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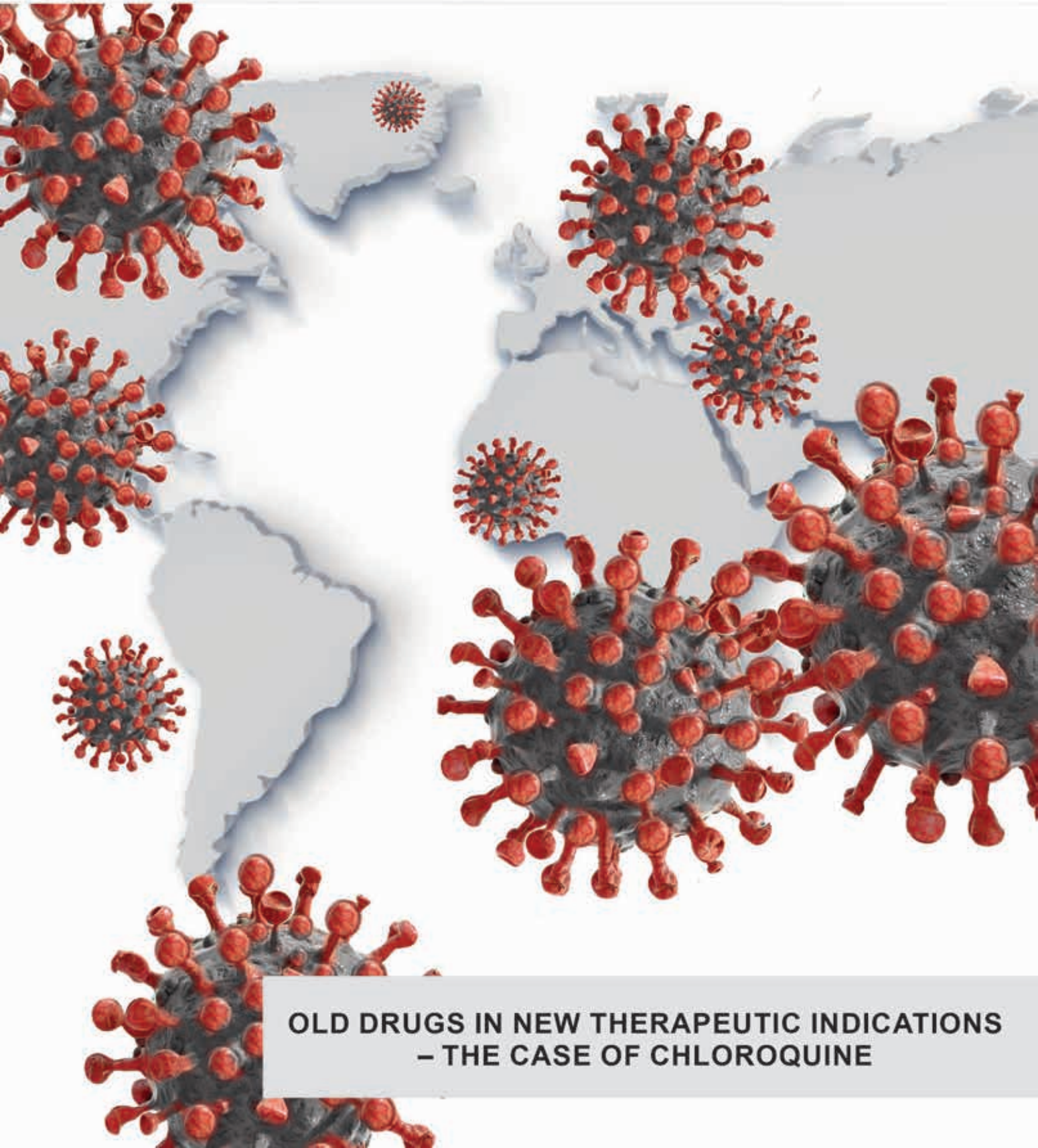

OLD DRUGS IN NEW THERAPEUTIC INDICATIONS – THE CASE OF CHLOROQUINE

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Dear readers!

Coronovirus pandemic has dominated our social, economic and political environment. Nowadays, humanity efforts all over the world are focused on controlling the disease and its effects. The researchers in every part of the globe are working on fast SARS-CoV-2 tests, vaccines and medicines curing COVID-19. The shape of the world that we will be living in depends on when and how we defeat the pandemic.

But we can't focus only on one problem. There are other issues, equally important, that wouldn't wait or disappear, just because we wish to. Even if we are able to effectively defeat the disease, we will encounter the next challenges, including water deficiencies.

Today, despite that it is not a hot summer yet, we can see the consequences of the drought. Fires that consume huge areas of forests, even swamps and mosses in the present conditions are hard to be extinguished. The rain would help, but it doesn't want to fall. Food prices' rise, as a consequence of drought in agriculture, will be the successive, most visible effect. We made nothing to store our ground water that falls as rain or snow. It flows almost directly to the sea. Polish energetics system is based on carbon power stations what consumes the huge amounts of water to cool down the power blocks and it will make our situation even worse.

This is the last moment to manage our resources in a reasonable way. The water becomes our most valuable resource. The mankind too much interferes with the natural environment and does not take the climate changes into account.

All of it is the huge challenge for us, as a society and even bigger is for the people who rule our country. The burden of minimizing the losses lies with them.

Let us give up then the idle political discourse and let the researchers to speak. Let's start listen to the specialists' opinions, analyze the facts, draw the conclusions and let's take the appropriate action.

Michał Szota
Editor in chief

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OLD DRUGS IN NEW THERAPEUTIC INDICATIONS – THE CASE OF CHLOROQUINE

ZNANE LEKI W NOWYCH WSKAZANIACH TERAPEUTYCZNYCH – PRZYPADEK CHLOROCHINY

Summary: *Drug reposition is a viable strategy of pharmaceutical R & D, considerably reducing risk, cost and time needed for drug registration and implementation. Chloroquine, designed already in 1930 as a synthetic replacement for scarcely available alkaloid quinine, a traditional malaria treatment, was recently proposed as an antiviral substance, with putative efficacy in some cases of SARS COVID infections. This unexpected connection has revived interest in drug repositioning at large and in particular in the context of identifying antiviral preparations, critically needed in time of COVID-19 pandemia. The paper recounts the story of development of synthetic antmalarials and describes modern chemoinformatics tools, which can efficiently assist synthetic chemists in planning and executing both: drug repositioning and API manufacturing.*

Keywords: *drug repositioning; antivirals; antimalarials; Chematica; artificial intelligence*

Streszczenie: *Zastosowanie znanych leków w nowych wskazaniach terapeutycznych (repozycjonowanie leków) jest obecnie akceptowane jako skrócona ścieżka do rejestracji i autoryzacji rynkowej nowego specyfiku. Przykładem takiej drogi znanej substancji do leku o nowym zastosowaniu jest historia chlorochiny, zaprojektowanej w latach 30-tych ubiegłego wieku w charakterze zastępstwa trudnodostępnej substancji pochodzenia naturalnego – chininy, skutecznej w leczeniu malarii. Według dostępnych danych chlorochina może się okazać przez długi czas pandemii jedynym specyfikiem o działaniu terapeutycznym w infekcjach wirusowych SARS COVID. W artykule przedstawiono rolę nowoczesnych narzędzi chemoinformatycznych, takich jak Chematica, we wspomaganiu zarówno procesu repozycjonowania leków, jak i syntezy chemicznej substancji o zastosowaniach farmaceutycznych i medycznych.*

Słowa kluczowe: *repozycjonowanie leków, substancje o działaniu przeciwwirusowym, leki przeciwmalaryczne, Chematica, zastosowania sztucznej inteligencji w chemii i farmacji*

Introduction

Progress in pharmaceutical industry depends on continuous technical innovation often originating in academic environment, subsequently absorbed by global business organizations, and always limited by ethical issues prescribed by pharmaceutical law regulations. Since the costs of radical innovation in drug research and development are exorbitant, concerns regarding R&D efficiency tend to dominate the sector's development strategies. In a reasonable attempt to re-evaluate pharmaceutical industry's assets and resources, factors such as structural diversity of drug candidates, their availability from either natural or synthetic origins, or the ability to boost the discovery process by modern IT tools all come into consideration. Unfortunately, new molecules and corresponding new chemical entities require long times and massive investment to progress through all segments of drug design and development pipeline and, hopefully to obtain marketing authorization as a new drug. Modern pharmacology, based on systems biology and equipped withan array of omics technologies, such as genomics, proteomics and metabolomics, recognizes ability of small molecule ligands to engage in variety of noncovalent interactions. Specificity of drug pharmacodynamics appears more like an idealization than biological reality, in which multiple interactions with variety of macromolecular targets may be operative. Practical observations in medicinal applications of available chemicals – ranging from natural products abundant in and utilized by ethnopharmacology to the targets of contemporary, sophisticated multistep syntheses of the newest API substances–indicate clearly that therapeutical assignment of a given medicine can evolve in time considerably, as new knowledge accumulates. Consequently, drugs are sometimes dropped from lists of applied medicines but also shifted between therapeutical categories and regimens. In this context, it is always judicious to consider new medical interventions for the privileged compounds already registered as drugs [1-3].

Drug repositioning as a new trend in pharmaceutical industry

Efficient pharmaceuticals are vigorously sought in most therapeutic areas, though the need is particularly pressing for rare and infectious diseases. For example, ca. 6,800 rare diseases and conditions exist, for which ca. 300 approved drugs are applied, but the most of the ailments have no assigned pharmaceutical treatment. In the area of infectious diseases, new medicines are also urgently needed in view of microbial pathogens' genetic plasticity and their frequent mutations resulting in acquired drug resistance. At any rate, continuous progress in research on drug molecular targets and mechanisms of their action can change our perception of drug profile and its applicability, and even evoke a switch in its therapeutical indication. Aspirin, which functioned for ca. seven decades as a popular antipyretic, has finally had its pharmacological role assigned as an anti-inflammatory inhibitor of cyclooxygenases, responsible for synthesis of prostaglandins [4]. Some examples of more radical changes in specifications and applications of known drugs, described in current literature as repositioning, repurposing, redirecting, or reprofiling, are summarized in Table 1 below. The seminal paper in which drug reposition ideology was outlined [1] compared the traditional ***de novo*** drug discovery and development process with some of the abbreviated repositioning procedures: It concluded that considerable reduction of time and risk is possible on the way of known drug substances towards registration and market under new therapeutical indication. Obviously, a drug candidate being repositioned has typically already completed some phases of development like ADMET and formulation studies. Repositioning can sometimes take rather unexpected and dramatic turns. As a case in point, a once popular sedative thalidomide was

Table 1. Examples of drugs for which an alternate therapeutic indication was approved by registration

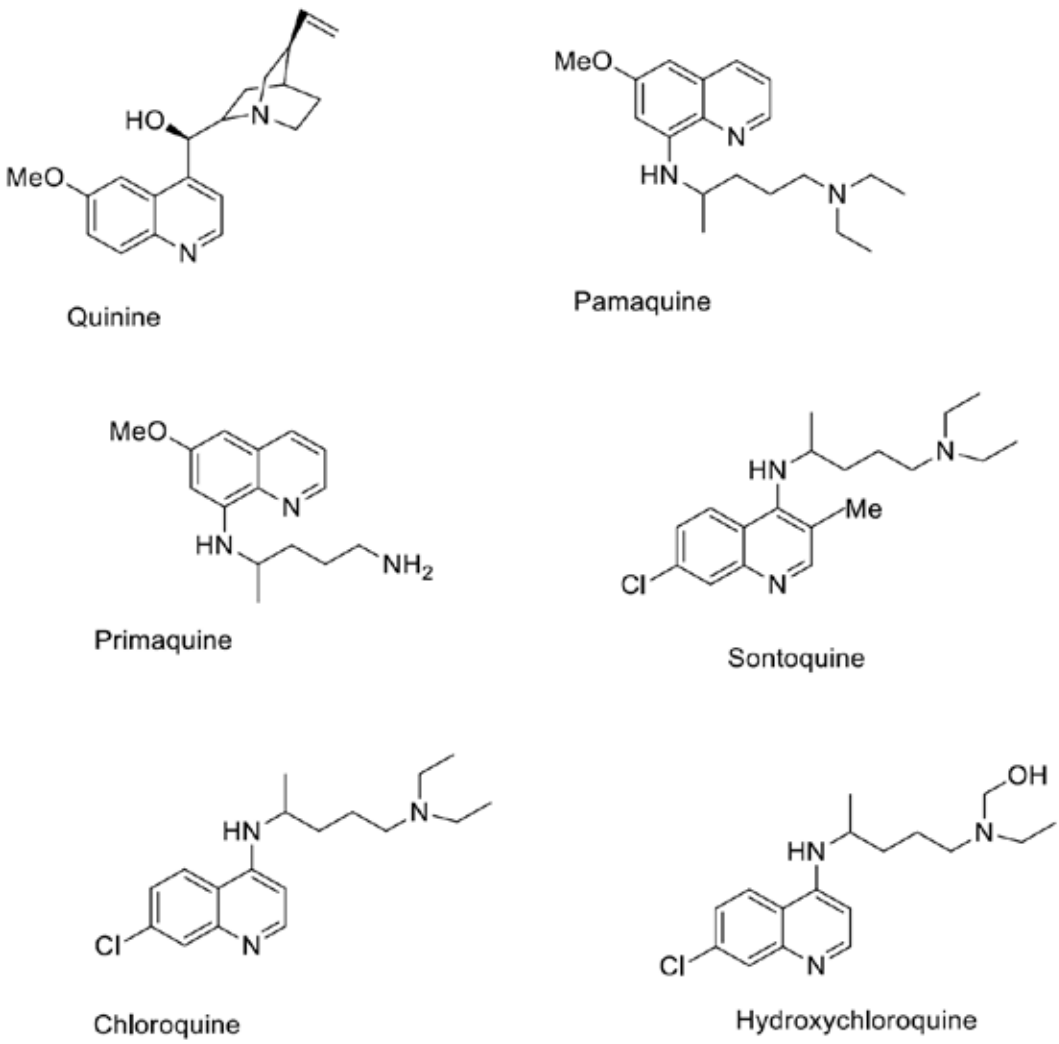
Drug name	Primary indication	Alternative indication
Amantadine	influenza	Parkinson's disease
Amphotericin	antifungal	leishmaniasis
Aspirin	antipyretic	antiplatelet COX inhibitor
Atomoxetine	depression	ADHD
Bimatoprost	glaucoma	eyelash hair growth
Bromocriptine	Parkinson's disease	diabetes
Bupropion	depression	smoking cessation
Celecoxib	osteoarthritis	colon and breast cancer
Chloropromazine	general sedative	tranquilizer
Chloroquine	antiparasitic	antiviral
Colchicine	gout	recurrent pericarditis
Colesevelam	hyperlipidemia	diabetes type 2
Dapsone	leprosy	malaria
Disulfiram	alcoholism	melanoma
Doxepin	depression	antipruritic
Eflornithine	depression	ADHD
Finasteride	benign prostatic hyperplasia	hair loss
Gabapentin	epilepsy	neuropathy
Galantamine	anaesthesia	Alzheimer's disease
Gemcitabine	antiviral	anticancer
Methotrexate	anticancer	psoriasis
Minoxidil	hypertension	hair loss
Naltrexone	opioid addiction	alcohol withdrawal
Nortriptyline	depression	neuropathy
Premetrexed	mesothelioma	lung cancer
Raloxifene	contraceptive	osteoporosis
Ropinirole	hypertension	Parkinson's disease
Sildenafil	angina	male erectile dysfunction
Thalidomide	sedation	leprosy
Topiramate	epilepsy	obesity
Tretinoin	acne	leucemia
Zidovudine	cancer	HIV/AIDS

withdrawn from the market as a cause of skeletal birth defects in at least 15 000 children, but it later made a successful comeback as a TNFα inhibitor with indication for treating condition named erythema nodosumlaprosum (ENL), one of typical inflammatory developments in leprosy. Further studies of thalidomide revealed its anti-angiogenic activity, prompting its widespread off-label use for the treatment of primary multiple myeloma cancer. Thalidomide example shows clearly that drug repositioning may be a viable therapeutic and also a business option [1-3]. Present repositioning efforts are generally based on registered ***drug libraries*** such as SCREEN-WELL (FDA; Enzo Life Sciences); LOPAC (Sigma Aldrich); Spectrum Collection (Microsource); UCFS Small Molecule Discovery Center Library, or the NIH Chemical Collection Library and Chemical Genomics Center. These small collections (FDA approved drugs list contains less than 2 000 compounds) are often supplemented by drug candidates under investigation, in advanced phases of clinical trials [5]. As a result, three different groups of API compounds are pursued as candidates for repositioning: currently used drugs with valid registrations, drugs discontinued for any reason, and drug candidates in clinical trials with ongoing investigation of the mechanism of action. Recent bibliometric review of drug repurposing activity, based on PubMed (MEDLINE) data revealed a relationship between 35,580 individual chemical entities and 4,333 diseases or medical conditions. Based on PubMed article count listing many thousands of papers for each: drug – disease – article axis [6], it has been estimated that for many established medicines - including prednisolone, dexamethasone, ascorbic acid, cyclosporine, aspirin, hydrocortisone, metothrexate, vit. E, propranolol, doxycycline, indomethacin, etc. – the count of diseases examined is in the hundreds. In recent years, much of repurposing effort based on theoretical and computational approaches has focused on antiviral drugs, in connection with recurring Ebola, Denga and Zika viral epidemics. These trends likely reflect advancing research of viral proteins, and the reasoning that broad spectrum antiviral agents are good first-line candidates for clinical trials and experimental treatments of newly emerging pathogens [7].

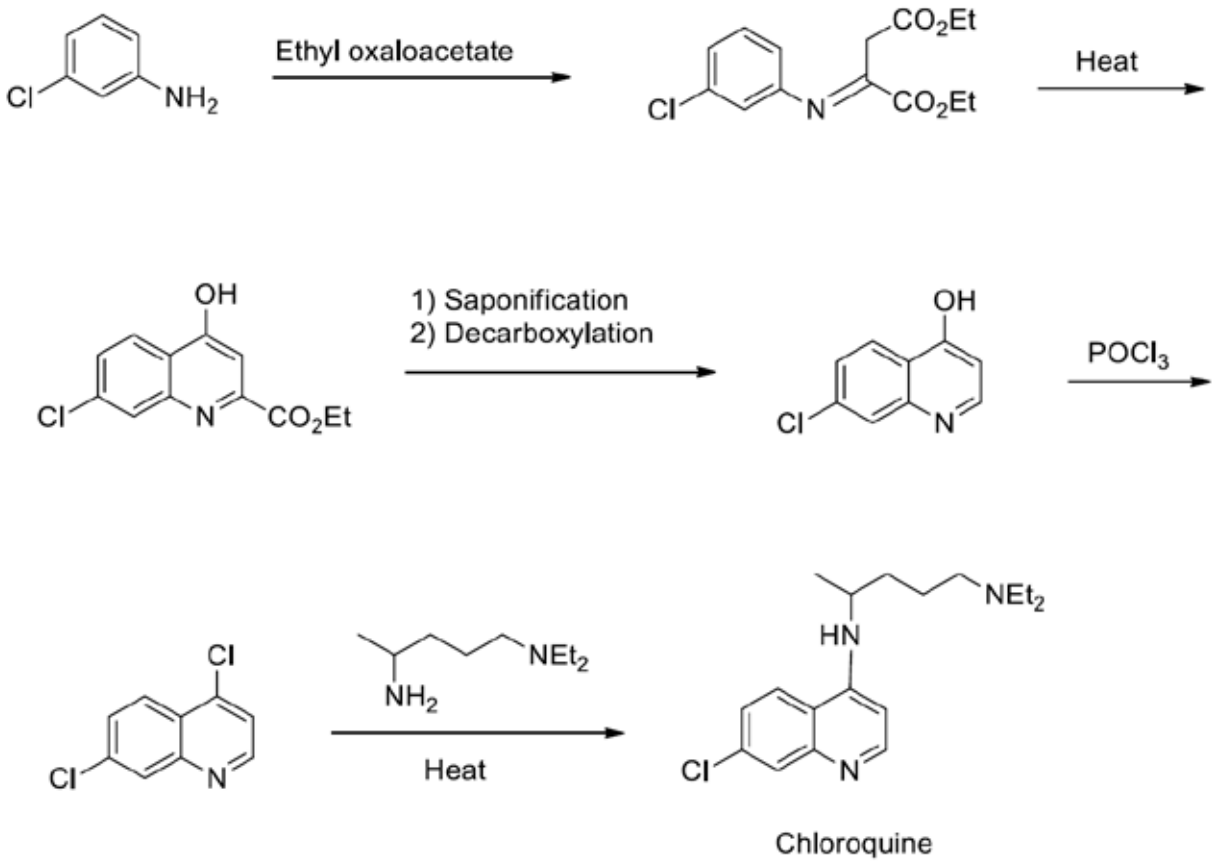
Development of synthetic antimalarials

Malaria is one of the most devastating diseases, affecting more than 400 million people with current worldwide mortality estimates between 1.5 and 2.7 mln per annum. The condition is known since the antiquity and its treatment has left many records in ethnopharmacology as well as in early history of

Fig. 1. Structures of alkaloid quinine and antimalarial aminoquinolines



Scheme 1. The first synthesis of chloroquine



modern medicine. For centuries, ***Cinchona*** tree (indigenous to South America) bark extracts were considered an effective treatment against malaria, which prompted the search for its active principle. Alkaloid quinine was isolated in 1820 by P. Pelletier and J. Caventou and it became principal antimalarial agent for the next century. Natural tree bark sources were initially monopolized in their native habitats but were later successfully transplanted, principally to Java island [4]. The isolated active compound defied practical chemical synthesis because of its complicated structure and stereochemistry (academic formal synthesis of quinine was completed by R. B. Woodward and W. von Eggers Doering in 1944 but it was never scaled up), which resulted in dramatic shortages of antimalarial drug substance, suffered by allied forces practically throughout the entire second world war. The need for effective synthetic replacement of quinine mobilized considerable research effort in German Bayer company, which later became I. G. Farben, with many thousands of new heterocyclic compounds synthesized and tested in relatively short time. In 1928, the structure of quinoline derivative antimalarial drug pamaquine, backed by some active, patented analogs (sontoquine, chloroquine) was announced in Germany and parallel research started in Britain, led by Robert Robinson in University College London and subsequently continued by Robert Elderfield at Columbia University in New York [8,9]. Eventually, competition between isomeric aminoquinoline derivatives active as anti-plasmodium agents was resolved by indicating chloroquine, with basic substitutent placed in position 4- as the drug of choice for the eradication of a relatively benign form of malaria caused by ***Plasmodium vivax*** parasite transmitted by mosquitoes [10,11].

New indications for chloroquine

Recently, the subject of drug repurposing for viral infectious diseases attracted considerable attention in connection with some epidemic events, and, most recently, in the context of the ongoing Covid-19 pandemia. Emergence of highly pathogenic severe acute respiratory syndrome (SARSCoV) in China in 2002/2003 was responsible for an epidemic with over 8000 infected people and ca. 10% mortality (www.cdc.gov). During the Middle East Respiratory Syndrome outbreak in 2013, caused by a coronavirus called MERS-CoV, attempts for repurposing known drugs were made, targeting the pathogen jointly with SARS-CoV-2 [13]. A library of 290 compounds was screened for antiviral activity, from which 27 promising candidates were selected, among them well known antiparasitic drugs such as chloroquine, hydroxychloroquine and mefloquine. The present Covid-19 outbreak took place in Wuhan, China at the end of last

year. WHO released the official name of 2019-nCoV as SARS-CoV-2. In January 2020, the first whole-genome sequence of SARSCoV-2 was published, which helped to develop tests for selection of infected patients. Several viral proteins have been identified (SARS main protease; coronavirus spike protein; nucleocapsid protein) some of which are suitable as targets for drug development [14]. In Poland, where chloroquine phosphate is available as preparation Arechine, indicated for malaria, additional marketing authorization for SARS-CoV-2 was acquired at the beginning of 2020 by its manufacturer: Adamed; the drug is recommended exclusively for hospital use. Ultimately a vaccine is likely to be the first specific treatment for the virus but its development must take several months at best. At present, the vintage antimalarial chloroquine appears to be a viable candidate for repositioning as an antiviral agent. Although conclusing evidence for its efficacy is still lacking, there are some encouraging though preliminary reports advocating its use for the treatment of SARS-CoV-2 infection, at a dose 500 mg of phosphate or 300 mg free base, to be taken 3 times a day, orally, for no more than ten days [15]. Interestingly, if this regimen becomes approved more widely, it will pose a considerable challenge to current API manufacturing capacity.

Availability of active pharmaceutical ingredients and pharmaceutical intermediates

We have recently pointed out that general availability of medicines can no longer be taken for granted, as a result of shifting practically all API manufacturing industry to Asian countries [16]. Not surprisingly, the drug availability crisis worsened with the emergence of the Covid-19 pandemic. In view of rather poor prognosis for quick elaboration of an efficient antiviral vaccine and even less likely perspective for a discovery of a new drug targeting one of essential viral proteins, the quest for alternative solutions to the global health danger becomes a matter of great importance and urgency. In particular, repurposing the abovementioned antimalarial chloroquine may be one option for a supportive remedy in anti-Covid-19 treatment. It should be pointed out that successful drug repositioning cases completed thus far resulted from rather serendipitous preclinical pharmacology observations, whereas contemporary chemoinformatics has at its disposal uniquely powerful tools for rational investigation of issues related to multitarget pharmacology. In connection with the case of chloroquine , two practical chemoinformatic topics come to focus. First is the matter of systemic support to the „pencil-assisted" design of synthetic pathways, practiced by organic chemists for more than a century. Recently, original achievement of Polish chemists – the so-called **Chematica** software platform for autonomous, computer – driven planning and optimization of multistep syntheses – has been described, expanded and validated, also experimentally, for a variety of targets important to medicinal chemistry and pharmaceutical industry [17-20]. A very important feature of **Chematica** is its integrated approach to the questions of plausibility and availability: chemical (chemical reaction knowledge-base), legal (IP surrounding intermediate and target molecules, based on compound and reaction databases), and economical (commercial data for starting materials and/or intermediates). Thus, even for such simple molecule as chloroquine, with a rather apparent synthetic scheme (Scheme 1), multiple manufacturing pathways can be generated in order to manage a crisis situation generated by incidental unavailability of a raw material or a manufacturing site. Such synthetic planning has, in fact, been recently performed as is described in ***https://chemrxiv.org/articles/Computer-Assisted_Planning_of_Hydroxychloroquine_s_Syntheses_Commencing_from_Inexpensive_Substrates_and_Bypassing_Patented_Routes_/12026439***. The second topic concerns rational approach to repositioning, based on achievements of artificial intelligence (AI) as applied to chemoinformatics methods in medicinal chemistry. The **Allchemy** team, also originating from Poland but operating mostly on the US market, has been developing sophisticated algorithms, based on recently elaborated molecular similarity tools, which allow the use of „big data" for the selection of appropriate lead compounds („parent molecules" exhibiting desired biological activity), from which progeny of novel candidates with already known structures can be obtained promptly. Interested readers can read about this approach at ***https://chemrxiv.org/articles/Suggestions_for_second-pass_anti-COVID-19_drugs_based_on_the_Artificial_Intelligence_measures_of_molecular_similarity_shape_and_pharmacophore_distribution_/12084690***. Evidently, this pragmatic solution can bypass the need for drug target identification, which makes it particularly useful when the time factor is decisive. In a broader context, these and similar advances illustrate aptly that chemistry can – and perhaps should –be perceived as a system, composed of millions of structures and comparable number of chemical reactions. As outlined above, new methods based on AI are being elaborated, which allow to manage such system as a network of molecular objects with an array of defined properties and their possible logical or chemical transformations, fit for coding in formal languages suitable for computer programs, but also for more traditional forms of scientific communication, like graph schemes, supplemented with 2D and 3D chemical formulae. While these tools are now primarily scientific, their industrial application is imminent as already demonstrated in present quest for new means to fight the SARS-CoV-2 pandemia.

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ESTIMATION OF THE LEVEL OF GREENHOUSE GAS EMISSIONS IN ANIMAL PRODUCTION

SZACOWANIE POZIOMU EMISJI GAZÓW CIEPLARNIANYCH W PRODUKCJI ZWIERZĘCEJ

Summary: *The aim of the present paper is to show the level of greenhouse gases' emission coming from animal production in Poland. The animal production in 2015 was a source of 39.8 % of GHG emissions of which 30.7 % came from intestinal fermentation and 9.1% derived from animal manure. The animal production has also its share in the emissions resulting from the energy consumption in agriculture; therefore, its participation in the total GHG emission is equal to ca. 50%. Factors affecting the level of greenhouse gases' emissions include: the species, animal breed, performance stage, housing and feeding system and also, the way of natural manure management.*
The foreign literature review shows the chosen methods of GHG emission measurements. The direct methods such as respiration chambers are expensive and labour-consuming; therefore, the indirect methods have been also presented, e.g. the estimation of methane emissions, produced by the dairy cattle, based upon the fatty acid profile in milk.

Keywords: *GHG emission, animal production, measurement, calculations, structure*

Streszczenie: *Artykuł ma na celu przedstawienie wielkości emisji gazów cieplarnianych z produkcji zwierzęcej w Polsce. Produkcja zwierzęca w 2015 r. była źródłem 39,8 % emisji gazów cieplarnianych z polskiego rolnictwa, przy czym 30,7% to fermentacja jelitowa, 9,1% pochodziło z nawozów naturalnych. Produkcja zwierzęca, w ramach zużycia energii w rolnictwie ma także swój udział w emisjach, dlatego łącznie jej udział w całkowitej emisji GHG wynosi około 50%. Do czynników mających wpływ na wielkość emisji gazów cieplarnianych zaliczamy: gatunek, rasę zwierząt, fazę użytkowania, system utrzymania i żywienia a także sposób zagospodarowania nawozów naturalnych.*

W wyniku przeglądu literatury zagranicznej przedstawiono wybrane metody pomiaru emisji GHG. Metody bezpośrednie, takie jak komory respiracyjne, są drogie i pracochłonne, dlatego przedstawiono także metody pośrednie, np. szacowanie emisji metanu przez krowy mleczne na podstawie profilu kwasów tłuszczowych.

Słowa kluczowe: *emisja GHG, produkcja zwierzęca, pomiar, obliczenia, struktura*

Introduction, aim of the work, materials and the methods of analyses

According to the data of the National Centre for Emissions Management (KOBiZE) [Olecka Et Al.], about 29 850 thousand tons of greenhouse gases in CO_2 equivalent (CO_2e) in 2015 derived from Polish agriculture. The mentioned value did not include the emission from the energy carriers in agriculture; according to the methodology employed in the inventory of greenhouse gases, it was included in the part "energy".

Value of carbon dioxide equivalent (CO_2) is calculated by multiplying the mass of the particular gas emission and the corresponding global warming index (GWP) which is the indicator, comparing the quantity of the heat absorbed by the mass of the given GHG in relation to the amount of the heat absorbed by the same quantity of carbon dioxide.

GWP is calculated basing on the results of the effects of impact of one kilogram of a particular gas on the climate warming during the defined time interval, being usually 20, 100 or 500 years in comparison to the impact of one kilogram of CO_2 for which GWP was adopted as 1. Value of GWP for methane as adopted in the present work is equal to 25 and for nitrous oxide it is 298.

According to the data of KOBiZE, the participation of agriculture in the national greenhouse gas emissions (excluding LULUCF) was equal to 7.68%. In the case of the particular gases, the mentioned participation was strongly differentiated and it was shaped as follows: for carbon dioxide – 0.16%; for methane – 29.81% and for nitrous oxide – 78.03 % of the national emission.

Despite its relatively low participation in the total mass of GHG emission in Poland, the agriculture has a big share in methane and nitrous oxide emission. A similar situation is in

other countries what has been confirmed by the data from the foreign literature; it is followed from the mentioned materials that the majority of the GHG other than CO_2 emitted all over the world, comes from the agriculture. Its participation in the total emission of methane (CH_4), nitrous oxide (N_2O) and fluorinated gases, calculated into carbon dioxide (CO_2) is equal to 53% [Beach Et Al. 2015]. In Poland, the discussed participation amounts to 40%, so, it is by 13 percentage points lower than the world mean.

When considering the GHG emission caused by the use of energy carriers in Polish agriculture, the participation of the mentioned sector of the national economy in CO_2 emission in 2015 amounted to 4.29%, that is, it was by 3.39 pp higher than the value given by KOBiZE; its participation in the structure of GHG emission in Polish agriculture was equal to 27%. In this case, the participation of nitrous oxide and methane (36% each in the structure of GHG, emitted as a result of the agricultural activity in Poland) was higher than that of carbon dioxide.

The participation of fluorinated gases was equal to ca. 1%. In total, the greenhouse gases other than CO_2 constituted 73% of the total GHG emission in Polish agriculture and 39.6% of the emission of the mentioned gases in the whole national economy of Poland [PAWLAK 2017]. According to the EPA data [2017], the participation of the world agriculture in the emission of greenhouse gases other than CO_2 in 2015 was equal to 49.2% and was by 9.6 pp higher than in Poland. The discussed share in the particular regions of the world is strongly differentiated. In 2015, it varied from 16.1% in the Middle East countries up to 78.2% in the countries of the South and Middle America.

In 2015, the highest quantity (39.8%) of greenhouse gases, emitted in Polish agriculture, came from the animal production, including 30.7% resulting from enteric fermentation and 9.1% coming from livestock natural manure management (Fig.1). Due to the fact that animal production has also its share in the emission, caused by the energy consumption in agriculture, its total participation in the total GHG emission from the Polish agriculture should be estimated at ca. 50%. Animal production is, therefore, a serious source of the emission of greenhouse gases. It determines the meaning of the activities aimed at the reduction of the level of the mentioned emissions in the discussed sector of the agricultural production.

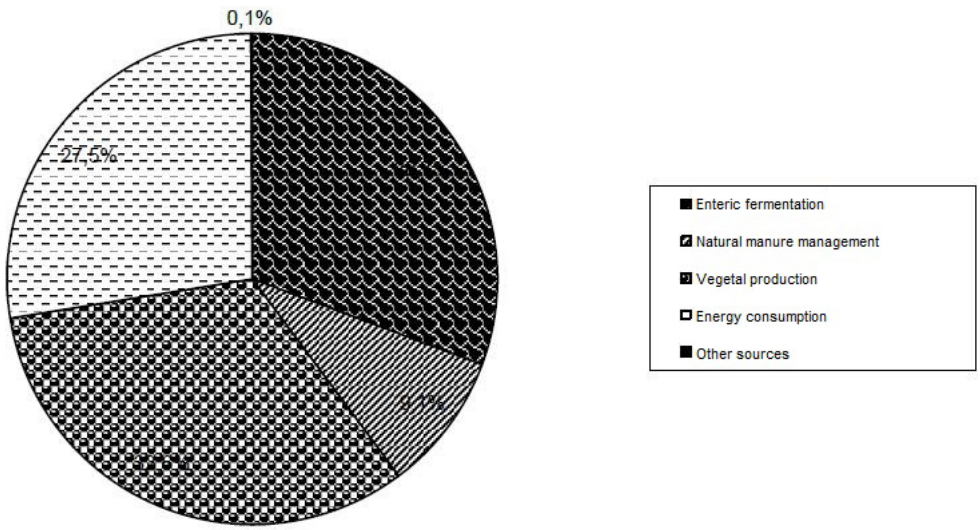
The aim of the present paper is to analyze the role of animal production in the emission of greenhouse gases, with the consideration of their sources and of various types of the conditions, affecting the level of the discussed emissions as well as the method for their measurement and assessment.

The analysis is based upon the review of the national and foreign literature, describing the present situation in respect of GHG emissions in the animal production, the employed methods for their measurement and also, the possibilities of their estimation on the grounds of the parameters of the respective animal products.

Demand on food and the environmental challenges

Dynamically increasing population, especially in the developing countries, causes the increase of demand on food.

Fig. 1. Emission of greenhouse gases in Polish agriculture in 2015 according to the sources [PAWLAK 2017]



In the conditions of the limited and, in some parts of the world, a decreasing area of agricultural land, it is necessary to intensify the agricultural production via increase of the plant yield and the productivity of farm animals.

It is connected with the necessity of increasing the outlays on production means, inter alia, on mineral fertilizers, plant protection agents and energy carriers. In turn, it causes the unfavourable consequences for natural environment, manifested by the increase of the emissions of harmful compounds, including greenhouse gases which deteriorate the quality of soil, water and air. Moreover, in certain parts of the world, a tendency to increase the agricultural areas at the cost of forests is being observed e.g. in the cases of tropical forests in Brazil and Indonesia.

The additional threat to the environment protection consists in the fact that the plants acting as carbon dioxide absorber are decreasing and the potential changes in climate may cause the desertification of new areas of our globe. Meanwhile, the populations in the developed countries demand the increase of the quality of the food products. It is connected with the necessity of supplying the consumers with the information about the place and manufacturing process of the products (traceability of food product).

Meeting the mentioned above requirements is connected with the increase of the unitary manufacturing costs. On the other hand, the main problem in the poor countries is to ensure the sufficient food quantities at the prices affordable for a given population, and to limit hunger zones.

In connection with the above situation, a serious dilemma arises: the increase in food production requires the additional outlays on manufacturing means; their production in non-agricultural zone and their application in the agricultural production are connected with the GHG emission.

The increase in food production should therefore take place together with the simultaneous reduction of the greenhouse gases' emission. It is not the easy task as the current challenges connected with the reduction of GHG emission at the global scale require that the rate of the reduction in the intensity of the GHG emissions must exceed the increase of the productivity, indispensable for meeting the global demand on food [Rawnsley Et Al. 2018].

The discussed challenges concern, *inter alia*, animal production, the participation of which in food production as well as in GHG emission is meaningful.

In the future, the agricultural producers will have probably to consider the introduction of the changes in organization of the agricultural production and the application of different combinations of plant species cultivation or farm animal husbandry and the related changes in their management.

In connection with the above, Antle Et Al [2018] suggest the popularization of the methods of evaluating the impact of such adaptations, being called "inter-system adjustments" and "propensity score matching". On the grounds of the application of the mentioned methods in the selected example, the authors found significant differences between the obtained results which, however, do not seem to be connected with the characteristics of the examined systems. The method employed in the estimation of the productivity of the new system introduces the element of uncertainty to the adaptation analysis. The further studies aimed at evaluation of the alternative methods of the inter-systemic adaptation analysis and the related uncertainties are necessary.

The ruminants such as cows, sheep and goats produce the greatest quantities of methane. In the animal production, methane is produced in the gastrointestinal tract of ruminants (as a result of intestinal fermentation) and in the conditions of anaerobic decomposition of animal natural manure. In cow rumens, there are found ca. 150 billion microorganisms. After completion of the cellulose fermentation, the ruminants swallow the digested food and then it is passed to the successive chambers of the stomach. The whole process is called rumen-reticulum cycle which is composed of a complicated combination of the spasms of the appropriate parts of the forestomachs. In the normal run of the fermentation processes in cow, 25-30 litres of gases are produced during 1 hour. The greatest quantity of the mentioned gases are expelled by belching and only a small part is absorbed by the rumen mucosa or passes to further segments of alimentary tract.

Brittante Et Al. [2018] employed the following indicators, characterizing the methane production as a result of methane fermentation:

- Yield of methane emission, measured in grams and calculated into unit of dry matter [g ·kg^{-1}];
- Intensity of methane emission, measured in grams per one kg of standardized milk [g · kg^{-1}];
- Daily methane production from one cow [g · day^{-1} · head^{-1}].

The studies of the cited above authors showed that the values of the majority of the mentioned indicators of methane emission as a result of intestinal fermentation – excluding the yield of methane emission – was increased in the successive lactation periods, from the first one beginning.

The system of animal housing and the frequency of manure removal had a big influence on the emission of greenhouse gases.

The studies conducted in a free-stall dairy cattle barn in Italy revealed that the application of rubber mats on the concrete floor caused the increase of the emission of ammonia, carbon dioxide, nitrous oxide and methane, irrespectively of the way of manure removal. On the other hand, the application of robot for removal of the manure and by this, the increase of the frequency of

Tab.1. The percentage structure of gases in cow rumen according to individual traits and feeding method [own development on the grounds of Moate Et Al. 1997]

Specification	Carbon dioxide [%]		Methane [%]		Nitrogen [%]	
	from – to	Mean	from – to	Mean	from – to	Mean
Before grazing	53.5–74.5	65.5	24.8–40.5	30.9	1.2–6.0	3.8
After grazing	72.3–80.3	75,9	19.0–23.1	22.2	1.0–4.6	1.7

cleaning the floor in the premises, caused a significant reduction of the GHG emission [Chiumenti Et Al. 2018]. The microclimate in the cow barn has the indirect influence on the GHG emissions.

The composition of gases in the cow rumen is dependent on the method of feeding and individual traits of the animal what is supported, *inter alia*, by the results of the studies carried out in Australia [Moate Et Al. 1997]. During the mentioned studies, the composition of gases before and after pasture grazing was compared. The results referring to the animals which were not subjected to the bloat-preventing agents are given in Tab. 1.

Milk production is connected with a high methane emission, resulting from the methane fermentation in alimentary tract of ruminants, managed in agricultural farms. It is necessary to undertake the measures aimed at the reduction of the mentioned emissions. To carry out properly the discussed activities, it is necessary to have the results of the appropriate measurements of GHG emissions, caused by farm animals.

Measurements and estimation of ghg emissions coming from farm animals

Inventory of gas contaminations is carried out basing upon the international methodologies IPCC (eng. Intergovernmental Panel on Climate Change) and EMEP (eng. European Monitoring and Evaluation Programme). In the calculations, standard indicators of GHG and ammonia are mainly utilized. From the analysis of available national and foreign literature it is followed that there are significant discrepancies between the values of the emission parameters. It is affected by many factors such as period of measurements, different micro- and macroclimatic conditions as well as the application of different measuring devices. The studies were conducted mainly in the premises with litter-free housing system; only some of them concerned litter housing system what may result from the relatively small popularity of this type of management in the West Europe. In the studies of gas emissions, conducted in the Wielkopolskie Voivodeship, in pig fattening house on a deep litter, the daily emission of the examined gases was calculated as a ratio of value of their concentration in the studied building and the daily air exchange in the building. The daily indicator of the emission of GHG and ammonia was considered as a quotient of the daily emission of gases and animal body weight; BW of the animals during the measurements was calculated from the results of weighing of the random chosen 5 porkers from each pen. The mean body weight of the porker in the pen was the arithmetical mean of the weighed pigs [Mielcarek Et Al. 2014].

The studies of the methane emission as a result of enteric fermentation in the animals are conducted in the respiration chambers. Placement of the animals in such chambers causes stress what affects the feed intake and, in consequence, CH_4 emission. The research stands require improvements, ensuring the limitation of stress and by this, improvement of the values of the obtained results of the studies [Llonch ET Al. 2018]. The results of the direct measurements of the GHG emissions in the animal production should be, therefore, treated with a certain caution.

Besides it, the measurements of greenhouse gases' emission produced by the animals are difficult and expensive [Brittante Et Al. 2018; Christie Et Al. 2018]. In the light of such situation, Brittante Et Al. [2018] suggest the application of indirect method for the assessment of the methane emission by the dairy cows on the grounds of fatty acid profile in milk. It consists in the utilization of the relationship existing between the activity of microorganisms in the rumen and the particles available for milk synthesis in the mammary gland. When utilizing a gas chromatography of the high number of milk samples coming from 1 158 Swiss Brown cows, managed in 85 farms, the mentioned authors analyzed individual profiles of fatty acids. They verified two equations, applied in the assessment of the methane emission as a result of methane fermentation. They found that the results of the following calculations: the mean estimated yield of methane emission, measured in grams and calculated per one unit of dry matter ($21.34 \pm 1.60\ g \cdot kg^{-1}$), intensity of the methane emission, calculated in grams per one kg of standardized milk ($14.17 \pm 1.78\ g \cdot kg^{-1}$) and daily methane production from one cow ($357 \pm 109\ g \cdot day^{-1} \cdot head^{-1}$) were similar to the earlier published results of the measurements.

When utilizing the data referring to the cheese products coming from milk of the individual cows, the estimated intensity of the methane emission was calculated in terms of one kg of fresh cheese ($99.7 \pm 16.4\ g \cdot kg^{-1}$) and per one unit of mass of solid parts in cheese ($207.5 \pm 30.9\ g \cdot kg^{-1}$).

In the traditional and modern dairy farms, which used maize silage in feed rations, a higher estimated intensity of the methane emission was found in comparison to the farms which did not employ the mentioned type of feed. Also, there was found a very high variability of the parameters of the methane emission as a result of methane fermentation in the particular milk-producing farms (from 0.33 to 0.61 of total variance) what suggests the need of limiting the methane emission. The obtained results revealed a sufficient accordance between the indicators of the methane emission, resulting from the methane fermentation and estimated on the grounds of the analysis of fatty acid profile in milk, and the data coming from the current knowledge, obtained basing on the expensive studies in the respiration chambers. It is however necessary to conduct the further studies with the consideration of other breeds and populations of the dairy cattle, allowing evaluating the meaning of genetic variability and potential of the mentioned phenotypes for utilization in breeding programmes aimed at the reduction of methane emissions.

Less optimistic results were obtained by Van Gastelen Et Al. [2018] who studied the relationships between CH_4 emission and fatty acids and volatile and non-volatile metabolites in milk of the dairy cows. The data coming from six series of the tests of HF cows were utilized; in feeding of the mentioned cows, 27 dietary sets were applied. The nutrition of the cows included a wide range of diets, based upon the feeds differentiated in respect of quality and participation of grass or maize silage. The measurements were conducted in climatic respiration chambers. The following measurements were carried out: methane production (in g per day), yield of methane production (g per one kg of dry matter, DMI) and intensity of methane production (g per one kg of standardized milk in respect of fat and protein content, fat-and protein corrected milk, FPCM). The presence of fatty acids in the milk samples was analysed by the gas chromatography; for volatile metabolites – by the gas chromatography with the application of mass spectrometry and for non-volatile metabolites – by the NMR method (Nuclear Magnetic Resonance). The quantity of dry matter (DM) was equal to 15.9 ± 1.90 kg · day^{-1} (mean ± SD), FPCM yield amounted to 25.2 ± 4.57 kg · day $^{-1}$, CH_4 production – 359 ± 51.1 g · day-1, CH_4 yield – 22.6 ±2.31 g · kg^{-1} DMI and the intensity of CH_4 emission – 14.5 ± 2.59 g · kg^{-1} FPCM.

The results show that the changes in the individual concentrations of milk metabolites may be related to the process of methane production in the rumen. Some of the mentioned relationships were connected with the diet whereas the other ones were partially dependent on FPCM yield. Then, the prediction models were developed and verified basing upon the root mean squared error of prediction (RMSEP), analysis of adaptation coefficient (R2) and random ten-fold cross validation. The best models, describing the correlation between the fatty acid level in milk and methane emission enabled the estimation of production, yield and intensity of the methane emission at RMSEO equal to 34 g · day^{-1}, 2.0 g ·kg DMI and 1.7 g · kg FPCM and values of adaptation coefficient R2 amounting to 0.67, 0.44 and 0.75, respectively. The potential of prediction of the methane emission on the grounds of the separate consideration of volatile as well as non-volatile metabolites was low, irrespectively of the type of the gauge of CH_4 emission. It was supported by the low values of adaptation coefficient R2 (<0.35). The models in which the total level of fatty acids and of volatile and non-volatile metabolites was considered as selective variables, allowed estimating the intensity of methane production at the level of adaptation coefficient = 0.80. The obtained results suggest that the content of volatile and non-volatile metabolites in the milk allows better understanding of methane production process in gastrointestinal tract of the dairy cows. They do not however, justify the measurements of the volatile and non-volatile metabolites as the basis for estimation of methane emission by the dairy cattle. On the other hand, there is a certain potential of utilizing the fatty acid level in milk for estimation of CH_4 emission and in the studies on the better understanding and reduction of the methane emission caused by the dairy cows.

The results of the measurements and estimates of GHG emissions, caused by the animals constitute the basis for verification and updating the indicators, used during the inventory of greenhouse gases in the national scale. The methodology of the National Greenhouse Gas Inventory (NGGI) according to which the GHG emissions in Australia are estimated every year, has been subjected since 1990 to the changes gradually with obtaining the new results of the studies. The change in estimation of GHG emissions connected with milk production, as introduced in 2015 in relation to reporting year 2013 consists in the application of the results of the calculations, employing the Australian Dairy Carbon Calculator (ADCC). In 41 Australian agricultural farms which produce milk with the application of different technologies, the comparative studies of the estimation of GHG emissions using the new method were carried out (being employed the first time in 2015) and the earlier applied method. It was found that the GHG emission intensity, calculated by the newer method, was increased by 3.0%, from 1.05 to 1.07 kg of CO_2 equivalent in terms of the conversion kilogram of milk, considering the protein and fat content. In the spatial system, the declines up to 4.6% were recorded; the maximum increase was up to 10.4%, depending on the region. In the total set of the results of the studies, the increase in methane production from intestinal fermentation as well as from manure management was recorded; on the other hand, the emission of nitrous oxide coming from the manure management as well as CO_2 emission caused by energy consumption and production of nitrogen fertilizers and industrial feeds in the "pre-agricultural" stage (manufacture of agricultural production means). The methane fermentation is still the main source of GHG emissions in animal production, so it will remain the subject of intensive studies. The change in the methodology demonstrated however the meaning of natural manure management and the scientists and the farmers-practitioners will have to pay more attention to the mentioned problem [Christie Et Al. 2018].

The estimation of the methane emissions in the case of one-year old sheep in the national inventory of New Zealand adopts values of the emission intensity indicator at the level of 20.9 g of CH_4 as calculated into one kg of DM consumption by the one year-old sheep. The mentioned data deriving mainly from the studies during which the feed consumption was determined as CH_4 emissions, were indirectly estimated using the sulphur hexafluoride marker. When utilizing the data collected in New Zealand in the years 2009-2015, during which consumption was precisely recorded and CH_4 emissions were measured for at least 48 h in the respiration chambers (n=817), there were updated the algorithms for the estimation of methane production by the sheep; the mentioned values were later recommended to be applied in the national inventory of greenhouse gases. One equation for all age categories of the sheep, based upon the daily methane emission in terms of kg of dry matter consumption (In (g CH_4 ·day^{-1}) = 0.763 x In (DMI) 3.039) explained 76% of the changes in CH_4 emission. The classification of the data set into two age categories supplied two alternative equations: (sheep>1 year of life), 1n (g CH_4 ·day^{-1}) = 0.765 x 1n (DMI) 3.09 and (sheep <1 year of life), 1n (g CH_4 · day^{-1} · day^{-1}) = 0.734 x 1n (DMI) + 0.05 (metabolizable energy) + 2.46. The analysis of conformity suggests that the better adjustment of the data is obtained when applying two algorithms. The application of the updated algorithms in the national inventory caused small changes in estimated values of the emissions both in the specified years and between the particular years [Swanson Et Al. 2018].

The pastures are a significant source of methane coming from enteric fermentation but the available techniques for quantitative determination of the level of methane from the mentioned source in the scale of herd are limited. Coates Et Al. [2018] studied the suitability of the system of measuring the eddy covariance for a long term monitoring of CH_4 emission as a result of intestinal fermentation coming from the grazing cattle. The measurements were carried out in two sites: in the middle of a big pasture and in the vicinity of drinking place where the animals were gathering during the day. Location of cattle was monitored by the stop motion technique and the obtained information, together with the application of stochastic model of Lagrange's dispersion were utilized to interpret the stream of eddy covariance and to obtain the indicators of CH_4 emission, as calculated into one animal. The initial measurements on the pastures were difficult due to a quick moving of the cattle within the pasture but the feed supplement place in the direction opposite to the wind blowing helped to keep the animals in the measurement zone. It was found that the methane emissions coming from the cattle in the central part of the pasture were higher and more variable than in the drinking place. When combining the results from the both mentioned places, the methane production at the level of 0.43 g · kg^{-1} of the body weight was obtained; the mentioned value is found within the range of the results reported in other publications, containing the data on the CH_4 emission by the animals present on the pastures. The knowledge of behaviour of the animals staying on the pastures enables the most appropriate distribution of measuring points; together with the application of Lagrange's stochastic model, it may have the practical application during a long-term monitoring of the methane emission in grazing sites.

Amer Et Al. [2018] submitted the methodological assumptions for determination of weight of the factors, considered in determination of the values of indexes applied in the evaluation of the consequences of the selection of breeding animals; its aim is to reduce the level of GHG emission intensity. Factor of GHG emission for breeding purposes was defined as a ratio of the total emission and weighted combination of indicators, characterizing the results of agricultural production. The results of weighting may be employed as linear weights in the way which strengthens the role of all adopted breeding goals before the consideration of the intensity of the greenhouse gases' emission. The calculations, performed with the application of the developed methodology have been utilized in determination of the parameters and definition of assumptions, necessary for linking each change in genetic trait with the expected changes in the GHG emission in animal production. A potential effect of a given trait as calculated into relative number of emitting animals, per one reproduction female, has a direct impact on the level of the emission; the discussed effect is weakened by the production from additional animals. Besides it, each genetic trait may potentially change the level of GHG emission, generated by the animal and, in consequence, affect the level of their production. The discussed methodology has been employed in a form of a simple application in the dairy cattle breeding in Ireland. The profits, resulting from the genetic changes in respect of reduction of greenhouse gases' emission, as assessed with the consideration of the existing tendencies in milk production and fertility and survivability of the cows, were determined. The majority of the profits were identified as causing the increase of milk protein production in terms of one cow, although the profits resulting from the genetic improvement of the survival via the reduction of GHG emission from the herd population were also meaningful.

It was estimated that during the recent 10 years, as result of genetic changes in respect of production, fertility and survival traits, the intensity of GHG emission in Irish milk production has been reduced by ~ 5%. The present acceleration of the trends of genetic changes allows supposing that the reduction of the greenhouse gases' emission by the successive 15% during the coming 15 years may be expected.

Summing up

The animal production in 2015 was a source of 39.8 % of GHG emissions in Polish agriculture, of which 30.7 % came from intestinal fermentation and 9.1% was a result of animal manure management. Due to the fact that the animal production has also its participation in the emission, caused by energy consumption

in agriculture, its total share in the total emission of greenhouse gases (GHG) originating in Polish agriculture is equal to ca. 50%.

The emission of the greenhouse gases in animal production is dependent, inter alia, on the animal species, stage of their performance (e.g. age, lactation number), housing system, feeding system, as well as the way of removal and storage of manure which is also a source of harmful emissions.

Dynamically increasing number of the world population causes the increase in the demand on food. Under the conditions of the limited, and in certain parts of the world, the decreasing area of the agricultural land, it is necessary to intensify the agricultural production via the increase of the plant yield and the productivity of farm animals; it is connected with the necessity of increasing the outlays on the production means, and with the increase of the greenhouse gases' emission. In the discussed situation, the need of improving the performance in the agricultural production so as to meet the increasing demand on food all over the world, with the simultaneous minimization of a negative impact on the environment is more and more universally perceived.

The studies of the methane emission as a result of the intestinal fermentation in the animals are carried out in the respiration chambers. Placement of the animals in the mentioned chambers causes the stress what affects the feed intake and, in consequence – CH_4 emission. The results of the direct measurement of GHG emission in the animal production should be therefore treated with a certain caution. Moreover, the measurements of the animal emission of the greenhouse gases are difficult to perform and expensive. Therefore, certain researchers apply the indirect methods for estimation of GHG emissions.

The estimation of the methane emission by the dairy cows by the indirect method may be performed on the grounds of fatty acid profile in the milk, with the utilization of the relationships between the activity of microorganisms in the rumen and the particles available for milk synthesis in the mammary gland.

The results of the measurements and estimates of GHG emission by the animals constitute the basis for verification and updating the indicators, used during the inventory of the greenhouse gases at the national scale.

In the studies on the methane emission, caused by the enteric fermentation taking place during cattle grazing on the pastures, the system of monitoring the animals' movements by the stop motion techniques; the obtained information together with the stochastic model of the Lagrange dispersion is utilized in the interpretation of eddy covariance and in obtaining the CH_4 emission indicators as calculated per one animal. The knowledge of the behaviour of the grazing animal enables the most appropriate distribution of measuring points.

In the evaluation of the consequences of the selection of breeding animals with the aim to determine the parameters and to outline the assumptions necessary for linking each change in genetic trait and the changes in the intensity of GHG emission in the animal production, the method of the weights of the factors considered during the determination of the indicators, used in the calculations, is utilized.

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YIELD FORECASTING USING ARTIFICIAL INTELLIGENCE

PROGNOZOWANIE PLONÓW PRZY UŻYCIU SZTUCZNEJ INTELIGENCJI

Summary: *The article reviews and analyzes literature for application of artificial intelligence in forecasting of crop yield. Yield forecasting models were based on neural networks, fuzzy logic or hybrid solutions. When designing new yield forecasting models, analyzes of the main factors of components that are important for yield forecasting should be performed. This is to eliminate unnecessary or negligible factors for forecasting. It is also important to review the databases that will be used for forecasting. The data with unusual numerical results that differ significantly from reality should be deleted. This will improve the quality of the databases and, as a result, will give better forecasting results. In more complex cases, it would be recommended to create hybrid solutions combining neural networks and fuzzy logic to combine the advantages of both solutions.*

Keywords: *artificial intelligence, hybrid solutions, fuzzy logic, neural networks, yield*

Streszczenie: *W artykule wykonano przegląd i analizę literatury dla zastosowań sztucznej inteligencji przy prognozowaniu plonów. Modele prognozowania plonów były oparte o sieci neuronowe, logikę rozmytą lub rozwiązania hybrydowe. Przy projektowaniu nowych modeli prognozowania plonów należy przeprowadzić analizy głównych składowych czynników, które są istotne dla prognozowania plonu. Ma to na celu eliminację czynników zbędnych lub mało znaczących dla prognozowania. Istotne jest również dokonanie przeglądu baz danych, które zostaną wykorzystane do prognozowania.*

Słowa kluczowe: *sztuczna inteligencja, rozwiązania hybrydowe, logika rozmyta, sieci neuronowe, wydajność*

Introduction

Jayram and Marad [2012] found that accurate forecasting of crop yield is of increasing importance in the developed and the developing countries and everywhere where agricultural production is carried out. Reliable forecasts are expected due to the cost-effectiveness of the agricultural production and a high involvement of mechanical equipment. Sawasawa [2003] showed that knowing the size of crop yield before plants harvesting is important for decision-makers and politicians, especially in the regions with major climate changes and a capricious weather. It allows them to make a decision about buying cereals in case of their shortage or selling in case of their excess. This is related to food security, the risk of which can also be assessed using fuzzy logic belonging to one of the methods used in artificial intelligence [Kadir and Inni, 2013]. Plant production can take place in the field or in greenhouses and plastic tunnels. Field production is closely related to the weather [Baruth and Inni, 2008]. In greenhouses, on the other hand, production is rather independent on the weather conditions [Qaddoum i inni, 2013]. Yields in plant production depend on several overlapping factors that usually change relative to each other at the same time, in a non-linear way [Boniecki & Niżewski, 2010]. This makes it difficult to predict yields using traditional methods. Boniecki and Niżewski [2010] proposed the use of procedures based on the artificial intelligence methods. Artificial intelligence appeared as a new field of knowledge along with the development of science. According to Kwatera [2016], artificial intelligence is a relatively new interdisciplinary field of science, a subject of great expectations and lively debates. In a theoretical sense, it combines the issues in the field of computer science, psychology, anthropology, mathematics, electronics, neurophysiology and philosophy. This serves to solve problems based on natural cognitive processes of man [Bartman 2017].

Objective, scope and methodology of work

The aim of the study was to review the artificial intelligence methods used to forecast crop yields. The scope of the work was to specify the methods and factors used in these methods that

were utilized to forecast yields, and to prepare a brief description of the basics of the developed crop forecasting models. Literature analysis was adopted as the methodology of work.

Literature analysis

Niedbała et al. [2005] analyzed the assumptions for modelling sugar beet crop using artificial neural networks. Based on the literature information, own research and the conclusions from the regression analysis, they selected the following factors important for the needs of neuronal forecasting: soil bonitation class, level of organic and mineral fertilization expressed in the pure NPK component, sowing date and seed sowing standard, final plant density, date of beet harvest, temperature, sunshine and precipitation. Factors causing a decrease in the quality and quantity of the crop (diseases and pests) were omitted because it was assumed that their appearance was earlier detected and appropriate preventive measures were taken. The authors created, learned and tested various types of networks to select an artificial neural network with the right topology. MLP multi-layer perceptron networks were chosen for use due to lower error values. The designed network correctly predicted the sugar beet yield based on the input data provided. The authors conclude that the artificial neural networks can be an efficient tool for forecasting the effects of agricultural production not only in the case of sugar beet.

Boniecki and Niżewski [2010] designed, implemented and tested an IT system based on artificial neural network technologies that allowed forecasting the yield and starch content in potato tubers. This system forecasted the results on the basis of the following input data: average annual temperature, average annual amount of precipitation, potato variety, and average rainfall in the agrotechnical period and average temperature in the agrotechnical period. The authors used the Neural Networks package implemented in the Statistica v 7.1 IT system. The best yield prediction results were obtained by generating a RBF (Radial Basis Function) type topology with 5 input variables, 23 hidden neurons and one output neuron. In the case of starch forecasting, the best results were also obtained through the use of RBF networks. However, in this case, it turned out that the average rainfall of the agrotechnical period was variable with a negligible low weight for forecasting. Thus, input variables were reduced to four. 90 neurons were contained in the hidden neuron layer and one output neuron was used. The authors developed an IT system which they called 'Ziemniak'. This system contained previously described neural networks. The system made short-term forecasts of yield and starch content in potato tubers in an efficient and convenient way. The fact that the best results were obtained through the use of RBF type neural networks pointed to the non-linear nature of the relationship between input and output factors.

Qaddoum et al. [2013] used evolving fuzzy neural networks to predict the yield of tomatoes grown in greenhouses. This type of network was decided because they have the following advantages: the ability to model non-linear relationships within systems, resistance to imprecise, incomplete and uncertain input data. The advantages of this type of network have been revealed in the applications in various fields of technology related to forecasting, control, optimization and pattern recognition [Moraes & Machado, 2005]. As input variables, the temperature inside the greenhouse, the amount of CO_2 in the atmosphere, the water vapour pressure deficit in the air and the intensity of solar radiation and the history of previous crops were used. They adopted tomato yield per square meter as the output variable. The authors compared the results of the use of evolving fuzzy neural networks to predict the yield of tomatoes grown in the greenhouses for the use of a regular neural network and found that evolving fuzzy neural networks had a lower forecasting error than ordinary neural networks and required the last lower computing power

An average of 90% accuracy in predicting weekly fluctuations in tomato yields was achieved. In addition, the combination of the application of fuzzy logic in neural networks allowed reducing the sensitivity of the results for the adopted model of tomato yielding from imprecise input data. Its important feature was the inclusion of fuzzy logic inference rules (if-then rules) for each of the input variables. The authors stated that the network they developed and fully trained could be replaced by a set of if-then principles. An improvement of this system could be proposed by Frausto i Pieters [2004] by the use of neural networks to model the temperature inside the greenhouse as a function of external air temperature, air humidity, sunlight and cloudiness. For research they chose a network with one hidden layer of neurons. They stated that the network they proposed gave good results for long periods of operation, but they did not provide a statistical evaluation of their results.

Another solution would be the use of neural networks proposed by Singh and Tiwari [2017] for one-day prediction of average daily temperature and average daily relative humidity in the greenhouse based on input variables such as registered maximum temperature and minimum and relative humidity in the greenhouse, as well as average wind speed and insolation outside the greenhouse. As a result of research, an optimal network was built having 6 neurons in the input layer, 4 neurons in the hidden layer and 2 output neurons. The authors conducted a statistical analysis of the results and found that for the optimal network between the actual measured temperature and the predicted temperature, the mean square error was 0.711 °C and the mean absolute error was 0.558 °C. Between the measured and predicted humidity, the mean square error was 2.514% and the mean absolute error was 1.976%.

Jayram and Marad [2012] used a fuzzy logic system to forecast sorghum yield. They considered combinations of various plant characteristics that affect yield such as days for 50% flowering, the percentage of insect damage, plant height, inflorescence length, inflorescence weight, and number of ovules. There was found a very high correlation identified as a logarithmic relationship between the height of the crop and the length of the inflorescences with the mean square error value of 1.39. About 1000 data from reality were available. About 70%

of this data was used to train the system. The remaining 30% of the data was used to test the yield forecast. As a result of simulations and tests, the system was finally selected as input to the system: days for 50% flowering, height of inflorescences, weight of inflorescences, and the number of ovules. Very good forecasts made by the system were found.

Stathakis et al. [2010] created an adaptive inference system based on neural networks and fuzzy logic for forecasting wheat yield. As input data, some of the parameters of the crop growth simulation model used in the WOFOST system [Supit et al., 1994] were selected, such as soil moisture, the amount of biomass above the ground and the amount of biomass contained in the roots. In addition, information obtained from remote sensing in the form of a normalized differential vegetation indicator (NDVI English abbreviation) was used. NDVI values were collected every 10 days and were divided into two periods to create two different time profiles. The first period covered the data from the time of sowing to harvest (until August 1). The second period covered the data from the time of sowing to the point of heading (until June 1). This was done to investigate the differences between early crop prediction (when heading) and late forecast (during crop ripening). For comparison, an ordinary neural network was created that did not use fuzzy logic.

The ordinary neural network turned out to be completely unstable in its behaviour. In contrast, the neural network in conjunction with solutions derived from fuzzy logic gave quite good results. Overall forecasting accuracy averaged 74% for both the first and second periods. The authors suggested improving their system by taking into account the results of modelling dry matter production and meteorological factors such as temperature, amount of precipitation, snow depth, etc. The system can be improved by using genetic algorithms to select the optimal number of input parameters and their values.

Guo and Xue [2012] proposed forecasting wheat yield in the state of Queensland, Australia by testing and training the neural network. They stated that the yield depends on many factors such as the area of cultivation, water consumption, rainfall and temperature variability, seed quality, terrain topography, soil quality, emergence of diseases and pests, etc. It turned out that some of these factors are irrelevant to the time factor. Efforts have been made to use statistics to identify relationships between these factors and to use neural networks to map the effects of some of these factors on the crop yields. The complexity of the problem required the creation of a multi-criteria hybrid system that would take into account all or most of these factors in order to achieve a satisfactory level of monitoring crop growth and yield forecasting. First, historical data in the state of Queensland were statistically examined. As a result of this analysis, the following factors were determined that had the greatest impact on wheat yield: crop area, rainfall and temperature.

Secondly, unusual results for designated factors were removed to achieve better results of future forecasts. Thirdly, a neural network was created, the operation of which was based on data from previously determined factors. The authors showed that their neural network with 100 nodes predicted wheat yield with an average absolute error of 2.06%, a maximum error of 9.64% and a standard deviation of 2.96%. It was stated that at the beginning a statistical analysis (multifactorial regression) should be carried out to identify the most important factors affecting the yield. This analysis should also help detect unusual data values to remove them from the data set and identify trends in the data changes.

Only then you can build and train a neural network. In the future, the neural network can be expanded by taking into account other factors.

Kumar et al. [2010] applied fuzzy logic to time series to predict wheat production in the experimental fields of the University of Agriculture and Technology in Pantnagar, India. Time series were created based on available yield data from 1981-2002. Three models based on fuzzy logic were created. The first of these was based on Chen's arithmetic [1996]. The second one was built using modified medium weights. The third of them was a time-unchanging model. Crop forecasts were made using all three models. It turned out that they gave very similar results with an average error of around 11%. The mean square error was 138.458, 135.105 and 140.901 for these models, respectively.

Aggarwal et al. [2017] used a fuzzy logic system to forecast rice production yield. This system was based on the analysis of fuzzy time series of historical data on rice yields and forecasting future yield on this basis. They proposed dividing the range of predicted yields into 7 equal intervals and compared the results of forecasting with divisions into 9 and 11 equal intervals proposed by other authors. The system operation was assessed on the basis of the average forecasting percentage error and mean square error, which were respectively: 3.45% and 22.737.5 for 7 ranges, 3.75% and 28.088,6 for 9 ranges and 3.13% and 23.478, 1 for 11 compartments. The system with 7 compartments gave the best results.

Kandala and Prajneshu [2002] proposed a method based on fuzzy regression using remotely collected data. The input data came from photographs of crops taken in the visible and near infrared range. Based on these calculations, a normalized differential vegetation index (NDVI abbreviation) and vegetation index (RVI abbreviation) were calculated. According to the results of ANSARI et al [1999], these indicators are closely correlated and cause the problem of collinearity of these indicators. This results in an increase in standard errors for test results using these indicators. The methods used so far using principal component analysis, dorsal regression, etc., did not give satisfactory results and were not reliable. Only using the fuzzy regression method allowed to obtain satisfactory results. However, the authors did not provide errors or any statistical evaluation of the results obtained.

Summary and conclusions

Advances in the development of artificial intelligence have made it possible to solve the problems of combining non-linear factors with a high degree of uncertainty and with low-quality data into working models for forecasting future yields. This was

done successfully for all kinds of plant species. These models used information from one to several factors. Researchers have proved that it was possible to forecast yields correctly based only on data on the history of yields collected over a dozen or so decades. Crop forecasting was also carried out using more factors. There was a limitation of data availability.

To develop yield forecasting models, solutions based only on neural networks or fuzzy logic were used, as well as hybrid solutions combining these two issues. In the case of designing new models for yield forecasting, it would be advisable to carry out an analysis of the main components of factors that are important for yield forecasting in order to eliminate redundant or insignificant factors for forecasting. It would also be important to review the databases that will be used for forecasting. The data with unusual numerical results, which differ significantly from reality, should be removed. This will improve the quality of the databases and, as a result, will give better forecasting results. In more complex cases, it would be recommended to create hybrid solutions combining neural networks and fuzzy logic to achieve the synergy of the advantages of both solutions.

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VOICE IN DISCUSSION ON THE LOWER VISTULA RIVER CASCADE

GŁOS W DYSKUSJI NA TEMAT KASKADY DOLNEJ WISŁY

Summary: *The Lower Vistula term concerns the Vistula River at 391 km-long segment from the mouth of the Narew River where a considerable increase of the catchment area and the level of flows takes place. Due to the total amount of the managed water, the Lower Vistula River is a basic resource of hydro energy in Poland in spite of the small gross head in total, amounting to ca. 70 m and a very uneven flow. The utilization of the mentioned energy potential was based upon the plan anticipating a cascade of the possibly high water damming up, and the power plants with the storage work systems. Water navigation was expected to become the equivalent user of the cascade.*

Key words: *Lower Vistula, cascade, water damming*

Streszczenie: *Określenie Dolna Wisła dotyczy Wisły o długości 391 km od ujścia Narwi, gdzie następuje znaczący przyrost zlewni i wielkości przepływów. Dolna Wisła ze względu na ogólną ilość prowadzonej wody stanowi w kraju podstawowy zasób energii wodnej, mimo w sumie niewielkiego łącznego spadu brutto, wynoszącego ok. 70 m oraz bardzo nierównomiernego przepływu. Wykorzystanie tego potencjału energetycznego bazowało na planowaniu utworzenia kaskady możliwie wysokich piętrzeń wody, z elektrowniami o szczytowym charakterze pracy. Równorzędnym użytkownikiem kaskady miała być żegluga wodna.*

Słowa kluczowe: *Dolna Wisła, kaskada, spiętrzenie*

The implementation of the cascade was commenced in the sixties of the 20th century from the highest water barrage in Włocławek, with water head H = 11.5 m, with the storage power plant of discharge Q_i = 2150 m³/s, being more than twice higher than the mean flow. The construction of the successive barrage in Ciechocinek, which was expected to create the compensating reservoir for the electric energy plant in Włocławek has not been undertaken until now. The decades-long storage work system in the Włocławek power plant has brought about the erosion of the Vistula River bed above the barrage what is a threat to the stability of the dam.

In the power plant at the Ciechocinek barrage and later on, at the barrage with the changed name Nieszawa, there was anticipated the flow system work, with the installed discharge Q_i = ca. 1200 m³/s, i.e. ca. 1.3 $Q_{śr}$.

The suggestion of the discussed barrage under the name Siarzewo, being prepared by the Energy Sector, provides for the damming H = 8.5 m and construction of power plant with discharge Q_i = 1800 m³/sec. The installed capacity of the power plant was designed for the conditions of the head which would be created after the erosion of the lower stand. The intensive erosion was expected as the run-off from the Siarzewo barrage would occur to a natural segment of the river bed where the fluctuations of the water level between the mean flows (SNQ) and the installed flow, led down by the power plant were equal to ca. 2.5 m. The size of the fluctuations of the mentioned water levels would not be reduced by the targeted implementation of the next barrage at Solec Kujawski, being situated at the distance of 51.6 km from Siarzewo.

Fig. 1. Map of the Vistula divided into zones
Source: www.doi.prz.edu.pl

The work of hydro plant in the peak system with discharge Q_i = 1800 m³/s causes that with the damming H = 8.5 m. the energy head with the mentioned flow will amount only to 4.9 m. the reduction of the installed discharge to Q_i = 1200 m³/s and the change into the basic work scheme may increase production of the energy plant by more than 20%.

Map 1. Characteristics of the Lower Vistula Inland Waterway (from 684,000 km to 942.300 km)

The existing barrage in Włocławek divides the Lower Vistula River Cascade into two parts. The upper part should be considered as being commenced at the Vistula River from the future barrage, stabilizing the level of water in the Warsaw Vistula River (km 524.5) and at the Narew River from the Dębe barrage. The lower 267 km-long part begins below Włocławek. According to the analyses and the preliminary proposal of the National Water Management Polish Waters („Wody Polskie"), in this part, there is anticipated the implementation of 5-barrage cascade (Variant W3C) with the parameters shown in Tab. 1.

The main purpose of the mentioned barrages is to utilize the energetic and navigation potential of the Vistula River below Włocławek.

Tab.1. The parameters of Lower Vistula River Cascade according to the project of the National Water Management „Wody Polskie"

Parameters	Cross-section of damming/Reservoir				
	Siarzewo	Solec Kujawski	Chełmno	Grudziądz	Gniew
Km of river	706.4	758.0	801.5	835.0	876.3
Level of damming, m above sea level	46.0	37.5	29.0	22.0	15.0
Height of damming H_{br} m	8.5	8.5	7.0	7.0	7.2
Size of head at SSQ m	6.1	6.7	5.5	4.0	5.7
Length of stand, km	31.9	51.6	43.5	33.5	41.3

The basic assumptions result from the situation and the long-time analysed connections. During the recent updating, the Tczew barrage has been given up. From the statement it is followed that after the years since development of the first conceptions of the cascade, its basic drawbacks have not been changed.

The suggested cascade may utilize only 38.2 m of the damming height H_{br} and ca. 28 m of head at SSQ 83% and 60% respectively, from the theoretical head H_{br} = 46 .0 m. The shortest stands are found in Siarzewo (31.9 km) and Grudziądz (33.5 km) reservoirs. The Solec Kujawski reservoir has the longest stand, i.e. 51.6 km. The natural river bed from Gniew to the estuary has a length of 65.2 km.

From Siarzewo to the mouth of the Drwęca River, there are the shallow sites which require dredging. The similar segments of shallow sites occur below the Brda River (km 767 – 782), in the region of Chełmno (806 – 815) from the mouth of the Mątowa River to Opaleń (km 850 – 860) and in the region of Tczew (km 905 – 920). The implementation of high damming shall not, therefore, eliminate completely the segments of shallowing.

Below the Siarzewo and Gniew barrages, the natural river segments are found where the intensive erosion may occur.

Fig. 2. Wisła at the height of Siarzewo (May 2016)
Source: www.commons.wikimedia.org

Apart Siarzewo, the power plants, being situated at the barrages, have the installed discharges 1300 m^3/s each and they will probably work according to the scheme of sub-peak work.

For few years, after having signed the AGN Convention by Poland, the Lower Vistula River Cascade has obtained a strong support as the element of the international waterways: E70 in the segment from the Brda River mouth to Nogat and E40 in the segment from Gdańsk to Warsaw.

However, the indisputable approval of directions and international parameters of water ways, as established several dozen years ago without our participation, may not affect the support of the economic justification of the purposefulness of the Cascade implementation. The water way with the parallel direction from the west to the east is more important direction for Poland and the role of the Cascade may result from its linking with the mentioned parallel way.

The waterway may be fully utilized as late as after the completion of its last segment what may cause a long period of freezing the outlays, limiting the general effectiveness of the Cascade.

The heights of water lifting (8.5/7.0 m), as established for the adopted location of the barrages, correspond to the levels of the so-called determining (design) water flow, creating a big flood threats; for their limitation, it is necessary to prepare and maintain appropriately the expensive technical equipment. The discussed heights of damming:

- Deplete the capacities of inter-embankments to retain water at the flood flows (e.g. for Siarzew, the flood protecting capacity is equal only to ca. 10 million m^3);
- Cause a serious effect on the adjacent territories, requiring the performance of work and protective devices;
- Require rebuilding of majority of the flood embankments into side dams with considerably higher technical requirements and costs;
- Cause the concentration of flood flows on the width of the weir cross-section;
- Require deep foundations of the construction under the complicated water and river bed conditions.

Fig. 3. Energa S.A. investment project in Siarzewo - visualization of the Siarzewo Water Step prepared by Biuro Projektów S.
Source: www.wody.gov.pl/aktualnosci

The arguments concerning the purposefulness of considering the waterway in the cascade with a small quantity of locks to reduce the locking time are disputable. The time of locking is also dependent on some other factors, e.g. the effectiveness of navigation stock. There is an unrepeatable occasion for creating the completely new stock.

In the solutions of the Lower Vistula River Cascade, variant of lower damming of the order H = 4.0 ÷4.5 m has never been exhaustively analysed.

Only variant of the so-called Small Cascade with the adjective „ecological" (organic) revealed a certain link to such system of cascade. The mentioned variant (ESR) is referred to for the

justification of the choice of high water lifting (Variant W3C). Due to the range and accuracy of the mentioned elaboration, it could not give the results which might serve for the comparison with the high damming cascade, being always recognized as the only one variant of the Lower Vistula River development.

When developing the conception of the Small Cascade (variant ESR) with 11 barrages, the possibility of utilizing the cascade of barrages with the similar damming heights has not been employed although it would unify the solutions of the barrages and power plants. In the electric energy plant, the equal discharges Q_i = 1400 m^3/sec were adopted but the heights of the lifting amounted from 2.6 m to 5.2 m, causing a considerable differentiation of the solutions and difficulties in the implementation.

We should, however, pay attention to the fact that in the variant of the Small Cascade it is possible to eliminate the segments of shallow sites and the utilization of the water fall is significantly higher than in variant W3C. The general height of the Cascade dammings is equal to 41.75 m and the sum of the falls at the flows SSQ is 37.4 m what constitutes as much as 90% and 81% of the theoretical head H_{br} = 46.0 m, respectively.

Fig. 4. South Przegalina Lock.
Source: www.rzgw.gda.pl

Fig. 5 South Przegalina Lock, view of the upper gate from the water level.
Source: www.rzgw.gda.pl

The problem of the implementation of the cascade with lower damming is very important. From the nature of the river bed and the inter-embankments it is clearly followed that the application of dammings on the levels of shore water may create a new quality of investing and exploitation of the cascade; the more so because the values of flows on the whole length of the Cascade are inconsiderably changing.

The water engineering investments are generally long-lasting but also expensive and have a significant influence on the environment. The later „adaptations" or „supplements" are difficult and sometimes, impossible. Therefore, the programme of the investments must be precisely thought out and comprehensively justified. It will be the invested money of every citizen who should be considered as a shareholder. It is necessary to anticipate the possibility of their visits at the objects on each stage of the implementation and exploitation and to ensure the reasonable return of the costs and dividends.

Coming back to Siarzewo, we should remember that the barrage below Włocławek has to meet two basic goals: „supporting" the barrage in Włocławek and obtaining the appropriate compensating capacity for power plant in Włocławek. Meanwhile, the Siarzewo barrage looks like a successive Włoclawek, which may cause now the similar problems shifted into the Ciechocinek region and below it.

When designing Siarzewo, the main problem of the investor included probably the installation of maximum capacity and overcoming the different ecological and administrative barriers.

The installation of maximum possible power excluded the consideration of dividing the reservoir ***via*** the implementation of indirect barrage in the region of Bobrowniki.

The analysis of the two-barrage Siarzewo could be valuable for the determination of typical solutions and the application of uniform equipment and advanced pre-fabrication in the successive barrages of the Cascade with dammings up to 4.5 m what may decisively facilitate its implementation. Two damming constructions, replacing one, twice higher construction may be noticeably cheaper than the mentioned one.

The Lower Vistula River Cascade with the application of dammings of height H = 4.0÷$.5 m should be supplemented with the barrages in Tczew and Przegalina in the lower part and the „supporting" barrage in Dębe on the Narew River and the barrage on Warsaw Vistula River.

The barrages on the Narew River and The Vistula River in Warsaw would commence the Lower Vistula River Cascade from the top. The barrages Tczew and Przegalina would facilitate the inflow of the sea ships as far as to Tczew and would allow the implementation of the modern linking of the Vistula River Lagoon and Gdańsk and Tczew, with four exits to the sea.

Summing up of the argumentation

The Lower Vistula River has a big energetic and navigation potential. It is justified to run the activities aiming at the management of the existing potential as a whole or in the parts.

The development of the mentioned potential is possible via the implementation of the cascade of the lifting barrages.

The management of the Lower Vistula River Cascade should be understood as a system of lifting barrages with uniform damming of the order from H = 4.0 to 4.5 m commencing from the Warsaw Vistula River and Dębe on the Narew River and ending at the Przegalina barrage, with the consideration of the existing Włocławek barrage, with untypical damming up H = 11.5 m.

The dammings up to 4.5 m, eliminating variants with dammings of height up to 8.5 m, as being considered until now, are found in the range of the levels of shore water, what facilitates:

- Reduction of the size of weir via inclusion of floodplain of inter-embankment to let pass WW;
- Maintaining the majority of the existing flood embankments without the necessity of their rebuilding into side dams;
- The complete exchange of the stored water during 2 – 3 days as early as at low flows;
- Preservation of the natural possibilities of retaining the flood waves in the existing inter-embankments;
- Limitation of the effect of damming on the adjacent environment;
- Stimulation of economic development of the neighbouring regions along the whole length of Lower Vistula River Cascade (in Polish: KDW) via arrangement of greater quantity of building sites and river passages.

The management of KDW by the application of the barrages with the uniform height of damming:

- Creates a waterway with similar depths on the whole length of the stands;
- Enables designing the typical technical solutions with the application of significant pre-fabrications and stream-like system of the implementation of barrages;
- Facilitates starting a profitable production of technological equipment.

In respect of the energetic utilization of KDW, giving up the system of peak work scheme is advised.

To justify the economic purposefulness of energetic utilization of the potential of the Lower Vistula River, the author of the present paper would recommend the performance of comprehensive analysis of technical solutions together with the application of greater number but smaller traditional turbines in power plant in vertical system, facilitating their build-in in weir constructions.

In the case of a shallow river, the application of smaller turbines limits the depth of the power plant situation. In rather complicated background on the Lower Vistula River, each decrease of the foundation depth will have a decisive influence on the costs and acceleration of the implementation.

The unification of the technological and energetic equipment for the whole KDW would facilitate the start up of the national production.

The implementation of the Lower Vistula River Cascade requires considering the theoretical, even being not widely employed solutions; in the engineering practice, the application of the cascade of lower barrages is a normal matter. It is better to think twice or thrice before commencing the field work, requiring the use of enormous financial means and their freezing for the period of the cascade implementation.

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THE FIRST POLISH CABLEWAY KUŹNICE – KASPROWY WIERCH

PIERWSZA W POLSCE KOLEJ LINOWA KUŹNICE - KASPROWY WIERCH

Summary: *The article presents the process of establishing the first Kuźnice-Kasprowy Wierch cableway in Poland until its persecution in March 1936. It was then the first cableway in Poland and the largest of its kind in the world. It was also then the first investment of this type in Poland and the sixties in the world. Despite the passage of 80 years, the cable car still carries passengers.*

Keywords*: cableway, Kuźnice, Kasprowy Wierch, Tatra Moutains*

Streszczenie: *Artykuł przedstawia proces powstania pierwszej kolei linowej w Polsce Kuźnice-Kasprowy Wierch aż do jej otrwacia w marcu 1936 r . Była to wtedy pierwsza kolej linowa w Polsce i największa tego typu na świecie. Była to również wtedy pierwsza inwestycja tego typu w Polsce i sześćdziesiąta na świecie. Mimo upływu 80 lat wspomniana kolejka linowa wciąż przewozi pasażerów.*

Słowa kluczowe: *kolej linowa, Kuźnice, Kasprowy Wierch, Tatry*

Intruduction

The cableway Zakopane Kuźnice – Kasprowy Wierch, situated in the Middle Tatra Mountains, as being the first aerial cableway in Poland and the greatest one in the world, was opened to the public use on March, 15, 1936. It was the first investment of this type in Poland and the sixtieth one in the world. In spite of 80 years of time elapse, the mentioned cableway still transports the passengers.

Historical view

The contemporary President of the Polish Skiing Union and the vice-minister of transport, engineer Aleksander Bobkowski was the initiator of building the cableway. As early as in 1934, The Central Design Office of Polish State Railways (PKP) commenced, at the instruction of the Ministry of Transportation and Communication, the field studies and measurements with the aim to establish the run of the railway's route. The decision on the construction was undertaken in July 1935. The especially set up company under the name „Society for Building and Operation of the Cableway Zakopane (Kuźnice) – Kasprowy Wierch", with the seat in Warsaw, was the investor. The architect Aleksander Kodelski, Eng., became the President and Technical Director of the mentioned company. The shareholders were as follows: Polish State Railways, League for Support of Tourism, Polish Travel Office Orbis, and the Society for Skiing Promotion and Gdańsk Shipyard.

Fig. 1. Aleksander Bobkowski (in the middle)

On July 24, 1935, Engineer Medgard Stadnicki was appointed as the manager of the building site and Engineer Borys Lange became the deputy manager. The detailed timetable specified the extremely short building time for such investment – 7 months. It was decided to develop the discussed investment by the self-build method. At first, ca. 600 persons were employed. The qualified stone masons, sawyers and carpenters were recruited not only from the Podhale and Sądeckie regions, from Cracow and Tarnów but also from the very remote territories of Vilnius region. The field work was commenced on August, 1, 1935. During the last two months of construction, the employment was increased up to 1000 workers.

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The total length of the cableway is 4.2 km. Due to the impossibility to perform such long carrying ropes and due to the bending of the route visible on the project plan, the whole line was divided into two segments: 1) Kuźnice (1032 m above sea level) – Turnie Myślenickie (1360 m a.s.l.) with length of 1974 m and difference of the levels equal to 328 m and 2) Turnie Myślenickie – Kasprowy Wierch (1965 m a.s.l.) with length of 2290 m and difference of the level amounting to 605 m. the total difference of the levels from the initial to the final station is 933 m.

The ropes are suspended between the stations on 6 steel towers, being from 14 to 32 m high. The length of the spans varies from 123 to 998 m. The elevation of the lines above the Kasprowy Valley in certain places of the second segment is equal to several hundred metres. The buildings of the cableway stations were built from reinforced concrete and granite. All stations were equipped with the waiting rooms, cash desks, roofed platforms, sanitary facilities, central heating system, electric light, sewage and water pipeline systems and, even, small office flats and few rooms for tourists. The Turnie Myślenickie station (situated in the middle) contained: transformers, spare current-producing ggreagte and 2 engine rooms, serving independently the upper and lower segments. On the mentioned above station, the passengers from the lower segment move to the car of the upper segment and vice versa. Apart from the mentioned above facilities, the station Kasprowy Wierch has also glass-wall restaurant room 912 X 8 m) where there is a vast view of the wonderful panorama of the Tatry mountains.

Development of the cableway to the Kasprowy Wierch was the world record; not only in respect of the length of the route but also in respect of the speed its performance. The peculiarities of the construction – apart from the unusual event in Poland – include difficult communication and transportation (mountainous territory, steep and sloped rock hill sides, lack of roads), lack of water and sand in the site, etc., and very difficult climate conditions. The frequent and dense fogs,

Fig. 2. . Construction of the Kuźnice upper station

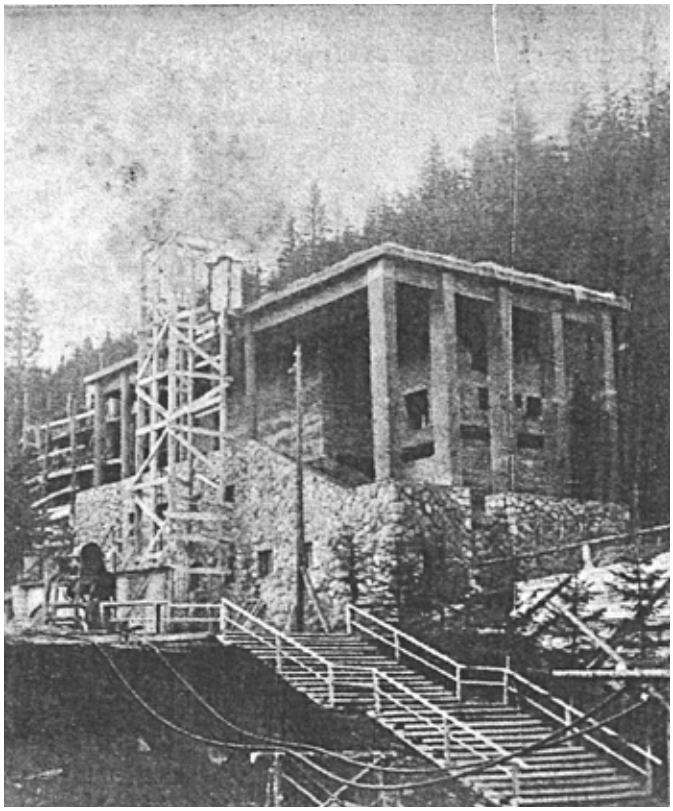
strong and often-occurring winds (18 foehn (in Polish: halny) winds during one winter – the record of the Tatry Mountains), snow and frost were many times the cause of inhibiting the work. The sand was delivered by railway from Nowy Targ to Zakopane and further, to Kuźnice and Myślenickie Turnie by cars, and finally, to Kasprowy Wierch; at the beginning in the bags, carried by the carriers and the Hucul horses and later on, by the auxiliary aerial cableway, suspended on the temporary wooden supports. The wagons of the mentioned cableway of 700 kg capacity performed 25 – 45 runs per day. The mentioned cableway worked all the time by day and night, stopping its work only during strong halny winds.

Almost all work with concrete, reinforced concrete and bricklaying was carried out in winter, usually on the quickly hardening concrete Alca-Electro, produced in Poland. Bricklaying and placing the concrete was performed at the open air and at the frost reaching up to – 14°C. After 24 hours, the boarding could be already taken off the concrete and the structure could be loaded as its endurance was equal to several-day strength of the concrete on the usual cement.

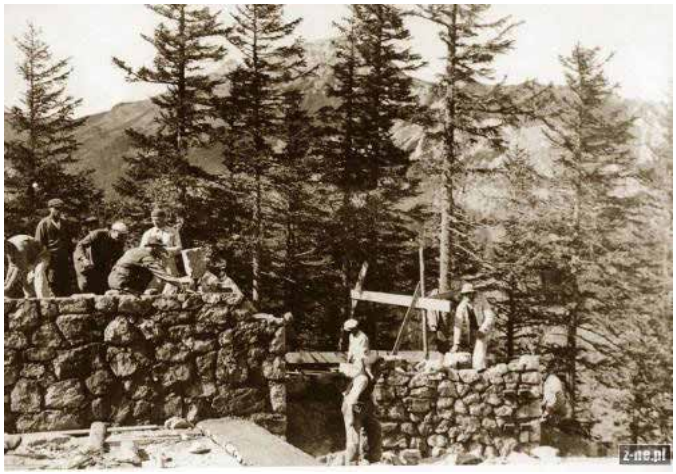
On the Kasprowy Wierch, the work with concrete and bricklaying was conducted in the exceptional way, in a special wooden temporary structure with dimensions 20 X 12 X 15 m inside which the central heating system and electric lamps, fed from the mobile current-producing aggregate were installed. The walls of the discussed structure were insulated with 5-cm plates of Heraklith (plate of wooden wool). The insulation itself, without heating, ensured the temperature by 10°C higher above the ambient temperature inside the discussed building. A part of water used for concrete was melted from the snow using a coil, connected with the heating installation.

The most difficult operations included performance of the supporting tower no 5 and no 6, being found on the steep, craggy rock hillsides, over a few hundred meters abyss of Kasprowy Valley. The foundations of each tower consist of 4 concrete blocks of ca. 25 – 30 m^3 capacity each of them; their task is to counteract the reactions of wind, directed upwards and amounting to – according to statistical calculations – up to 50 tons. The foundations of the building situated on the Kasprowy Wierch were placed on the granite rock; the towers of the upper segment and of the station Myślenickie Turnie are situated on limestone and those ones of Kuźnice are found on hard clay. The excavations were performed in many places using pneumatic tools and dynamite. The riveting of the towers was also carried out mechanically, using pneumatic hammers with the application of mobile compressors.

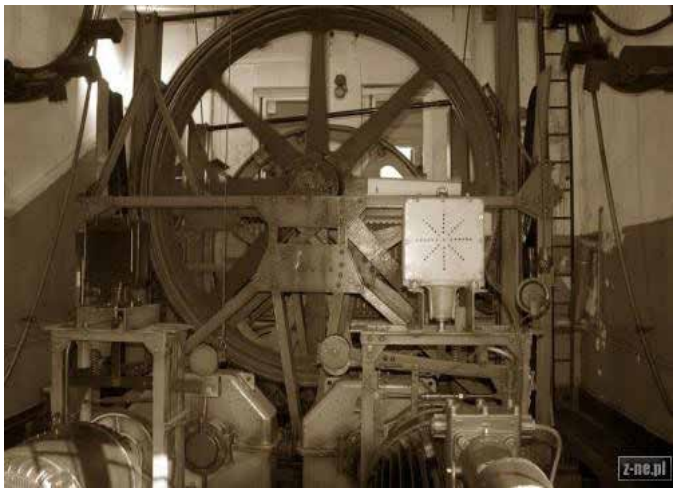
Fot. 4. Construction of the Kuźnice bottom station



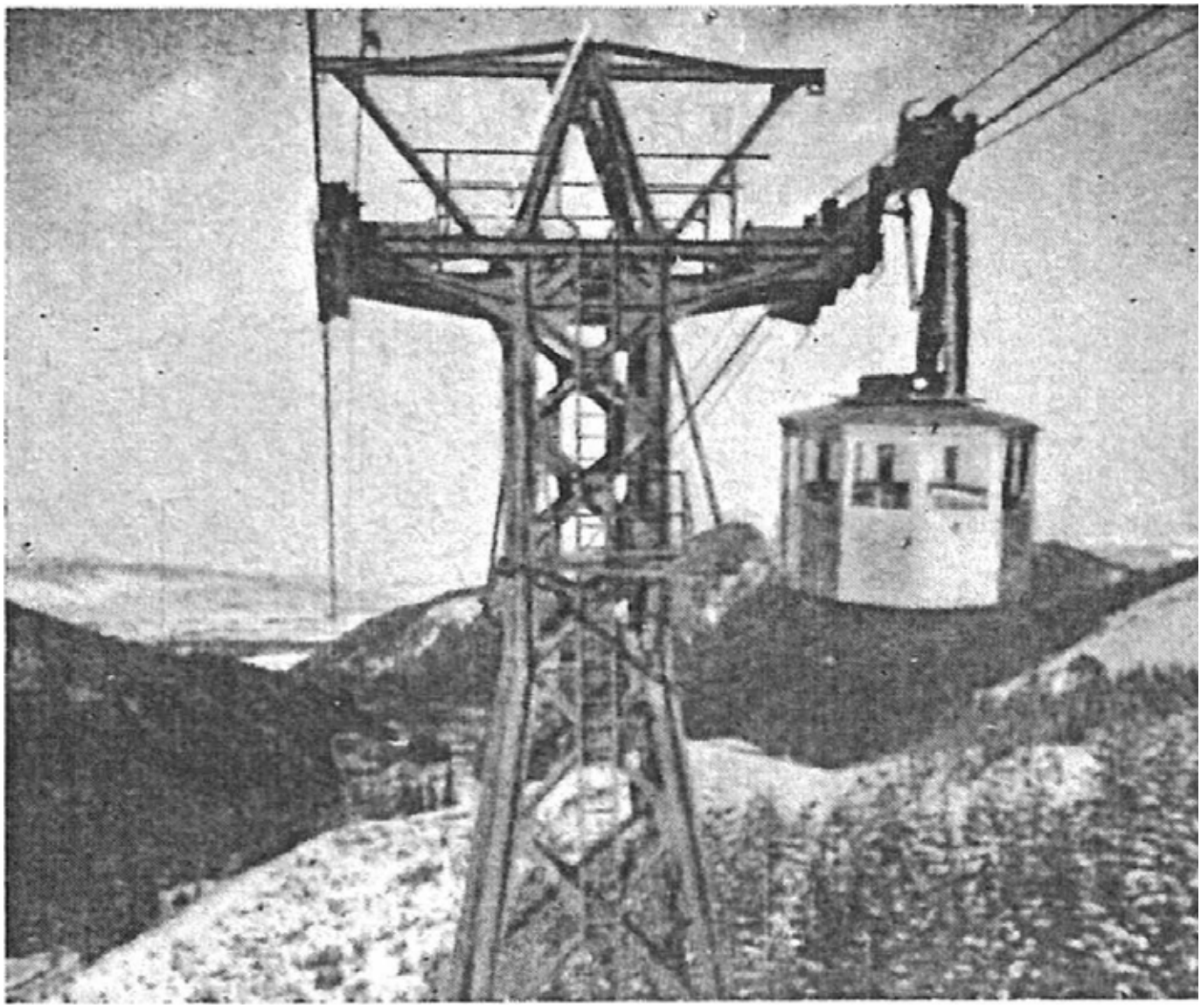
Fot. 3. Construction of the Myślenickie Turnie intermediate station



Fot. 5. Engine room on Kasprowy Wierch



Fot. 6. Historic car



For transportation of rope carriers with the diameter of 45 mm in the lower segment and of 48 mm in the upper one, and with the weight of 30 tons each of them, being wounded on the drums, there were used 4 conjugated tractors which transported the drums from the railway station Zakopane to Kuźnice; then, the ropes were rewound and overhauled further and higher using the so-called motor jacks. The tensile strength of the ropes' wires is equal to 100 – 180 kg/mm^2. The admissible loading of the ropes at the lower segment is 203 tons, of the upper one – 229 t. The weight of 1 current meter of the rope corresponds to 10.9 and 12.4 kg/m. the total cost of 4 rope carriers amounted to 180 000 PLN. The drive, main and auxiliary ropes have the diameter of 21 mm and 17 mm. All ropes were produced at the factory in Sosnowiec. The upper ends of the rope carriers were fixed on the reinforced concrete drum with diameter of 3.0 m on which 3 coils of the ropes on each were placed. The lower end of each rope was loaded with the counterweight, produced from the reinforced concrete, weighing 45.5 tons, and inserted to a special well, 10 m deep. Thus, the tension of the ropes remained unchanged, at any position of the car and temperature variations. The both mentioned reasons caused only elevation or lowering of the counterweight within the limits of 2.0 m.

Fot. 5. Minister Aleksander Bobkowski during the opening of the cablecar

Mechanical devices

The cableway was performed as double-track railway, so, each segment had 2 rope carriers. There were 4 wagons (cars), 2 for each segment. The cars were produced from a light metal and suspended on 8-wheel trolley. To increase the resistance of the wind strengths, the wagons had a shape of dodecagons. The capacity of one wagon was for 30 persons; including 8 seats. The glass of the windows was made from cellophane. 5the won weight of the car was equal to 1.5 t ; with the full load – 4.0 tons. The speed of the travel was 5 m/s that is, 18 km/hour. Each car was equipped with telephone, ring signalisation, 2 brakes (electric and mechanical0 and life-securing facilities, serving the evacuation of the passengers on the route using the hemp rope and canvas pants – in the case of a longer pause in travel. At the moment of pushing a red button in wagon, the electromagnetic brake at the station stopped the power supply and arrested the movement of both cars in a given segment. The mechanical brake could be applied by pulling down a hand and it acted directly on the ripe carrier, embracing it with the spring tongs; simultaneously, it switched the power supply off.

The both segments if the cableway were equipped with double electric drive: the main drive with the engine of 80 KM power, moving the cars with the speed of 5 m/s and the auxiliary one (spare) with the 35 KM power, developing the speed of 2 m/s. Each of the drives had a separate toothed gear and constituted a closed unit. In the case of damage of the main drive, the driver of the cableway switched the power supply to the auxiliary engine. All engines were placed in the separate engine rooms in the station Turnie Myślenickie where there was also found the three-phase transformer of voltage 5000/380/220 V, being supplied from the urban power station in Zakopane. In the case of the pause in the energy supply, e.g. caused by damage of the aerial cables, the Turnie Myślenickie station was furnished with the three-phase current-producing aggregate of 50 KW power with Diesel engine. The mentioned aggregate ensured a drive for the change of the upper or lower line with the speed of travel equal to 2 m/s.

The both cars of each segment were linked with one drive rope with a closed circle. For tensioning of the rope, a concrete block of 6 ton weight, attached to the sliding sledges of the lower line wheel was employed. Analogically, the auxiliary drive ropes were assembled. To switch the car onto the supporting drive, e.g. in the case of damage of the main drive, breaking the drive rope, etc., the car conductor left the wagon via the opening in the roof, climbed to the top, released the main rope and attached the holder to the auxiliary rope.

The safety facilities

Each drive was equipped with 3 brakes: one on a drive wheel, the second – on the motor shaft, being activated by electromagnetic device at the moment of pushing the button in the driver's compartment or in any of the wagons of a given segment. The third brake acted also on the motor shaft by automatic releaser if a normal speed of travel was exceeded due to inattention of the driver. The approaching of the drain and its entrance to a final segment was signalised automatically by a ring and red light on the cabin of the driver.

The situation of the wagons was visible on the "indicator of distance", being found before the driver of the cableway. Two graphic signs, denoting the wagons, were moved using the appropriate gears along the scale on which the supporting towers, stations and final segments were marked. To stop automatically the car on the station, the bumper was installed at the very end of rope carriers. The bumper had a spiral spring, the aim of which was as follows: mechanical resistance, switching the power supply off and activation of the brake. The drive ropes – both main and auxiliary – were simultaneously telephonic cables between the wagons and the driver's cabin. To this end, all rope wheels and rollers on the supporting towers were insulated.

On the tops of some towers, there were the anemometers of a special construction, linked with the electric cables (via the rope carriers) with a ringing device in the cabin of the driver. The mentioned ring became activated when the strength of the wind (in the direction perpendicular to the rope exceeded 38 kg/m^2 (20 m/s). then, the movement of the wagons should be stopped as the pressure of the wind on the empty wagon, constituting 1/16 of its weight, could cause the vertical deviation of the wagon by 10 degrees. Having such deviation, the wagon - when passing the towers – would have to touch the fender.

The steel constructions, mechanical and electric equipment were produced by Gdańsk Shipyard. The construction and reinforced concrete work and the walls were performed by the engineering company Oppman and Kozłowski from Warsaw and, partially, by the management of the building site in the self-build system. The project of the reinforced concrete constructions was developed by the Design Office of the Ministry of Communication and Transport, with the participation of the author. The architectonic project was developed by architect, Aleksander Kodelski, engineer. The construction was implemented by the Society of Building and Operation of the Cableway, Ltd., 51% of its shares were owned by Polish State Railways (PKP).

The majority of the work was carried out on the credit conditions. The long-term credit was granted by PK and the short-term (up to 3 years) was given by the Gdańsk Shipyard, engineers Oppman and Kozłowski and other national suppliers. The total cost of the construction amounted to ca. 2.8 million PLN and of a kilometre of cableway – 665 thousand PLN. In a very short time, a great engineering work was created; it placed Poland in the rank of the states with a high technical and touristic culture. If we anticipate only 200 „travels" per day (during the second Sunday after opening, the cableway transported 1000 passengers) and

Fig. 8. Contemporary car

expect the one-side travel (e.g. skiers) and assume the mean price of travel ticket at 6 PLN (the contemporary cost of the return ticket amounted to 8 PLN), the total cost of building the cableway should be amortised during 10 years.

The construction and start-up of the cableway caused the successive investments; observatory at the Kasprowy Wierch, the yellow route for pedestrians (the so-called „ceprostrada" in Polish) (leading from Morskie Oko to Szpiglasowa Przełęcz) and hotel at Kalatówki plain.

The first modernization was conducted in 1961; it included the exchange of the cars for the new ones. In 1985, on the occasion of the Jubilee of the 40th anniversary of the Cableway construction, Warsaw Documentary Film Studio produced film about the history of its building, entitled „Ku Szczytom Tatrzańskim" („Towards the Tatra Mountain Peaks"). On May, 6, 2007 there was the last course of the cableway, being the oldest one in Europe, before its complete renovation. The effects of the conducted renovation have included: the higher speed of the cars (8 m/s, and during passing the supports – up to 6 m/s); the sliding platform, serving for entrance at the particular stations instead of the traditional platform; the change of the wagon's drive from the weight tensioning into the constant tensing on the drums; instead of one rope carrier, two for each wagon (8 rope carriers in total); new, higher supports with a wider span of the rail tracks (instead of 4.5 m, they have 7 – 8 m, depending on the support); the change of the arrangements inside the stations. The new wagons have twice greater capacity (maximum 60 persons) than that one dating back to the seventies. In the cars, the double sliding manually opened door is installed on the both sides of the wagon's cabin. The cabins have the panoramic windows, manufactured from the darkened acrylic glass. The wagons are mounted on the rope carriers using 16-roller trolley. Instead of two drivers, setting up the wagons, the cableway is controlled by computer. According to the plan, the modernization was completed in December, 15, 2007. The President of the Republic of Poland, Lech Kaczyński opened officially the Cableway after the general reconstruction in January 18, 2008.

For 80 years, the Cableway has transported more than 40 million passengers.

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REFLEXIONS AFTER THE WORLD DAY OF ENGINEER

REFLEKSJE PO ŚWIATOWYM DNIU INŻYNIERA

We have many different "Days", being marked in the calendar and celebrated, e.g. Day of Miner, having a long tradition, Day of Fireman, Day of Teacher, Days of the Sea, Day of Child, Women's Day, Day of Grandmother and Grandfather, Day of Forget-me-Not in May and even the Day of Cat!

Since this year, we have also celebrated the World Day of Engineer, what occurred the first time not only in Poland but all over the world. It was initiated by the 6th World Engineers Convention (WEC) which was held in November 2019 in Melbourne (Australia) and established the 4th day of May as the World Day of Engineer. The mentioned day date was chosen on the remembrance of 4 March 1968. It was just the day when the representatives of 50 engineering associations from the whole world under the patronage of UNESCO (United national Organization for Education, Science and Culture) met in Paris with the aim to establish the World Federation of Engineering Organizations. The Federation of Engineering Associations NOT (Poland) supported the mentioned initiative and declared the active participation in the mentioned celebrations.

The first Polish celebration of the Day of Engineer was inaugurated in Poznań. This year, the 4th day of March was celebrated as the World Engineering Day for Sustainable Development. Poznań University of Technology was the host of the discussed inauguration which was attended by a wide group of the representatives of different engineering environments from technical universities, research institutes and business and

Fig. 1. Jacek Bańcerek receives the Euro-engineer diploma

Fig. 2. Tadeusz Słomka, Rector of AGH University of Science and Technology in Cracow

Fig. 3. Tomasz Łodygowski, Rector of Poznan University of Technology

Fig. 4. Łukasz Mikołajczyk, Wielkopolska Voivode

economy sectors. The ceremony was opened by His Magnificence Rector of the Poznań University of Technology, Prof. dr. Hab. Tomasz Łodygowski, Ph.D.

From among many addresses, we should mention a special one, by the Prime Minister of the Republic of Poland, Mateusz Morawiecki; the address was delivered to the participants of the meeting by the Wielkopolska Voivode Łukasz Mikołajczyk. We may read, inter alia, as follows: "The Poles "possess a gene of innovativeness"; they have the capacity of breaking the schemes and managing the untypical situations. As we live in the period of great economic changes, we have a big chance to utilize the possibilities, offered by the fourth industrial revolution. It builds completely new perspectives and completely new spaces. The engineering talents are our national good". Congratulations on the occasion of the World Day of Engineer, together with the own reflexions on the mission of the creators of engineering were also delivered by the Undersecretary of the State at the Ministry of Development, Mr Robert Nowicki.

The Federation SNT-NOT was – and will be in the future – the chief organizer of the celebrations of the Day of Engineer

Fig. 5. Robert Nowicki, Undersecretary of the State at the Ministry of Development

in Poland. The President of the Federation, Ewa Mańkiewicz-Cudny informed that NOT has undertaken the initiative of annual celebrations of the World Day of Engineer which is the occasion to remind the enormous contribution of Polish engineers to the to the civilization development of the world and to present the future directions in engineering, considering the social, culture, economic and climate conditions.

The Rectors of the greatest Polish technical universities – Prof. dr. hab. Jan Szmidt, Ph.D., Rector of Warsaw University of Technology and also, the Chairman of the Conference of the Rectors of Academic Schools in Poland, and Prof. dr. hab. Tadeusz Słomka, Ph.D., Rector of the Stanisław Staszic AGH University of Science and Technology in Cracow, the Chairman of the Conference of the Rectors of Polish Technical Universities concentrated their addresses on the education of engineers in quickly varying environment.

According to the announcement of the President of SNT-NOT, the program of the first celebration of the Day of Engineer included the presentation of the contribution of Polish engineers to the national as well as to the world heritage. The presentation of many known and unknown persons of the technical world, entitled:" Polish engineer throughout the history" was delivered by Prof. dr. Józef Gawlik, Ph.D., the member of the Central Commission for Degrees and Titles, academic teacher of the Tadeusz Kościuszko Cracow University of Technology.

The presentation of Prof. dr hab. Roman Słowiński, Ph.D., the Vice-President of Polish Academy of Sciences, the scientific worker of Poznań University of Technology on "the role of artificial intelligence in the acceleration of the scientific research and technological innovations" was the far-reaching prognostic that the future Days of Engineer will discuss always current and interesting subjects. The lecturer showed a short film from Japan in which the possibilities of AI (artificial intelligence) in respect of supporting the blind persons were presented. Owing to the mentioned application, they will be able to move independently in the world little available for them; they will be also able to use the applications allowing them to know whom

Fig. 5. Students of the Poznań University of Technology exhibited their work
Pictures: Tomasz Grzelak

they meet (or pass, even only to say "hello"). They will also facilitate the recognition of mood and humour of the passing people!

It is only one of the improbable examples and the possibilities, created owing to AI (artificial intelligence) being probably not completely understood by all people until now. The rhetorical question of the lecturer was also justifiable: whether the AI, as having the improbable computing and causative capacities, will not release itself from its objective treatment by man and will not become itself the subject, with transcendental properties?

We do not know exactly what will be the effects of less or more secret plans of work on the creation of computer – machine – which will be not only furnished up with the attributes, reserved until now for human brain and its recognition but it will itself generate and take over such possibilities!

We may, therefore, expect as early as to-day that the development of engineering, as increasing in the exponential rate, will deliver the subjects for the successive, annual meetings within the frames of the celebration of the World Day of Engineer.

The National Centre for Research and Development in Poland was the partner of the World Day of Engineer.

Janusz Kowalski

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