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# ALUMINUM SURFACE MODIFICATION FOR ANTIMICROBIAL PROPERTIES

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# Abstract:

The lack of new and effective medical countermeasures may leave people defenceless against the growing number of multidrug-resistant (MDR) strains of bacteria and fungi. Human pathogens can survive many days on surfaces after contact. Continuous and complete disinfection under uncontrolled conditions is practically impossible. For this reason, it is crucial to develop surface modifications that will provide a protective layer against microbes without the need for additional actions. In this work, we present our solution based on the processes of anodizing and electrodeposition of silver for use on aluminum surfaces. Our coating exhibits strong antibacterial properties, with bacterial count reduction of over 99.9% against nosocomial pathogens like *S. aureus*, *P. aeruginosa* and *K. pneumoniae*. Its application potential and overall durability make it a promising solution for implementation in hospitals and other public environments.

# **Keywords:**

aluminum, anodized, electrodeposition, antimicrobial, silver

# Introduction

One of the most current global health and development threats is the growing at an alarming rate number of multi-drug resistant (MDR – Multi Drug Resistant) strains of bacteria and fungi. The lack of effective drugs deprives doctors of the ability to defend people against pathogens that threaten life and health. According to the WHO report [1] on antimicrobial drug resistance, there is a possible scenario that the 21st century will mark the beginning of the post-antibiotic era. In this era, seemingly minor infections can become fatal. The situation is the most serious in places of particular exposure to these microorganisms – in hospitals.

*Staphylococcus aureus, Pseudomonas aeruginosa, Klebsiella pneumoniae* and *Candida albicans* are the common source of nosocomial infections. Despite great efforts, it is not possible to completely remove them for hospital spaces. In the age of progressive viral infections, co-infections can often lead to serious illnesses requiring hospitalization. That is why prevention involving the sanitization



of the surface is so important. Human pathogens can survive for many days on the surface after contact [2]. In fact, continuous and complete disinfection of surfaces that may have come to contact with human pathogens is practically impossible, even in a hospital environment. For this reason, it is crucial to look for surface modifications that will provide a protective layer against pathogens without the requirement of continuous disinfection.

Aluminum and its alloys are one of the basic materials used in industry. Due to its properties and aesthetic value, aluminum products are often in direct contact with people. The method of protecting aluminum surfaces is anodizing. It is a process which causes the formation of a metal oxide (Al<sub>2</sub>O<sub>3</sub>, alumina) layer on its surface, when electric energy flows through the metal in a suitable bath [3]. This layer constitutes a protective barrier against environmental conditions as well as adds number of characteristics including electrical insulation to the manufactured details [4-5]. In the case of aluminum products, anodizing is usually completed with sealing [6-7]. It is a high-temperature process that allows the pores on the anodized surface to be closed. The resulting coating, apart from protecting the detail, has no unique biological properties. By modifying this process, it is possible to obtain the properties desired by the users. Typically, an additional step is performed between anodizing and sealing. By bathing the detail in a dye solution before sealing, we can give it any color by sealing the pigment in the pores of the alumina formed on the surface [8]. The advantage of this approach is the ability to trap small-molecule substances in the pores of aluminum oxide, however, by closing them, they cannot migrate from the surface and interact with the surroundings.

The standard process described above is not suitable for creating antimicrobial coatings as the antimicrobial agents would be encapsulated in the alumina layer after the sealing. This can limit the possibility of contact between the agent and pathogens. For this reason, it was necessary to develop a process that would allow to obtain details with appropriate aesthetics and durability, which would also have antimicrobial activity.

Among the many agents suitable to be embedded in that kind of coating, silver seemed to be the best choice. Its medical and antimicrobial properties have been known since 1000 BC, when vessels made of silver were used as a safe way to store potable water [9]. Silver and its nanoparticles exhibit great antibacterial and antifungal properties against variety of pathogens with clinical significance [10-12]. Silver ions are able to interact with DNA by binding to its bases which result in braking of hydrogen bonds [13]. They can also cause an inactivation of enzymes and other proteins that contain sulfur and phosphorus [14]. On the top of that, silver may also react with the oxygen dissolved in the water and generate reactive oxygen forms [15]. All these actions lead to an inhibition of cell division and irreversible damages the cell envelope and contents of microorganisms [16].

# **Materials and methods**

# Fabrication of the coating

The standard procedure for preparing an antimicrobial coating on an aluminum alloy consisted of the following steps:

- 1. Preparation and cleaning of the detail.
- 2. Bath anodizing, obtaining alumina layer thicknesses ranging from 5 to 30 µm.
- 3. Electrodeposition of silver in the pores of alumina.



# 4. Rinsing and drying.

For the experimental purposes, the fabrication was performed on the aluminum alloy PA9 samples in the form of plates with dimensions of  $10 \times 10$  mm, marked with serial numbers. Initial surface preparation included degreasing of the material using an acid solution (Blitz Galvo Alu TS, Klara-MK S.C., Poland) for 5 minutes and rinsing in tap water. Subsequently, light digestion in ammonium fluoride solution (Alumon AC-70, MacDermid Enthone Sp. z o.o., Poland) was carried out for 1 min. The etching was performed with 30% NaOH solution for 1 min at the temperature of 50 °C. The whole batch was rinsed again with tap water. The anodizing was carried out at 17 °C in a bath containing 20% H<sub>2</sub>SO<sub>4</sub>. The process lasted between 15 and 90 minutes using a current density of 1 A/dm<sup>2</sup>. The coating was then activated in concentrated HNO<sub>3</sub> and successively rinsed first with tap water and then with demineralized water. The silver electrodeposition in the anode was carried out in a bath consisting of a mixture of 2-5 g AgNO<sub>3</sub> and 100 g 96% H<sub>2</sub>SO<sub>4</sub> per 1 dm<sup>3</sup>. This final step required the use of an electric voltage of 10 V with a frequency of 100 Hz for 30 seconds. The obtained coated samples have been washed with demineralized water and dried using a compressed air.

# Structural analysis of the surface

Schottky Field Emission Scanning Electron Microscope (FE-SEM; JSM-7800F, JEOL Ltd., Japan) connected to an X-ray dispersive spectroscopy (EDX) analyzer was used to capture the microstructure image of the obtained antimicrobial coatings. The microscopic observations were made using the electron beam acceleration of 5 kV.

# Analysis of the coating durability

The surface roughness was determined with an atomic force microscope (AFM; Nanite AFM, Nanosurf AG Liestal, Switzerland) using a non-contact module with a force of 55 mN on a 50×50  $\mu$ m surface.

The surface hardness testing was performed by nanoindentation method (NanoTest Vantage, Micro Materials Ltd., UK) using a Berkovich three-sided pyramidal diamond indenter with an apex angle of 124.4 °. Hardness tests were carried out with loads of 25, 50 or 200 mN at a temperature of 20 °C. The time of increasing the value of the load force from zero to maximum was 20 seconds. The tests were performed so that the sample was under maximum load for 5 seconds. Subsequently, the maximum immersion depth of the indenter and the plastic depth were calculated. Additionally, plastic and elastic energy, as well as surface elasticity were estimated. All experiments were performed in quadruples.

# Preparation of bacterial and fungal cultures

Three bacterial reference strains: *Staphylococcus aureus* PCM 2602, *Pseudomonas aeruginosa* PCM 2563, *Klebsiella pneumoniae* PCM 2064 and one fungal representative: *Candida albicans* PCM 2566 from Polish Collection of Microorganisms (WFCC, No. 106) were chosen to estimate the antimicrobial properties of the surface.

Microorganisms from the cryogenic suspensions were inoculated onto a solid brain-heart infusion (BHI; BTL, Poland) medium and incubated for 24 h in 37 °C. The next day, a single colony of either microorganism was transferred to a glass test tube containing 4 ml of liquid BHI medium



and incubated with shaking (150 rpm) for 5-6 h in 37 °C. After the incubation, the obtained cultures were diluted to McFarland standard optical density of 0.5 for bacteria ( $\sim 1 \times 10^8$  CFU/ml) or 3.0 for the yeast ( $\sim 3.1 \times 10^8$  CFU/ml).

#### Determination of antimicrobial activity of the materials

The antimicrobial activity of the materials was tested against the pathogens using a modified method: ASTM E2180-07 2012 (Standard Test Method for Determining the Activity of Incorporated Antimicrobial Agent(s) in Polymeric or Hydrophobic Materials). This method involves molten agar suspension (agar slurry) as an inoculum carrier. The agar slurry is formed by adding 3 g/dm<sup>3</sup> bacteriological agar to a 0.85% saline solution, autoclaving for 15 min in 121 °C and then cooling to 45 °C.

Prior the experiments, the control and test samples (10 mm x 10 mm) were placed in triplicates in 24-well plates (Sarstedt, Germany) and sterilized by UV light. Next, 300  $\mu$ l of standardized bacterial or fungal culture was added to 2.7 ml of molten agar slurry (45 °C) in 5 ml eppendorf tube and well mixed. Subsequently, 50  $\mu$ l of such prepared mixture was pipetted onto a middle of each test and control sample to form a thin layer. The final concentration of microorganisms on specimens were approximately  $7.5 \times 10^5$  cells/ml for bacteria and  $1.55 \times 10^6$  cells/ml for yeast. The microplates were incubated for 24 h in 37 °C in humidity above 75% to prevent the drying of the agar slurry inoculum. After the incubation, the tested samples were transferred using sterile tweezers into separate tubes containing 3 ml of 0.85% saline solution. Next, the tubes were placed into a noncavitating sonic bath and sonicated for 1 min (37 kHz). Sonication was followed by 1 min of mechanical vortexing to facilitate the complete release of the agar slurry from the samples. Finally, the serial dilution of obtained suspensions was performed and each dilution was spread onto a solid BHI medium. The agar plates were then incubated for 24 h in 37 °C. After the incubation, colony number for each dilution was counted and recorded to determine the average percent reduction using the following equation (1):

$$\% reduction = \frac{(a-b)\times 100}{a}$$
(1)

where:

- *a* = the average number of microorganisms recovered from the incubation period of control samples;
- b = the average number of microorganisms recovered from the incubation period of test samples.

# **Results and discussion**

#### Surface structure

The analysis of the obtained results did not reveal any significant and visible differences between the surfaces of the same thickness before and after electrodeposition of silver as shown on the attached FE-SEM images (Fig. 1a-d). Although, there are differences in surface microstructure when



compared to the samples of different layer thickness. The higher the thickness, the more rough and less uniform the surface appears.



Fig. 1. FE-SEM surface images of the obtained coating on PA9 aluminum alloy samples: a) control sample – thickness 10 μm without silver; b) sample – thickness 10 μm with electrodeposited silver; c) control sample – thickness 30 μm without silver; d) sample – thickness 30 μm with electrodeposited silver

#### Roughness, hardness and wear resistance of the coating

The mechanical properties obtained in the nanoindentation test are presented in Tab. 1 and 2. As can be seen from the data contained in Tab. 1 and 2, the hardness and Young's modulus of the coatings vary within large limits, depending on the applied load and the thickness of the coatings. However, in any case, the hardness of the coating is significantly greater than that of the substrate, which was 0.14 GPa.

Such a large range of variability of the obtained results may indicate that the  $Al_2O_3$  layer cracked and collapsed during the nanoindentation tests. That kind of cases may be due to the fact that during the fabrication of coatings or during the electrodeposition of silver particles, the substrate material directly under the coating was etched. This occurrence eventually led to loss of support of the coating and its collapse during the nanoindentation test.

Sample	Maximum force [mN]	Hardness [GPa]	Roughness Sa [nm]
10 µm	50	9.51	214.33
10 µm + Ag	50	0.73	350.79
20 µm	200	1.12	217.44
20 µm + Ag	200	0.26	236.84
30 µm	200	1.90	311.51
30 µm + Ag	200	2.06	908.56

Tab. 1. The average results of the hardness and roughness measurements performed on a given type of coating

Source: own calculations

Tab. 2. The average results of the durability and wear resistance measurements performed on a given type of coating

Sample	Maximum force [mN]	Maximum immersion depth [nm]	Plastic depth [nm]	Young's modulus [GPa]	Plastic energy [nJ]	Elastic energy [nJ]	Surface elasticity [%]
10 µm	50	1427.97	1190.70	60.75	21.57	9.16	30.13
10 µm + Ag	50	7478.08	4612.99	1.40	105.68	107.05	50.32
20 µm	200	10493.75	7604.63	3.44	519.11	449.72	46.45
20 µm + Ag	200	25532.52	15831.62	0.50	1228.70	1455.74	54.22
30 µm	200	7142.41	6527.16	20.18	418.85	100.84	19.52
30 µm + Ag	200	6809.46	6570.00	52.69	388.91	40.76	9.60

Source: own calculations



# Antimicrobial activity





Fig. 2. Log<sub>10</sub> reduction of the number of viable microorganisms exhibited by coating with increasing thickness of anodized layer in relation to control samples against: a) *S. aureus*, b) *P. aeruginosa*, c) *K. pneumoniae*, d) *C. albicans*. Log<sub>10</sub> reduction = 3 corresponds to eradicating 99.9% of a target microbes

#### Source: own calculations

A truly bactericidal and/or fungicidal agent is capable of reducing the initial number of microorganisms by a minimum of 3 logarithms (99.9%) [17]. The antimicrobial activity demonstrated by the analysed surfaces differed depending on the thickness of the anodized layer. Its highest effectiveness was observed against Gram-negative bacteria: *Pseudomonas aeruginosa* and *Klebsiella pneumoniae*. The mean percentages of reduction of the number of bacteria compared to the corresponding control samples for the surfaces with a thickness of 5 to 30  $\mu$ m against *P. aeruginosa* were: 99.9993%, 100%, 100% and 100% respectively, and 100%, 99.998%, 99.9996% and 99.996%, respectively against *K. pneumoniae*. In the case of gram-positive bacteria *Staphylococcus aureus*, the anodized surfaces with a layer thickness of 20 and 30  $\mu$ m showed the highest efficiency. The bacterial count reduction in relation to the control was equal to 100%. The most resistant to surface activity was the representative of the kingdom of fungi, *Candida albicans*. The determined percent reduction in the number of yeast cells did not exceed 99.75%. In this case, the highest reduction rate was observed for the layer thickness of 20  $\mu$ m. Despite the fact that such activity cannot be considered a fully fungicidal effect (no reduction of the initial number of microorganisms by 3 logarithms), estimated reduction rate suggests a substantial growth inhibition.

The obtained results were mainly influenced by differences in the structure and composition of the cell wall of the microorganisms on which the experiments were carried out. The Gram-negative bacteria cell wall consists of lipid A, lipopolysaccharide and peptidoglycan, whereas that of Gram-positive consists mainly of peptidoglycan [18]. The results suggest that silver ions as well as active oxides generated by the electrodeposited layer possess a highly effective biocidal activity against all tested bacterial strains regardless of cell wall structure. As fungi, yeast cells possess higher resistance to adverse conditions, not only because of significant differences in the thickness and composition of the cell wall, but also thanks to a variety of unique defense mechanisms against harmful environmental factors, including the ability to chelate metal ions by metallothioneins [19-20].



# Conclusions

The obtained coating exhibit strong antibacterial properties leading to a complete eradication of the exposed bacteria and to some extent to the inhibition of growth of pathogenic yeasts. Its high application potential and mechanical properties make it a promising solution to implement in hospitals and other public environments contributing to increase in control of sanitary safety.

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# STATE OF QUALITY AND FOOD SAFETY IN POLAND

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# Abstract

In order to ensure the highest quality and safety of food, measures are taken at every stage of production to ensure the quality of the final product. It is equally important that the product is safe for the consumer. For this reason, Polish products on the domestic and international food market are supervised in accordance with the latest regulations. Supervision results are the basis for creating conclusions and recommendations. This article summarizes the publications on the quality and safety of food produced and sold on the Polish market. The results of controls carried out by official food control bodies in recent years indicate the need to develop recommendations for conducting activities to preserve the health of the society. Numerous deficiencies in food safety control as well as in food production, distribution, trade and advertising were revealed. First of all, the need to restructure the authorities responsible for food safety in the country and the need to divide competences between individual inspections in order to ensure control of all areas of food production was indicated.

# **Keywords:**

food safety, food quality, food evaluation and control

# Introduction

Food products, especially industrially processed food products, go a long way from where they are produced to where they are consumed. At each stage of this pathway, there are taken steps to ensure the quality of the end product. It is equally important that the product is safe for the consumer. The safety of the product means that it is not a threat to health and life, neither after a single consumption, nor as a result of repeated consumption. In order to achieve such a goal, each stage of product handling must be carried out in a defined, standardized way. In Poland, the legal framework for food safety is defined by the Act of August 25, 2006 on food and nutrition safety [1]. Separate legal provisions apply to products classified as foodstuffs for particular nutritional uses and dietary supplements. These are the Regulation of the Minister of Health of 18 November 2021 amending the regulation on the composition and labeling of dietary supplements [2, 3]. The provisions are in line with the provisions of the European Community Regulation No. 178/2002 of the European Parliament and of the Council of Europe of January 28, 2002 [4]. Control at each stage of the food chain should be carried out in accordance with the international standard ISO 22000 [5, 6].



The food control system in Poland includes internal and external controls. Internal control is carried out by the manufacturer and is based primarily on the principles of Good Hygienic Practice (GHP) and Good Manufacturing Practice (GMP). GMP and GHP provisions focus on the principles of hygiene at individual, properly planned production stages. In turn, Hazard Analysis and Critical Control Points (HACCP) is a systemic procedure aimed at identifying hazards and estimating the potential risk of food safety hazards. In practice, it consists in the implementation of developed standards that eliminate possible threats at every stage of production. The process of its implementation is associated with expanding nutritional knowledge and increasing the involvement of the production staff in caring for food safety [7].

External control is carried out by institutions authorized to carry it out, in accordance with the law. Controls in food production places are carried out by the State Sanitary Inspection, the Veterinary Inspection, the Trade Inspection, the Commercial Quality Inspection of Agricultural and Food Products and the State Plant Health and Seed Inspection. The inspections of foodstuffs for particular nutritional uses and dietary supplements are carried out by the Chief Sanitary Inspectorate [8]. Poland is a producer and exporter of food on a global scale. Exports mainly include meat and its products, cereals and cereal products, sugar and confectionery, as well as tobacco and tobacco products. In recent years, both production and exports have increased [9]. The largest importers of Polish products are the countries of Western Europe and the United States. The awareness and expectations of consumers regarding food quality and safety are also growing all over the world. The fulfillment of these requirements is carried out by maintaining high production standards. Polish products on the international food market are additionally monitored in accordance with the latest regulations in force in the target countries [10].

# Aim of the study

The methods of producing safe food described in legal acts are subject to ongoing supervision. The results of the supervisions are the basis for creating conclusions and recommendations. This review article aims to summarize recent publications on the quality and food safety produced and traded on the Polish market. The Authors' attention is focused on the production of meat and its products, the problem of using food additives and supervision over the dietary supplements market.

# Noticeable problems with the quality and safety of food

# Quality and safety of meat industry products

Optimal meat acquisition requires appropriate breeding conditions and slaughter under controlled conditions. Specialized knowledge is required on how to maintain animal welfare and, at the same time, to ensure the safety of manufactured products intended for consumption [11]. In accordance with applicable law, animals intended for food slaughter cannot be treated with antibiotics, because these substances remain in the obtained raw material and then end up in the human body. In justified cases, the use of an antibiotic must be properly documented, and the raw material from treated animals must not be used for consumption. Natural preparations, for example based on garlic, are now commonly used to support the health of farm animals [12]. An audit carried



out at the slaughterhouse in 2019 showed that sick cows were slaughtered, and the following revealed incorrect transport of injured animals [13]. In addition, several dozen tons of meat containing antibiotic residues were found on the market, and the controlled documentation did not justify the administration of antibiotics to animals. As a result of the inspection, it is proposed to change the formula for registering the animal treatment process from the start of breeding to slaughter [14].

# Quality and safety of dietary supplements

Dietary supplements are products the consumption of which supplements the daily nutrition with substances that are beneficial to health, but have no therapeutic effect. Their placing on the market does not require meeting any specific conditions. The composition of the preparation is declared by the manufacturer or the entity responsible for marketing, but the conformity of these declarations with the actual state is checked selectively. Thus, the consumer cannot be sure that the purchased product contains the ingredients described on the packaging in the declared amount, free from contamination. It is also uncertain whether the preparation contains ingredients omitted in the description, with a potentially adverse effect on the body [8]. Products available via the Internet go directly to the recipient and are almost completely beyond the possibility of controlling and verifying the quality of the preparation. It is extremely difficult to obtain samples of their contents for research. Specifications recommended as reducing body weight and improving sexual function turned out to be a special group of products - the inspection showed that the declared composition, especially the advertised description of the action, was incompatible with the actual composition [8]. The distribution of preparations that did not obtain a marketing authorization in Poland was also disclosed. This fact indicates an insufficient level of reliable public knowledge about dietary supplements [15]. It is worth noting that a properly balanced diet should provide all nutrients, including vitamins (excluding vitamin D3) and minerals, eliminating the need for supplementation [16]. However, potential consumers did not have sufficient access to information on the risks associated with supplementation, which currently results in the widespread, often unnecessary, use of supplements.

The Supreme Audit Office after analyzing the risk associated with the dietary supplements market in Poland, recommended conducting social and information campaigns aimed at making the public aware of rational supplementation. These actionss should be carried out by the Ministry of Health. It was also suggested to introduce legal provisions regulating the presentation of a given supplement, both on the product packaging and in the advertisement. The main proposal is to make impossible to advertise the dietary supplement as a healing - and to enforce this provision [17].

# The surveillance of food additives

The use of food additives by producers is primarily aimed at extending the shelf life of the product and improving its organoleptic properties. The permissible content of a given substance / additive in the product and the acceptable daily intake are specified in legal acts and should be controlled at national and international levels [18]. Excessive consumption of selected food additives may be associated with adverse effects on the body. Regular use may contribute to the development of, inter alia, allergies and digestive disorders [19]. Knowledge about the substances added to food is not common. Most consumers do not pay attention to the type and amount of such substances in individual products. There is also not widely available information on how not to combine certain



products of the food industry in the diet so as not to cause accumulation of substances added to them in the body. So far, no strategy for comprehensive education of the society in this area has been developed [18].

Monitoring the actual consumption of such compounds remains a problem. Assessing how much and what substances end up in the body is very difficult methodological. Similarly, linking certain disease symptoms with the consumption of defined substances added to food products is subject to a large error. The State Sanitary Inspection focuses its control in the field of food additives mainly on their commercial quality. Apart from a few substances selected annually, health aspects are not analyzed. There are also no studies on the risk of excessive supply of food additives with the diet, their accumulation in the body and their interactions [10].

#### **RASFF** alerts for products manufactured in Poland

Rapid Alert System to Food and Feed is located in the countries belonging to the European Union. Its essence is the cooperation of institutions that make up the notification and control network. It is used to quickly detect and warn about dangerous food products. Currently, it based on the basis of the Commission Implementing Regulation (EU) 2019/1715 of 30 September 2019. The information on the occurrence of a food hazard to the relevant administration authorities should take place within 48 hours of its identification [20].

In the last few years, over one hundred notifications were issued in Poland, concerning microbiological contamination and the presence of pesticide residues in food products. Among the European Union countries, Poland took first place as a country whose exported food was reported as hazardous food [10]. In 2021, in the period from January to September, 273 products of Polish origin were indicated as dangerous. This is almost 2.3 times more frequent than the number of notifications for products manufactured in Germany [10]. The analyzes carried out in the countries participating in the RASFF show, first of all, the presence of microbiological contamination of Polish products. Most often they concerned the presence of Salmonella in poultry and eggs. In turn, Listeria monocytogenes was found mainly in fish and their preserves, meat, but also in fruits and vegetables [21, 22].

Because of the emerging signals of insufficient supervision over the process of production and distribution of foodstuffs in Poland, the Supreme Audit Office took action in accordance with its powers. Their effects were published in the form of the report "The scope of the food safety control system in Poland - the current state and the desired directions of changes" [10].

# Analysis of the causes of shortcomings in the control of food quality and safety

# Tasks, competences and cooperation of food control institutions

In the current law system, one area subject to control is regulated in many legal provisions. In recent years, the institutions of the external control system for food safety in Poland have carried out inspections of entities in accordance with the interpretation of their competences. Nevertheless, these controls turned out to be duplicated by various institutions in relation to the same entity, performed due to the lack of definition of the competences held on each other. Moreover, the control activities were not justified by the increased health risk arising in the areas of official controls.



As a result of misunderstandings arising in the areas of operation of the Veterinary Inspection and the State Sanitary Inspection, the control of animal products was inconsistent. Also, government administration units were not provided with information on illegal production and trade in agri-food food. The lack of definition of the division of competences of the Trade Inspection and the Commercial Quality Inspection of Agricultural and Food Products resulted in neglect of educating the public about food additives [23].

# Staff and equipment challenges

There is a staff shortage in food quality and safety supervising institutions. For this reason, there were too few inspectors in a given area of production plants, which could have an indirect negative impact on food safety. In some cases, the audits carried out showed that the percentage of controls performed by the Chief Sanitary Inspectorate was too small in relation to the size of the dietary supplements market. Moreover, the Supreme Audit Office indicates that, compared to the European Union, too few food samples are collected in Poland in order to examine herbicide residues. Deficiencies in the necessary laboratory equipment make it impossible to properly monitor contaminants in food, and too long analyzes of samples do not allow for effective elimination of contaminated products from the market. These phenomena have a complex cause. One of the most important factors is the relatively low salary offered to people who require specialist knowledge and broad competences [10].

Due to the misunderstandings that occurred in the field of food safety control, the Supreme Audit Office recommends simplifying the law, which would clearly indicate the scope of competences of individual authorities in this regard, as well as establishing a superior institution that would supervise lower levels of control inspections, similar to the European Union member states, in which the presence of the parent institution has reduced the number of misunderstandings.

# **Supreme Audit Office Recommendations**

Supreme Audit Office proposes to prepare new inspection regulations and educate employees in order to expand their competences. In addition, the recommendations also include standardization of laboratory databases, which will also affect the efficiency of research.

Recommendations regarding irregularities in the area of food additives include, first and foremost, a market research that will enable the assessment of undesirable phenomena. The research would cover the amount of additives consumed by the public, assessing the interactions between consumed additives, food ingredients, supplements and medicinal products. On this basis, it will be possible to develop and introduce the necessary legal provisions. The next step is to develop methods to enforce manufacturers' compliance with these regulations [10].

# Summary

The recently published results of analyzes and RASFF data suggested that the problem of food quality and safety in Poland requires a systemic approach. The results of inspections carried out by official food control institutions in recent years have indicated the need to develop recommendations



for carrying out activities to maintain the health of the society. This was confirmed by the Report of the Supreme Audit Office on the Food Safety Control System in Poland. Numerous irregularities in the control of food safety as well as in the production of food, its distribution, trade and advertising were revealed. First of all, the need to restructure the authorities responsible for food safety in the country and the need to divide competences between individual inspections in order to ensure control of all food-producing areas was indicated. It is necessary to increase the care for the quality of food products from the earliest stages of production to its distribution, and to tighten the control of products at all stages of their formation and market circulation. Along with these activities, broad social education is essential - pressure from informed consumers can prove to be an important factor in manufacturers' efforts to maintain the highest quality of their products.

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# THE SYNTAX OF SELECTED LEGAL ACTS

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# Abstract:

The article presents results of syntactic research conducted on selected legal acts. The research material constitutes 600 utterances from six acts that can be sorted in three most important branches of the Law - Civil Law, Criminal Law, and Administrative Law (one key substantive law act and one procedural law act per each branch). The quantitative analysis of syntactic parameters has been performed with the use of traditional syntax description model. The results acquired in ten fields are collated with results of other statistical research conducted on legal, scientific, and artistic texts in order to determine the stylistic and syntactic properties of examined legal acts. The quantitative analysis is supplemented by the qualitative analysis of description.

# **Keywords:**

legal acts, statistics, syntax, legal text

# Introduction

Legal language is considered to be one of the most characteristic languages or one of the more individual stylistic variations of language. However, there is too few studies on this specific language to this day, but recent years gave multiple important publications. Following the initiative of Stanisław Mikołajczak set thirty years ago in text titled *Składnia współczesnych ustaw sejmowych* (*The syntax of contemporary Sejm acts*), in this article I present the results of statistical research on syntax of six legal acts essential for the Polish legal system.

The purpose of research is to indicate the characteristic syntactic features of article part of legal texts and, in addition, undertake thoughts on transformations of the Polish legal language. It seems that despite the increasingly louder and more clearly repeated postulation on the legal clarity, the texts of Polish legal acts are still constructed using Polish language that is not simple and legible enough. This article is a response to the need of partnership between linguists and lawyers in the scope of linguistic shape of the Law.



# Preliminary

The statistical method is one of the most precise methods of describing language. Until now, it was used to examine scientific texts [1], artistic prose of the Interwar period [2], works of Bolesław Prus and Stefan Żeromski [3], or Witold Gombrowicz's prose [4]. However, not only epic texts were analysed. Twenty years ago, in the Library of Poznan Polish Studies appeared Małgorzata Rybka's book titled Zamieszkać w zdaniu. O składni tekstów poetvckich Czesława Miłosza (To inhabit a clause. On the syntax of poetic texts of Czesław Miłosz) [5]. The indicated quantitative method is used in particular to examine the style of a specific type of texts or specific author. Until now, there was no work, which would describe the syntactic properties of legal texts in a relatively comprehensive manner. As Justyna Jedlikowska points out, "Nonetheless, the conducted query allows me to notice that these issues [related to the style of legal texts – WK] has probably not elaborated in detail by linguists so far. The lack of such elaborations is disturbing due to the rich traditions of utilising mathematical methods in linguistics." [6]. As the beginning of Polish linguistic statistics should be considered the publication of the first scientific article from this scope, The Origin and Growth of Plato's Logic with an Account of Plato's Style and of the Chronology of his Writing by Wincenty Lutosławski. The work from 1896 has shown how statistical methods can be used to determine the chronology of Plato's works. The golden age of statistical linguistics falls on the period from 1920s to 1950s, however many important works from this scope were also published at the end of previous millennium. However, it seems that statistical linguistics was slightly forgotten in the face of development of various syntactic models. Quantitative studies are exceptionally time consuming, require taking time and possessing basic knowledge from the scope of mathematics or precise mathematical statistics [6]. Therefore, it is not possible to agree with Jedlikowska's remark that the opportunity to save time by the researcher is the cornerstone of success of statistical methods in linguistics [6]. Quite the contrary, in literature a particular attention is paid to time spent on conducted research, which is related with the sample size or multiple aspects of examined factors [7]. However, it is true that the results of research are relatively accurate when compared to other methods, which are first and foremost based on the researcher's intuition [8]. Additionally, they give the possibility to draw conclusions about the whole examined lingual material on the basis of analysis of its portion. The conclusions are reliable enough as the error margin while using this method is small.

# **Research sample**

The first difficulty that a researcher undertaking the performance of syntactic analysis on a specific type of texts meets is the selection of research sample. It would seem that excerpting utterances from a text should pose no problem. However, this issue is complex and extremely important in the context of study reliability. Therefore, at the beginning it is necessary to precisely indicate research material, sample size, and its selection method. Research conducted in this article aim to characterise the syntax of Polish legal acts in a relatively comprehensive manner. For that purpose, I have analysed selected acts from three basic branches of the Law: Civil Law, Criminal Law, and Administrative Law. Aside from the imposed division of the Law due to its topic, it can also be divided while taking into account the criterion of subject of regulation of that Law. At that



point we acquire the division into material law (provisions of the Law, which state directly about rights and obligations, warrants and prohibitions of legal entities and determine sanctions for failing to observe them) and procedural law (provisions of the Law that regulate proceeding before judicial and public administration authorities) [9]. As Joanna Helios points out, "When analysing the division into material and procedural law, it is necessary to also take into account the division into substantive and procedural standards occurring in the jurisprudence. Substantive standards are defined as first degree standards. Using these standards or their unconditional observance has a direct influence on actual social order. Substantive standards also influence standards of second and higher degrees, that is, procedural standards." [10]. By observing this criterion, I decided to analyse one key material and one procedural act from each branch. In the end, the research material consisted of:

- 1. Act of 23<sup>rd</sup> April 1964 Civil Code and Act of 17<sup>th</sup> November 1964 Civil Procedure Code,
- 2. Act of 19th April 1969 Criminal Code and Act of 19th April 1969 Criminal Procedure Code,
- 3. Act of 28<sup>th</sup> November 2014 Law on Civil Status Records and Act of 14<sup>th</sup> June 1960 Administrative Procedure Code.

In literature it is indicated that in order to make research reliable, the selected sample must possess several qualities - it should be uniform, numerous enough, taken randomly, and as dispersed as possible. The uniformity requirement has been met through the selection of utterances from the article part of indicated legal acts and therefore, only provisions of commonly applicable Law have been subjected to analysis.

The sufficient quantify is widely commented by researchers. It is difficult to clearly indicate how many utterances should be analysed in order to make the result reliable. As Frances Clegg stresses, "This problem has no easy or general solution and each settlement depends on various factors, which sometimes cannot be specified at earlier time" [11]. In the most important work constituting as background for this research, The syntax of contemporary Sejm acts, Stanisław Mikołajczak has based his work on a sample of 500 utterances [12]. However, the most often adopted sample from examined texts is 200 utterances. This number is quite often repeated in both material [13] and theoretical [14] works. The research conducted by me has been based on a sample of 200 utterances from legal acts sorted into three branches of the Law indicated above. I have taken 200 utterances from the Civil Code and the Civil Proceeding Code, 200 utterances from the Criminal Code and the Criminal Procedure Code, and 200 utterances from the Law on Civil Status Records and the Administrative Procedure Code. To me, the division into branches of the Law is definitely more important than division into material and procedural law. Nonetheless, in research I took into account Acts with varied characteristics as the work claims to possess the quality of being as comprehensive as possible or being universal in the context of the Polish Law. At the same time, it should be remembered that the sample size first and foremost depends on the demanded accuracy of calculating the language parameter the researcher took interest in instead of population size, i.e. size of a given phenomenon in the examined text [15]. Because this research was not intended to show rare phenomena, but instead make a structural characteristic of a community, it seems that the sample of 600 utterances will be sufficient [7].

The third quality of a proper sample, the random selection, is considered to be crucial in the context of the whole process of collecting research material [7]. Due to the exceptionally high quantity of source material, the research conducted by me has the nature of partial research as



complete research would take too long to conduct and would delay the publishing of results. As a consequence, I adopted the representative method, for which the most important task is the ability to draw conclusions on the basis of statistical sample with whole community. The method I used to draw the sample can be described using four parameters:

- 1. dependent sampling,
- 2. individual sampling,
- 3. single-step sampling,
- 4. limited systematic sampling.

Dependent sampling means that a utterance once chosen to the sample was not included back in the general population, that is, it did not participate in further sampling. In that way I avoided the possibility of examining the same structure several times, which could falsify the received results. We deal with individual sampling when a single unit is sampled from the whole structure – in my case this meant sampling a simple utterance from texts constituting the source material. Single-step sampling consists of direct choosing unit from a population, in this case a utterance from texts. This means that there exists only single step of sampling. Limited systematic sampling allows to acquire the effect of a dispersed sample. It consists of including every n<sup>th</sup> element of the general population in the sample. Counting all utterances from indicated legal acts in order to learn which utterance should be qualified in the research sample would take too much time. However, Ruszkowski proposes a certain modification to systematic sampling. Namely, the researcher should divide number of pages of texts it is interested in by the number of utterances, which the researcher wants to subject to research [7]. I adopted such modification when sampling the research sample for this research. I summed up the number of pages of acts included in each of three mentioned branches of the Law, after which I each time divided the acquired result by 200 as I set this number of utterances as appropriate to analyse interesting parameters of examined legal acts. The acquired results have allowed me to determine how many utterances from sampled pages should be subjected to research. Each time those were the first utterances, which started on a given page. Therefore, the final property of the research sample selection method (limited systematic sampling) simultaneously constitutes the execution of postulation for dispersing it as much as possible [14].

# Syntactic description model

The final element that requires explaining before moving on to the presentation of received results is the selection of syntactic description model. The contemporary linguistics differentiates four models of syntactic facts description [16]. Thus, there are: transformative generative model, non-transformative generative model, semantic model, and the so-called traditional syntax. In this research I will use the fourth model, the final version of which was shaped by Zenon Klemensiewicz [17, 18]. However, I will take into account certain modifications of Stanisław Jodłowski [19]. This choice is dictated by several factors. Firstly, the designed readers of this work are not only linguists, but also lawyers. Such shaping of the recipient group requires the adjustment of syntax description model to information possessed by readers. In Poland, the traditional syntax remains the most popular method of describing syntactic phenomena, which is taught in elementary and higher schools. In this regard, this model quite often is the only one known in the public awareness of Poles, who do not have



philological education. Therefore, in order to make the presented results understandable for recipients, it is necessary to use conceptual apparatus known to them. Secondly, statistical research cannot function in isolation. The presentation of properties of analysed text is possible only after comparing the results with results of other studies. So far, this type of works uses mainly traditional syntax as it allows to sort syntactic categories by material. In the light of these arrangements, the weaker, but still significant arguments will be the invariability or small variability of its category [20], as well as representatives of other syntactic concepts referring to its arrangements [21].

# **Key terminology**

In the end, it is worth to also indicate the method of understanding the basic, most significant phrases, as well as (hence) modifications, that I adopt from Jodłowski. The key phrase that requires explanation is "clause", which Klemensiewicz introduced to reflections on syntax. He counted over two hundred definitions of this phrase while stating that this undermines the purpose of undertaking attempts at definition. In this work I adopt the orthographic definition of "clause". It is relevant in the situation of examining a written text and in addition it does not raise or rarely raises doubts [22]. "Simple utterance" and "compound utterance" are phrases that should also be explained. The former is characterised by possessing a single predicate. The latter can be recognised as it contains two or more predicates. I adopt the indicated nomenclature even when a predicate is elided. Quoting from Jodłowski, I use the phrase "participial elliptical clause" to define what Klemensiewicz called "annunciation" and therefore it is a utterance, in which the adverbial participle is the central part. In contract, I treat adjectival participles as grammatical modifiers. Among the types of compound utterances quoted from Jodłowski I add exclusive clauses. I adopt that compound utterances with first build-up profile are such utterances, that consists of two subclauses, where one utterance is a main clause and the other is a subordinate clause. The component is the smallest unit that I differentiate in the process of syntactic analysis. Although indication of text expressions is less problematic, the researchers significantly more often use components and because one of the main advantages of the adopted research method is the possibility to compare results of various studies, I therefore adopt the concept of component quoted from Ruszkowski and Mikołajczak.

# **Examined parameters**

In the process of statistical analysis of research sample syntax in chosen six acts belonging to three branches of the Law, I examine the following parameters:

- 1. the number of simple utterances and compounds utterances in the total number of utterances;
- 2. the participation of parataxis and hypotaxis in the total number of compound utterance conjunctions;
- 3. the participation of specific types of connections in the total number of paratactic conjunctions;
- 4. the participation of specific types of connections in the total number of hypotactic conjunctions;



- 5. the number of hypotaxis degrees and average number of hypotaxis degrees in compound utterances (build-up profile);
- 6. the number of component utterances in compound utterances and average number of component utterances in compound utterances (linear development of compound utterances);
- 7. the number of components in simple utterances and subclauses and average number of components in simple utterances and subclauses (linear development of simple utterances and subclauses);
- 8. the number of structural development levels and average number of structural development levels for simple utterances and subclauses (build-up profile);
- 9. the linear development of simple utterances and subclauses taken into five length classes;
- 10. the participation of specific component types in the total number of components and participation of specific types of phrases in total number of phrases.

Of course, the Mikołajczak's article from 1994, *The syntax of contemporary Sejm acts*, will be the background for research. The background will also cover Mikołajczak's book from 1990, *Składnia tekstów naukowych. Dyscypliny humanistyczne (The syntax of scientific texts. Humanities)*. In order to enrich the context, I will also sometimes refer to analyses conducted on prose texts of Witold Gombrowicz, Bolesław Prus, Stefan Żeromski and in the general aspect of the artistic prose of the Interwar period. I chose this catalogue due to the same research method, the same (to an appreciable extent) examined parameters, and the same (or close) solutions of disputable issues (e.g. multiplicity of compounds or numeration of build-up profiles of compound utterances). In addition, prose texts are closer to written texts of acts than, for example, language of youth or spoken language.

# **Research results**

The first examined parameter is the number of simple utterances and compounds utterances in the total number of utterances. The Criminal Law clearly stands out in the scope of selected branches of the Law as only 22% of utterances in examined acts are simple utterances. The participation of simple utterances in Civil Law and Administrative Law is 37.5% and 34% respectively. The total value of this parameter for the examined material is at the level of 31.2%. It is assumed that the determined participation of simple utterances in the total number of utterances can constitute as an indicator for narrative nature, be a characteristic distinctive feature of a given author, or suggest simplicity (or the absence thereof) in capturing the presented contents. In order to determine whether the occurrence degree of simple utterances indicated for legal acts is big, small, or average, it is necessary to refer to subject literature. Simple utterances constitute 42.2% of utterances in scientific texts, 42.1% in Gombrowicz's prose, 41.1% in Prus' works, 37% in Żeromski's works, and 42.1% in the artistic prose of the Interwar period. The parameter in acts examined by Mikołajczak is at the level of 67.2%. The result can be surprising. In legal acts examined by Mikołajczak at the beginning of 1990s, the participation of simple utterances is twice as big as their participation in acts vital for the Polish legal system at the beginning of 1920s. Where does that change come from? Perhaps it is the result of varied research material - in general, Polish acts are less comprehensive than acts called codes or laws that I have examined. In addition, there is 30 years



of difference between both studies, so it is possible that subsequent amendments have contributed to the increased syntactic structure complexity. The small percent of simple utterances suggests a high level of correlation between information passed by indicated texts and "dependent" method of including description. Simple utterances are defined as more compact, easier to understand, and clear while their often use might be the characteristic of simplicity in capturing issues [23]. Information passed on using simple utterances is exceptionally expressive, autonomic, and usually are also considered to be extremely important. The natural consequence of the small number of simple utterances is great participation of compound utterances, which cover 68.8% of examined legal texts. It should be pointed out that this type of utterances is much richer in information and much more complex and thanks to the variety of relative meanings between its parts it is possible to express all dependencies, which occur in the described world [24]. The researchers stress that this form has downright unlimited potential to shape text in terms of communication and stylistics [3]. Therefore, a more thorough learning the structure of compound utterances has such a great significance in the scope of stylistic and syntactic description of a text.

Another interesting parameter is the participation of parataxis and hypotaxis in the total number of compound utterance conjunctions. Compound utterance conjunctions in each of the examined branches of the Law are clearly dominated by hypotactic conjunctions rather than paratactic conjunctions (Civil Law - 74.6% to 25.3% ratio; Criminal Law - 75.6% to 24.4% ratio; Administrative Law - 79.1% to 20.9% ratio). In the general overview of legal acts, the tendency is the same and mean result amounts to ratio of 76.4% of hypotactic conjunctions to 23.6% of paratactic conjunctions. This is not a surprising result once we consider the similar result of this parameter in scientific texts (74.9% of hypotactic conjunctions). The results of syntactic analysis of Gombrowicz's prose and artistic prose of the Interwar period (over 80% of hypotactic conjunctions) locate the legal material in the middle of table containing texts used to indicate the research background. This parameter is exceptionally important. Parataxis is considered to be the simplest form of constructing compound utterances. Researchers agree that it constitutes as a phenomenon typical for spoken language [25]. As Krystyna Pisarkowa stresses, "In speech, we more often use simple utterances than compound utterances. In compound utterances we prefer parataxis over hypotaxis" [26].

The participation of various type of paratactic conjunctions in analysed legal texts will be exceptionally significant. While cumulative parataxis brings text closer to spoken Polish language, the resultative parataxis considered to be the most intellectualised form of parataxis will most certainly raise no such associations. Quoting from Klemensiewicz, I differentiate five types of paratactic conjunctions (cumulative, disjunctive, contrapositive, resultative, and inclusive). Quoting from Jodłowski, I add a sixth type, the exclusive conjunction, and adopt this classification in this work. The distribution of specific conjunction types in analysed texts belonging to three indicated branches of the Law is quite diverse. Criminal and Administrative Law are clearly dominated by cumulative parataxis (53.2% and 69% respectively while in Civil Law it is the second most often occurring conjunction (35.5%) with disjunctive conjunctions being the most numerous group (43.5%). In general, the big participation of disjunctive parataxis in all types of paratactic conjunctions can be recognised as a distinctive feature of Polish acts (39% in Criminal Law and 20.7% in Administrative Law). The third significant type of paratactic conjunction is contrapositive conjunction (3.9% in Criminal Law, 12.9% in Civil Law, and 10.3% in Administrative Law). The lack



of any resultative subordinate clause in the analysed six hundred utterances from various Polish acts is astonishing. Inclusive and exclusive utterances have a marginal participation in all types of conjunctions present in the analysed legal texts. It is worth to compare the acquired results with results of texts examined so far. First of all, it should be pointed out that cumulative utterances, which constitute 52.6% of utterances for all examined acts, come last among the selected research background. For example, the cumulative parataxis covers 69.9% of all paratactic conjunctions in scientific texts, 76% in Gombrowicz's prose, 81% in Prus' works, and 91.5% in Żeromski's works. However, researchers stress that there is no direct dependency between the participation of cumulative utterances (the simplest type of parataxis) and the degree of text intellectualisation [27]. The second least complex type of parataxis is contrapositive parataxis, which differs from cumulative conjunctions with greater intellectual load. Its participation in all analysed legal texts amounts to 9% and is quite low when compared to scientific texts (20.3%), or prose texts (several percent in each case except Żeromski's works, where it amounts to 7.2%). Disjunctive parataxis is the last conjunction significant in the context of examined legal texts. It constitutes 34.4% of all paratactic conjunctions in the analysed legal texts. For comparison, the second highest result among the selected research background belongs to scientific texts (3.8%). However, this result cannot be recognised as reliable as Mikołajczak added disjunctive parataxis and inclusive parataxis together. The result showing solely the participation of disjunctive parataxis is presented in Gombrowicz's prose, where it amounts to 3%. Thus, the difference is exceptionally big as it exceeds 30%. The disjunct is captured mainly thanks to conjunctions "albo" or "lub" ("or") (which de facto from the point of view of legal logic contains a conjunctive element) is distinctive for legal provisions both when indicating a legal situation and provision's recipient (legal standard hypothesis) and when imposing behaviour (legal standard disposition). Less frequently it appears at the moment of imposing possible results of incorrect action (legal standard sanction). The situation is similar when determining methods of settling a given issue in procedural law. For the order of argument, it should be added that no inclusive paratactic utterances appear in all examined legal acts (inclusive utterances constitute 0.3% while exclusive utterances constitute 3.6%). These results do not differ too much from results acquired during studies of scientific and prose texts.

The second type of compound utterances are hypotactic utterances, which can express a dependency between states of affairs in the fullest and most precise manner possible. Among them it is possible to differentiate subject, attributive, complementary, predicative, and adverbial conjunctions. The adverbial conjunctions are divided into subtypes: clause of time, clause of place, clause of goal, clause of cause, clause of effect, clause of method, clause of degree and measure, clause of condition, clause of concession, and clause of accompanying factor (accessory). Criminal Law and Civil Law texts are dominated by adverbial conjunctions – 42.7% and 53.1% respectively. Attributive conjunctions are the most often used conjunctions in Administrative Law (58%). The second most often used conjunction in Criminal Law and Civil Law is attributive hypotaxis (39.3% and 41.4% respectively) while the second place in the scope of Administrative Law is taken by adverbial hypotaxis (35.6%). The participation of complementary conjunctions constitutes a small percent that amount to 5.9% for Criminal Law, 6% for Civil Law, and 5.9% for Administrative Law. A distinctive feature of Criminal Law is the relatively big participation of subject utterances (10%) when compared to Civil Law (1.6%) and Administrative Law (0.5%), which is related to the



specific type of legal provisions occurring in the Criminal Code ("who does x is subject to y"). None of examined texts contains predicative conjunctions. In the scope of adverbial hypotactic conjunctions, the most often used conjunction is adverbial hypotaxis of condition (over 25% in each branch of the Law), time (from 3.2% to 6.7%), method (from 3.2% to 4.2%), and accompanying factor (from 1.6% to 3.8%). The remaining types of adverbial hypotaxis in total amount to less than 1% for all examined branches of the Law. However, the presented results will take an actual meaning only after they are compared to results of other researchers. Therefore, it is worth to indicate that legal texts are characterised by the greatest participation of attributive hypotaxis among the collected research background (46.3%). These results are confirmed by Mikołajczak's research, who does not closely characterise the structure of compound utterances, but indicates that attributive conjunctions occur the most often. The second highest result belongs to scientific texts (37%). The next result is smaller by over 10% [28]. In texts collated with legal acts, complementary subordinate utterances constitute almost 1/4 of hypotactic conjunctions. Results acquired for the examined acts significantly differ from indicated results. Complementary utterances in legal acts do not exceed 1/16 (5.9%) of all utterances. Adverbial hypotaxis is the second most often occurring type of hypotactic conjunctions in compound utterances of legal acts (43.8%). The indicated result does not differ significantly from results from Gombrowicz's prose (48.5%) and artistic prose of the Interwar period (45.4%). The least number of adverbial conjunctions can be found in scientific texts (20.8%). The big participation of adverbial hypotaxis in legal texts stems out from numerous condition structures in provisions of the law ("if x, then y"; "in the event of x, y"; "in case of x, y"). Adverbial utterances of condition cover 31% of all hypotactic conjunctions. The second place was taken by adverbial utterances of time (5.1%) and third place – by adverbial utterances of method (3.9%). The last significant type of adverbial hypotactic conjunction is accompanying factor hypotaxis (2.4%). The remaining types of adverbial utterances do not exceed 0.5%. Conditional utterances appear relatively often also in scientific texts (18.3%). Therefore, it is necessary to reject Klemensiewicz's statement that conditional hypotaxis is rarely observed [29]. Although the results acquired for legal acts in the scope of adverbial hypotaxis significantly differ from results of other examined texts, they should not surprise when considering the specific construction types of provisions. One of them, conditional parataxis ("if x, then y"; "in the event of x, y"; "in case of x, y"), was already mentioned in the deliberations [12]. Another type of legal provision is a provision that utilises adverbial conjunctions of time ("when x, then y"; "whereas x, then y"). The faint participation of adverbial conjunctions of effect and goal might raise contemplations due to the nature of legal provisions (which impose or prohibit determined behaviours while simultaneously indicating sanctions in case of failing to observe them).

The next examined parameter is the number of hypotaxis degrees and average number of hypotaxis degrees in compound utterances (build-up profile of compound utterances). The examined texts are dominated by utterances with single subordinate level (73.4%) and it is a tendency occurring in all analysed legal texts [30]. Utterances with second subordinate level amount to a much smaller amount (18.1%). The examined texts contain very little utterances with no subordinate level (in which all subclauses are compound utterances) – 6.5%. A faint percent is constituted by utterances with third subordinate level (1.7%) and four and more subordinate levels (0.2%). Considering the above, the number of hypotaxis levels for specific branches of the Law amounts to 1.21 level of hypotaxis for Criminal Law, 1.11 level for Civil Law, and 1.15 level for Administrative Law, which in total



gives 1.16 level of hypotaxis for all examined legal acts. In texts constituting as a background for results presented by me, only Mikołajczak when examining scientific texts differentiated zero level hypotaxis (i.e. counts only paratactic utterances) and its percentage participation amounting to 31.3%. In each text, the most numerous utterances have first subordinate level (42.4% in scientific texts, 80% in Gombrowicz's prose, 73.2% in Prus' works, 82.7% in Żeromski's works, 77.4% in artistic prose of the Interwar period; as a reminder, in legal acts it amounts to 73.4%). The participation of utterances with subsequent subordinate levels in all analysed texts is quite similar. The only, although small, surprise can be the faint participation of utterances with very high build-up profile (4 and more hypotaxis levels) in legal acts. This parameter amounted to 0.2% for the examined acts while for scientific texts it was 3.6%. It is a significant difference that at the same time indicates that the complexity level of legal texts is smaller than in scientific texts. This thesis is reflected in results of average number of hypotaxis levels for specific types of texts -1.16 levels of hypotaxis for legal acts, 1.2 levels for scientific texts, and 1.27 levels for prose in general.

The analysed parameter must be compared with the number of component utterances in compound utterances and average number of component utterances in compound utterances. In the scope of analysed Criminal Law utterances, the most complex compound utterance consisted of seventeen subclauses (for comparison, the most complex compound utterance in Civil Law and Administrative Law had ten utterances in each branch). Of course, the least complex level of compound utterances is one consisting of two subclauses. In that regard, the average number of subclauses in compound utterances for Criminal Law is 2.97, for Civil Law - 3.19, and for Administrative Law – 3.11. In total, one compound utterance consists of 3.09 subclauses. The average number of subclauses in compound utterances in almost all considered texts constituting as a background for my research is smaller and amounts to 2.89 for scientific texts, 3.51 for Gombrowicz's prose, 2.88 for Prus' works, 2.51 for Żeromski's works, and 2.8 for artistic prose of the Interwar period. The summary of this parameter with build-up profile of compound utterances leads to the following conclusions. Therefore, it should be stated that legal acts are characterised by a significant horizontal development of compound utterances, but have a relatively small vertical development. It is possible to observe an often use of paratactic conjunctions in compound utterances or the use of numerous, singular interjections in the course of main utterance. While the first solution can encourage a clear and legible text, the second solution is disturbing and can contribute to considerable complexity of passed content. However, my experiences related to syntactic analysis of legal texts indicate that Polish legal acts are characterised by often interjections into the course of main narration. These interjections often constitute as a reference to other provisions and their contents, to definitions, and to other legal acts.

After concluding the analysis of compound utterances in examined texts it is time to move on to refer results acquired in the process of syntactic partitioning of simple utterances and subclauses. The first parameter, which is extremely important in this context, is the length of simple utterances and subclauses measured with number of components measured with number of components. Firstly, we should indicate discrepancies that appear in the scope of specific branches of the Law, as well as simple utterances and subclauses. This will be the best depicted by the following Tab. 1.

	length of sin measured	nple utterances an with number of co	d subclauses omponents	average length of simple utterances and subclauses measured with number of components				
	simple utterances	subclauses	total	simple utterances	subclauses	total		
Criminal Law	4-32	1-42	1-42	10.68	7.15	8.92		
Civil Law	3-52	1-53	1-53	11.25	6.93	9.09		
Administrative Law	4-76	1-75	1-76	16.93	9.09	13.01		
total (sum/average)	3-76	1-75	1-76	12.95	7.72	10.34		

Tab. 1. The length of simple utterances and subclauses measured with number of components measured with number of components

#### Source: own calculations

By comparing the results above with results acquired by Mikołajczak and Ruszkowski, we should first and foremost point out that the average length of simple utterances and subclauses measured with number of components in all texts is smaller than in case of legal acts (the value for scientific texts amounts to 9.34 compontent per clause and 6.58 for prose in general). This leads to a conclusion that both simple utterances and subclauses are exceptionally well developed. The results between simple utterances and subclauses cannot differ significantly, although the subject literature used to treat both construction in a separate way because of the considerable differences in their structure. It is assumed that simple utterances are more developed than subclauses, which due to their function in compound utterance must have a limited horizontal development in order to not make the message too complex. However, this principle is not widely used in legal texts. Although the average length of simple utterances and subclauses measured is different (12.95 in simple utterances and 7.72 in subclauses), it does not contradict the existence of exceptionally well-developed constructions in subclauses (comp. Tab. 1. length of simple utterances and subclauses measured with number of components). This process certainly does not help with text's comprehensibility, which in turn does not carry out the legal clarity postulation.

Similarly, to compound utterances, in order to acquire the complete image of a given syntactic structure for simple utterances and subclauses it is necessary to compare the length of a clause (horizontal development) with build-up profile and thus with relations between components, level of their depth, or complexity. Data concerning the numbers of structural development levels (from-to) and average number of structural development levels for simple utterances and subclauses (build-up profile) for the analysed legal acts are presented in the Tab. 2 below [31].

Tab. 2. The number of structural development levels (from-to) and average number of structural development levels for simple utterances and subclauses (build-up profile)

	number of s	structural develop (from-to)	oment levels	average number of structural development levels for simple utterances and subclauses			
	simple utterances subclauses total				subclauses	total	
Criminal Law	3-9	2-13	2-13	5.43	5.49	4.96	
Civil Law	3-14	1-10	1-14	5.72	4.5	5.11	
Administrative Law	3-18	2-15	2-18	6.46	4.94	5.7	
total (sum/average)	3-18	1-15	1-18	5.87	4.64	5.26	

Source: own calculations

When compiling data concerning the horizontal development (number of components) and vertical development (build-up profile), we can formulate the following conclusions. The texts of analysed legal acts in the scope of simple utterances and subclauses are characterised by exceptionally great level of structural development when compared to results indicated by other researchers (maximum number of components in other texts is 68 for Żeromski's works. Sadly, Mikołajczak did not provide the value of examined parameter for scientific texts. His statements end on a table containing column titled "16 and more components"). In contrast, the average number of components for specific text categories is as follows: 9.34 for scientific texts, 2.78 for Prus' works, 7.63 for Żeromski's works, and 10.34 for legal acts. The average number of structural development levels amounts to 3.5 for scientific texts, 2.23 for Prus' works, 4.03 for Żeromski's works (however, this index concerns only simple utterances as there is no data for subclauses), and 5.26 for legal acts. Thus, it is easy to notice that simple utterances and subclauses of the examined legal texts are relatively the longest ones and simultaneously have the biggest complexity level. Such procedure has allowed the legislator to include the maximum number of contents in each utterance. Unfortunately, because of that the utterances generally are complex, difficult to understand, and highly murky.

Deliberations in this scope should be completed by reflections on the participation of simple utterances and subclauses of various length in the total number of simple utterances and subclauses. The results are not surprising. In the examined legal acts, the most numerous utterances consist of 4-6 components (32.85%) and 7-9 components (20.21%). The most numerous utterances in almost all texts constituting as background for this research consist of 1-3 components (44.1% for Żeromski's works and 50.9% for Prus' works). The second place in indicated cases is taken by 4-6 component utterances (35% for Żeromski's works and 35.7% for Prus' works). The case is different for scientific texts – the most numerous utterances consist of 4-6 components (37.7%) and 1-3 components (37.2%). The third place in each of the examined texts constituting as background for this research is taken by 7-9 component utterances (14.8% for scientific texts, 9.4% for Żeromski's works, and 11.7% for Prus' works). Legal acts represent different results. In particular, they are characterised by high participation of long utterances (10-15 components – 16.39%) and exceptionally long utterances



(16 and more components -11.11%). The same parameter for scientific texts amounts to levels of 8.1% and 2.2% respectively. The results of these studies only confirm the length of simple utterances and subclauses of examined legal acts, as well as their high complexity level.

Components, that is, the participation of specific component types in the total number of components and participation of specific types of phrases in total number of phrases constitute as the last examined element. As Ruszkowski points out, "The statistical structure of phrases, also called the secondary parts of a utterance, has a greater meaning for the stylistic visage of a text" [2]. Thus, greater attention will be paid to them. In the scope of distribution of specific phrases in their total number, attention is drawn to the high percentage participation of grammatical modifiers (52.1%), which exceeds the participation of the said phrases in prose texts, but is smaller than participation in scientific texts (57.7%). Grammatical modifiers are an exceptionally universal phrase as they can refer to subject, object, and adverbial. This probably explains their high frequency in all of the examined texts. They are used to precisely determine subjects and enrich the cognitive content of defined word. Grammatical modifier can also be used to rhythmise a utterance although this function will probably have greater meaning in artistic texts. There is no doubt, however, that a great number of grammatical modifiers is an expression for author's aim at specificity and accuracy of a description. This factor will have a great application in the analysis of legal acts.

In contrast, the participation of adverbials is small (16.3%), even when referred to the remaining considered texts (scientific texts had the second lowest result of 18.6%). The purpose of adverbials is to precise time, place, cause, condition, effect, goal, method, and other circumstances of a phenomenon. Adverbials are significant in the context of reconstructing legal standard hypothesis, which indicates circumstances under which the recipient has to behave in a determined way, from legal provisions. For that reason, adverbials in the analysed texts are dominated by utterances of time, condition, method, and accompanying factor. The participation of utterances of time and place in the total number of adverbials in the examined legal acts, as well as their participation in scientific texts, is almost identical (respectively 20.12% utterances of time and 30.72% utterances of place in legal acts are characterised by great (in relation to other considered texts) participation of utterances of condition (4.39%), which in the remaining analyses of results were marginalised and placed in the "other" category. The participation of indicated adverbials is related to particular structures of legal provisions, which were already mentioned above.

The average participation of objects in the total number of phrases (31.6%) should not be surprising. Researchers adopt that objects are used to achieve the effect of dynamism of the text. Objects constitute a recall to patterns of spoken Polish language. Therefore, they appear more often in dialogue parts of prose texts while their participation in narrative parts is smaller. This stems from the fact that legal provisions are formulated without aim to achieve dynamism effect.

# Conclusions

The conducted syntactic analysis of six key material and procedural acts from three branches of the Law (Criminal Law, Civil Law, and Administrative Law) has allowed to mark few features characteristic for the syntax of Polish legal acts. Firstly, the compound utterances, simple utterances,



and subclauses are characterised by exceptionally great scope of horizontal and vertical development. This means that the utterances are very long while simultaneously are characterised by quite high complexity of relations between subclauses in compound utterances and exceptionally high complexity of relations between subclauses in simple utterances and subclauses. Secondly, their length points to the possession of a great number of contents – they are overflowing with information. Thirdly, the legislator uses numerous interjections in the course of main utterance to precise the passed contents. Such process results in small number of hypotaxis levels at a significant horizontal development. Fourthly, syntactic structures show particular constructions of legal provisions resulting from the fact that they constitute as the source of reconstructing legal standards, which in turn are characterised by quite stable "hypothesis-disposition-sanction" construction. Because of that, the great number of adverbial utterances of condition, time, and method is not surprising. Fifthly, the legislator uses numerous grammatical modifiers, which determine not only subjects, but also objects and adverbials, in order to precise the presented contents. All of the presented observations allow to formulate one, superordinate statement: the Polish legislator is committed to passing on as much information as possible while achieving the greatest utterance accuracy possible. However, it is necessary to state with regret that adding subsequent subclauses and components ruins the effort. The postulation on the legal clarity will never be carried out if its syntactic structure remains unchanged.

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positivism, 27% for Young Poland, 31.6% for the Interwar period, and 39.6% for years 1945-1970. The result acquired for legal texts places somewhere close to results achieved for texts written in the Interwar period. This shows the deviation of this result from standard for 21<sup>st</sup> century. According to Śliwiński's research, the participation of simple utterances in the total number of utterances increases over time. See W. Śliwiński, *Udział zdania pojedynczego w języku pisanym współczesnej polszczyzny: Z zagadnień języka artystycznego: materiały I konferencji naukowej poświęconej problematyce języka literatury zorganizowanej przez Instytut Filologii Polskiej UJ (The participation of simple utterance in the written language of contemporary Polish language: From the issues of artistic language: materials from the 1<sup>st</sup> conference dedicated to the topic of literature language organised by the Faculty of Polish Philology at JU), J. Bubak, A. Wilkoń (red.), Kraków: Scientific Volumes of the Jagiellonian University 1975.* 

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- [28] It is worth to point out that this parameter for specific styles of Polish language is as follows: 16.34% for official style, 16.39% for journalistic style, 6.15% for slang style, 22.6% for artistic style, and 22.45% for scientific style. See A. Stypko, Zdania przydawkowe w różnych stylach funkcjonalnych współczesnej polszczyzny (Attributive utterances in various functional styles of contemporary Polish language), Poradnik Językowy Magazine (1985), vol. 1, p. 5-30. Depending on the adopted nomenclature, theoretical legal texts will fall under official style or official-chancellerial style. Still, this result significantly differs from findings made by me (16.34% vs 46.3%). However, it should be remembered that legal texts are just a fragment of official style texts. This group will also include requests, applications, statutes, rulings, etc. As a side note I highlight that results acquired by Mikołajczak for scientific texts also considerably differ from researcher's results (37% vs 22.45%).



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# **PSEUDOINVERSE BINARY MATRIX (N×2)**

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#### Abstract:

The paper presents considerations concerning the existence of a pseudo-inverse binary matrix of the  $n \times 2$  type. The conditions for the existence of such a matrix were presented. Given are mathematical formulas to calculate the elements, if it exists. The relationships between the elements of the matrix A and the elements of the pseudo-inverse matrix B are presented in Tab. 1, 2 and 3. Three sums were defined for the given matrix A: *SUMA*1 - xor sum of the first row, *SUMA*2 - xor sum of the products of the corresponding elements of the first row and the second line, *SUMA*3 - xor sum of the pseudo-inverse binary matrix. The elements of the binary pseudo-inverse matrix are determined on the basis of the knowledge of the matrix of a given A and these three sums. An example of finding a binary pseudo-inverse matrix is given.

#### **Keywords:**

binary matrix, pseudo-inverse, xor operation

# Introduction

The idea of the pseudo-inverse matrix was first presented in April 1920 by Eliakim Hastings Moore (1862-1932) at the 14th Western Conference of the American Mathematical Society at the University of Chicago [1, 5].

Independently of it, in 1955 Roger Penrose presented a generalized inverse matrix, i.e. a generalization of the concept of an inverse matrix to rectangular matrices. From their names, these matrices are called pseudo-inverse Moore-Penrose.

Much earlier, in 1903, the idea of the pseudo-inverse of integral operators was proposed by Fredholm, a Swedish mathematician, co-founder of the theory of integral equations.

John von Neumann (1903-1957) published "On regular rings" in 1936, which also featured the idea of pseudo-inverse matrices.

In 1949, the Chinese mathematician Yuan Tseng Yung introduced in his works [7, 8] generalized inverse operators in the Hilbert space.

The idea of introducing the "inverse matrix" into a rectangular matrix was presented in 1951 (independently of Moore, von Neumann and Tseng) by the Swedish surveyor and mathematician



Arne Bjerhammar (1917-2011) in the work "Rectangular inverse matrices with special reference to geodetic calculations".

# Definition and properties of the pseudo-inverse matrix

Let *A* be a matrix over the field of real or complex numbers. Matrix *B* is a generalized inverse of A if it satisfies the following four conditions:

$$A \cdot B \cdot A = A, \quad B \cdot A \cdot B = B, \quad (A \cdot B)^* = A \cdot B, \quad (B \cdot A)^* = B \cdot A$$
 (1)

where \* denotes Hermitian conjugation of matrices [10].

Hermitian conjugation of a matrix is a combination of the transposition and complex conjugations performed on a matrix in general, i.e.

$$if \quad A = \{a_{ij}\}, \quad to \quad A^* = \{\overline{a_{ij}}\}, \tag{2}$$

where is  $\overline{a_{ji}}$  complex conjugate of the number  $a_{ji}$ . It can also be written as [11]

$$A^* = \overline{A}^T = \overline{A}^T \,. \tag{3}$$

Complex conjugate - unary algebraic operation defined on complex numbers consisting in changing the sign of the imaginary part of a given complex number.

Conjugation of a complex number in algebraic form z = a + bi, where  $a, b \in R$ , is a number  $\overline{z} = a + bi$  called conjugate number to z [12].

For a matrix over the field of real numbers, the Hermitian conjugate is equivalent to matrix transposition. The SVD distribution according to the singular values of matrix *A* is used to find the pseudo-inverse matrix.

Matlab has a function to calculate the pseudo-inverse Moore-Penrose matrix. This is a function called ",pinv" (B = pinv (A)) [9].

Since a binary matrix has only 0 or 1 elements, a pseudo-inverse matrix does not always exist.

The aim of this work is to show how to find a binary pseudo-inverse matrix of type  $(n \times 2)$  in case of its existence.

# Pseudo-inverse binary matrix with two lines

Considerations concerning a binary pseudo-inverse matrix of the  $(m \times n)$  type can be found in [3]. Due to the fact that for a binary matrix of the  $(2 \times n)$  type, it is easy to determine whether there is a pseudo-inverse matrix and its elements can be easily determined in the case of its existence, therefore this work deals with this issue.

Given is a binary matrix  $A(2 \times n)$ 

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \end{bmatrix}.$$
 (4)

We want to consider if there is a pseudo-inverse binary matrix



$$B = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \\ \vdots & \vdots \\ b_{n1} & b_{n2} \end{bmatrix}.$$
 (5)

If so, how to find the elements of this matrix? We will only work with the numbers 0 or 1. Instead of adding and subtracting, we will be using the "xor" operation. As a reminder we give: 0 xor 0 = 0, 0 xor 1 = 1, 1 xor 0 = 1, 1 xor 1 = 0. In the calculations we will use the sign  $\oplus$  instead of "xor". Multiple summation will be marked with the symbol  $\sum_{\oplus}$ , instead of the usual summation symbol  $\sum_{\oplus}$ .

Four conditions must be met for the pseudo-inverse matrix.

**Condition 1.**  $A \cdot B = (A \cdot B)^T$ .

We have

$$A \cdot B = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \end{bmatrix} \cdot \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \\ \vdots & \vdots \\ b_{n1} & b_{n2} \end{bmatrix} = \begin{bmatrix} \sum_{\substack{n \\ \oplus i=1}}^{n} a_{1i} b_{i1} & \sum_{\substack{m \\ \oplus i=1}}^{n} a_{1i} b_{i2} \\ \sum_{\substack{m \\ \oplus i=1}}^{n} a_{2i} b_{i1} & \sum_{\substack{m \\ \oplus i=1}}^{n} a_{2i} b_{i2} \end{bmatrix}.$$
 (6)

For  $A \cdot B = (A \cdot B)^T$  there must be

$$\sum_{\substack{\oplus i=1\\ \oplus i=1}}^{n} a_{1i} b_{i2} = \sum_{\substack{\oplus i=1\\ \oplus i=1}}^{n} a_{2i} b_{i1} .$$
(7)

To facilitate further entries, we will adopt the following symbols:

$$s_{1} = \sum_{\substack{\oplus i=1\\ \oplus i=1}}^{n} a_{1i}b_{i1}, \quad s_{2} = \sum_{\substack{\oplus i=1\\ \oplus i=1}}^{n} a_{1i}b_{i2}, \quad s_{3} = \sum_{\substack{\oplus i=1\\ \oplus i=1}}^{n} a_{2i}b_{i1}, \quad s_{4} = \sum_{\substack{\oplus i=1\\ \oplus i=1}}^{n} a_{2i}b_{i2}.$$
(8)

**Condition 2.**  $A \cdot B \cdot A = A$ .

We have

$$A \cdot B \cdot A = \begin{bmatrix} a_{11}s_1 \oplus a_{21}s_2 & a_{12}s_1 \oplus a_{22}s_2 & \dots & a_{1n}s_1 \oplus a_{2n}s_2 \\ a_{11}s_3 \oplus a_{21}s_4 & a_{12}s_3 \oplus a_{22}s_4 & \dots & a_{1n}s_3 \oplus a_{2n}s_4 \end{bmatrix}.$$
(9)

For  $A \cdot B \cdot A = A$  to be equal, it must be:

$$s_1 = 1, \quad s_2 = 0, \quad s_3 = 0, \quad s_4 = 1.$$
 (10)

**Condition 3.**  $B \cdot A = (B \cdot A)^T$ .

We have

$$B \cdot A = \begin{vmatrix} b_{11}a_{11} \oplus b_{12}a_{21} & b_{11}a_{12} \oplus b_{12}a_{22} & \cdots & b_{11}a_{1n} \oplus b_{12}a_{2n} \\ b_{21}a_{11} \oplus b_{22}a_{21} & b_{21}a_{12} \oplus b_{22}a_{22} & \cdots & b_{21}a_{1n} \oplus b_{22}a_{2n} \\ \vdots & \vdots & \vdots \\ b_{n1}a_{11} \oplus b_{n2}a_{21} & b_{n1}a_{12} \oplus b_{n2}a_{22} & \cdots & b_{n1}a_{1n} \oplus b_{n2}a_{2n} \end{vmatrix}$$
(11)

For  $B \cdot A = (B \cdot A)^T$  there must be

$$b_{i1}a_{1j} \oplus b_{i2}a_{2j} = b_{j1}a_{1i} \oplus b_{j2}a_{2i}.$$
(12)

**Condition 4.**  $B \cdot A \cdot B = B$ .



We have

$$B \cdot A \cdot B = \begin{bmatrix} b_{11}s_1 \oplus b_{12}s_3 & b_{11}s_2 \oplus b_{12}s_4 \\ b_{21}s_1 \oplus b_{22}s_3 & b_{21}s_2 \oplus b_{22}s_4 \\ \vdots & \vdots \\ b_{n1}s_1 \oplus b_{n2}s_3 & b_{n1}s_2 \oplus b_{n2}s_4 \end{bmatrix}.$$
(13)

For an equality to be  $B \cdot A \cdot B = B$  it must be:

$$s_1 = 1, \quad s_2 = 0, \quad s_3 = 0, \quad s_4 = 1.$$
 (14)

The same relationship is given by the formula (10).

S

What conclusions can be drawn from considering conditions 3 and 4. Must be  $\sum_{\oplus i=1}^{n} a_{1i}b_{i1} = 1$ .

This equality only holds if there is an odd number of indices ,i'' such that  $a_{1i}=1$  and  $b_{i1}=1$ . Otherwise, this sum would be 0. Let us denote this set of indicators as *Ws*1. So, we have

$$\sum_{\substack{\oplus i \in Ws1}} a_{1i} = 1 \quad and \quad \sum_{\substack{\oplus i \in Ws1}} b_{i1} = 1.$$
(15)

Too  $\sum_{\oplus i=1}^{n} a_{2i}b_{i2} = 1$ . This equality only holds if there is an odd number of indices "i" such that  $a_{2i}=1$ 

and  $b_{i2}=1$ . Otherwise, this sum would be 0. Let us denote this set of indices as Ws2. So, we have

$$\sum_{\substack{\oplus i \in Ws^2}} a_{2i} = 1 \quad and \quad \sum_{\substack{\oplus i \in Ws^2}} b_{i2} = 1.$$
(16)

Let us consider the equation (12) for each ,j". We sum up by sides because of  $,i \in Ws1$ ", and then sum by sides because of  $,i \in Ws2$ ". Considering (15) and (16) we have

$$a_{1j} \oplus a_{2j} \sum_{\oplus i \in W_{S1}} b_{i2} = b_{j1} \oplus b_{j2} \sum_{\oplus i \in W_{S1}} a_{2i}, \quad a_{1j} \sum_{\oplus i \in W_{S2}} b_{i1} \oplus a_{2j} = b_{j1} \sum_{\oplus i \in W_{S2}} a_{1i} \oplus b_{j2}.$$
(17)

To facilitate further entries, we will adopt the following symbols:

$$u_{1} = \sum_{\oplus i \in W_{S1}} b_{i2}, \quad u_{2} = \sum_{\oplus i \in W_{S1}} a_{2i}, \quad u_{3} = \sum_{\oplus i \in W_{S2}} b_{i1}, \quad u_{4} = \sum_{\oplus i \in W_{S2}} a_{1i}.$$
(18)

We get the following system of two equations

$$a_{1j} \oplus a_{2j}u_1 = b_{j1} \oplus b_{j2}u_2.$$
<sup>(19)</sup>

$$a_{1j}u_3 \oplus a_{2j} = b_{j1}u_4 \oplus b_{j2}.$$
<sup>(20)</sup>

Assuming that  $u_1$ ,  $u_2$ ,  $u_3$ ,  $u_4$  can take the values 0 or 1, we get the following combination of equations (19) and (20).

No	$u_1$	$u_2$	И3	$u_4$	Equation (19)	Equation (20)
1	0	0	0	0	$a_{1i} = b_{i1}$	$a_{2i} = b_{i2}$
2	0	0	0	1	$a_{1j} = b_{j1}$	$a_{2i} = b_{i1} \oplus b_{i2}$
3	0	0	1	0	$a_{1j} = b_{j1}$	$a_{1j} \oplus a_{2j} = b_{j2}$
4	0	0	1	1	$a_{1j} = b_{j1}$	$a_{2j} = b_{j2}$
5	0	1	0	0	$a_{1j} = b_{j1} \oplus b_{j2}$	$a_{2j} = b_{j1} \oplus b_{j2}$
6	0	1	0	1	$a_{1j} = b_{j1} \oplus b_{j2}$	$a_{1j} \oplus a_{2j} = b_{j1} \oplus b_{j2}$
7	0	1	1	0	$a_{1j} = b_{j1} \oplus b_{j2}$	$a_{1i} \oplus a_{2i} = b_{i2}$
8	0	1	1	1	$a_{1j} = b_{j1} \oplus b_{j2}$	$a_{1j} \oplus a_{2j} = b_{j1} \oplus b_{j2}$
9	1	0	0	0	$a_{1j} \oplus a_{2j} = b_{j1}$	$a_{2j} = b_{j2}$
10	1	0	0	1	$a_{1j} \oplus a_{2j} = b_{j1}$	$a_{2j} = b_{j1} \oplus b_{j2}$
11	1	0	1	0	$a_{1j} \oplus a_{2j} = b_{j1}$	$a_{1i} \oplus a_{2i} = b_{i2}$
12	1	0	1	1	$a_{1j} \oplus a_{2j} = b_{j1}$	$a_{1j} \oplus a_{2j} = b_{j1} \oplus b_{j2}$
13	1	1	0	0	$a_{1j} \oplus a_{2j} = b_{j1} \oplus b_{j2}$	$a_{2j} = b_{j2}$
14	1	1	0	1	$a_{1j} \oplus a_{2j} = b_{j1} \oplus b_{j2}$	$a_{2j} = b_{j1} \oplus b_{j2}$
15	1	1	1	0	$a_{1j} \oplus a_{2j} = b_{j1} \oplus b_{j2}$	$a_{1j} \oplus a_{2j} = b_{j2}$
16	1	1	1	1	$a_{1i} \oplus a_{2i} = b_{i1} \oplus b_{i2}$	$a_{1i} \oplus a_{2i} = b_{i1} \oplus b_{i2}$

Tab. 1. The form of equations (19) and (20) for different values of  $u_1$ ,  $u_2$ ,  $u_3$ ,  $u_4$ 

#### Source: own calculations

From equation (20) we determine  $b_{j2}$  and insert it into equation (19).

$$b_{j2} = a_{1j}u_3 \oplus a_{2j} \oplus b_{j1}u_4, \quad a_{1j} \oplus a_{2j}u_1 = b_{j1} \oplus (a_{1j}u_3 \oplus a_{2j} \oplus b_{j1}u_4)u_2.$$
(21)

By transforming further we get

$$a_{1j} \oplus a_{2j}u_1 = b_{j1} \oplus a_{1j}u_3u_2 \oplus a_{2j}u_2 \oplus b_{j1}u_4u_2.$$
<sup>(22)</sup>

$$b_{j1} \oplus b_{j1}u_4u_2 = a_{1j} \oplus a_{2j}u_1 \oplus a_{1j}u_3u_2 \oplus a_{2j}u_2.$$
<sup>(23)</sup>

$$b_{j1}(1 \oplus u_2 u_4) = a_{1j}(1 \oplus u_2 u_3) \oplus a_{2j}(u_1 \oplus u_2).$$
(24)

Formulas (24) and (21) are used to determine the pseudo-inverse matrix on the basis of  $u_1$ ,  $u_2$ ,  $u_3$ ,  $u_4$  values.

It should be noted that  $u_2$  and  $u_4$  in formula (24) cannot be simultaneously ones. Then we have

$$b_{j1} = a_{1j}(1 \oplus u_2 u_3) \oplus a_{2j}(u_1 \oplus u_2), \quad b_{j2} = a_{1j}u_3 \oplus a_{2j} \oplus b_{j1}u_4.$$
(25)

Note that in line 16 of Tab. 1, the form of equations (19) and (20) is identical. This situation requires separate analysis. There are two identical equations here:  $a_{1j} \oplus a_{2j} = b_{j1} \oplus b_{j2}$ . This equality can occur in two cases:

$$(b_{j1} = a_{1j} \quad and \quad b_{j2} = a_{2j}) \quad or \quad (b_{j1} = a_{2j} \quad and \quad b_{j2} = a_{1j}).$$
 (26)

For the first case, it should be:

$$s_1 = \sum_{\oplus i=1}^n a_{1i} b_{i1} = \sum_{\oplus i=1}^n a_{1i} a_{1i} = \sum_{\oplus i=1}^n a_{1i} = 1, \quad s_2 = \sum_{\oplus i=1}^n a_{1i} b_{i2} = \sum_{\oplus i=1}^n a_{1i} a_{2i} = 0, \quad (27)$$

$$s_{3} = \sum_{\oplus i=1}^{n} a_{2i} b_{i1} = \sum_{\oplus i=1}^{n} a_{2i} a_{1i} = 0, \quad s_{4} = \sum_{\oplus i=1}^{n} a_{2i} b_{i2} = \sum_{\oplus i=1}^{n} a_{2i} a_{2i} = \sum_{\oplus i=1}^{n} a_{2i} a_{2i} = 1.$$
(28)

Let us denote by Ws3 a set of indices ",i" such that  $a_{1i}=1$  and  $a_{2i}=1$ . We have then

$$\sum_{\substack{\oplus i \in Ws3}} a_{1i} = 1, \quad \sum_{\substack{\oplus i \in Ws3}} a_{2i} = 1, \quad \sum_{\substack{\oplus i \in Ws3}} a_{1i}a_{2i} = \sum_{i=1}^n a_{1i}a_{2i} = s_2 = 1.$$
(29)



We got a result contradicting the second equation (27). So the situation that  $b_{j1}=a_{1j}$  and  $b_{j2}=a_{2j}$  does not form a pseudo-inverse matrix.

For the second case, we have

$$s_1 = \sum_{\substack{\oplus i=1 \\ \oplus i=1}}^n a_{1i} b_{i1} = \sum_{\substack{\oplus i=1 \\ \oplus i=1}}^n a_{1i} a_{2i} = 1, \quad s_2 = \sum_{\substack{\oplus i=1 \\ \oplus i=1}}^n a_{1i} b_{i2} = \sum_{\substack{\oplus i=1 \\ \oplus i=1}}^n a_{1i} a_{1i} = \sum_{\substack{\oplus i=1 \\ \oplus i=1}}^n a_{1i} a_{2i} = 0, \quad (30)$$

$$s_{3} = \sum_{\oplus i=1}^{n} a_{2i} b_{i1} = \sum_{\oplus i=1}^{n} a_{2i} a_{2i} = \sum_{\oplus i=1}^{n} a_{2i} = 0, \quad s_{4} = \sum_{\oplus i=1}^{n} a_{2i} b_{i2} = \sum_{\oplus i=1}^{n} a_{2i} a_{1i} = 1.$$
(31)

Let us denote by Ws3 a set of indices ",i" such that  $a_{1i}=1$  and  $a_{2i}=1$ . We have then

$$\sum_{\substack{\oplus i \in W_{s3}}} a_{1i} = 1, \quad \sum_{\substack{\oplus i \in W_{s3}}} a_{2i} = 1, \quad \sum_{\substack{\oplus i \in W_{s3}}} a_{1i}a_{2i} = \sum_{\substack{\oplus i = 1}}^{n} a_{1i}a_{2i} = s_1 = s_4 = 1.$$
(32)

It is consistent with the first equation (30) and with the second equation (31). On the other hand, the second equation (30) and the first (31) will be satisfied when there will be an even number of ones in the rows of the matrix A. So for item 16 in Tab. 1 we take the equations  $b_{j1}=a_{2j}$  and  $b_{j2}=a_{1j}$ .

# Determining the pseudo-inverse matrix from the matrix A

In Tab. 1  $u_2=u_4=1$  also appears in lines 6, 8, 14. From Tab. 1 we remove lines with numbers 6, 8, 14, that is, those where there are no solutions or matrix *A* has one line with only zeros. We transform the equations so that the elements  $a_{1j}$  and  $a_{2j}$  are expressed by  $b_{j1}$  and  $b_{j2}$ .

No	$u_1$	$u_2$	<i>u</i> <sub>3</sub>	$u_4$	$b_{j1} =$	$b_{j2} =$
1	0	0	0	0	$b_{j1} = a_{1j}$	$b_{j2} = a_{2j}$
2	0	0	0	1	$b_{j1} = a_{1j}$	$b_{j2} = a_{1j} \oplus a_{2j}$
3	0	0	1	0	$b_{j1} = a_{1j}$	$b_{j2} = a_{1j} \oplus a_{2j}$
4	0	0	1	1	$b_{j1} = a_{1j}$	$b_{j2} = a_{2j}$
5	0	1	0	0	$b_{j1} = a_{1j} \oplus a_{2j}$	$b_{j2} = a_{2j}$
7	0	1	1	0	$b_{j1} = a_{2j}$	$b_{j2} = a_{1j} \oplus a_{2j}$
9	1	0	0	0	$b_{j1} = a_{1j} \oplus a_{2j}$	$b_{j2} = a_{2j}$
10	1	0	0	1	$b_{j1} = a_{1j} \oplus a_{2j}$	$b_{j2} = a_{1j}$
11	1	0	1	0	$b_{j1} = a_{1j} \oplus a_{2j}$	$b_{j2} = a_{1j} \oplus a_{2j}$
12	1	0	1	1	$b_{j1} = a_{1j} \oplus a_{2j}$	$b_{j2} = 0$
13	1	1	0	0	$b_{j1} = a_{1j}$	$b_{j2} = a_{2j}$
15	1	1	1	0	$b_{j1}=0$	$b_{j2} = a_{1j} \oplus a_{2j}$
16	1	1	1	1	$b_{i1} = a_{2i}$	$b_{i2} = a_{1i}$

Tab. 2. Finding the elements of the pseudo-inverse matrix depending on the values of  $u_1$ ,  $u_2$ ,  $u_3$ ,  $u_4$ 

#### Source: own calculations

We will now check for each row of Tab. 2 whether the four conditions for the existence of the pseudo-inverse matrix are met based on the equations given. We will also find the values of three sums:

$$SUMA1 = \sum_{\oplus i=1}^{n} a_{1i}, \quad SUMA2 = \sum_{\oplus i=1}^{n} a_{1i}a_{2i}, \quad SUMA3 = \sum_{\oplus i=1}^{n} a_{2i}.$$
 (33)

For row no. 1 we have

1. 
$$\sum_{\oplus i=1}^{n} a_{1i}b_{i1} = \sum_{\oplus i=1}^{n} a_{1i}a_{1i} = \sum_{\oplus i=1}^{n} a_{1i} = 1$$
,



when the number of ones in the first row of A is odd.

2. 
$$\sum_{\oplus i=1}^{n} a_{1i} b_{i2} = \sum_{\oplus i=1}^{n} a_{1i} a_{2i} = 0$$
,

when the number of ones on the same positions in the first and second rows of the matrix A is even.

3. 
$$\sum_{\oplus i=1}^{n} a_{2i} b_{i1} = \sum_{\oplus i=1}^{n} a_{2i} a_{1i} = 0$$
,

when the number of ones on the same positions in the first and second rows of the matrix A is even.

4. 
$$\sum_{\oplus i=1}^{n} a_{2i} b_{i2} = \sum_{\oplus i=1}^{n} a_{2i} a_{2i} = \sum_{\oplus i=1}^{n} a_{2i} = 1 = SUMA3$$
,

when the number of ones in the second row of A is odd.

We have here: *SUMA*1=1, *SUMA*2=0, *SUMA*3=1.

We continue like this with the remaining lines of Tab. 2 and spot possible contradictions. These contradictions appeared in the lines of Tab. 2 numbered: 2, 3, 5, 6, 9, 11, 12, 15.

From Tab, 2 we eliminated the rows in which there was a contradiction, instead of the values  $u_1$ ,  $u_2$ ,  $u_3$ ,  $u_4$  we put three sums: *SUM*1, *SUM*2, *SUM*3. We get Tab. 3.

No	SUMA1	SUMA2	SUMA3	$b_{j1} =$	$b_{j2} =$
1	1	0	1	$b_{j1} = a_{1j}$	$b_{j2} = a_{2j}$
4	1	0	1	$b_{j1} = a_{1j}$	$b_{j2} = a_{2j}$
7	1	1	0	$b_{j1} = a_{2j}$	$b_{j2} = a_{1j} \oplus a_{2j}$
10	0	1	1	$b_{j1} = a_{1j} \oplus a_{2j}$	$b_{j2} = a_{1j}$
13	1	0	1	$b_{j1} = a_{1j}$	$b_{j2} = a_{2j}$
16	0	1	0	$b_{j1} = a_{2j}$	$b_{j2} = a_{1j}$

Tab. 3. Simplified Tab. 2

Source: own calculations

There are four combinations of sums in this table: 1 0 1, 1 1 0, 0 1 1, 0 1 0. We write the elements of matrix *B* in the form

$$b_{j1} = w_1 \cdot a_{1j} \oplus w_2 \cdot a_{2j}, \quad b_{j2} = w_3 \cdot a_{1j} \oplus w_4 \cdot a_{2j}.$$
(34)

The relationships between the sums and the coefficients  $w_1$ ,  $w_2$ ,  $w_3$ ,  $w_3$  are as follows:

SUMA1	SUMA2	SUMA3	$b_{j1} =$	$b_{j2} =$	$W_1$	<i>W</i> 2	<i>W</i> 3	$W_4$
1	0	1	$b_{j1} = a_{1j}$	$b_{j2} = a_{2j}$	1	0	0	1
1	1	0	$b_{j1} = a_{2j}$	$b_{j2} = a_{1j} \oplus a_{2j}$	0	1	1	1
0	1	1	$b_{j1} = a_{1j} \oplus a_{2j}$	$b_{j2} = a_{1j}$	1	1	1	0
0	1	0	$b_{j1} = a_{2j}$	$b_{j2} = a_{1j}$	0	1	1	0

Tab. 4. Relationships between SUM1, SUM2, SUM3, and the coefficients w1, w2, w3, w3

#### Source: own calculations

We have such a dependency here:  $w_1$ =SUMA3,  $w_2$ =SUMA2,  $w_3$ =SUMA2,  $w_4$ =SUMA1.

So the elements of the pseudo-inverse matrix B, in the case of the existence of this matrix, we calculate from the formulas:

$$b_{j1} = a_{1j} \cdot SUMA3 \oplus a_{2j} \cdot SUMA2 = a_{1j} \cdot \left(\sum_{\oplus i=1}^{n} a_{2i}\right) \oplus a_{2j} \cdot \left(\sum_{\oplus i=1}^{n} a_{1i}a_{2i}\right), \tag{35}$$



$$b_{j2} = a_{1j} \cdot SUMA2 \oplus a_{2j} \cdot SUMA1 = a_{1j} \cdot \left(\sum_{\oplus i=1}^{n} a_{1i}a_{2i}\right) \oplus a_{2j} \cdot \left(\sum_{\oplus i=1}^{n} a_{1i}\right).$$
(36)

#### **Example 1**

Given matrix A. Check if there is a pseudo-inverse matrix B. If this matrix exists, specify its elements.

$$A = \begin{bmatrix} 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 & 1 \end{bmatrix}.$$

Based on the formulas (33) we have

$$SUMA1 = \sum_{\oplus i=1}^{n} a_{1i} = 0$$
,  $SUMA2\sum_{\oplus i=1}^{n} a_{1i}a_{2i} = 1$ ,  $SUMA3 = \sum_{\oplus i=1}^{n} a_{2i} = 1$ .

We calculate the elements  $b_{j1}$  based on the formula (35):

 $b_{11} = 1 \oplus 1 = 0$ ,  $b_{21} = 0 \oplus 1 = 1$ ,  $b_{31} = 1 \oplus 0 = 1$ ,  $b_{41} = 0 \oplus 0 = 0$ ,  $b_{51} = 0 \oplus 1 = 1$ .

We calculate the elements  $b_{j2}$  based on the formula (36):

$$b_{j2} = a_{1j} \cdot SUMA2 \oplus a_{2j} \cdot SUMA1 = a_{1j}.$$

 $b_{12} = a_{11} = 1$ ,  $b_{22} = a_{12} = 0$ ,  $b_{32} = a_{13} = 1$ ,  $b_{42} = a_{14} = 0$ ,  $b_{52} = a_{15} = 0$ .

The pseudo-inverse matrix has the form (four conditions for the existence of the matrix are met):

$$B = \begin{bmatrix} 0 & 1 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 & 0 \end{bmatrix}^{T}$$

# Conclusion

The authors undertook to answer the question whether there is also a pseudo-inverse zero-one matrix for a rectangular zero-one matrix of the  $(2 \times n)$  type. This topic has not been discussed in the literature so far. It turned out that there is a pseudo-inverse matrix for some matrices and not for others. The paper presents a method of finding such a pseudo-inverse binary matrix. Binary matrix *A* and the pseudo-inverse *B* matrix must meet the following conditions:  $A \cdot B \cdot A = A$ ,  $B \cdot A \cdot B = B$ ,  $A \cdot B = (A \cdot B)^T$ ,  $B \cdot A = (B \cdot A)^T$ . By describing these conditions and transforming them, simple formulas (35) and (36) were obtained for determining the elements of the pseudo-random matrix *B* on the basis of the elements of matrix *A*. Important quantities in these calculations are three sums: *SUM*1 denoting the sum of the elements of the first and second rows of the matrix *A* and *SUM*3 denoting the sum of the elements of the second row of the matrix *A*. These sums appear in equations (35) and (36). Tab. 4 can be used to determine if there is a binary pseudo-inverse matrix. Only four specific combinations of three sums: *SUM*1, *SUM*2, and *SUM*3 give a solution. Only when we find that there is a pseudo-inverse matrix, we apply formulas (35) and (36).

In the future, the authors of the paper intend to use a pseudo-inverse binary matrix of the ( $n \times 2$ ) type to encode the transmitted information.

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# MOTIVATION IN LEARNING FOREIGN LANGUAGES IN THE ERA OF REMOTE LEARNING

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#### Abstract:

Nowadays, children and young people are discouraged from learning foreign languages. There are many problems in language learning caused by remote learning as well as isolation. Schoolchildren have very large gaps in knowledge that are very difficult to make up. All this causes reluctance and lack of motivation to continue learning. Therefore, a number of actions are being taken that can improve the situation and help students develop their language competences.

# **Keywords:**

motivation, foreign languages, remote learning, learning

# Introduction

The article is devoted to the issue of motivation in learning a foreign language and the changes that motivation undergoes under the influence of remote learning. The text attempts to identify motivating and demotivating factors for part-time learning. The article also provides tips on how to shape students' motivation in online education.

Remote education in connection with the COVID-19 epidemic began unexpectedly. For some from day to day, for others from week to week. This caused a kind of disturbance of everyday functioning. Remote learning took place in kindergartens, schools at universities. Regardless of the duration of the pandemic, facilities must and will have to face it, doing their best. Currently, everything is returning to normal, but the epidemic has left its mark on the psyche of children and young people, which affects the effects of school work. The twenty-first century, characterized by ubiquitous digitality, has defined the direction of remote education moving towards online education. Even now, when many schools have returned to full-time teaching, e-learning offers are offered by numerous institutions and universities. A wide range of digital tools designed to conduct online classes, e-learning platforms, digital educational resources, seemed to create great opportunities for the course of remote education, in this difficult period for the world. However, the very first days, and then weeks, showed that the situation is much more complex than everyone originally thought. Technological equipment of institutions, availability of equipment and the Internet in homes, the level of digital competence of teachers and students, the availability of digital teaching materials, the methodology of online teaching, and above all a number of social issues related to



distance education have made remote education a very big challenge both for the institutions themselves, as well as - above all for teachers and students [1]. At the time of switching to remote mode, there were problems that took months to solve them and work out their work standards.

The time associated with remote learning, which for millions of students around the world has become a daily reality over the past two years, is over. There is no doubt that the lessons conducted via the Internet have had a negative impact on the physical and mental condition of children and adolescents, but not everyone has felt their negative effects. One of the first actions that was taken almost all over the world in the face of the spread of the coronavirus was to close schools and switch to a remote learning system. According to UNESCO data, the pandemic has interrupted the education of more than a billion children around the world. This has had an impact on the mental and physical state of adolescent children. Psychiatrists note the increased number of reports of anxiety and depression and impaired sense of security in the youngest.

However "he results of the researchers" analyses are not conclusive, they indicate that environmental and family factors and the mental state in which children were before the pandemic play a large role in feeling the effects of remote learning [2]. With the closure of many educational institutions, children were deprived of the opportunity to participate in physical education classes and most additional physical activities. Remote learning also limited the movement that children and young people had in connection with their daily commute to school and meetings with their peers. In many cases, not attending school has affected the eating habits of minors. It seems that students have become accustomed to the new standards and we can observe an internally motivated group of young people, which gives reason to believe that these are people who feel a strong need to learn languages. However, the experience of almost one and a half years of remote education allows you to feel a turn in the motivation of young people to learn. In the environment of teachers, voices are heard signaling a decrease in students' involvement in participating in lessons, as well as fulfilling school duties. Similar opinions come from parents. They complain about helplessness in the face of the absence of children from classes, difficulties in convincing children to learn using the existing arguments [2].

In order to be able to work effectively with the student, it is worth looking at the difficulties that he encounters in the educational process. Recognizing obstacles will allow the teacher to understand the student and adjust the ways of motivating the group to work, as well as shape the classes so that they serve less motivated listeners and are attractive to the more motivated. In the literature on the subject you can find many results of research on factors that may discourage remote learning. Among the difficulties that appear most often in online teaching, Lidia Pokrzycka [3] based on research mentioned:

- technical problems (lack of Access to the Internet, poor quality of connections, hardware shortages),

- living conditions,

-lack of motivation,

— a large amount of material transmitted without prior, precise explanation of what it is intended to be used for.

Although the above-mentioned difficulties apply to students – that is, the elderly and those more experienced in learning compared to high school students – a significant part of these problems may



concern teenagers. The most demotivating factors among young people were: fatigue and bad mood, the need to constantly be in front of a computer screen or other electronic device, inability or a problem with concentration in an online lesson. Other factors: the need for more own work, technical problems, problems with the organization of one's own time, uncertainty about returning to the stationary mode of learning, excess of materials received, excessive requirements set by teachers, too many theories during classes. Pokrzycka [3] - on the basis of research conducted among journalism students - stated that the important value of remote learning for participants are: freely chosen learning time and individual pace. In the case of high school students, flexible learning time should not matter much, because school lessons are obligatory according to a fixed plan and theoretically the student cannot choose any hours of classes. Many teachers wonder if the use of digital materials, which is actually becoming an everyday reality in remote learning, has a positive effect on the student. It seems that much depends on the students' awareness, on the goals they set for themselves, and on their intrinsic motivation, which teachers awaken, maintain or, on the contrary, extinguish. Does learning a foreign language online work? - it is worth asking this question at the end of this part of the article. "It's hard to say" - this is how most of the interested parties themselves answer.

As motivating factors for learning the language students mentioned conducting lessons in a practical and interesting way. Therefore, you should try to present the material in such a way that students understand what they will need it for and in what situations it can be used. These postulates also appear in the literature on the subject in the form of three principles of teaching foreign languages (the principle of communicativeness, the principle of situationality, the principle of cognitive). They make it easier to motivate students to interact in a foreign language. Indeed, "communication in a foreign language is one of the most motivational practices of language education. The ability to communicate in a foreign language increases students' self-esteem" – admits Anna Grabowska [4]. And it seems that there is now a great need to raise the self-esteem of students. How the material will be presented and the lesson conducted has a very big impact on the interest of students in it. In the era of the Internet and access to a variety of materials, we have enough opportunities to prepare an interesting and motivating language lesson. If the lesson is interesting, we will meet with the approval of students who will approach the form of remote learning in a different way. They will simply be more engaged. Motivation to learn a language requires the involvement of both parties. Not only the teacher, whose role in this process is, of course, crucial.

Motivation is at the heart of success in the learning process. It allows you to create a desire to act and participate in remote education. Meanwhile, online course programs usually do not take into account motivating components and assume that the will to act depends solely on the factors on the part of the learner. Sometimes motivating factors are introduced, but there are far too few of them. No action is possible if there is no will to act, but will is generally not possible without proper motivation. Motivating participants of remote learning prepares for the decision to act, but the decision itself can be made only when there is a will to act. Activities supporting learner activity can take place on three levels:

- supporting motivational processes,
- supporting volitional processes,
- ensure the dominance of positive emotions in the learning process.



For psychologists, motivation is the orientation of views and the need to perform a specific action. Motivation refers to the factors that explain the totality of the reasons and needs used in the action that activate, determine, or regulate individual behavior. Which of the given reasons or which need will be used in a given case depends, m.in, on the perception of achieving goals (e.g. improving the image, passing the subject, obtaining a diploma).

Very often in the literature there is a view about the need to maintain a high level of motivation, which is particularly emphasized in relation to courses conducted in the form of e-learning. The fact is that the number of people dropping out of studies and courses conducted remotely is relatively high. Therefore, in order to reduce the scale of this phenomenon, the aim is to achieve high motivation at all levels of remote learning. External activities consist in presenting the meaning of the subject, its role, the benefits of obtaining a diploma of completion of a course or studies. In this context, attention is also paid to the element of novelty, which evokes curiosity, and this in turn the desire to know. External actions, aimed openly at creating the will to act, affect the so-called external motivation. Meanwhile, in addition to external motivation, there is also - much more important - intrinsic motivation, which is generated independently by the learner. It is usually produced on the basis of facts that the individual takes from various sources and on the basis of the emotional state at the time of determining the level of motivation. It follows that, compared to directly motivating learners, it is better to provide them with information that affects the motivation of the group. Negative motivation occurs when the learner does not see the reasons and needs that would cause his action. It occurs quite often in the case of remote learning, when online courses do not contain motivational elements, and the loneliness of the learner and the lack of support from the teacher or group of learners undermine the sense of learning. This creates a negative attitude towards e-learning courses, and in extreme cases leads to the abandonment of such courses after they have started. It can also affect other course participants through negative statements, comments on discussion forums or directly by underestimating the statistics of people completing a given course. Introducing components that shape positive motivation not only reduces the action of negative emotions, but also strengthens the will to act. Cognitive psychology already recognizes the impact of the emotional environment on the motivations of learners and on the will to act. The constructivist approach also provides guidance on the shape of such an environment, where the student, through a variety of forms of communication, finds the best solutions for himself. Meanwhile, studies of motivation in both sexes no longer show such significant disproportions. Only slight differences in the intrinsic motivation of girls and boys were noted. Motivation is temporary and varies depending on the age of the learner. You can notice an earlier increase in motivation in girls, which is associated with puberty. Emotional-motivational components can play an important role in the presentation of natural material, including mainly physics. Especially in the case of girls and young women, where the influence of such factors is greater than the cognitive and operational-logical components, the level of motivation can be increased even to a significant extent by using "elements of experience" [5]. Showing films with elements of dramaturgy, introducing colorful animations, simulations of physical processes, as well as interesting nature experiments in which you can participate online, should contribute to a positive attitude towards the subject. Motivation influences the will, and the will is the basis of all actions. Remote learning, as one of the forms of action, requires specific techniques to support motivation and will, due to the frequent loneliness of learners and numerous cases of resignation from online courses.



Therefore, it is necessary to have incentive-volitional interactions, ensuring the effectiveness of remote learning courses and high comfort of work of people learning in this way. The scope of the literature on the problem of motivational processes is not broad enough. However, the importance of motivation is emphasized and selective guidelines for its use in some cases are presented. It is difficult to globalize this issue, because the type of effective factors may be different for each individual, especially in the situation of using emotional components. It is known, however, that direct and explicit motivating effects usually have the opposite of the intended effect if they are too intense. Instead, it is recommended to provide information that affects intrinsic motivation and to shape the learning environment in such a way that internally convinces the learner to participate in the course. Past achievements lead to the creation of an online learning environment in which systematic steps will be carried out to support high motivation. Regular interactions in the form of diverse external stimuli should primarily support intrinsic motivation. They will specifically support the education of girls and young women. They can also develop the activity of cooperative groups, where motivating elements can be used in a natural way. The motivating role of the teacher is very important, which should be to help children, as far as possible, to gain confidence in their own abilities by giving them opportunities to succeed, by encouraging them rather than censoring them when they fail, and by showing personal faith in themselves and their individual abilities. Prevention emphasizes the role of using rewards to educate proper norms of human behavior and perseverance in action. It's important to make the right decision about how often to reward a particular action. Psychologists have been dealing with negative reinforcements for the longest time. They pointed out their destructive effect on the learner's personality, especially when they occurred frequently, lasted a long time and had great strength. Many teachers signal consciously and unconsciously that they value someone as a human being, that they consider them capable of developing the skills needed to cope with their work. The task of the teacher is always to help the learner reach his potential in such a way as to protect the self-esteem of a particular student. Each person is different and differs in the scale of their needs, sensitivity to criticism, resistance to stress – strong people with high self-esteem will be less sensitive than someone with low self-esteem, but in all cases this means assigning students tasks that are adequate to their competence. It also means drawing attention to successes rather than failures and giving personal work to students when possible with a few words of encouragement. The task of the teacher is to help children understand and correct mistakes, to treat criticism carefully, to emphasize with their actions and words that, no matter what happens, every student can count on the teacher's help.

And what does the average lesson look like conducted in a remote form? Some educators also indicated the use of tools such as Skype or Messenger, publicly available educational resources on the Internet, recorded videos and made them available to students – among the indicated methods of conducting online education, there were also 18 uses of telephone conversations. Teachers used educational videos, presentations and educational pictures. Most of the lessons were conducted exemplary. Unfortunately, among the many well-developed lesson units, there were those that not only required refinement, but the involvement of the teachers themselves. The discouragement of students is certainly caused by a situation of isolation and fatigue. There is no substitute for socializing and learning within the walls of the school. However, an interesting lesson and a committed teacher



is the greater half of the success on the way to motivation. Currently, we have a huge amount of opportunities that we can use to prepare an interesting lesson, so you should use them.

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