STRATEGIES OF OCCUPATIONAL HAZARD PREVENTION IN MANUFACTURING

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Abstract: This article presents the results of verification of existence and nature of relationships between the types of preventive means used and the structure of individual companies from the industrial processing sector. As part of our research work, we identified the level of use of technical means, organisational means and personal protection means in the particular divisions of the industrial processing sector, we determined the structure of individual companies from the particular divisions, and then, using the Tau Kendall correlation coefficient, we also confirmed the existence of relationships between the level of use of technical means and the structure of the analysed individual manufacturing system companies.

Keywords: manufacturing systems, occupational hazards, safety at work

1. Introduction

Both in the case of accident and illness, occupational hazard prevention is the key action in shaping safe and healthy work conditions in manufacturing systems. Preventive actions should not only be based upon known hazards that occurred and brought about dangerous events in the past, but also upon the hazards that have been noticed recently in work environment elements, in the tasks being performed, and the way the employees behave. Properly designed work hazard prevention should constitute a set of various tools aimed at eliminating or restricting hazards within the work environment and activities that promote and shape the human ability to behave safely, that is, in fact, to care for their own health or life. Using tools and activities of only one kind in the selective manner does not lead to proper results. A satisfactory effect can only be brought about by proper selection of means focused at the reduction of hazards within the environment and means that improve human performance in these conditions.

2. Occupational hazard prevention

Beginnings of hazard prevention date back to the 30s of the last century, when Heinrich developed 10 accident prevention axioms [1]. Fast development of the preventive actions concept took place as late as in the 70s. According to Haddon [2], prevention can be active or passive in nature. Active prevention means are connected with the necessity for a man to take a decision upon the way such means should be used, whereas passive prevention means occur independently of people, under the influence of the hazard that has occurred. Then, Catalano and Dooley [3] distinguished between two groups of preventive actions: the so-called proactive (anticipating) activities, and reactive activities. The objective of the proactive prevention is to reduce or limit hazards, whereas the objective of the reactive prevention is to increase the ability of a human being to cope with hazards. In the 80, Anderson and Menckel [4] divided preventive actions into: primary prevention actions, i.e. those that do not allow for injury or illness to take place; secondary prevention actions, i.e.

those that result in prompt recovery of health; and tertiary prevention actions, i.e. those that limit injury or illness effects. Also at that time, there emerged an approach to prevention processes that used risk management procedures, i.e. hazard identification, risk assessment, and taking risk handling decisions [5].

Modern prevention concepts are based upon the assumption that accidents result from human presence in dangerous conditions, as well as from unsafe human behaviour, no matter what conditions there are [6]. Several researches, such as Zacheratos et al. [7] and Wallace and Vodanovich [8] have suggested that organisation systems have influence on individuals, in particular on safe behaviour. They also suggest that accidents are more likely to happen in automated environments. Prussia et al. [9] studied the interaction between social factors and technical factors at the systems level, focusing mainly on physical safety hazards, work pressure, and perceived safety climate. Vincent et al. [10] suggest that paying great attention to the design and ergonomic aspects of equipment and implementation of safety devices also has a positive effect on fatigue and cognitive overload of surgeons. Komaki et al. [11] have studied the impact of worker behaviour on safety and conclude that training and reinforcement help in preventing accidents at work. They also suggest that safety programs including preventing programs are ineffective without systematic assessment.

Therefore, preventive programmes are oriented towards changing surrounding conditions and human behaviours. In this context, activities oriented towards improving human ability to cope with hazards are referred to as relative prevention actions, whereas those that make it impossible to make a dangerous error or those that prevent any undesirable effects of wrong actions from happening are referred to as absolute prevention actions. Activities focused upon conditions – hazards – that recommend making use of technical or organisational safety means, are referred to as technical prevention or engineering prevention, whereas procedures that improve human behaviours are referred to as psychological prevention – behavioral prevention.

Engineering prevention generally adopt an approach called "design for safety" or "integrating safety into design" [12]. Most of strategies of engineering intervention include incorporating shields and guards with the equipment, and providing personal protective equipment to the operator. But, design for safety is not always a viable option for existing work-systems. However, if human errors are treated as instances of human-machine or human-task misfit, then frequent instances of misfits are the symptoms of design errors, requiring job redesign [13]. Incidents that increase exposure to energy can be modified through job redesign under certain condition [14]. Several studies reported that job redesign and ergonomic interventions lead to improvement in safety, increased job satisfaction and reduction in musculoskeletal disorders [15].

Behavioral prevention generally related to education and training interventions [16, 17]. However, effects of behavioral interventions on occupational prevention are not conclusively examined. Designers of safe behavior programs assume unsafe behavior as the prime cause of accidents, and overlook other casual factors [18], but ignore biological limitations.

The most popular approach to designing and selecting means in hazard prevention processes is using the ten rules that have been formulated by Haddon in the 80s of the 20th century, whereby, in the first sequence, reduction and elimination of hazards is preferred, and then making use of means that make people resistant to impacts that are exerted by these hazards.

3. Research methodology

The main objective of the research works we have conducted was to verify the existence and nature of relationships between the types of preventive means being used and the structure of individual manufacturing system companies from the industrial processing sector. Hence:

1/ we identified level of use of technical means TM, organisational means OM, and personal protection equipment PPE in the particular divisions of the industrial processing sector,

2/ we determined the structure of individual companies from the particular divisions of the industrial processing sector by identifying shares of definite-size companies: U1 – from 10 to 49 employees, U2 – from 50 to 249 employees, U3 – from 250 to 999 employees, and U4 – more than 1000 employees, and

3/ we calculated Tau Kendall correlation coefficients for the adopted initial hypotheses that assumed that a statistically significant relationship occurred between the level of use of appropriate types of preventive means and the structure of individual companies.

Our work comprised the years 2009-2013, as in 2008, there occurred a change in the classification of businesses, including within the industrial processing sector, as part of which a new division into branches was introduced that also added some entirely new branches [19]. In performing our work, we used statistics as gathered for each year by the Central Statistical Office in Poland, based upon the Z-10 form used to study work conditions in companies that employ minimum 10 employees [20] and data concerning structural changes groups of national economy companies, gathered based upon the RG-1 form [21].

In order to verify relationships between the adopted variables, the Tau Kendall correlation coefficient was used from the area of non-parametrical tests, as the analysed sample only comprised 24 cases, and distributions of variables were not normal distributions. The Tau Kendall coefficient adopted its values within the interval (-1;1) and made it possible to identify both the force and the direction of relationships.

Identification of the existence and nature of relationships between the types of preventive means used and the structure of individual manufacturing system companies from the industrial processing sector may constitute a starting point in adopting properly oriented work health and safety improvement policies.

4. Research results

4.1. Analysis of preventive means used

The objective of the first stage of our research works was to identify the level of use of determined types of preventive means in the particular divisions of the industrial processing sector. Three basic types of preventive means used to eliminate or restrict occupational hazards in manufacturing systems were identified: technical means, organisational means, and means of personal protection.

Technical means may include for example: making use of work mechanisation or automation, installing a reliable ventilation systems, making use of protective devices at process lines, etc. Organisational means may include for example: changes in the organisation of work or at work stand, introducing breaks from work, shortening working hours at work stands, introduction of rotation at work stands, etc. On the other hand, means

of personal protection can be divided into means of protection of: upper limbs, lower limbs, head, face and eyes, hearing, respiratory tract, those that isolate the entire human organism against danger, means of protection against fall from height, etc.

Based upon data concerning the number of persons in case of whom appropriate preventive means were used (technical means, organisational means, and means of personal protection) and the number of persons in case of whom it was found that risks occupational hazard risks had been eliminated or reduced, the level of use of given technical means – TM, organisational means – OM, and personal protection equipment – PPE was identified in %, assuming that preventive means could have been used independently of one another.

Figure 1 lists average levels of use of particular types of preventive means for the period 2009-2013 – AMT, AOM, and APPE.
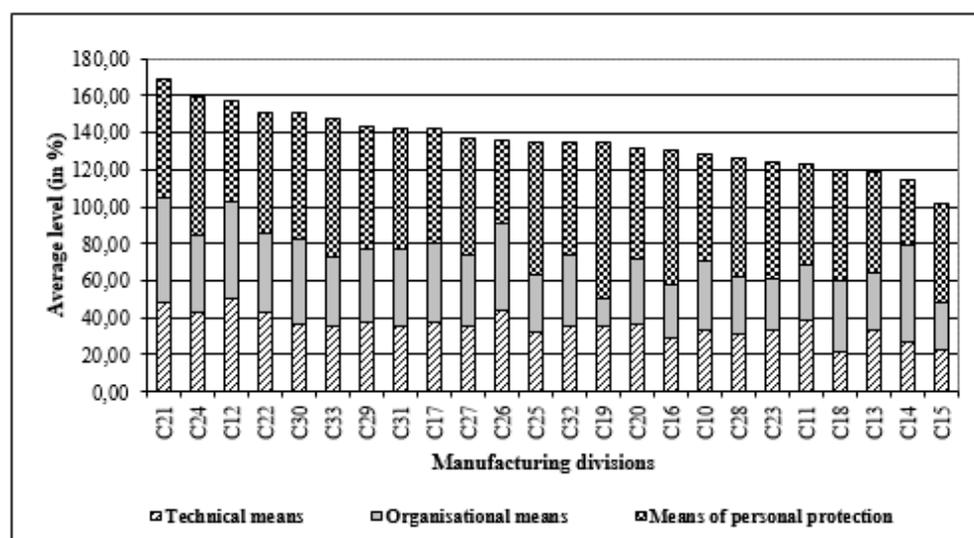
Manufacturing: C10- of food products, C11- of beverages, C12- of tobacco products, C13- of textiles, C14- of wearing apparel, C15- of leather and related products, C16- of wood and cork products except furniture; manufacture of articles of straw and plaiting materials, C17- of paper and paper products, C18- printing and reproduction of recorded media, C19- of coke and refined petroleum products, C20- of chemicals and chemical products, C21- of basic pharmaceutical products and pharmaceutical preparations, C22- of rubber and plastic products, C23- of other non-metallic mineral products, C24- of basic metals, C25- of fabricated metal products, except machinery and equipment C26- of computer, electronic and optical products, C27- of electrical equipment, C28- of machinery and equipment n.e.c., C29- of motor vehicles, trailers and semi-trailers, C30-, of other transport equipment, C31- of furniture, C32- other manufacturing n.e.c., C33- repair and installation of machinery and equipment.

Fig.1. Average levels of use of preventive means in the particular divisions of the industrial processing sector for the period 2009-2013, in %
Source: Own work based upon statistical information

Divisions of the industrial processing sector were ranked according to the average value A of identified levels of use of preventive means – A for C21 was 56.22% and for C15 – 33.90%. The highest values of levels of use of determined types of preventive means were

observed in case of technical means: 49.95% for C12, in case of organisational means: 57.05% for C21, and in case of personal protection means: 84.52 for C19.

4.2. Analysis of the structure of individual companies

The objective of the second stage of our research works was to determine the structure of individual companies from the particular divisions of the industrial processing sector, i.e. the average share of definite-size companies: U1 – from 10 to 49, U2 – from 50 to 249, U3 – from 250 to 999 and U4 - more than 1000 employees, in the total number of companies within a given division of the industrial processing sector.

Figure 2 lists average shares of definite-size companies in the particular divisions of the industrial processing sector for the period 2009-2013 – AU1, AU2, AU3, and AU4.
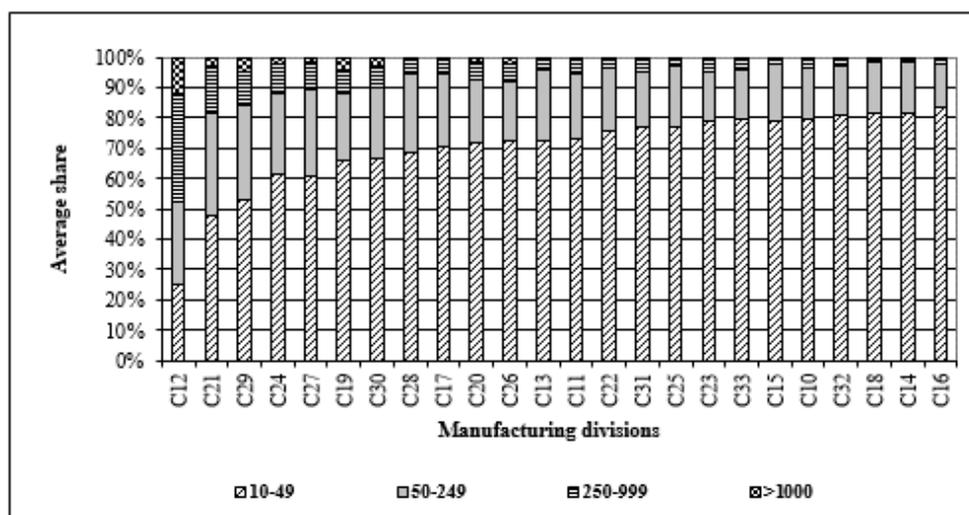

Fig.2. Average shares of definite-size companies in the particular divisions of the industrial processing sector for the period 2009-2013 in % (the way C divisions are marked is clarified in Figure 1)
Source: Own work based upon statistical information

Divisions were ranked according to the standard deviation value DEV for average shares – DEV for C12 was 9.79 and DEV for C16 was 39.36. The highest shares of definite-size companies were observed in case of companies that employed from 10 to 49 persons: 24.86% in C12, from 50 to 249 persons: 33.97% in C21, from 250 to 999 persons: 1.23% in C14, and more than 1000 persons: 0.11% in C32.

4.3. Analysis of relationships between preventive means used and the structure of individual companies

The objective of the third part of our research work was to identify the existence and nature of relationships between the types of preventive means used and the structure of individual manufacturing system companies from the industrial processing sector.

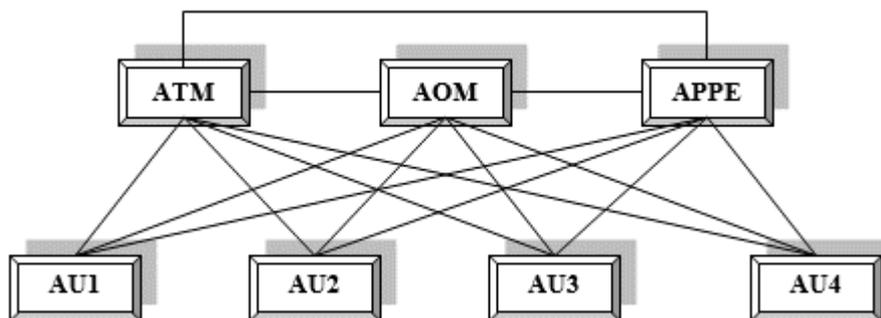Therefore, zero hypotheses were adopted, which assume that there occur relationships as presented in Figure 3.

Fig.3. Graphic representation of verified relationships
Source: Own work

Due to a small size of sample N = 24, in order to verify the relationships, the Tau Kendall coefficient was used, which is a non-parametrical equivalent of the Pearson's correlation coefficient. Table 1 lists results of analysis of the autocorrelation between average levels of use of preventive means ATM, AOM and APPE.

Tab.1. Results of analysis of the Tau Kendall correlation for "means-means" relationships

Nonparametric statistics: Tau Correlation of Kendall, N = 24, significant level α = 0.05								
X variable, Y: average level of the preventive means utilization								
Tau	Z	p	Tau	Z	p	Tau	Z	p
ATM & AOM			AOM & APPE			APPE & ATM		
0.47101	3.2245	0.0012	-0.0507	-0.3472	0.7284	0.0144	0.0992	0.9209
Tau – T. Kendall coefficient (-1;1)								
Z – the value of the Z – statistic testing the significance of the T- coefficient								
p – the level of probability for Z – statistic								
ATM - average level of the technical means utilization								
AOM - average level of the organizational means utilization								
APPE - average level of the personal protection equipment utilization								

Source: Own work based upon statistical information

It follows from the analyses we have carried out that there only occurs a statistical relationship between the average level of use of technical means (ATM) and the average level of use of organisational means (AOM). This relationship is directly proportional in nature, which means that the increase in the level of use of preventive technical means was accompanied by the increase in the level of use of organisational means (AOM).

Table 2 lists results of analysis of the correlation between average levels of use of preventive means ATM, AOM and APPE and average shares of definite-size companies AU1, AU2, AU3 and AU4.

It follows from the analyses we have carried out that there only occurs a statistical relationship between the average level of use of technical means ATM and the structure of individual companies of divisions of the industrial processing sector, described by means of shares of definite-size companies AU1, AU2, AU3 and AU4, whereas this relationship is varying in nature. The increase in the average share within the structure of companies that employed from 10 to 49 persons (AU1) was accompanied by the fall in the average level of

Tab.2. Results of analysis of the Tau Kendall correlation for "means-structure" relationships

Non-parametric statistics: Tau Correlation of Kendall, N = 24, significant level α = 0.05 X variable: average level of the preventive means utilization Y variable: average share of different –size companies								
	Tau	Z	p	Tau	Z	p	Tau	Z	p
Y　　X	ATM			AOM			APPE		
AU1	-0.5000	-3.4230	0.0006	-0.2319	-1.5874	0.1124	-0.1377	-0.9426	0.3459
AU2	0.3623	2.4804	0.0131	0.2391	1.6371	0.1016	0.0434	0.2976	0.7659
AU3	0.5724	3.9191	0.0001	0.2464	1.6867	0.0917	0.1667	1.1410	0.2539
AU4	0,5145	3.5222	0.0004	0.1739	1.1906	0.2338	0.1769	1.1621	0.2613
Tau – T. Kendall coefficient (-1;1) Z – the value of the Z - statistic testing the significance of the T - coefficient p – the level of probability for Z – statistic AU1 - average share of enterprises employing from 10 to 49 persons AU2 - average share of enterprises employing from 50 to 249 persons AU3 - average share of enterprises employing from 250 to 999 persons AU4 - average share of enterprises employing above 1000 persons ATM - average level of the technical means utilization AOM - average level of the organizational means utilisation APPE - average level of the personal protection equipment utilization								

Source: Own work based upon statistical information

use of preventive technical means, whereas the increase in the average share of companies that employed more than 50 employees (AU2, AU3 and AU4) was accompanied by the increase in the average level of use of technical means.

5. Summary

Companies use various strategies and preventive means in order to eliminate or reduce hazards which restrict hazards' access to people and people's access to hazards, which make people immune to destructive influence of hazards, and which reduce the already existing effects of hazards that were not counteracted on time. Thus, strategies of occupational hazard prevention are highly individual in nature in this context. Not all preventive activities as proposed by researchers can be used in each company. Hence, in order to select the most appropriate activities, appropriate criteria should be used, which most frequently include: conformance of such activities with regulations, their cost for the company, effects for the employee, their durability, range of impact, application time, and risk transfer possibility [22]. Based upon these criteria, the possibility to use particular preventive actions and their expected efficiency levels are compared.

The objective of the research works we have conducted was to verify the existence and nature of relationships between the types of preventive means used and the structure of individual manufacturing system companies from the industrial processing sector. Our work covered: to identify levels of use of technical means, organisational means and personal protection means in the particular divisions of the industrial processing sector, to define the structure of individual companies of the particular divisions, and to verify the adopted hypotheses using Tau Kendall correlation coefficient.

As a result of the research work we have conducted, we found that there were relationships between the level of use of technical means and the structure of individual manufacturing system companies of the industrial processing sector, whereas the observed relationships were differing in nature: the increase in the average share within the structure

of companies that employed from 10 to 49 persons was accompanied by the fall in the average level of use of preventive technical means, whereas the increase in the average share of companies that employed more than 50 employees was accompanied by increase in the average level of use of these means. For other means, no relationships were observed. Therefore, it can be presumed that in case technical means are used as part of preventive actions, the activity cost criterion prevailed over the activity durability criterion.

To end, it should be noted that the very decision as to selection of the type of preventive actions provides no guarantee that they will turn out to be efficient. It is extremely important to make use of them in day-to-day practice, which involves appointing persons in charge and completion deadlines, as well as making proper information available upon the need for and importance of these activities in providing for safe and healthy work conditions.

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